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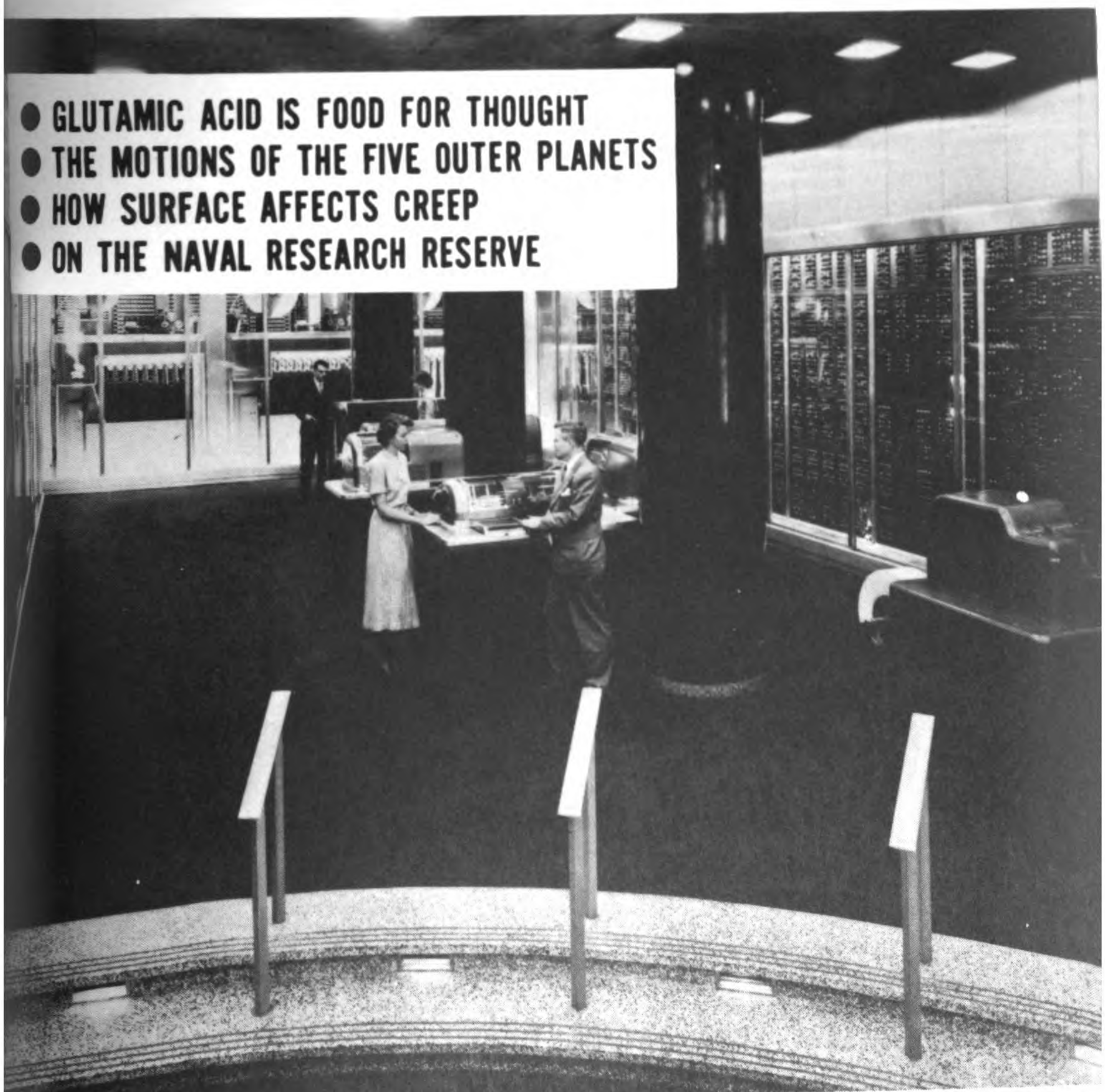
RESEARCH REVIEWS

- GLUTAMIC ACID IS FOOD FOR THOUGHT
- THE MOTIONS OF THE FIVE OUTER PLANETS
- HOW SURFACE AFFECTS CREEP
- ON THE NAVAL RESEARCH RESERVE



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

NAVEXOS P-510

COVER PHOTO: A view of the inside of the IBM calculator used for the work described in "The Motions of the Five Outer Planets" (pp. 6-13). In a few weeks this tremendous mechanism performed calculations that would have taken the operator of an ordinary electric desk calculator 80 years! It is helping scientists of the U. S. Naval Observatory and Yale University Observatory in ONR-sponsored work expected to be of great value in solving navigational problems.

Approved by Bureau of the Budget, 13 April 1948.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research

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DEPARTMENT OF THE NAVY ★ OFFICE OF NAVAL RESEARCH ★

Editorial Notes

With this issue, Research Reviews completes its third year of publication. Its record for this period is presented in the index on pp. 23 to 30. It seems appropriate at this time to review the general aims of the magazine and to examine its accomplishments during its first years of existence.

When Research Reviews was established by ONR in January 1948, its purpose, as set forth in the first issue, was "to discuss for a wide audience interesting phases of research progressing through the sponsorship of this office." A study of the index reveals that more than 150 articles on various phases of ONR's basic research program have been published. The subjects included range from ecology to underseas warfare, and represent almost every important phase of the contract research program that can be discussed without impinging on military secrecy. Projects at universities, at hospitals, and at industrial laboratories have been covered, and work at the ONR laboratories has been described.

As to the "wide audience" mentioned in the first issue, the distribution list and the requests received indicate that the Reviews is sent to a number of different groups whose interests are widely diversified. Today the magazine is seen by scientists in universities and industrial laboratories who are working on Government contracts, by the scientists at ONR and other agencies, by the men of the Fleet, by research administrators, and by Research Reserve officers throughout the country.

As ONR's only periodical available to all of the Navy Research Reviews has a unique opportunity to be of service. It is essential that men in the Fleet and men in the Reserve know what the Navy is doing to support the basic research that is so vital to any far-reaching advances in science or technology. For the scientists who read the magazine, it should provide the means of becoming acquainted with work in fields of research outside of their own particular interests. This is especially important today in this age of specialization, when research has become so vast that one scientist's total efforts must of necessity be confined to a very small area. Such an expert must still have cognizance of the ideas and methods of workers in other fields, because it is only through the constant exchange of ideas and information that scientific progress is made on a large scale. Research Reviews should provide material assistance in this vital exchange.

A salient fact that should be noted is that all the articles in the Reviews are actually written by the scientists themselves--not by editors or research administrators. In other words, the articles are direct reports from men actually engaged in the research described. Thus, the scientist not only has an opportunity to impart his ideas directly to his fellow-scientists but he also has immediate access to his non-scientist audience--the men in the Fleet and in the Reserve. Those in the latter groups are therefore given an excellent opportunity for attaining insight into the methods and aims of the worker in basic research. Such insight, it is felt, is essential to the continuing support of the ONR program, and will contribute much to the advancement of fundamental knowledge as well as to the improvement of the Navy's efficiency.

Glutamic Acid Is Food for Thought

by
Samuel P. Bessman
Children's Hospital

The brain is unique among body tissues in that it is highly selective in its metabolism. With the exception of one substance, only carbohydrate can maintain the respiration of isolated brain tissue. This substance is glutamic acid--a nitrogen-containing (amino) acid present in combined form in all food protein to the extent of about five percent.

In the living individual the metabolism of the brain can be diminished markedly by depriving it of glucose. Such deprivation causes the electrical activity of the brain (as measured by the electroencephalograph) to be altered in a characteristic manner, and recent investigations have demonstrated an accompanying drop in the oxygen consumption of the living organ. Eventually, when the glucose concentration of the blood falls to a certain level, unconsciousness ensues, frequently accompanied by convulsions. The administration of intravenous glucose, however, reverses this chain of events, and restores normal cerebral activity. Further investigation has shown that consciousness can also be restored by the intravenous administration of glutamic acid or glycine, another amino acid. These observations take on added significance in the light of the recent discovery by Waelsch and his co-workers, of the effect of glutamic acid on mental deficiency.

In an investigation of techniques for treating epilepsy, many methods of producing a slightly acid change in the blood of the patients were tried by these investigators, since it was realized that such a change relieves some epileptic symptoms. However, known methods for producing the acid change were relatively unsatisfactory, and Waelsch therefore suggested the use of glutamic acid hydrochloride, because it is the salt of a normal constituent of food. The patients so treated not only showed the beneficial effect to be expected from the acid treatment, but improved strikingly in mental alertness and apparent intelligence. Similar results were obtained with a larger group of epileptics. Later, a series of experiments with animals, undertaken by Zimmerman, suggested that the learning ability of young rats was improved if they were fed glutamic acid. These results are now the subject of some controversy, having been confirmed by one group and denied by two others.

Samuel P. Bessman (M.D., Washington University Medical School, St. Louis, Missouri) served with the U. S. Public Health Service from 1946 until 1948 when he became a Fellow of the Research Foundation of Children's Hospital, Washington, D. C. His principal interests have been biochemical and clinical studies of the metabolism of glutamic acid and related substances which are significant in the metabolism of the brain. He is a member of the American Board of Pediatrics and a Fellow of the Pediatric Department of George Washington University Medical School. His work on the project described in this article is supported both by ONR and by the International Minerals and Chemical Corporation.

Experiments using a control group have shown a significant improvement in the intelligence quotients of mentally deficient children treated with glutamic acid. Although there have been several negative reports as to the effectiveness of this treatment, it appears that if cases are selected according to the criteria of the original investigators, results similar to theirs can be obtained. This conclusion is based on the study of over 150 children for a period of two years or more. The oldest child tested was 14 years of age; most of the subjects were younger.

The difficulty in evaluating the effect of glutamic acid as a means of improving mental function is threefold: First, crudeness of the methods of testing intelligence; second, inadequacy of controls; third, lack of knowledge of the nature of mental deficiency. We have attempted to compensate for the lack of definition of any single test by employing, as have others, a number of standard tests. Even so, no intelligence tests have as yet been standardized in regard to particular individuals, so there is no clear basis for assuming that any test will give the same result in a particular individual over a period of years. This fault is a result of the way tests are developed. When a new one is devised it is given to large groups of people at various age levels, and average scores are computed from the performance of these experimental groups. But in each group there are many individuals who fall above and below the average, and there is no assurance that the individual who was in the lower part of the younger group would be in the lower part of an older group when he came to that particular age. It is for this reason that we have chosen as the best control the continuing performance of the individual patient, rather than the average for any group. This brings us to the somewhat questionable adequacy of controls and the variability of mental deficiency. If two groups of mental defectives are compared they must be absolutely matched as to type of mental deficiency, mental age, chronological age, and possibly sex. The last three requirements are relatively easy to meet, but, with the exception of a small group of very specific types of mental defectives such as mongoloids and cretins, there are no rigorous categories. Our knowledge of mental deficiency is so limited that there is very little agreement upon classification of the various types, particularly as to causes, although it is generally acknowledged that there are many. Thus, we are at about the same stage in the analysis of mental deficiency as medicine was when diseases were described as "miseries." If we were to give penicillin to every patient who came to the hospital we would probably be able to conclude, from a statistical analysis of the results, that penicillin is a good drug; however, since we can differentiate among various diseases, we can be enthusiastic about penicillin for a particular disease, and on the other hand, we can be sure of its uselessness in other cases. The objective in this phase of our study is to find, from our own observations, some criteria useful in selecting those cases which can be expected to respond to glutamic acid treatment. If we find such a group we shall, in all probability, have also succeeded in identifying a specific type of mental deficiency.

At present, however, we try to keep records on a particular patient for a year or more before instituting treatment. After the therapy is begun we interrupt it at intervals to substitute different food materials, or different forms of glutamic acid, so that we may determine whether the effects noted are due to the glutamic acid administered or if they

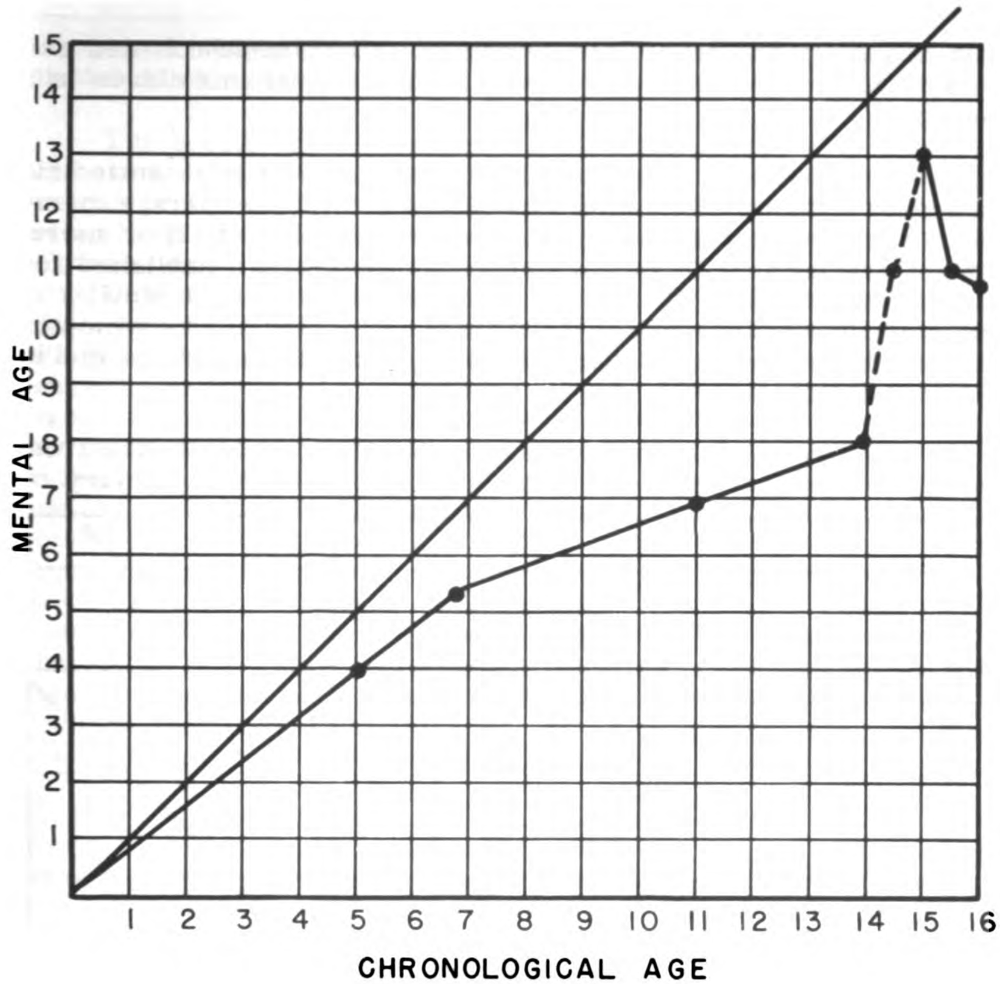

Figure 1. Effect of glutamic acid treatment on child of low mentality

are due instead to the marked alteration in the diet caused by feeding large amounts of a single protein constituent.

To illustrate our results, we have selected two cases. The first demonstrates the effect of glutamic acid on a child of low mentality. In Figure 1 the diagonal line represents the "normal" ratio between the ordinate, mental age, and the abscissa, chronological age. This ratio, known as the Intelligence Quotient, is equal on this diagonal to 100. The curve represents the tests made over a period of two years, and the dotted portion is the period when the child was taking glutamic acid. The gradual leveling off of the curve around the age of 12 years, illustrates the slow deterioration of mental defectives. Even though these children do grow mentally they progress at a slower and slower rate. When treatment with glutamic acid began, however, a sharp rise in intelligence quotient occurred, and the curve approached "normal". At this time spontaneous reports were received from the patient's public school teachers who were unaware of the treatment, but remarked on her amazing improvement in her studies. Her behavior at home became that of an adolescent girl instead of that of a six or eight-year-old child, as it had been previously. But as soon as treatment was stopped the curve fell off, and within twelve months it had reached a point where it probably would have been if no treatment had been given. Together with this measured drop came reports of failure in school, and reversion at home to the habits and activities normal in children half her age.

The second case (Figure 2) illustrates the effect of glutamic acid on a child of "normal" intelligence. This child was the average member of an above-average family, all of whom had I. Q.'s of 125 or more. Since three serial tests over a period of three years established for him a constant I. Q. of 100, he was, in relation to his family, similar to the mentally defective child in the average home. But after six months of glutamic acid treatment this child's I. Q. was 116, and at the end of a year it had reached 125.

In apposition to these results one definite conclusion derived from our studies is that when the brain is grossly damaged by injury or

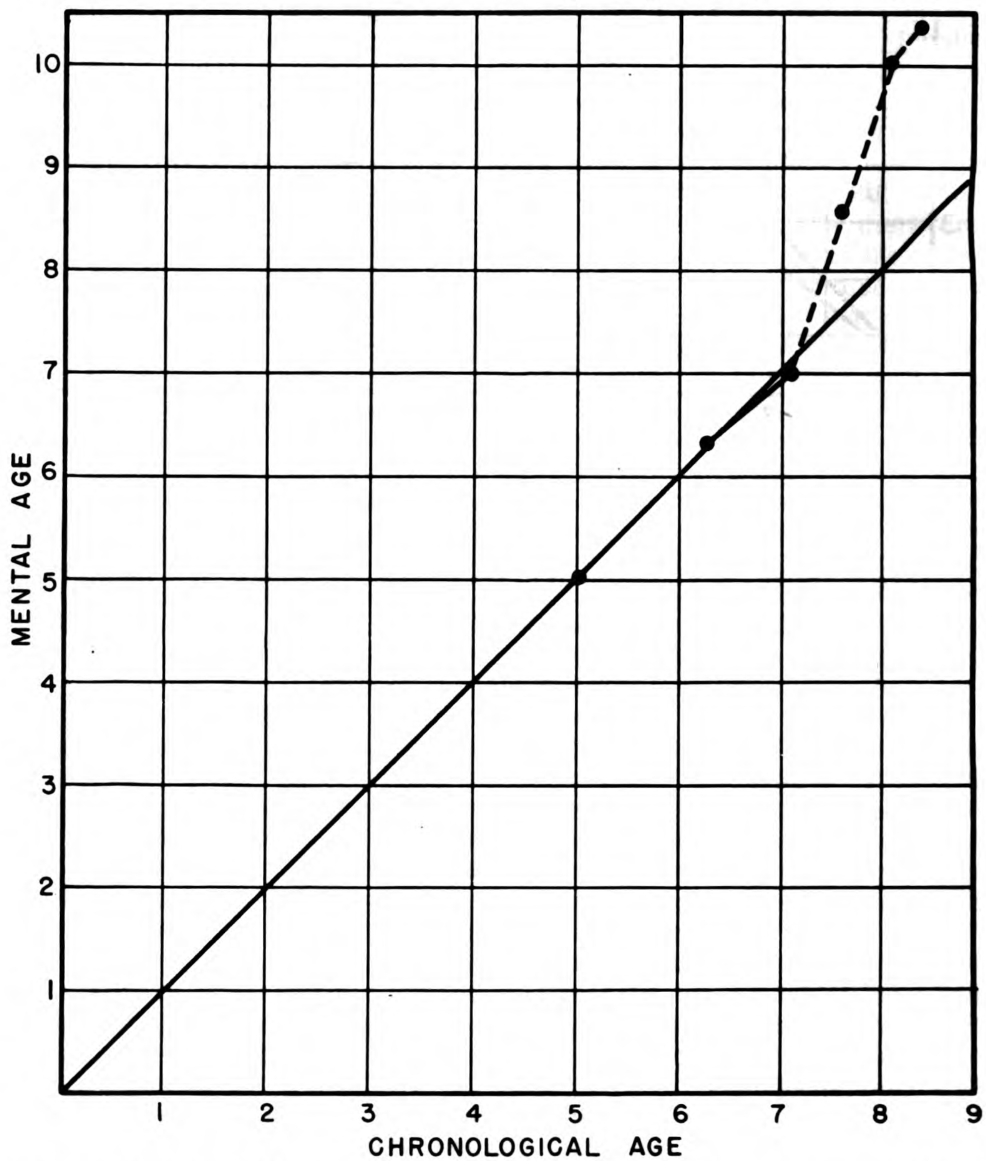

Figure 2. The effect of the glutamic acid treatment on a child of "normal" intelligence.

encephalitis (sleeping sickness) we can expect no improvement from treatment with glutamic acid.

The questions raised in the clinical use of glutamic acid prompt further study of its role in the metabolism of the brain. Analysis of the various organs and tissues of the body reveals that the highest concentration of glutamic acid is in the brain, where it is present to the extent of three times the concentration of sugar in the spinal fluid. That this large concentration of glutamic acid is characteristic of brain tissue is shown by the fact that it varies relatively little from species to species. (We have tested mouse, rat, guinea pig, rabbit, cat, calf, and man.) This unusual localization of a particular food substance to a particular organ, together with the previously mentioned effect of glutamic acid on recovery from the symptoms of low blood sugar, and on the maintenance of the respiration of surviving brain tissue, suggests that glutamic acid has a function peculiar to the metabolism of brain. This view is supported by a recently reported study with mice, which demonstrated the protective effect of glutamic acid against the mortality produced by frequent convulsions. Although other studies have shown that glutamic acid apparently does not prevent convulsions induced by drugs or electric shock, this latest work on mice provides further evidence that glutamic acid is important in cerebral metabolism. This protective effect is perhaps analogous to the protective effect of glucose upon the liver when that organ is under stress.

One of the major problems now facing us is the source of the relatively enormous amounts of glutamic acid in the brain. Chemical analysis shows that when glutamic acid is injected intravenously into rats or mice none of it gets into the brain within periods up to four hours. If this is the case, then glutamic acid must either be formed in the brain, or it must be absorbed from the blood very slowly. Experiments with brain tissue slices from rats show that both of these reactions are possible. The slices take up glutamic acid from the surrounding medium, or, if they have no glutamic acid in the medium, but only glucose, they synthesize it.

Although pathways for the disposal and production of glutamic acid in the brain have been sketched out, no explanation of the specific role of this substance in brain metabolism has been forthcoming. The most obvious possibility--that it functions as a regulator of carbohydrate oxidation in the brain--is being explored.

Clinical experimentation with glutamic acid may not only provide means of coping with some forms of mental deficiency, but it may also indicate methods for increasing mental efficiency, for speeding recovery from coma, and for preventing the mental damage that frequently follows severe infections of the brain. Theoretical research is providing the basis for further investigation, which we hope, may prove of great value in treating the ill and the mentally handicapped.

* * *

The Motions of the Five Outer Planets

by
G. M. Clemence and Dirk Brouwer
U. S. Naval Observatory and Yale University Observatory

Measuring the motions of the planets and devising a rigorous theory to represent these motions have played a basic role not only in developing physical science, but also in solving practical problems such as those encountered in navigation. As the wealth of observational data accumulates over the years, however, the problem of adequately representing planetary movements by a consistent theory has become increasingly difficult. The recent advent of the electronic calculator has at last made it feasible to perform the theoretical analysis with accuracy far greater than that of the accumulated observations.

During the past three years a project has been underway to calculate the precise positions of the five outer planets of the solar system, Jupiter, Saturn, Uranus, Neptune, and Pluto. This work has been done as a portion of a cooperative undertaking (sponsored by the Office of Naval Research) of the U. S. Naval Observatory, the Yale University Observatory, and the Watson Scientific Computing Laboratory. The paths of the planets have been traced out for 400 years, from about 1660 to 2060, by calculating their actual positions at 40-day intervals. These five planets were chosen because of the influence they exert on the solar system. The first four are the controlling bodies (except for the sun), each being far more massive than all the other five principal planets and remaining material put together. Pluto, the outermost, although it has relatively small mass, exerts appreciable effects on the others. The effects of the remaining principal planets, Mercury, Venus, Earth, and Mars, are hardly appreciable, and can best be calculated separately from the main problem. The project described here involved many millions of arithmetic operations, and the discussion of many thousands of observations has produced results of a new order of accuracy.

At least two of the planets studied in this project have probably been of interest since man first became curious about celestial bodies; Jupiter and Saturn must have been among the earliest objects of intellectual curiosity. Before recorded history it was undoubtedly noticed that Jupiter appeared in the evening sky a month later each year, requiring twelve years for a complete circuit of the heavens, and that

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G. M. Clemence, a graduate of Brown University, joined the staff of the United States Naval Observatory in 1930, and became Director of the Nautical Almanac Office in 1945.

Dirk Brouwer was born in Rotterdam, Netherlands and studied at the University of Leiden. He came to this country in 1927 as a Fellow of the International Education Board at Yale and the University of California. Since 1928 he has been on the staff of the Yale Observatory. and became its Director in 1941.

In recent years the two authors have worked jointly on a long-term research program on the motions of the principa' 'anets.

Saturn moved among the stars at less than half of Jupiter's speed. During the few centuries immediately preceding the Christian Era, the Babylonian astronomers represented the observed motions by empirical arithmetical formulae; and somewhat later the Greeks represented them by means of hypothetical geometric systems of motions in space. The Greek theories of the planetary motions culminated in the system constructed by Ptolemy, some 1800 years ago. In this system, the motion of each planet is represented by superimposing one or more small circular motions in space upon a motion in a large circular orbit around the earth. The small circular motions account for the periodically varying speed with which the planet appears to move among the stars.

Ptolemy's system remained the accepted standard theory among astronomers for 14 centuries, and the combinations of circular motions were retained by Copernicus when, in the sixteenth century, he proposed the theory that the planets move around the sun instead of around the earth. Meanwhile, however, observations of the planets had become precise enough to show that their motions were not accurately represented by these theories. In the early seventeenth century, Kepler found that the orbits around the sun were ellipses, and formulated laws from which formulae and tables for computing the positions of the planets were prepared. But Jupiter and Saturn departed from Kepler's theory, and it was not until after Newton had formulated the theory of universal gravitation that a satisfactory explanation for the divergencies was advanced. Newton arrived at this theory in 1665 or 1666, but did not announce it until 1686. It postulates that every particle of matter in the universe attracts every other particle with a force along the line joining them, proportional to the product of their masses and inversely proportional to the square of the distance between them. If a planet were influenced only by the gravitational attraction of the sun, the orbit would be an exact ellipse; the observed departures from elliptic motion may be attributed to the disturbing effects of the other planets. Assuming the correctness of this simple law, it becomes theoretically possible to solve what may be called the fundamental problem of celestial mechanics: Given the positions and directions of motion of several bodies (say Jupiter, Saturn, and the sun), together with their speeds and masses (weights) at a particular time, it is required to find their positions at any other time.

Such a simple statement of the problem gives no idea of the formidable character of its solution. Ever since Newton's time the most eminent mathematical astronomers have devoted their lives to devising practical methods for solving it. The difficulty is illustrated by the fact that more than a century elapsed after the publication of Newton's theory before a mathematical representation of the motions of Jupiter and Saturn was obtained that came reasonably close to meeting the needs of that time.

Two methods of determining the motions of planets have proved to be successful in practice. In one, called the method of general perturbations, the coordinates of a planet in space are given by trigonometric series, in which the time remains an algebraic symbol. To find where the planet is, at any time, it is only necessary to substitute in the formulae a number expressing the years and fractions thereof since some initial epoch--let us say January 1, 1900, Greenwich Mean Noon. It is this method that has been used most for the principal planets. The latest application to Jupiter and Saturn was made about 60 years ago by G. W. Hill, an eminent mathematical astronomer then employed in the U. S. Nautical Almanac Office. The expression of his formula for the position of Saturn requires seven large pages, printed in small type; moreover, the tables that he devised for easy evaluation of the formula fill up 84 pages! Yet these complicated tables have been used for more than 50 years to calculate the positions of Saturn published annually in the navigational almanacs.

The method of general perturbations suffers from two drawbacks. In the first place, the amount of calculation is considerable and it is difficult to be sure that all of the significant effects have been taken into account. Comparison of Hill's tables of Saturn with actual observations, for example, shows that the tables are in error by continually increasing amounts. The errors are small, and are now only of theoretical importance, but before many more years they will be large enough to be of practical importance as well. Similarly, Newcomb's tables of Uranus and Neptune, constructed about 50 years ago, show increasingly large errors. The errors must be due to defects in the theory, but the precise nature of the trouble is not yet clear in every case.

The second drawback of the method of general perturbations, as it has so far been applied to planetary motions, is that although any value of the time can be substituted in the formula, the result is not necessarily valid. The formula can be used for only a limited period, perhaps a few hundred years on either side of the initial epoch, without serious loss of accuracy. Consequently the method is without value for tracing the motions of the planets over hundreds of thousands of years, or even millions, as we should like to do. Since it is probable that the limitation is not inherent in the method itself, several ways have been suggested for overcoming it, but a truly frightful amount of calculation would be involved. Although electronic calculators may solve the problem eventually, even the task of setting up a machine to perform the necessary operations automatically is a staggering one.

The other method that has been used for tracing planetary motions is called the method of special perturbations--in which the position of a planet is actually calculated step by step from the initial epoch. The steps are so close together that the planet does not move far enough from one step to the next to change the attractions of the other planets upon it by very much. This method also has two drawbacks. In order to find the position of a planet at any time it is necessary to calculate it for all the intervening times since the initial epoch; and if many steps are required it is necessary to use many significant figures in the calculations, to avoid excessive accumulation of error in the end-figures.

The method of special perturbations has not been much used for the principal planets; its applications have usually been to the minor planets and to comets, where the number of steps is not very great, and where the highest precision has not in general been required. In these applications it is assumed that the positions of the disturbing planets are already well enough known, so that at each step it has been necessary only to calculate the attractions of the principal planets (and of the sun) on the body being studied. The masses of the minor planets and comets are so small that they do not appreciably disturb each other, or the principal planets.

The application to the five outer planets of the solar system is by far the most extensive that has ever been made of the method of special perturbations. It is the first application in which the actions of the planets on one another have been calculated at each step, instead of assuming that the paths of all except one are known in advance. Thus, at each step, the attraction of each of the five planets on the other four was calculated, as well as the attraction of each on the sun. Each step of the integration involved 800 multiplications of large numbers, 100 divisions, 1200 additions and subtractions, and the recording of 3200 digits. The large number of steps made it necessary to use 14 decimals in the calculations.

So large an amount of calculation could not have been accomplished in a reasonable length of time without an electronic calculator of high capacity. Fortunately such a calculator was placed in operation in January 1948. This machine, the IBM Selective Sequence Electronic Calculator (see cover), was made available without cost to the project by Mr. Thomas J. Watson, Chairman of the Board of the International Business Machines Corporation. This machine was able, in less than three minutes, to make all of the calculations, in duplicate, for a single 40-day step. At each step the machine automatically compared the two independent results, and in case of disagreement it automatically repeated the calculation. Even electronic calculators make mistakes occasionally, but it was found that the machine was able to correct most of its mistakes on the second attempt. In case of disagreement on the second trial the machine stopped, indicating need for servicing. Several estimates were made of the time that would be required to make the calculation in the ordinary way, with an electric desk calculator. It appears that the ratio is in favor of the electronic calculator, by about 1000 to one! In other words, an operator with a desk machine, working 40 hours a week, might have done the job in about 80 years, if he had made no mistakes. Experience shows, however, that in work of this kind the occurrence of mistakes may double the time required. Furthermore, a mistake occurring at any step causes every subsequent step to be wrong. Thus, it is not certain that this work could have been successfully accomplished at all by ordinary methods.

As was mentioned earlier, the initial data required for solving the problem are the position, speed, and direction of motion for each planet at some initial epoch. To specify the position, three numbers are needed while the speed and direction each require two, making a total of six numbers for each planet, or 30 in all. These 30 numbers have to be determined by observing the planets with telescopes. When great accuracy is wanted it is necessary to have many observations, extending over a long period of time, and this is one reason why the calculations were extended so far into the past. The 30 constants of the orbits were known at the start with insufficient accuracy, but were improved by successive approximations. The first calculation extended for only 30 years. The resulting positions of the planets were compared with the observed positions, and the constants of the orbits were adjusted to bring about better agreement. Then a second calculation for 180 years was commenced, and carried out; after its completion a new comparison with observations was made, and the constants adjusted a second time. Another calculation was then made for the same 180 years, and another comparison with observations showed that the constants needed no further improvement. The final step was to extend the 180-year stretch to 400 years.

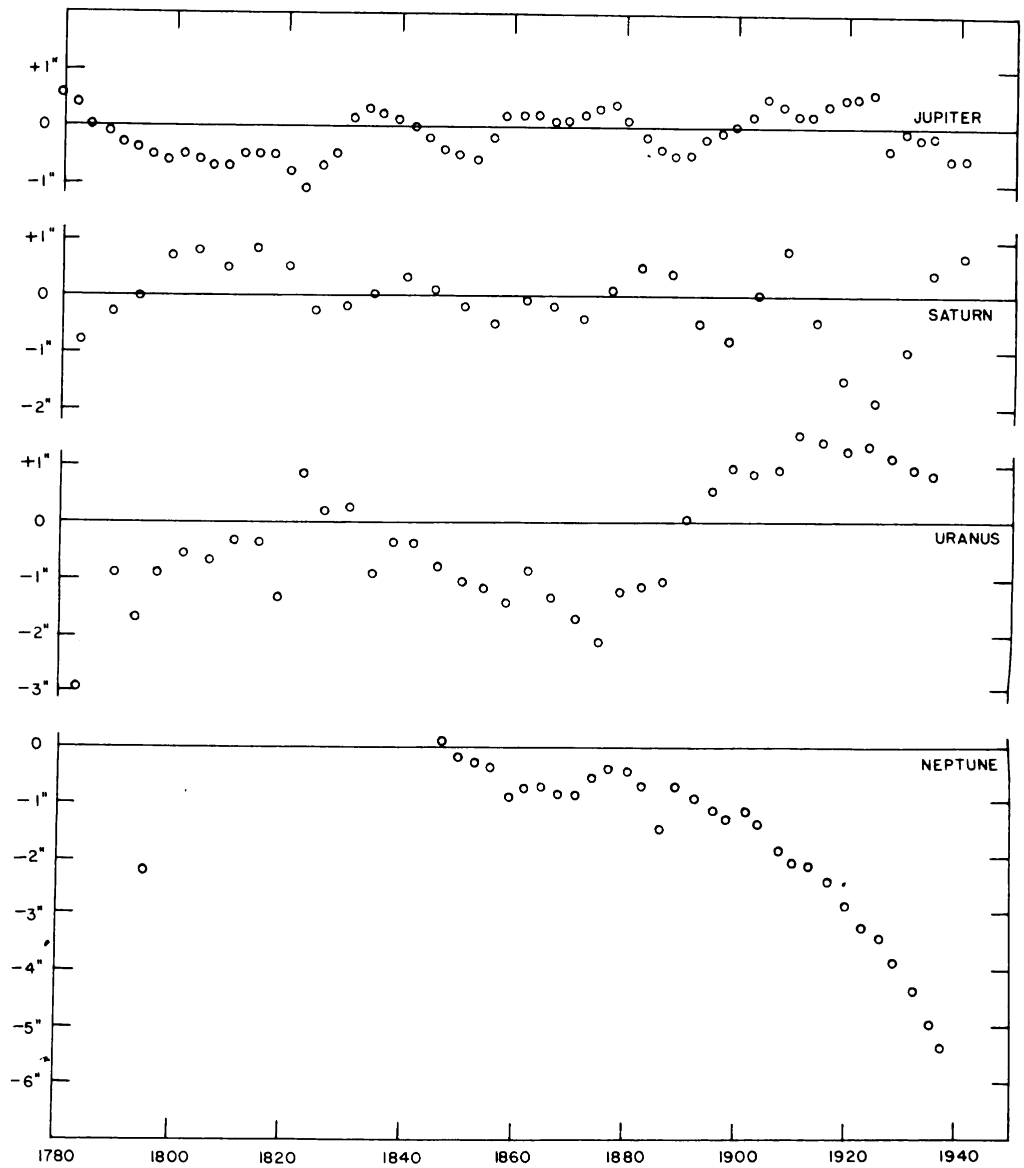


Figure 1. Observations compared with planetary tables

About 15,000 observations of Jupiter and Saturn were used in adjusting the constants of the orbits, but for Uranus and Neptune fewer observations were available. (Uranus was not discovered until 1781, and Neptune not until 1846.) For Pluto the number of observations was comparatively small, because this planet was the most recently discovered of the five. (It was first observed in 1930.) For this reason it may be expected that the calculations for Pluto will prove to be less accurate than the others, and by 2060 the error may be appreciable. It was still worthwhile to include Pluto in the work, however, on account of its influence on the other four planets; its motion is known with ample accuracy for this purpose.

The adjustment of the constants of the orbits by comparison with observations is a task of considerable magnitude. It has not yet been practicable to use electronic machines for this work, because too much discriminating judgment is needed at nearly every stage. Altogether

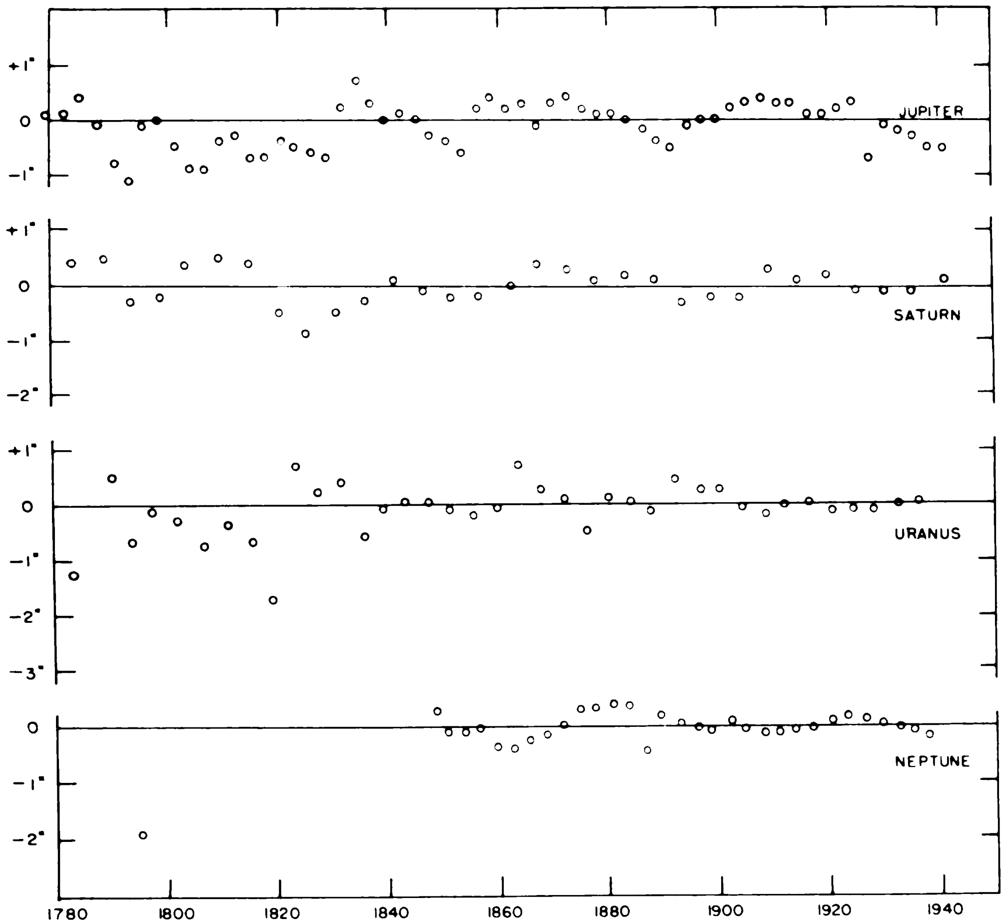


Figure 2. Observations compared with numerical integration.

several thousand hours of labor by expert astronomers were necessary, not counting the even larger task of making the original observations. Fortunately, however, much of the work had already been done several years earlier, with this very object in view; and during the course of the electronic calculations only a few hundred hours of an astronomer's time were needed. This work was done at the Yale Observatory and the Naval Observatory, principally by the two authors. The electronic calculations were planned and directed by Dr. W. J. Eckert.

Figures 1 and 2 contrast the representation of the observations by the planetary tables and by the numerical integration. A positive value of a residual indicates that the observed position in the orbit is ahead of the calculation.

The plots for Jupiter and Saturn in Figure 1 are of a somewhat different type from those for Uranus and Neptune. For the former two planets, the discrepancies between the observed positions and the positions predicted by Hill's tables were read from a smoothed curve drawn through the numerous residuals that represented the deviations from the tables for every year. Moreover, they were subsequently modified by a provisional adjustment of the elliptic motion which serves as the basis of the tables. In the case of Saturn this brings out very clearly the inability of the tables to represent the observed positions. For Uranus and Neptune the plotted residuals represent the deviations from the tables without any smoothing or adjustment. In the case of Uranus, such an adjustment would have produced a considerable improvement. The deviation of the path of Neptune from the tables since 1900 must be ascribed primarily to the omission of the attraction by Pluto from the tables. Pluto's existence was, of course, unknown 50 years ago, when the tables for Neptune were constructed. Finally, the observations of Neptune that were available when Newcomb constructed the tables covered only 50 years since the planet's discovery in 1846. There are, however, two precious pre-discovery observations made in 1795 when the planet was recorded as a ninth-magnitude star in the course of a series of observations of faint stars. The importance of the pre-discovery observations is that they are compatible with modern observations only if the attraction by Pluto with a mass comparable with the mass of the earth is included.

In connection with Figure 2, two points of importance should be kept in mind. First, the observations of Jupiter, primarily because of the large size of its disk, are considerably less accurate than those of the other planets. Second, the diagram shows that there was a considerable improvement in the quality of the observations about 1840 and again about 1900. In this light, the residuals for Saturn and especially Uranus look entirely normal. Large scatter is present before 1840, while improved representation is found from 1840 to 1900 and further improvement is shown since 1900. While the improvement since 1900 is also very noticeable in the case of Neptune, the residuals for this planet seem to have a systematic character. This may well be due to the fact that this planet moves very slowly among the stars--in fact at the rate of only two degrees a year. Thus for many years, the observations of the planet are based upon a comparison with the same stars in the same part of the sky. This tends to carry into the residuals the small systematic errors in the star positions.

Comparison with the observations as shown in the Figures does not complete the work. It was mentioned that in addition to the constants of the orbits, the masses of the planets must be known at the outset. Fortunately, reasonably good values for the latter were available from previous investigations, but improvement in these will be possible, when a more refined analysis of the present work can be made. In this connection, about a dozen observations of Uranus during the century preceding its discovery may be very useful for the evaluation of the mass of Pluto. These observations were made under circumstances similar to the observations of Neptune in 1795. Although they are of low accuracy compared with modern observations, their early date makes them at least interesting. The calculations in connection with these observations have not yet been completed.

As to the value of the work, there are two points of view to be considered: (1) The basic scientific value and (2) the immediate practical value. From the scientific point of view the object of studying the motions of celestial bodies is to learn more about how the universe operates. For two hundred years after Newton's formulation of his laws of motion it was thought that they would suffice to explain all of the celestial motions. The astronomer Leverrier, however, discovered, about a hundred years ago, that the planet Mercury did not move strictly in accordance with Newton's laws. The discrepancy remained unexplained until 1915, when Einstein formulated the general theory of relativity. Then it appeared that the discrepancy could be completely removed. But what is meant by complete removal? Only that the contradictions, if they exist, are smaller than the errors of the observations. As the observations continue to improve with the invention of new techniques of observation, it is always possible that a discrepancy will arise where none was known before. Then attempts to explain it may lead to a fundamental advance in knowledge. It is after this general pattern that all of the sciences advance.

It is known that gravitation is not the only force acting within the solar system. For example, the presence of meteors and the zodiacal light indicate something in the nature of a resisting medium. Whether this is dense enough to affect the motions of the planets appreciably is not known. The present work may help to provide an answer, or it may lead to knowledge about still other forces in the solar system.

As to the practical value of the present work, it is anticipated that it will suffice, so far as these planets are concerned, for the foreseeable needs of navigation for the next hundred years.

* * *

Bacteria Living Without Air Studied as Possible Causes of Gas-gangrene

This Gonzaga University scientist is operating an apparatus designed to investigate a variety of bacteria that live without air. Here he is replacing oxygen with hydrogen in jars where such "bugs" can be isolated for study. These organisms, which have received very little attention previous to this ONR-sponsored investigation, are believed to be possible causes of gas-gangrene and tooth decay.

How Surface Affects Creep

by
Milton R. Pickus
University of California

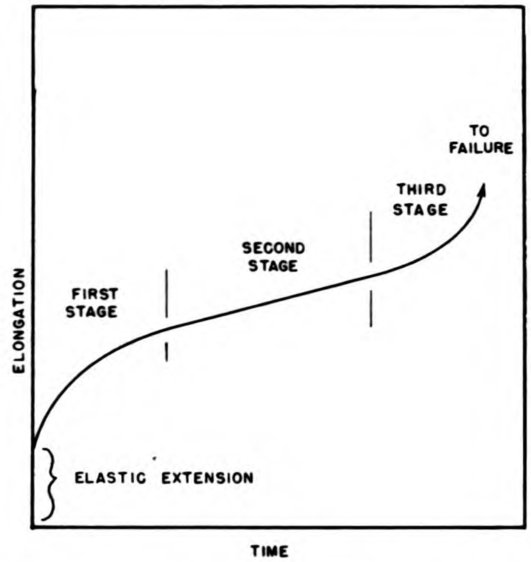
The phenomenon of creep in metals continues to receive a great deal of attention from both scientists and engineers. Reasons for the scientific interest are not hard to find, for creep is an important aspect of the larger problem of achieving an understanding of plastic flow. The interest of the engineer, however, is more immediate and pressing. With the rapid developments in jet engines, there is a growing need for metals that can retain their mechanical properties at higher and higher temperatures.

What is meant by creep of metals? It is the slow, continuous change in dimensions of a metal structure that occurs under service loading. In most structural engineering alloys, creep occurs only at elevated temperatures. The higher the temperature or the stress the more rapid will be the rate of creep. The behavior may be illustrated by considering the sequence of events that occurs when a load is hung from a metallic rod maintained at an elevated temperature. It will be found that upon application of the load, a practically instantaneous extension of the rod takes place. After this initial effect the specimen will continue to elongate, but at a gradually diminishing rate. This is usually called the first stage of creep. After a period of time that varies with the particular conditions of the test, a second stage occurs in which a fairly constant rate of elongation will be observed. The second stage is generally considered to be associated with atomic rearrangements which are due primarily to thermal agitation, while the external stress exerts mainly a directing influence. This stage is followed by an accelerating creep rate, which leads eventually to failure. The acceleration is regarded by some investigators as being a natural consequence of an increasing stress, due to the decreasing cross-section of the test specimen. In Figure 1, a graphical illustration of this situation is presented.

The interval of time over which these changes occur varies, of course, with the stress level and temperature. Under certain conditions, the final stage may not be reached for many thousands of hours. This emphasizes the importance of the subject from an engineering standpoint, for it is apparent that, although a member may easily withstand a certain stress at some elevated temperature for a short time, it may fail at a substantially lower stress maintained for a long period of time. One important implication of this fact is that in the matter of engineering design, a short-time test is obviously a dangerous criterion for predicting long-time service. Furthermore, until the mechanism of creep is thoroughly understood, the designer has only two recourses: To allow a very wide margin of safety (which does not completely eliminate all uncertainty) or to base the design on long-time tests under conditions of temperature and stress similar to those encountered in service.

Milton R. Pickus received his B. S. in 1934 and Ph. D. in 1938 from Yale University. From 1939 through 1948 he was Chief Metallurgist for the Parker Pen Co. Since 1948 he has been at the University of California, Berkeley Campus, working on an ONR-sponsored project in conjunction with Professor Earl R. Parker.

Figure 1. This is a typical curve showing the various stages of creep.



Obviously the best hope for obtaining accurate estimates of long-time performance from short-time tests lies in acquiring a basic understanding of the mechanism of creep. Consequently, much effort is being expended for this purpose.

Many factors contribute to the complexity of this undertaking. For one thing, engineering alloys contain several elements, and their influence on one another is a problem in itself. But even in the case of a single pure metal, there are a multiplicity of factors to consider. It is well known that all metals in the solid state are crystalline in nature. In the usual commercial forms they consist of an aggregate of crystalline grains, which, while they are generally too small to be seen with the unaided eye, are readily visible under the microscope. In the course of the deformation of such an aggregate, each grain exerts restraints on the deformation of its neighbors, and each individual grain can deform only in a restricted manner that conforms to the crystal structure of the metal in question. Furthermore, the size of the separate grains is not fixed but is susceptible of change with deformation and temperature.

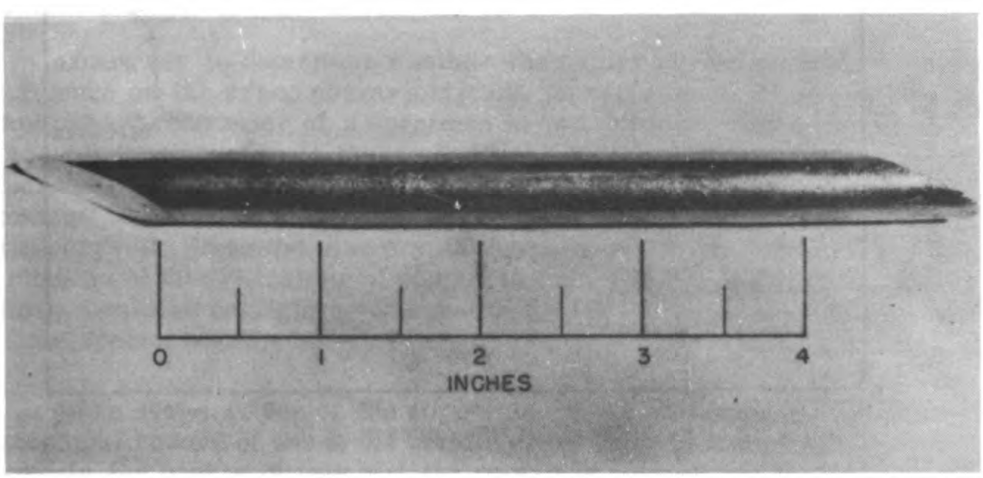


Figure 2. Zinc single crystal with basal planes exposed by cleavage.

In general, deformation tends to decrease the size of the grains, whereas heating tends to bring about an increase in size. Under certain controlled conditions it is possible to cause an individual grain to grow to a very large size, so that a test specimen may consist of one huge crystalline grain. It is quite common to employ such single-crystal specimens in the conduct of research investigations, because it is thought that before the behavior of a large aggregate can be successfully analyzed, it is necessary to know the behavior of the individual grains. Consequently, in the present investigation of creep, a large proportion of the work was done with single crystals--namely, those of zinc.

As a result of many investigations, the influence of a number of variables on the creep rate has been qualitatively determined. Among these variables are stress, temperature, microstructure, and composition. The influence of the state of the surface of the test specimen, however, has been largely overlooked in past investigations; yet our work shows that the nature of the surface may, in certain cases, govern the creep characteristics of the specimen.

The single crystals of zinc used in these tests were prepared in the following manner. First, a quantity of high-purity zinc was melted in a large pyrex test tube. The molten zinc was then drawn up into a long, 1/2-inch diameter pyrex tube by means of a vacuum pump, and held there until solidification occurred. The zinc rods thus produced were cut into convenient lengths of approximately nine inches and were individually sealed in evacuated pyrex tubes. Six of the sealed tubes were so placed in a vertical furnace that a temperature gradient existed from bottom to top. At the start of a run the temperature of the furnace near the top of the tubes was approximately 600°C, and near the bottom of the tubes about 475°C. (The melting point of zinc is 419°C.) Power to the furnace was supplied through a variac, the shaft of which was revolved by a variable-speed motor drive. When the temperature distribution in the furnace had come to equilibrium, the motor drive was turned on, with the result that the furnace cooled at a controlled rate. Under these conditions solidification of the zinc occurred first at the bottom of the pyrex tube, and the interface between the liquid and solid zinc moved slowly upward until all of the zinc was completely

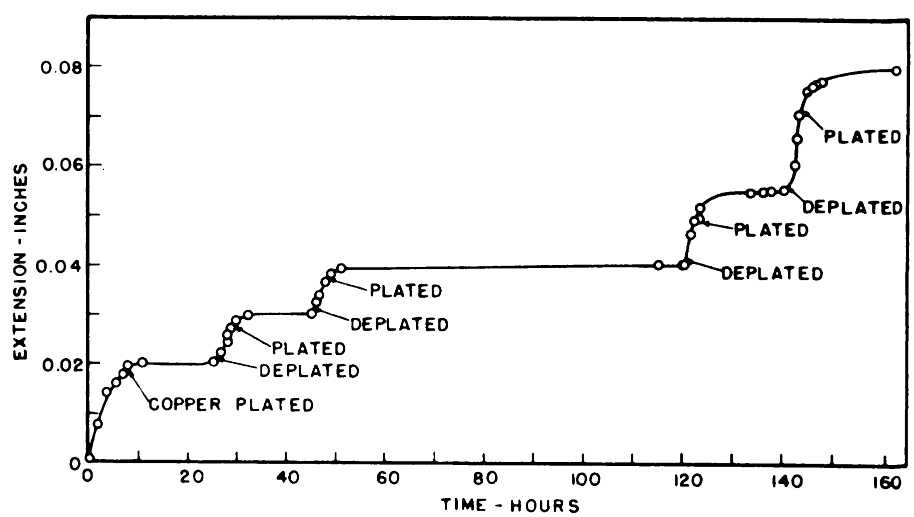


Figure 3. This curve shows the effect on a zinc single crystal of the application and removal of a layer of copper. The test temperature was 100°C.

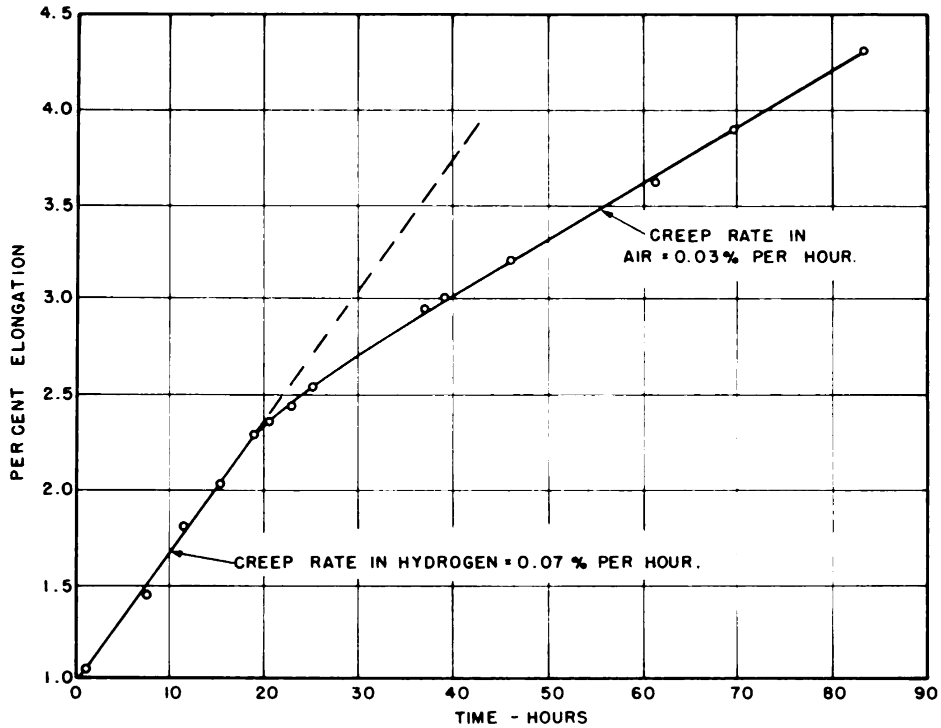


Figure 4. Comparison of creep rates in a single specimen of nickel under two different environmental conditions. Test temperature was 750°C.

solidified. The rate of cooling was controlled so that solidification progressed at a rate less than that at which a crystal, once started, could grow. Thus, once a crystal nucleus was formed, there was a good chance it would continue to grow until all the metal had solidified into one crystal. At faster cooling rates several nuclei would form, and a polycrystalline specimen would result. It was found that under the conditions employed in this work, the yield of single crystals was about 95 percent, with the other 5 percent of the specimens forming bi-crystals. One of these single crystals, with the basal planes exposed by cleavage, is shown in Figure 2.

In order to determine whether the nature of the surface had any influence on the creep characteristics, an experiment was designed to compare the behavior of a specimen in two different reproducible surface conditions. One of these conditions was simply a clean zinc surface. To obtain the other condition, a thin layer of copper, approximately 10^{-5} in. thick, was applied electrolytically to the surface of the zinc crystal. Since the zinc crystal had a diameter of 1/2 in. the contribution of this thin layer of copper to the tensile strength of the specimen would be negligible, unless the nature of the surface layer had some special significance.

The large effect of the copper is shown in Figure 3, which is a graphical record of one of the tensile creep tests on a zinc single crystal. In the course of this test the copper layer was alternately applied and removed. It may be observed that whenever the surface was copper-plated, extension or creep of the specimen completely ceased. Upon removal of the copper, creep re-occurred.

In another type of experiment involving a different set of conditions, similar surface effects were found for polycrystalline nickel. In this experiment, a specimen of nickel was mounted in a gas-tight furnace and loaded so that a convenient creep rate was obtained. With the specimen creeping at a uniform rate, alternate changes were made in the furnace environment. In one case an atmosphere of air was maintained, and in the other case an atmosphere of hydrogen. As shown in Figure 4, a very large difference in creep rates was found for the two environments. Heating in air produced a thin layer of a tenacious oxide, whereas the surface produced by heating in hydrogen was clean and bright.

These experiments show that under certain conditions, the surface condition may be a very important influence in creep behavior. The investigation is being pursued to determine the reasons for this influence. It is hoped that this work will add a few more facts to our knowledge, which will ultimately lead to an understanding of the mechanism of plastic flow in metals.

* * *

"Operation Midpac" Scientists Discover New Mountain Range Under the Pacific

An undersea mountain range comparable in size to the Rockies was discovered during "Operation Midpac," a 24,000-mile scientific voyage completed last month. The project was a joint expedition of the Scripps Institution of Oceanography (supported by the Office of Naval Research) and the Naval Electronics Laboratory. Two ships participated--the Scripps Institution's HORIZON and NEL's EPCE (R) 857.

The "Mid-Pacific Mountains," as scientists have named the new range, cover an area approximately 100 miles in width and 1,000 miles long between Hawaii and Bikini. Previously, investigators had discovered some of the peaks, but the existence of a range of such great size was unknown. The mountains rise about three miles from the ocean's bottom to within about a mile of the surface. With the aid of special equipment scientists of the expedition brought up skeletal remains of clams, sea urchins and coral from their peaks. These offered evidence that the mountains were once near sea-level, but this was probably millions of years ago. Dr. Revelle, Acting Director of Scripps Institution, pointed out that discovery of this range further discredits the belief held by many that the ocean's floor is a smooth, flat area. On the contrary, its contours are varied by numerous mountains and other rocky projections.

The expedition made many other studies of the ocean's floor besides the one that resulted in the discovery of the "Mid-Pacific Mountains". Findings of the scientists will be the subject of intensive study for many months.

On the Naval Research Reserve

Research Reserve Units are Activated in Athens, Ga. and in Miami, Fla.

Members of newly activated VNRRU 6-9 at Athens, Ga.

Two new units were added to the rolls of the Naval Research Reserve last month, with the activation of VNRRU 6-9 in Athens, Ga., and VNRRU 6-10 in Miami, Fla.

The group in Athens consists of 16 members, headed by Commanding Officer LCDR Aubie Rivers Robertson. LCDR L. I. Estep, Research Reserve Program Officer for the Southeastern area, represented the Office of Naval Research at the activation ceremonies. In his address to the new unit, LCDR Estep reviewed the history of ONR and the Research Reserve, emphasizing the latter group's function in assuring the readiness of qualified personnel in the event of mobilization. He also discussed the various sources of training available to the units.

In Miami, the new unit's activation orders from ADM Hayler were read by LCDR Williamson, who represented the sixth naval district. ONR was again represented by LCDR Estep. The Miami unit is headed by LT R. D. Kreske, a professor of Geography at the University of Miami, headquarters of the group. It is anticipated that in the near future another Florida unit, the one located at West Palm Beach, may become part of the Miami organization.

Naval Officer Procurement

ONOP was granted authority by the Chief of Personnel to reopen procurement on 1 November 1950 of candidates for appointment in the Naval Reserve for the following programs: General Line Program;

Electronics Specialist Program; Naval Architect Program; Petroleum Engineer Program; Civil Engineering Corps Program; Supply Corps Program; Chaplain Corps Program; General Line and Supply Corps Program for immediate active duty; and Merchant Marine Reserve Program. These programs are in addition to those which have been open, such as Regular Navy MC and DC, and Reserve electronics specialists. ONOP is authorized to complete the processing of all applicants who had been physically examined on or before 14 July for participation in programs then open for procurement.

Individuals interested in a commission should write to the Office of Naval Officer Procurement for information. The first letter should state age and physical defects, if any, and outline educational background.

Here is a brief outline of present requirements, which include some changes from "Pre-Korea":

(a) Vision: (1) Line for general service, 15/20
(2) Line for special service and staff corps, 4/20
Note: In all cases correctible to 20/20.

(b) Draft Status: Must be ineligible for induction except for Line and Supply Corps draft-eligible active duty program.

(c) Education: Basic qualification, four-year college degree from an accredited college or university.

(d) Experience: Line Specialist & Staff Corps
(1) None for Ensigns
(2) Five years in specialty for LTJG's.
Note: Veterans may count active service and graduate work as experience.

(e) Waivers: No waiver of any qualification will be considered.

(f) Officers' Qualification Test: Applicants must exceed Navy Standard OQT score.

The following programs are open:

Program	Age Limit	Active Duty
General Line, USNR	27	May be requested
Electronics SP, USNR	33	" " "
Naval Architect	33	" " "
Petroleum Engineer, USNR	27	" " "
Medical, USN and USNR	Details from ONOP	
Medical HP, USNR	" " "	
Internship	" " "	
Supply, USNR	33	May be requested
Chaplain, USN and USNR	33	" " "
Civil Engineer, USNR	33	" " "
Dental Corps, USN and USNR	Details from ONOP	
Medical Service Corps, USN	32	May be requested
NROTC	Details from ONOP	
Merchant Marine, USNR	" " "	
Line and Supply, USN (Female only)	25	May be requested
Line and Supply, USNR	26	Required

CIVIL DEFENSE II

VNRRU 6-5 at Gulfport, Miss. Plans Extensive Program for Aiding Local Civilian Officials

An extensive program has been mapped out by members of VNRRU 6-5 at Gulfport, Miss., to prepare the civilian population of that city for efficient action in case of emergency. The unit, commanded by LT V. O. Smallwood, USNR, is working in conjunction with Chief of Police Hart, the City's Civilian Defense Director. It is anticipated that the main function of the Reserve Unit will be in providing information and training for the civilian members of the community.

VNRRU 6-5's civilian defense project was a logical outgrowth of the radiological defense project which the unit had undertaken in July 1949, when the group was activated. Most of the members completed NAVpers 10775 (Elementary Nuclear Physics) by correspondence. Their training paralleled that offered by the Armed Services School at Keesler AF Base, which the reservists had the opportunity to visit, and where they could perform practical experiments. This training was supplemented by that provided at the Oak Ridge Nuclear Science Seminar, which was attended by many of the Reservists.

When the unit first started its work, no civilian defense had been organized in Gulfport, and the first problem was to find out exactly what possibilities existed for aiding the municipal government to organize the population. A study of this aspect of the situation was undertaken by Mr. Aho, a member of Unit 6-5, who gathered literature from several Federal agencies, including the Atomic Energy Commission and the Armed Forces Special Weapons Section. The most important document studied was the Hopley Report, which contained recommendations which have already been adopted by several State organizations. One significant point brought out by this report is the fact that radiological defense is only a small part of the total defense plan.

After Chief Hart's appointment as Civilian Defense Director, immediate planning was begun by the Unit 6-5 on projects that were considered essential to the execution of a successful program. It is believed that the reservists will be able to provide the greatest help in providing training in the following fields:

1. Medical and health services. (The Red Cross will be requested to provide a curriculum for the conduct of such training courses.)
2. Radiological defense.
3. Chemical defense.
4. Fire services and police services.
5. Engineering services.
6. Evacuation and civilian war aid.

The size of the unit will limit the scope of actual training conducted by the members, but the group can perform valuable services in coordinating activities within the city. Two methods of doing this will include use of local newspaper and radio facilities. In addition, lectures will be given by unit members, and by experts from Federal agencies to civic organizations. All films available on civilian defense will be shown to these and other key groups in Gulfport.

The general objective of the Gulfport unit's program will be to help train civilians, and, equally important, to help civilians to train themselves, because it is felt that wide dissemination of information will decrease demoralization in case of disaster. The unit will therefore make every attempt to educate the civilian population on the particulars of total warfare in the hope that if such an emergency should arise, the people of Gulfport will be able to deal with it effectively.

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*Articles are arranged chronologically under the ONR Division and Branch which have cognizance of the research described.

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Corey, E. L., February 1949
Cowles, P. B., April 1948
Cranberg, L., November 1948
Crandall, W. B., October 1950
Creutz, E., January 1949
Cross, J. B., February 1950

D

Daunt, J. G., November 1949
Dayton, R. W., September 1948
De Haven, H., May 1948
de Laubenfels, M. W., June 1950
Denny, J. P., November 1949
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Dravnieks, A., May 1949
Drucker, D. C., May 1948
Dugger, W. M., August 1950
DuMond, J. W. M., April 1950

E

Eisenstein, A. S., March 1950
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Estermann, I., September 1948

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Fenton, F., May 1950
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G

Geller, R. F., May 1948
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Gerhardt, J. R., June 1949
Glassman, S. F., July 1950
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Hess, H. H., February 1950
Hoagland, H., May 1948
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Hofstadter, R., September 1949
Hughes, R. H., November 1950
Hunt, W. A., April and October 1948
Hurley, P. M., September 1949

I

Iselin, C. O'D., August 1949

J

Jacobsen, L. S., April 1949
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K

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Kane, E. D., April 1949
Kaplan, N., July 1949
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Lewis, B., February 1948
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Lind, D. A., April 1950
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Livingston, R., January 1949
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M

MacGregor, C. W., March 1948
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Mark, H. F., July 1948
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McAllister, W. B., Jr., October 1948
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McReynolds, A. W., May 1949
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Norton, G. A., April 1949
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O

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Packchanian, A., January 1949
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Polya, G., November 1948
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R

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S

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Schwab, R. S., June 1949
Scobee, R. G., June 1948
Seymour, R. B., August 1948
Sharp, R. P., July 1949
Shelesnyak, M. C., February 1950
Sherwood, N. P., December 1948
Shumacker, H. B., Jr., January 1948 and March 1950
Sigel, M. M., July 1949
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Spangenberg, K., February 1949
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T

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V

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W

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Waters, L. L., October 1948
Weyl, W. A., July 1949
Whitman, A., February 1950
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Williams, R. D., November 1949
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Young, L. E., January 1950

Zapffe, C. A., January 1948 & November 1950

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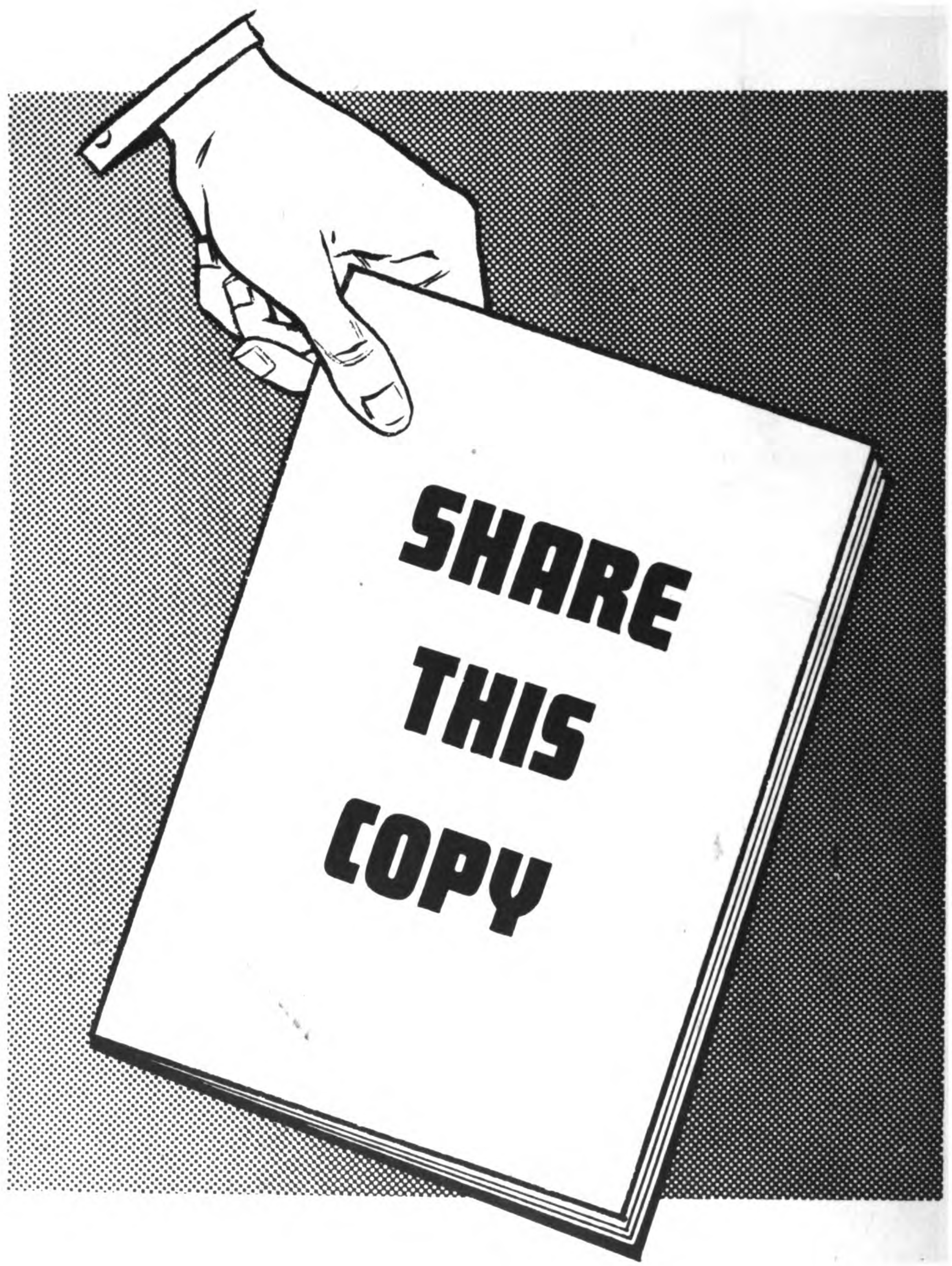
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