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RESEARCH REVIEWS

- STUDYING PLANT CELLULOSE
- JAPANESE SCIENCE AND TECHNOLOGY
- THE BIRTHPLACE OF STARS
- YIELDING OF MILD STEEL
- ON THE NAVAL RESEARCH RESERVE

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
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NAVEXOS P-510

CCVER PHOTO: Star pictures like this one made by the Mount Wilson Observatory 100-inch telescope are helping scientists to devise theories of the way in which the universe was formed. The dark shape shown in the center is the Horsehead Nebula, a cloud of matter which absorbs light from more distant stars. Many such clouds are now known to occupy the so-called "voids" of space. The part which these clouds may play in the formation of new celestial bodies is discussed in Dr. Lyman Spitzer's article, "The Birthplace of Stars" on pp. 12 to 18 of this issue.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research

Contents

JANUARY 1951

DEPARTMENT OF THE NAVY ★ OFFICE OF NAVAL RESEARCH ★

New Impetus For Basic Research

For a long time the existence of the Office of Naval Research has constituted the most tangible evidence that our Nation had recognized the immense promise which science offers us, not only in safeguarding our security, but also in assuring our progress in essential peacetime endeavors. Actually, the establishment of ONR was the first major step in granting the scientist his rightful place beside the statesman and the military man as a key figure in "promoting the general welfare."

The year which just ended added two important advances in our country's efforts to accord science its rightful place in the national scheme. It seems appropriate at this time to examine these developments, in the light of their relationship with ONR in the years ahead.

As the result of the Hoover Commission's study of the State Department in 1948, a committee headed by Dr. L. W. Berkner was appointed to study the role of science in foreign policy. Its recommendations led to new endeavors in international relations. First, a Science Office, headed by Dr. Herman A. Spoehr, has been established in the Department of State; second, plans have been made to establish science staffs at selected United States diplomatic missions abroad. ONR took an active part in the formulation of plans for both these new activities. Dr. Thomas J. Killian, the Research Group's Science Director and Deputy, served on Dr. Berkner's committee, and other ONR personnel also contributed their services by making special studies. This ONR participation was a natural outgrowth of the similarity between goals of the State Department program and those of ONR. It is reasonable to expect that close cooperation between the two groups will continue. Obviously, any progress made by the State Department in promoting a more facile flow of scientific information between nations will greatly assist the ONR program. Moreover, the existence of the ONR London Branch Office offers possibilities for expediting the establishment of the State Department's central science office in western Europe.

The year 1950 saw a great advance not only in protecting our scientific interests abroad, but also in furthering scientific progress at home. The National Science Foundation Act finally established what scientists and legislators had been striving for since 1944--an agency to assume broad responsibilities for promoting basic research and developing scientific talent. Naturally the question of ONR's relationship with this group is of great importance. At present there is general agreement among the committees of RDB that the Department of Defense, following Navy's lead, should be allowed and, in fact, encouraged, to continue the support of basic research at approximately the present levels. Naturally the Foundation program will result in some modifications of the military contract research program, but it is too early to predict the exact nature of these changes. But one thing, at least, is certain--ONR's five years of experience in the support of basic research should provide guidance to the new agency in setting up its own program.

The National Science Foundation and the State Department's Science Office culminate years of earnest, cooperative effort by scientists, administrators and legislators, and show significant progress in the Government's efforts to further the cause of research, both here and abroad. ONR was instrumental in this progress and will continue to make every possible contribution in the era of scientific development which lies before us.

FIGURE 1. CUTTING MICROSCOPIC PLANT SECTIONS AT — 19° C

Studying Plant Cellulose

by
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Cellulose is not only the basic raw material in many industries; it also has a long list of critical military uses. In plants it serves a structural purpose similar to that of an animal's skeleton. Plants, having no such bony frame, depend on rigid walls around each cell. These walls are composed mainly of cellulose, which is usually combined with other substances, though in some plants it occurs in a nearly pure state. The usefulness of plant cellulose depends in part upon its purity and in part upon the actual structure of the cellulose walls.

The plant forms cellulose from carbon dioxide which it absorbs from air, and from water which it absorbs through its roots. The process involves a complex series of chemical reactions. First, the carbon, hydrogen, and oxygen obtained from carbon dioxide and water are combined, by the green chlorophyll pigments, with energy from light to form carbohydrates. These include sugars and starches. Many of them are used up in the various chemical processes within the plant;

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others are synthesized, with addition of other elements, into fats or proteins; some are built into cellulose.

There is an important difference between cellulose and most other plant substances. The sugars, starches, fats, and proteins are all what the biologist calls metabolic substances--that is, they all have some part in the various life processes of the plant. Cellulose, on the other hand, is a purely structural substance. Once it is formed into the frameworks which surround the cells, it cannot be further utilized in the metabolism of the plant.

The natural formation of cellulose is one of the most economical manufacturing processes in existence. To accomplish it, plants (provided only with the ordinary conditions necessary to their growth) are able to make use of raw materials which are available in unlimited quantities. Furthermore, plants are exceedingly versatile in the formation of cellulose; some make products so crude that they can only be used to supply the paper pulp industry; others produce types of cellulose fine enough to supply high grade textile industries.

Because of the efficiency of the process, secrets of natural cellulose formation have long been sought. If we can learn the exact mechanism by which plants manufacture this substance we may be able to step up its synthetic production. This would have both practical and purely scientific advantages.

The practical aspects are obvious. Some kinds of cellulose products were in short supply during World War II, and may again be scarce in the present national emergency. Even now expanded civilian populations are making increasing demands upon existing supplies. Moreover, if we knew the details of cellulose manufacture in plants, we should have certain leads in the development of synthetic materials to substitute for, or to improve upon, those naturally available. Again, the ratio of cellulose to proteins, fats, sugars and starches is one of the determining factors in the food value of many plant products. A knowledge of the basic processes of its formation is a prerequisite to any designed attempts to alter relations between the production of cellulose, which as such has no human food value, and the production of food substances. These, of course, are the practical applications of cellulose research. The scientific applications are equally important. As an end reaction in a scheme of carbohydrate metabolism, the formation of cellulose has a particular biological significance; so do the chemical reactions and processes which precede its actual formation. Some of the facts derived from research in this field are bound to be of considerable value in general studies of carbohydrate metabolism relating to nutritional and medical problems in man and other animals.

Most attempts to study the formation of cellulose have concerned themselves with cotton, because this plant is economically so important and because its fibers are so nearly pure cellulose. In a way this has been unfortunate, because in cotton fibers so much cellulose is formed so rapidly that it is next to impossible to study the early processes by which the plant actually manufactures the material. It seems likely that a better source of information would be a study of some plant materials in which the cellulose is formed in smaller amounts, and less rapidly. For this purpose the corn plant is particularly useful because in certain parts of the root tips moderate amounts of cellulose are formed.

Moreover, a fair body of knowledge is available on the structure and chemical activities of these particular plant parts.

Roots of all plants grow principally by the activity of a relatively small number of cells located at the tip. These cells divide, sometimes at an amazingly rapid rate, and form new cells which become a part of the main root. These rapidly dividing root tip cells are actually embryonic units comparable in many respects to animal egg cells before they have begun to grow and before they have become differentiated into organs or parts of organs. Because of their embryonic nature, they provide an opportunity for studying cellulose in the very earliest stages of its formation.

The study of these early stages, however, involves certain technical difficulties. The root tips themselves are about half the size of the point of an ordinary lead pencil. Each one contains thousands of microscopic cells. The actual investigation is concerned with the cell walls and with the relations of chemical substances present in the cells to those present in the walls. Unfortunately the newly formed cell walls are something less than 1/50,000 of an inch in thickness! To study their structure it is necessary to handle them through a whole series of chemical and microscopic analyses. Furthermore, it is first necessary to remove the cell contents so that fats, proteins, and noncellulosic carbohydrates do not interfere with accurate analysis of the walls.

The problem of dealing with these extremely thin structures has been solved, in part, by techniques for preparing microscopic sections which are themselves only about 1/40,000 of an inch thick. In such sections it is often possible to find wall segments, spread out flat, from which all the adhering cell contents have been removed. The method for cutting such sections involves infiltrating the root tips first with paraffin and then with celloidin. This builds up a matrix which holds the individual cells and their walls firmly in position so that they can be cut with a microtome (a special instrument for cutting microscopic sections). The actual sectioning is then done in a room in which the temperature is held at -19°C (Figure 1). At this temperature the fragile pieces of root tissue embedded in paraffin and celloidin are sufficiently rigid to be cut extremely thin. But the procedure is by no means easy, for at this temperature a great deal of static electricity is built up. Even when all the instruments are grounded it is not possible to keep the thin sections from adhering to the microtome or suddenly floating off in the air to some other object. Moreover, it is impossible to do precision work for any extended period at this temperature. The procedure described, however, appears to be the only practicable method for producing ultra-thin sections of this type of material, and after certain details of the technique have been mastered, good results can be obtained.

Once this is accomplished, it is relatively easy to prepare the sections for study with either an optical or an electron microscope. A picture of these extremely thin walls of young plant cells can be obtained through the use of selective stains which color the cellulose but not the other wall components nor the cell contents. Examination shows that the walls of newly formed cells (unlike those of older cells, which constitute the source of cellulose fibers) contain only a relatively small amount of cellulose embedded in what appears to be an extremely thin proteinaceous layer (Figure 2). An open lattice-like arrangement of the cellulose in young cells develops into much heavier layers as the cell ages. The rate of change can be estimated, and differences in the cellulose structures can be correlated with various tissue functions such as support, translocation, or the mechanism of certain chemical processes. Once such a picture of the structural development has been obtained, it becomes possible to study certain chemical processes involved in the conversion of sugars to cellulose.

Among the handiest tools for investigating chemical activities in organisms are the radioactive elements. In this case radioactive carbon and radioactive phosphorus are most useful, since phosphorus is an important element in plant nutrition and carbon is a key element in cellulose. Radioactive carbon, designated as carbon^{14}, can be incorporated in carbon dioxide, which the plants will absorb through their leaves just as they absorb ordinary carbon dioxide (Figure 3). Once the radioactive element is within the plant its atoms can be traced by Geiger-Müller counts or by radioautographic methods. Their course can be followed through the plant from one organ or tissue to another, and through the sequence of chemical compounds of which they become a part as the result of chemical activity within the plant.

Cellulose, as an end product of certain carbohydrate reactions, represents the end of the trail for many carbon atoms in the plant. As an atom in sugar, fat, starch, or protein, carbon can be transferred by the plant's chemical activity to some other compound, and in a sense it just goes around and around within the plant's protoplasm. Once it is incorporated into cellulose, however, it is no longer available for any other use. Naturally, radioactive carbon atoms which become a part of the cellulose continue to emanate radiations. Their presence can be detected and used to study the compound of which they are a part.

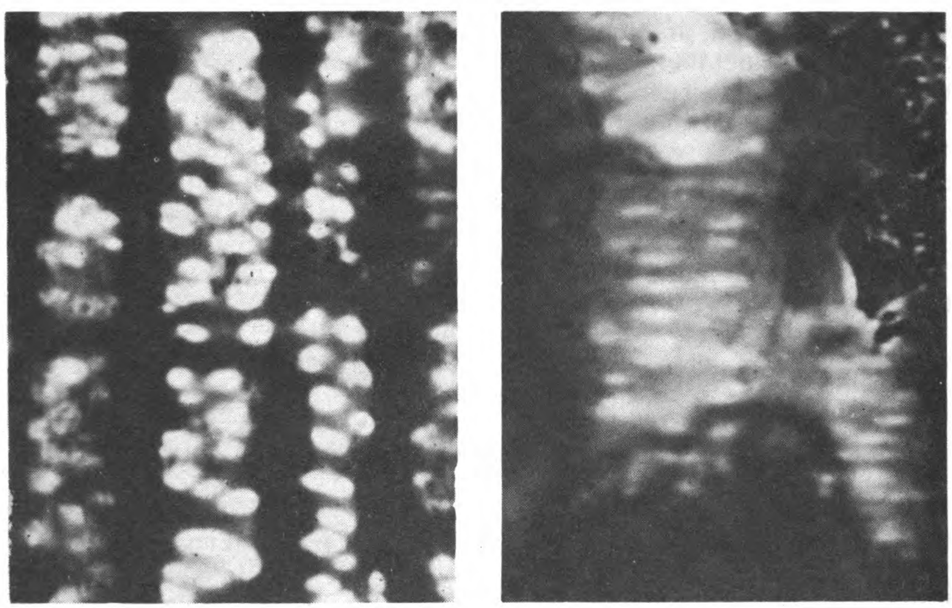

Figure 2. Photomicrograph of young cell wall (left) shows lattice-like distribution of cellulose, with large, non-cellulose areas. Photomicrograph of much older cell wall (right) shows sheet-like arrangement, with smaller and less distinct non-cellulose areas.

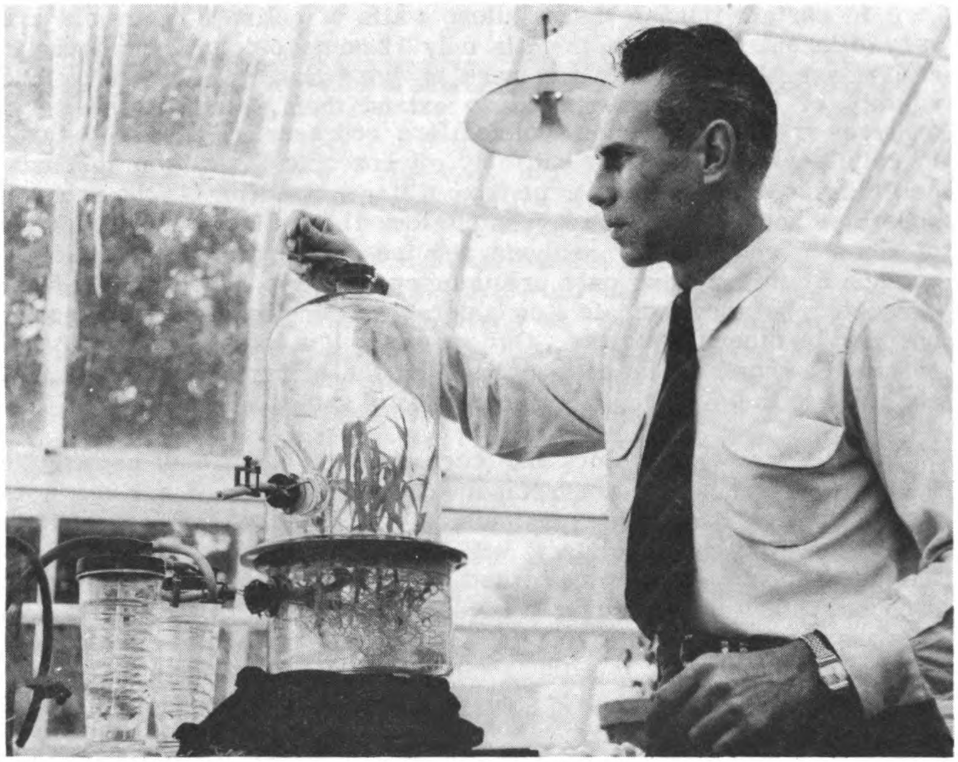

Figure 3. Young corn seedlings get a dose of radioactive carbon dioxide.

One of the best detection mediums for this particular study is a special emulsion which is very sensitive to radioactivity. Ultra-thin sections of plant roots are allowed to absorb radioactive carbon, then placed on emulsion-coated microscope slides. After a suitable exposure period the emulsion can be developed into a picture of the radiation paths from the carbon atoms. Since the technique involves adhesion of the thin root sections to the emulsion, the final preparation contains a picture not only of the radiation paths but also of the radiating root section. Thus, it is possible to pinpoint the location of the carbon atoms in the particular part of each cell in which they are lodged. In this way the biosynthesis of cellulose can be followed very closely by the accumulation of radioactive carbon atoms.

A limitation is that carbon occurs in all living cells, cellulosic or not. Hence, there are no clear-cut distinctions between the radioactive carbon atoms of cellulose, proteins and other cell components. A partial distinction can be made, however, when carbon tracer pictures are compared with those from other radioactive substances. This is where radioactive phosphorus becomes useful. Phosphorus, a key element in plant nutrition, is normally absorbed by the roots, along with other mineral elements in a water solution. For experimental purposes phosphorus can be introduced through the roots, or by special methods through the stems or leaves. Its role in the various substances formed within the plant is fairly well understood. Although it accumulates in considerable amounts in certain substances, it does not enter the cellulose molecules. Thus a correlation of radioactive carbon behavior and radioactive phosphorus behavior should give some leads regarding certain processes involved in cellulose formation.

In certain tissues the cellulose walls of cells 48 hours old are very different from those in cells only 12 hours old, or from those in cell masses which are forerunners of other tissues. To assure the validity of tracer results, and to extend them, standard chemical analyses are being made on root sections representing different stages in cellulose wall development. By microscopic dissection methods, cell masses of different ages or from different positions in the root are separated and analyzed. Progress is slowed by the fact that preparation of samples adequate for analysis requires dissection of thousands of roots. At this writing only preliminary analyses have actually been conducted, but they indicate a considerable extension of the information obtained by other techniques. Our results so far indicate that we shall eventually know a great deal more about the biosynthesis of cellulose and its part in the biochemical processes of growth and life.

Until much more work has been done, it is difficult to evaluate fully the importance of understanding certain phases of carbohydrate metabolism as they relate particularly to cellulose synthesis. It is likely, however, that such facts will have a bearing upon practical attempts to supply either more or better types of natural cellulose or to produce synthetic substitutes. It is also expected that this research will help answer questions relating to carbohydrate metabolism which are of so much importance in nutrition and hence in our planning of nutritional programs.

It is already apparent, too, that some of the adaptations of methods which have been developed will find considerable usefulness in research undertakings far afield from this particular cellulose problem.

Nutrition Conference to be Held in London During January under ONR Auspices

Representatives from various branches of the Nation's Armed Forces will attend a nutrition conference to be held under ONR auspices in London from 25 January through 1 February. Mr. William V. Consolazio, Head of ONR's Biochemistry Branch is already in London for the purpose of attending the meeting. Others expected to be present include representatives of Britain's Food Ministry and nutrition experts from various American universities and laboratories, many of them ONR contractors.

The general aims of the conference are to exchange information acquired since World War II on food problems, and to formulate some general conclusions about the state of knowledge of nutrition. It is expected that the conference will provide valuable information to ONR and other agencies within the Armed Forces on the problems associated with formulating realistic and productive programs in nutrition.

Japanese Science And Technology

by
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The recent emphasis on industrialization of countries in Asia draws attention to Japan's potential role in the introduction of technology to her neighboring nations. Since the Orient is industrially the most undeveloped region in the world, great transformations could be brought about there with presently available technology. Although Japan has been open to western ideas for only about eighty years, she has effectively learned to adapt them to her local problems and could therefore act as an intermediary in the industrialization of other eastern nations.

Because of her short period of contact with western technology and her isolation prior to and during the last war, Japan is roughly 15 years behind England and the United States. Exceptions to this are found in the applied fields indigenous to Japan--sericulture, agriculture, and fisheries--where the Japanese show outstanding skill not only in practical methods, but also in the application of recent scientific research. In some subdivisions of these fields Japan may possibly lead the world.

In the fundamental sciences Japan has learned to appreciate research and contribute to the advancement of knowledge. She has made major contributions to mathematics, physics, biology and chemistry. Throughout her isolation during the war, she was able to keep abreast of the field in theoretical nuclear physics. Only last year Hideki Yukawa was awarded the Nobel Laureate for his contributions to the meson theory. But the social structure in Japan and scarcity of equipment have restricted her contributions, except in a few instances, to the theoretical sciences.

Curiously, this creative ability of the Japanese has seldom been applied to industry. Industrial technology appears to have been directly imported from the West whereas fundamental science is deep-rooted. The theory has been advanced that the slave system in ancient Greece prevented an industrial revolution even when such brilliant scientific advances as Euclid's geometry were being made; it can likewise be reasoned that the feudal system in Japan discouraged the native development of that technology which had to be imported. The advances Japan made in sericulture, agriculture and fisheries were brought about primarily by her intelligent and industrious farmers and fishermen. She has had numerous brilliant scholars in the theoretical sciences, but these talents even today are rarely applied to practical problems.

Since the end of the war several noteworthy attempts to overcome the gap between fundamental science and industry have been made in Japan. The new Science Council of Japan and a governmental Scientific and Technical Administration Commission have been formed and private industrial laboratories such as the Scientific Research Institute have been organized. This Institute, formerly a non-profit organization called the Institute of Physical and Chemical Research (Riken), at one

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time received support both from private and governmental appropriations. The new Institute is a private corporation dependent solely on profit from its technical developments. It has some of the outstanding scientists in Japan on its staff, which is headed by Yoshio Nishina, an internationally known physicist. If the gap between science and industry is filled, it will be by such organizations as the new Institute and by a really effective coordination between the laboratories and plants of the larger industries.

England and Germany had the greatest prewar influence on Japanese science. Germany's influence, which was particularly prominent in medicinal fields, seems to have led to no significant scientific contributions to Japan during the war. A good illustration both of England's prewar influence and its effects can be obtained from an account of Professor J. A. Ewing's visit to Japan. From 1878 to 1883 Ewing was a Professor at the University of Tokyo, where he worked with the Japanese on his early researches in magnetism. The Japanese were encouraged by Ewing's success in carrying out research with the limited facilities available to him and rightly trace their own success in one of the few isolated cases of effectively applied science to the inspiration of his visit. Professor Kotaro Honda, one of the men Ewing influenced, received prizes from the Royal Society, the Faraday Society, and has had his commercial methods of producing magnetic metals adopted in western nations. After Ewing's visit, Japan recognized the need for trained personnel to build their railways, steamships and telegraph systems, and began negotiations to start a college of engineering. The first intensive construction of communication systems was started by foreigners after the ratification of the first treaty with Europe and America. Negotiations for training technical men were initiated by requesting export-import firms in Yokohama to import good teachers. An order was communicated to the Jardine-Matheson Company, who requested aid from Sir William Thomson, well known to the Company for his success in laying the Atlantic cable. Highly interested in the subject, Thomson promised to send some of the best graduates of the University of Glasgow to Japan. Among the men who went were Dyer (mechanical engineering), Divers (chemistry), Milne (mining), Ayrton (electricity), Perry (mathematics), Gray (telegraphy) and Alexander (civil engineering). This group formed the nucleus of the first college of engineering in Japan, called the Kobu-Daigaku.

At present Japan's technological problems are highly complicated. In an area about that of California she has a population of 80 million, increasing at the rate of about one million per year. Moreover the country at present can raise only about 80 percent of its food, since there are very limited natural resources. In addition, foreign nations have imposed trade barriers, partly due to Japanese actions during the war.

To meet this grave economic problem, Japan has industrious people, competent scientists, and the ability to adapt western technology to her indigenous needs. She hopes to use this imported technology plus her native scientific talent to conserve her limited resources through improvement of manufacturing industries which serve the export trade. It may also be possible for Japan to sell services of her technicians to neighboring nations interested in industrialization.

The other nations of the Orient are likely to imitate Japan by first developing agriculture, fisheries, ceramics and textile industries. Japan is eager to exchange technical know-how and manufactured goods for food and raw materials from her neighbors. She can export equipment for irrigation, fertilizing, transportation and communication, all necessary for industrialization.

Science During the Occupation

The occupation of Japan is controlled by the Supreme Commander of Allied Powers (SCAP). Part of SCAP's function is to implement the directives of the Far East Commission regarding science and technology. A thorough survey of Japan's scientific potential showed that she had contributed little scientifically toward the war effort. Some of her scientists had ideas for developing homing bombs and proximity fuzes but these never got beyond an elementary laboratory stage.

Japan is still prohibited from conducting any research with military applications. These limitations were based on the Potsdam recommendations and the Far Eastern Commission directives. The Japanese were informed that only research and teaching for the extension of scientific knowledge would be permitted. But economic limitations proved to be the real curb on research. SCAP has not emphasized restrictions, but has instead encouraged the scientists to tackle the immediate and pressing problems associated with food, clothing, housing, health and export.

There are no limitations on theoretical research in any field, or on publication of results. SCAP encouraged Japanese scientific organizations to resume their normal peacetime associations with international groups by allotting a limited amount of dollar and sterling funds for this purpose. The percentage of the national budget for science and technology was raised from 0.3 to 0.75 per cent, and emphasis was placed on those projects which could aid economic recovery. International mails are now open for the exchange of scientific and technical periodicals, books or manuscripts. Technologists are permitted to accept invitations from foreign institutions, but because of the pound or dollar shortage, expenses usually have to be supplied by the foreign institution.

Compared with the rest of Japan, the laboratories survived the bombings fairly well. Most damage was inflicted on those connected with industrial establishments although a few universities also suffered severely. The laboratories at the University of Literature and Science in Hiroshima and Nagoya Imperial University were probably the most severely damaged. Many others, for example those at the Imperial Universities of Tokyo, Kyoto, Kyushu and Hokkaido suffered no destruction.

The invading troops damaged some scientific apparatus, but considering the circumstances the damage was not great. Most publicity has been given to the destruction of four cyclotrons in Japan but this may even have helped Japanese science, for it drew attention to the place of science in society and the necessity for being reasonable.

Reorganization of National Bodies of Science

The occupation's fundamental policy on reorganization of the national scientific bodies was that any lasting reformation had to be initiated and implemented by the Japanese themselves. Occupation officials worked closely and on an equal basis with the Japanese scientists. Two groups from the United States National Academy of Sciences were sent to Japan to discuss problems of scientific organizations.

There were three important national scientific organizations in Japan at the close of the war--The Imperial Academy, The National Research Council and The Japan Society for Promotion of Science. The first two were governmental; the last, though private, received most of its money from the government. The functions of the three overlapped in some respects and the younger scientists in Japan considered that the old groups were not representative or effective. The more active scientists requested an opportunity of presenting plans for improved organizations. After long study by the Japanese, their Diet abolished the National Research Council. A new Japan Science Council (JSC) was chosen by election on 20 January 1949. The voters were the qualified scientists of Japan who numbered some 40,000. The present top officers of the Council are Dr. Naota Kamayama (Dean of Engineering at Tokyo National University) President; Dr. Yoshio Nishina (President of the Institute of Scientific Research, Ltd.) Vice President for Natural Sciences; and Dr. Sakae Wagatsuma (Professor of Law at Tokyo National University) Vice President for the Social Sciences and Humanities. Election of officers and members is to be held every three years. The Council consists of the following divisions:

Division 1	Literature, Philosophy and History
Division 2	Law and Politics
Division 3	Economics and Commerce
Division 4	Natural Sciences
Division 5	Engineering
Division 6	Agriculture
Division 7	Medical Sciences, including Dentistry and Pharmacy.

Each division has 30 members who represent various subdivisions and seven geographical districts of Japan.

The word "science", as used for organizational purposes in Japan, includes all fields of higher learning. The functions of the Science Council of Japan are (1) to promote science; (2) to introduce it into government and industry; and (3) to represent the scientists of Japan at home and abroad. It can be called upon by the government for advice on such matters as:

1. Distribution of grants and subsidies for scientific research.
2. Administration and budgets of governmental institutions and laboratories.
3. Guidance in researches, and in training scientists in universities or their attached institutes.

The Council is now a member of the International Council of Scientific Unions. National Committees have been formed for liaison among some 20 branches of science, including physics, chemistry, astronomy, botany and zoology. Some of these committees are members of International Unions.

On 20 January 1949 The Japan Imperial Academy became The Japan Academy of Science, an honorary organ of the Science Council, set up to award prizes for outstanding research. New members to the Academy are chosen by a joint committee of its own members and representatives of the Science Council.

A governmental body called the Scientific and Technical Administration Commission (STAC) was also formed on 20 January 1949. Its function was to help the government coordinate its scientific and technical interests in the various Ministries and to maintain close contact between governmental agencies and JSC. The present membership of this Commission consists of 10 representatives of the Science Council and 10 Vice-ministers of the Cabinet. The Prime Minister is the Chairman of the Commission. Article 2 of Law No. 253, 1948, which set up STAC states:

"The Commission shall deliberate and make recommendations on the following matters:

(1) Measures necessary for reflecting the reports or recommendations made by the Science Council of Japan to administrative bodies;

(2) Selection of matters which are to be referred to the Science Council of Japan for consultation by the Government;

(3) Method of execution of international enterprise concerning science and technology which should be carried out by the Government;

(4) Liaison and coordination of matters relative to science and technology which are under the jurisdiction of the government administrative agencies."

The explosion at Hiroshima dramatically demonstrated the status of science. Orientals have also realized that they must recognize the sociological and economic implications resulting from science. Since they live in the most undeveloped areas of the world, they recognize that their countries must undergo the greatest transformations. Although Japan is still far behind the West she has learned much about how to apply technology to local problems and could aid her neighbors in these transformations. A continuing study of the effects of this industrialization should be made in order that both the East and the West can direct their activities toward better understanding and cooperation.

Data for this article was gathered by Dr. Kelly during his stay in Japan, where he served as chief of the Army's Scientific and Technical Division. In connection with his work there Dr. Kelly was recently elected an honorary member of the Physical Society of Japan as a "sincere expression of gratitude for . . . contributions in assisting the rehabilitation of the Japanese field of physics." The election marked the first time that such an honor has been conferred by the Society. The American Physical Society also honored Dr. Kelly recently by appointing him midwestern representative of its Division of Electron Physics. His task will be to encourage research in this important field.

The Birthplace Of Stars

by
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Princeton University Observatory

A few decades ago astronomy was almost entirely concerned with the study of stars. Analysis of these huge radiating spheres of gas had provided a useful application of basic physical laws, and, in many instances, had led to important advances in physical theory. In particular, study of the stars provided the first indication of how nuclear energy might be released on a large scale.

It was only recently realized that there is about as much matter floating around between the stars as inside them (Figure 1). Now, the analysis of this interstellar matter (which consists mainly of enormously rarefied gas) has become an important part of astrophysics. Such studies have yielded information on the properties of matter under conditions not available in the laboratory. One result of such research, for example, was the first indication that an atom could emit radiation in the so-called "forbidden" lines. Another was the development of techniques that are now used to analyze the earth's upper atmosphere.

The results which these studies have yielded are important not only because they have many direct applications to terrestrial problems but also because they cast some light on cosmogony (origin of the universe), a topic which has fascinated men for centuries. Current research may increase our understanding of the formation of stars which seem younger than the rest of the universe and whose existence seems directly related to the presence of interstellar clouds.

Most stars, although they are much larger and more massive than the earth, and about as bright as the sun, are not very conspicuous among the myriads of other stars. There are a few, however, called "supergiants" which emit some ten thousand times as much light and heat as the others. The life spans of these brilliant bodies were calculated by determining the time required to burn all their hydrogen to helium. In the course of this process (which is the apparent source of all stellar energy) four hydrogen atoms combine to form one helium atom; thus, the amount of nuclear energy generated in a star composed initially entirely of hydrogen was readily calculated. It turned out that the supergiants, by astronomical standards, were short-lived for it was estimated that they burn themselves out in a mere hundred million years! The earth and most of the stars, on the other hand, are known to have existed for three billion years. Hence, a supergiant has a life span of

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Parts of this article were published in the September 1948 issue of Physics Today.

Figure 1. Luminous cloud of gas and tiny particles in the Constellation Sagittarius, photographed with the 100-inch Hooker telescope of the Mt. Wilson Observatory.

less than one tenth the age of the universe. Since there is no known way in which a star can remain dark for a long period of time and then start to emit light, we conclude that the supergiant stars now shining must have been formed in some way within the last hundred million years. Of course, nuclear physicists may have overlooked some important process by which a star can radiate a much larger fraction of its mass than the hydrogen-into-helium process liberates.

Assuming that these stars have, in fact, been "born" within the last hundred million years, the mechanism for their formation is a problem which astronomers may investigate with some hope of success. Within this interval, conditions in the universe have apparently not changed very much; therefore studies made now may actually indicate how supergiant stars originated in the past, and may even be developing at the present time.

The clouds of matter which float about between the stars are an obvious source of material for star formation. Recent investigations show that these clouds are, in fact, so closely associated with supergiants that a physical connection between them seems very likely.

In brief, observations reveal supergiant stars only in those aggregations of stars where interstellar clouds of matter are also present, i.e., only in spiral galaxies. These are flattened, disk-shaped systems some hundred thousand light years in diameter. Each one rotates about an axis perpendicular to the plane of its disk. The characteristic feature of these systems, from which they derive their name, is a pair of arms which apparently come out of the central nucleus and wind around the system (See Figures 2 and 3).

In the elliptical galaxies--which are not rotating so rapidly, are not so flattened, and show no spiral structure--no supergiant stars are found. In fact, long-exposure plates at the Mt. Wilson Observatory have shown that the stars in these systems have a sharp upper limit on their brightness, the so-called "critical" brightness; no star exceeding the critical brightness can be found, while below it myriads of stars appear on the photographic plate. This result is in marked contrast to spiral galaxies, where there are always one or two brilliant and a number of dimmer supergiants, and a gradually increasing number of fainter and fainter stars. This sharp upper limit on the brightness of stars in elliptical galaxies is just what one would expect if no new stars had been

Figure 2. Spiral galaxy in the Constellation Virgo, photographed with the Hale 200-inch telescope of the Mount Palomar Observatory

formed since the beginning of the universe, and if the brightest ones had burned up all their fuel and gone out.

Detailed examination of galaxies also indicates that clouds of matter between the stars are found only in spiral systems. In elliptical galaxies the vast stretches between the stars are very nearly empty, but in flattened spiral galaxies like our own there is about as much matter between as inside the stars. This association between obscuring clouds and supergiants is strengthened by the fact that in the closest galaxy, the great nebula in Andromeda, these bodies occur in exactly those regions where the obscuring clouds are most prominent.

Before we can accept the hypothesis that supergiant stars have, in fact, formed from these clouds we must investigate whether or not there is some process which could condense interstellar matter into stars. In this way we are led to consider the physical nature of the stuff between the stars, and the forces operating therein.

The dominant constituents of interstellar matter are believed to be individual atoms. These atoms absorb or emit light of particular wave-lengths, which can be measured accurately by use of the spectroscope. Measurements show that the density of the gas is about one hydrogen atom in each cubic centimeter, with other elements present as slight impurities. Thus, the interstellar medium is a much better vacuum than is ever obtained in a terrestrial laboratory. If a fly were to breathe a single breath into a vacuum chamber as big as the Empire State Building, the resulting density of the air would still be much greater than the density of the interstellar gas. Recent work has shown that the clouds of this gas are each about 20 light years across and

Figure 3. Spiral galaxy photographed edge-on with the 60-inch telescope of the Mt. Wilson Observatory.

move through space at varying velocities, ranging from 10 to 20 miles per second. Much more information is needed about them before any detailed conception can be formed of the way in which stars develop.

In addition to the separate atoms drifting about in space, small solid particles, or grains, are also present. Each grain is about 0.01 mil (0.00001") in diameter; 10,000 placed end to end would make a line about as long as a period on this page. Since their size is just about equal to the wave-length of visible light, they are most effective in absorbing and scattering light waves. Thus, these particles cause the general obscuration produced by the clouds shown in Figure 4. Particles of smaller size are presumably also present, but these do not produce such a noticeable effect, and can therefore not be detected.

The properties of these particles have been determined from accurate measurements of the obscuration which they produce in light of different wave-lengths. The grains seem to scatter more than they absorb; hence it seems likely that they are dielectric (nonconductors of electricity) rather than metallic in composition. If, as seems likely, these grains were produced by the cohesion of individual atoms, the enormous abundance of hydrogen relative to other elements would be expected to produce solid hydrogen compounds, in particular, ordinary ice. However, impurities of all other elements would also be present.

Studies of grain distribution indicate that their clouds are apparently identical with the gaseous clouds already described. Thus, whatever pushes atoms into clouds also pushes the grains together.

To discuss in detail how matter in space can condense to form new stars we must determine the physical conditions. In particular, we must combine observational evidence with our knowledge of basic physical principles, if we are to reach any conclusion about the forces acting on the different particles. Only in this way can we predict how the interstellar medium will behave under widely varied conditions.

In the immense vacuum between the stars, an interstellar particle spends most of its time moving in a straight line without interruption. Occasionally, one of two encounters may occur: With another interstellar particle, or with a light wave (photon). Physicists have not learned as much about such processes as astronomers would like, but they know enough for an approximate evaluation of effects produced by these various collisions.

Collisions between interstellar atoms and grains help determine the temperature of matter in space. Most collisions are elastic and the kinetic energy of the different particles is merely exchanged, so that velocities are distributed as in thermal equilibrium at some particular temperature. Photoemission of electrons from atoms or grains (on absorption of photons) raises temperature; inelastic collisions between atoms and grains lower it. Near a very hot bright star the gas will be heated up to about 10,000°K (18,000°F) but in other regions a temperature of about 100°K (-280°F) seems likely. This difference of temperature between regions is believed to produce cosmic currents, or winds, just as winds are produced on earth.

Some interstellar particles adhere on collision. Thus atoms form molecules, molecules stick together as larger molecules, and grains grow by slow accretion. This process was analyzed during the war by a number of Dutch astronomers, who found evidence that interstellar grains have probably evolved thus within the last few billion years. More accurate physical information on collisions at low energies is required to make this theory more quantitative.

Collisions between grains and photons are also important in star building; it is well known that light exerts pressure. Since starlight in a galaxy comes from all directions in the galactic plane, a single grain may be knocked this way or that by photon collisions, without any net motion. However, when several grains are present, shadows of one on another unbalance light's pressure, and photons striking from unshaded sides push the grains toward each other. The resulting force of attraction between grains is several thousand times greater than their gravitational attraction.

The further we go away from observational data the more uncertain our theories become. The mechanism of star formation is still in

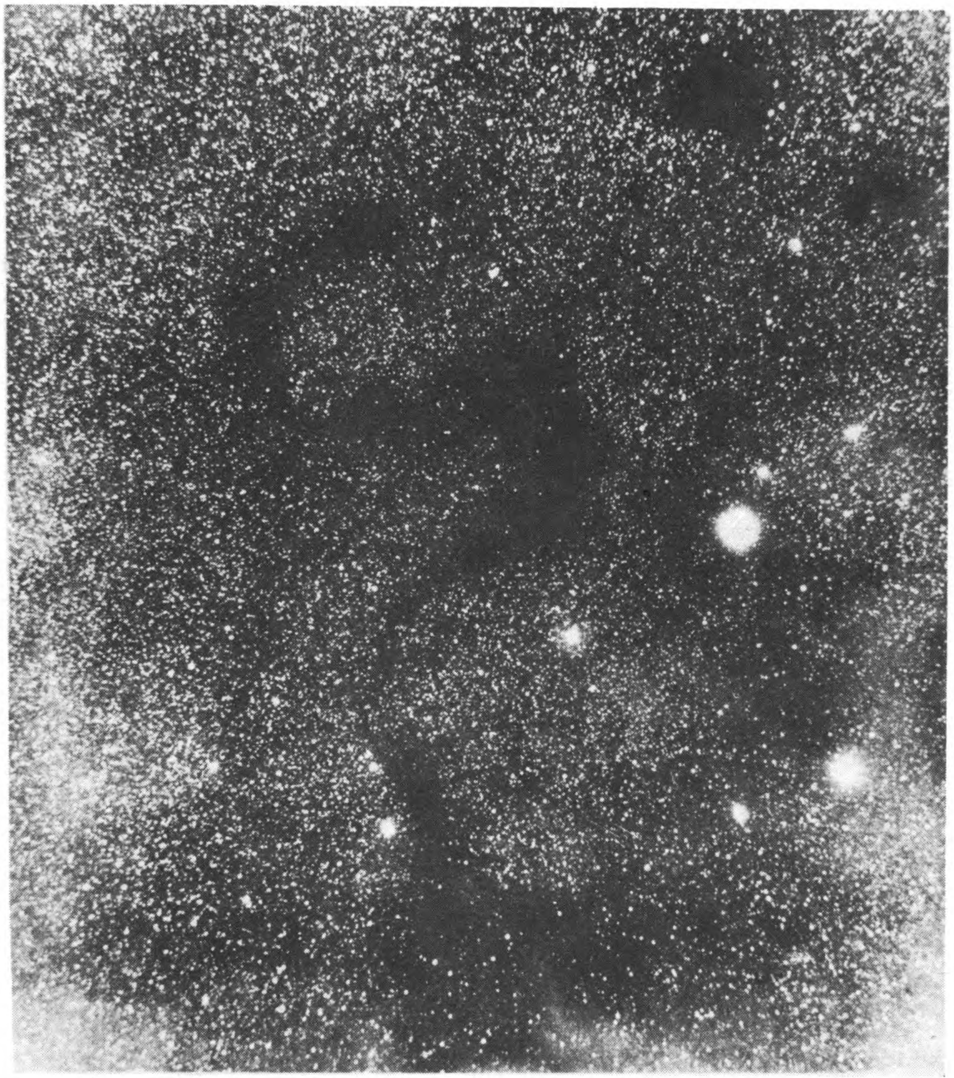


Figure 4. Compact dark clouds in the Milky Way. These objects may be protostars, contracting to form new stars

a rather speculative state. However, putting all the available information together does provide a reasonable preliminary picture of a process by which stars can be formed from interstellar matter.

It starts with an interstellar gas, formed at the same time as the rest of the universe. The first step is slow condensation of interstellar particles from the gas. After these particles have reached a certain size, photon pressure forces them together and they form, in about ten million years, an obscuring cloud. In this cloud, where density of grains is high, temperature tends to be low. In the surrounding region the high temperature produces high pressure, compressing the low-temperature, low-pressure cloud and increasing gas density in the cloud. This corresponds to the observed result that a cloud of grains is also a cloud of gas.

Currents produced by differences of temperature and also by the general rotation of the galaxy will tear some of these clouds to pieces;

but forces of condensation pull them together, and some clouds may be expected to go on contracting. The pressure of light becomes ineffective when the clouds become more opaque, shutting out the light. At this point gravitation takes over and tends to produce a further contraction. In this stage a cloud has a diameter of a light year or less. Small opaque clouds of this type, called globules, have been known for some time.

At least one serious difficulty impedes the acceptance of this mechanism. According to Newton's laws, the globule would whirl faster and faster as it contracted, tending to hurl itself to pieces before it ever became a star. Turbulent effects in the interstellar atmosphere and certain electrical effects, have been proposed as possible answers.

This picture of star formation is still in a formative stage. The work in progress is being carried out cooperatively by a number of astronomers all over the world. Perhaps when the 200-inch telescope probes further into thé secrets of space, and when progress in experimental and theoretical physics teaches us more about interstellar processes, we can outline with more assurance the detailed steps by which supergiant stars may be forming almost before our very eyes.

News of ONR Laboratories

Three Developments Announced by Naval Research Laboratory

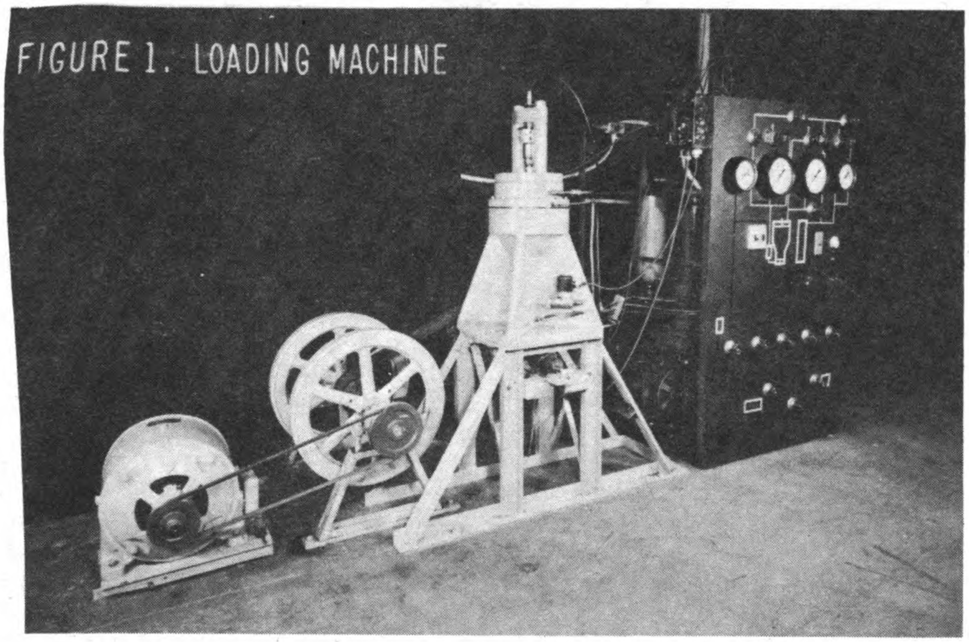
Two new badge-type devices have been developed for indicating how much radiation individuals have received. One of these **dosimeters**, as the devices are called, uses normally transparent salt crystals which turn blue upon exposure to gamma rays. The darker the blue, the greater the exposure. The other dosimeter uses a type of glass which, after it has been subjected to radiation, turns orange under ultraviolet light. Both devices are durable, inexpensive and simple to produce. They represent the latest developments in a program that began at the time of the Bikini tests, when single-dose indicators were needed to show how much radiation experimental animals had received.

* * *

A **filter paper** made of glass fiber has been developed. It is expected to be highly useful in gas masks and other military equipment. Tests have shown that the paper is 5,000 times more effective than commercially available filters. The new product is also simple to produce, and can be made with domestically available materials.

* * *

As the result of improved methods for processing **asbestos**, the United States is no longer dependent on foreign supplies, which until now were indispensable because of their high degree of purity. A new way has been found to remove from fibres grown in North America impurities which until recently had prevented their use in important military applications. The asbestos fibres are now cleaned by washing them instead of fluffing them with high-speed air or screening them. Fibres purified by the new process are suitable for use in electrical insulation. When Canadian asbestos, originally dull gray in color, was washed by this method, the product was bright white, and of excellent quality.



Yielding Of Mild Steel

by
D. S. Clark and D. S. Wood
California Institute of Technology

All materials deform in varying degrees under load. Although this is most obvious in a substance like the rubber in a tire, the phenomenon also occurs in the strongest steel. When the material returns to its original shape upon removal of the load, the deformation is termed elastic; when, on the other hand, the change in shape is permanent, it is called plastic. In any case, it is important for the designer to know how the degree of deformation is related to the size of the load.

Since the relation varies for each material it must be determined experimentally. It is usually presented in the form of a tensile "stress-strain" relation. Stress is the load per unit of cross-sectional area, applied axially to a bar of the material, while strain is a measure of the proportionate change in length of the bar. To calculate this relation, successively increasing stresses are applied, and the strain is measured for each value. Special machines have been devised for these tests. One such device is shown in Figures 1 and 2.

Donald S. Clark, Associate Professor of Mechanical Engineering at California Institute of Technology, received B.S., M.S., and Ph.D. degrees from that institution. He has been actively engaged in research on the dynamic properties of metals since about 1934, and is the author of a book, "Engineering Materials and Processes."

David S. Wood, who also received B.S., M.S. and Ph.D. degrees from CIT, is Assistant Professor of Mechanical Engineering there. In 1944 and 1945, he was employed at the Los Alamos Scientific Laboratories in New Mexico. Prior to this, he was engaged in research on propagation of plastic deformation waves in metals at the Institute under an NDRC contract.

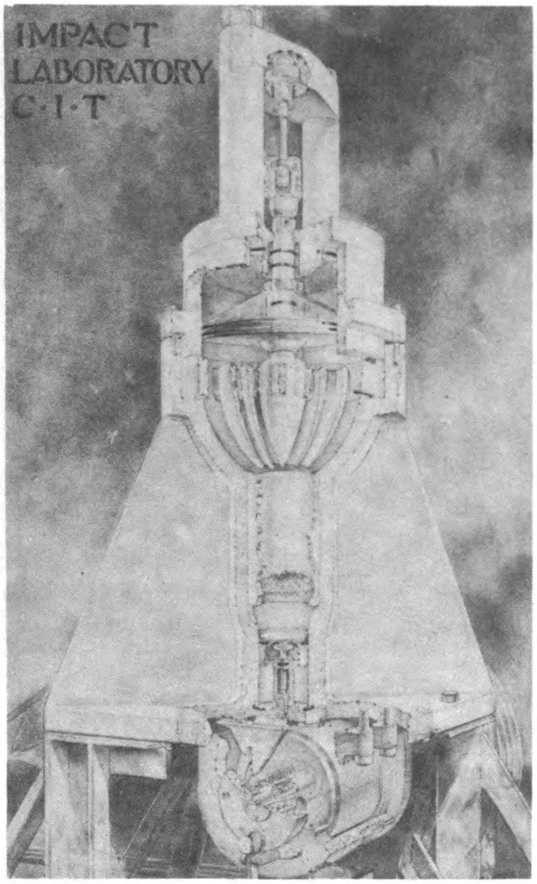


Figure 2. Cut-away view of loading machine.

The stress-strain relation typical for most materials is of the form shown in Figure 3, where the first part of the curve is a straight line. Along this line strain is elastic and directly proportional to stress. Beyond this first portion, the stress-strain relation is curved, and the strain is plastic. This means a stress exceeding the elastic limit has been applied, leaving a permanent strain in the bar.

Naturally the stress-strain relation of the most commonly used metal--mild steel--is of great interest to engineers, particularly because it behaves uniquely when subjected to stresses exceeding its elastic limit. Figure 2 shows that the stress-strain relation of this plain low-carbon steel is just like that for most other substances until plastic deformation begins. When this point (a in Figure 4) is reached, the stress decreases abruptly (to point b). Yet after this decrease in stress the material continues, from b to c to deform without the application of any additional load. In other words, up to a point, mild steel requires increasing stress to produce increasing strain; when the elastic limit is reached, however, strain continues to increase, even though there has been a sudden decrease in stress. This is called yielding; a and b in Figure 4 represent the upper and lower yield points respectively. Although the phenomenon has been recognized for many years, the mechanism by which it occurs has not been fully established.

Stress is not the only factor determining the yield point, for time also plays an important part.

To find out how long it takes for yielding to begin, a special machine was designed and constructed under a contract with the United States Air Force. With this device a specimen can be loaded to any desired stress up to 200,000 lb/in.^{2} within a period of seven milliseconds (0.007 second). Provision was made to measure the applied stress and the strain during the test as functions of time and to record the results on cathode-ray oscillographs. Figure 5 shows that after the stress reaches the value (x) for which the machine has been set, it remains constant.

Figure 4 shows the strain (x′) which corresponds to this stress. When the stress becomes greater than the static upper yield point (a in Figure 4) yielding will begin, but only if such stress is maintained for a certain amount of time. In other words, before the material starts to yield, it requires a conditioning period, which is called the delay time (t_0 to t_1).

When tests of this character are made at various constant stresses, different delay times are observed. In Figure 7, the constant stress is plotted against the logarithm of the delay time. The curve shows a stress considerably above the static lower yield point (b in Figure 4) can act for a short time without initiating plastic deformation. With higher stress, this time becomes shorter. This characteristic is significant to engineers who use mild steel, for it is apparent that stresses greater than those normally allowed in a structure can be tolerated provided they act for a very short period.

Delayed yielding is but one manifestation of the initiation of plastic deformation in mild steel. Some aspects of this mechanism are known, but many of its features are imperfectly understood. It is desirable, both for scientific and for practical reasons, to obtain a better

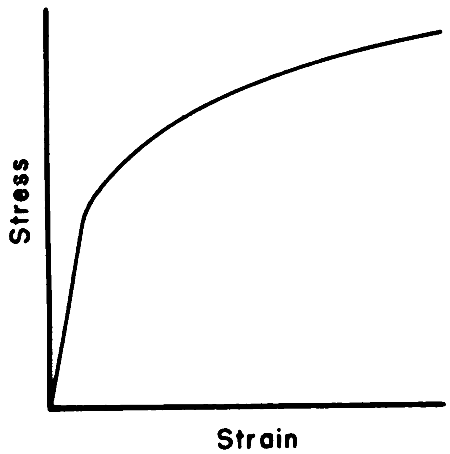


Figure 3. Stress-strain relation typical of most materials

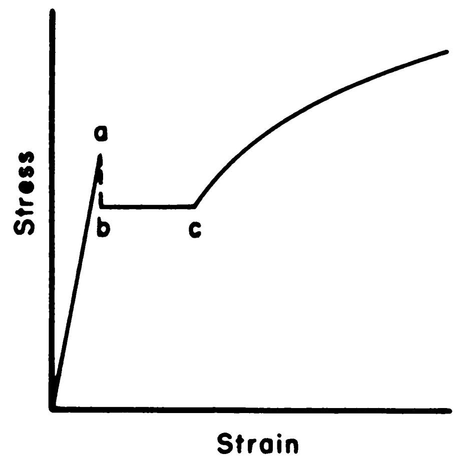


Figure 4. Stress-strain relation for mild steel

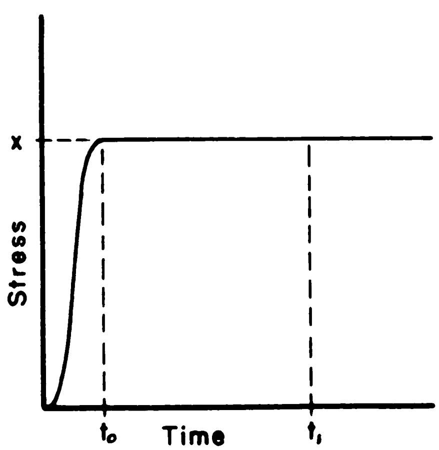


Figure 5. Stress-time relation for mild steel

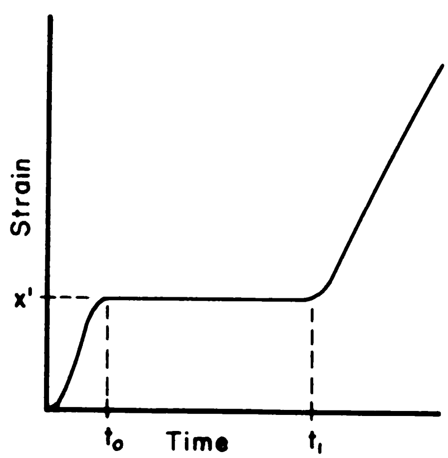


Figure 6. Strain-time relation for mild steel

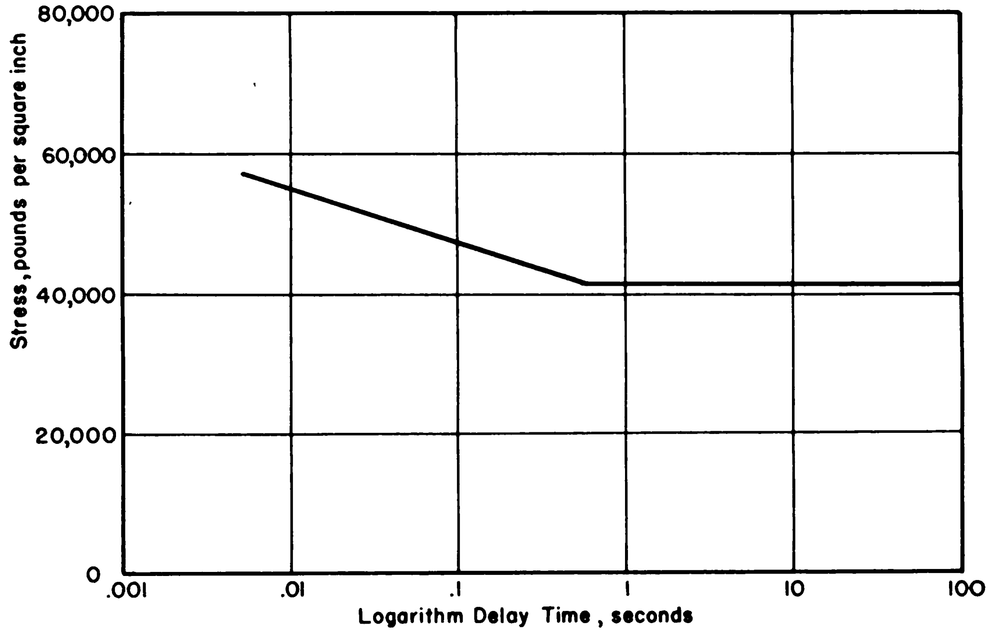


Figure 7. Stress-delay time relation for mild steel

understanding of this phenomenon. The study of mild steel treated in suitable ways and subjected to controlled external influences should aid us in doing so.

Temperature is one of the external influences which is of considerable interest in this connection. To study this phase of the problem, tests have been made over a range from -75° to 250° F. The results (shown in Figure 8) prove that the higher the temperature the shorter is the delay time. In fact at 250°F and above, the longest delay times are too short to be measured with the present equipment.

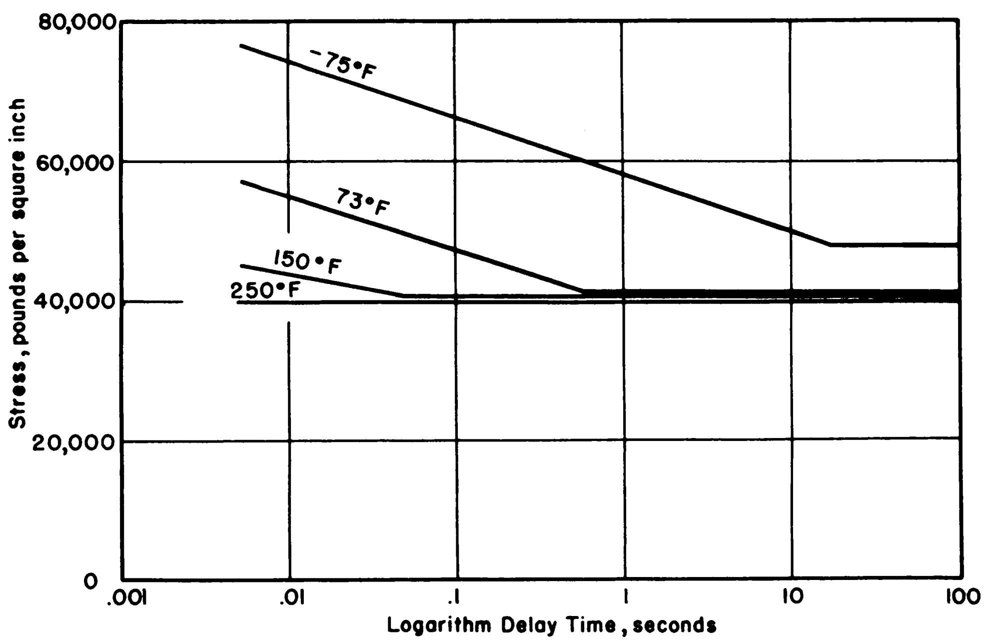


Figure 8. Stress-delay time relation for mild steel at various temperatures.

Another factor which is believed to have an effect on delay times is the amount of carbon and nitrogen in the steel. There has been rather good evidence that yielding is attributable to the presence of these two elements. Some investigators have removed practically all the carbon and nitrogen from mild steel, and the yield point has disappeared. The question then remains--when this is done, is the delay phenomenon eliminated?

To explore this phase of the problem, samples of mild steel have been treated in wet hydrogen to remove most of the carbon and nitrogen. When this was done, the yield point was eliminated, and the material had a stress-strain relation of the type shown in Figure 3. When the rapid load tests were made, however, a delay time for the initiation of plastic deformation was observed. When samples of the decarburized and denitrided steel were slightly recarburized and renitrided the static stress-strain relation was once again the type shown in Figure 4.

These results give substantial evidence that carbon and nitrogen play an important role in yielding, but so far a good picture of the mechanism has not been formulated. Research is being continued, however, in the expectation of learning more about the fundamental characteristics of engineering material.

Navy's Trainee Program Offers Employment Opportunities

The opportunity of working with well-known scientists in some of the world's finest laboratories is now offered to college students majoring in science or engineering. The Navy Student Aid Trainee Program, established to help in recruiting promising young scientists for Government work, makes it possible for sophomores and juniors (and in a few cases graduate students) to obtain summer employment in their chosen fields.

The trainee program offers the student a dual opportunity--the chance to acquire valuable experience and to earn money at the same time. Students who have completed at least one-half, but less than three-fourths of their training for a bachelor's degree will be assigned a GS-3 rating. Those who have finished three-fourths of their undergraduate work, but have not yet attained a degree, will be qualified for GS-4 positions. Higher grades may occasionally be offered to students working for advanced degrees or to those with appropriate working experience. The required educational credits must all be completed by June 30 of the year in which the student expects to be employed.

In addition to the educational requirements, the applicant must pass certain tests. One of these is an examination covering his knowledge in his own field of specialization. He is also tested on his spatial visualization, on his ability to evaluate scientific hypotheses and on his facility at mathematical formulation. Examination dates will be announced.

The opportunities of this program are not limited merely to one summer's employment, for in most cases these employees can return to their positions the following year. Those who are still undergraduates are qualified to resume training at a higher grade, while those who have received their degrees can often obtain permanent positions at GS-5 or GS-7 levels. In most cases applicants have a wide choice of locations, for the jobs are not only scattered throughout the United States, but are also available in some of the territories and even in foreign countries.

On the Naval Research Reserve

CIVIL DEFENSE III

Second Nuclear Science Seminar Held

Radiological defense, which today has become so important in the Nation's planning, was the theme of the Second Annual Nuclear Science Seminar, held last month in Oak Ridge, Tenn.

About sixty-five delegates from eastern and midwestern Research Reserve units received the latest information concerning defense against the effects of atomic attack. Armed with this information, Research Reserve units will be able to continue their assistance to local civil defense authorities in planning training teams for radiological defense.

RADM T. A. Solberg, Chief of Naval Research, made the opening remarks to the Reservists:

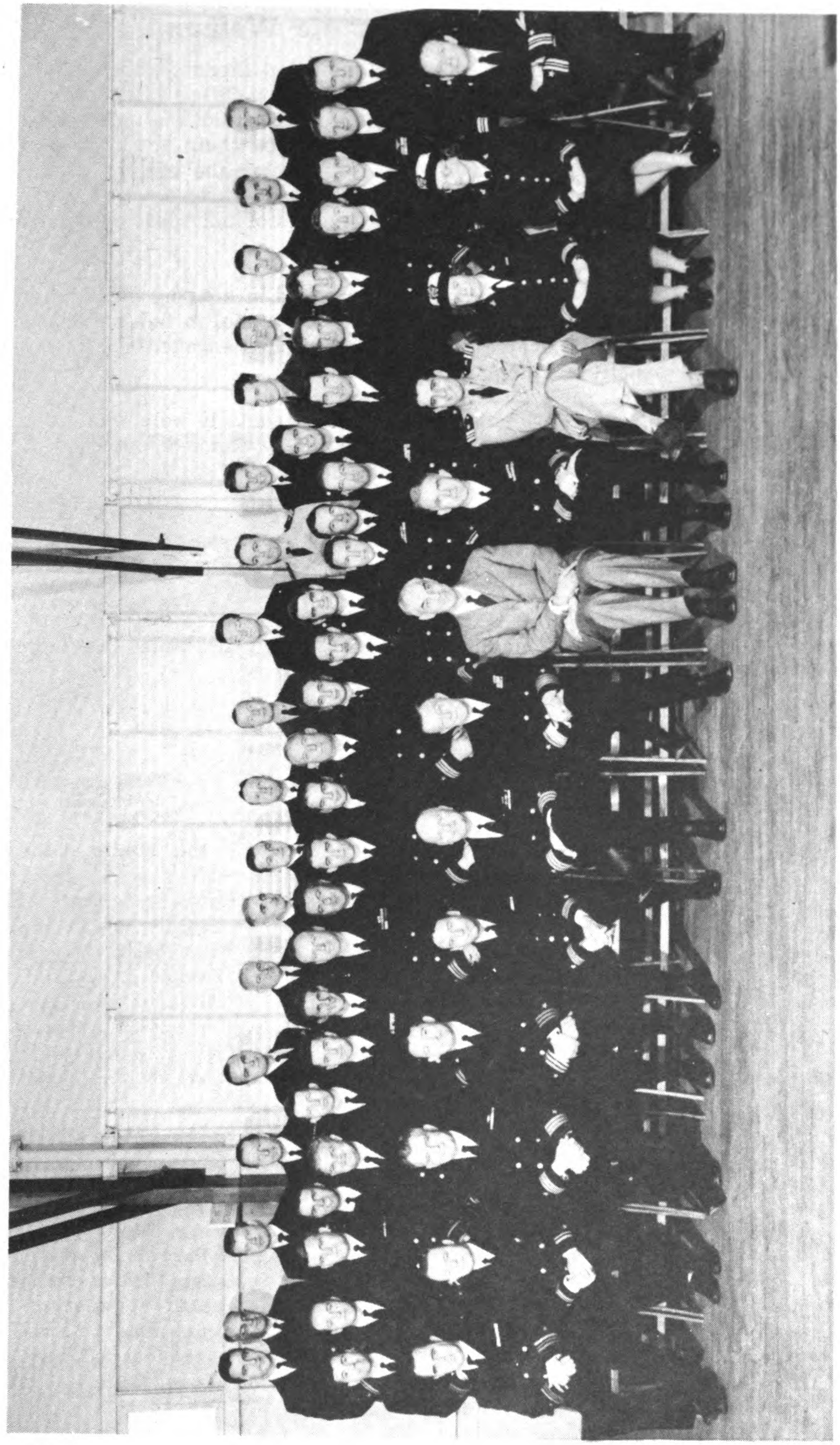
"I am indeed pleased to see that the Research Reserve has this year selected as their primary theme radiological defense, thus establishing the second annual seminar as an outstanding event in the history of the Research Reserve.

"Inasmuch as the present international situation has resulted in an accelerated program of atomic defense plans, this course in radiological defense should aid you in establishing the Research Reserve as an advisory agency in the over-all civil defense effort."

RADM R. W. Hayler, Commandant, Sixth Naval District, also welcomed the Reservists. Later a detailed discussion of the problems of radiological defense was given by RADM Garrett L. Schuyler, USN (ret.) who is Consultant on civilian defense research for the National Security Resources Board.

During the rest of the seminar the delegates heard a series of lectures by experts in every field of radiological defense. These talks included explanations of the basic mechanism by which atomic energy is utilized, descriptions of the medical aspects of atomic explosions, and discussions of methods of radiological defense. There were also demonstrations of special devices, and tours of the Oak Ridge facilities.

Reservists who attended the seminar were, left to right, first row: LCDR D. J. Mallon, LTJG R. O. Hutchison, CDR W. M. Richardson, CDR E. Hribar, LCDR B. R. Fisher, CDR F. L. Edmundson, RADM T. A. Solberg, RADM G. L. Schuyler, CDR R. Mayhew, LCDR P. Vissat, LT M. B. Mitchell, LTJG B. R. Porter, LCDR J. D. Baer; second row: LTJG A. Faloon, LTJG J. D. Train, ENS V. M. Kimmick, ENS D. A. Pitt, LTJG C. H. McBeth, LTJG P. F. Deisler, Jr., LT R. Radford, LTJG J. A. Rider, LCDR E. Meader, LCDR N. Cedrone, LTJG R. W. Kenniston, LTJG R. M. King, LCDR A. R. Robertson, LT G. Price, LCDR W. H. Lockman, LTJG N. Nolan, LTJG R. A. Moss, LTJG R. E. Loy, LTJG E. K. Parker, LTJG J. T. Holloway, LT M. Eicher, LT L. Brown, LTJG J. H. Coleman, LTJG R. E. Hall, LCDR A. B. Phillips, ENS E. B. Woods, LCDR W. A. Barker; third row: LTJG G. Murray, LCDR M. B. Gilmore, LTJG H. Brockington, LCDR W. E. Peterson, LTJG W. S. Johnson, LT K. R. Plank, LCDR J. R. Maloney, LTJG M. C. Laug, LCDR H. F. Rode, LCDR B. Powell, Jr., ENS E. Walker, LT P. Close, LTJG C. J. Clark, LTJG G. V. Wheeler, LTJG M. Schuessler, LTJG W. R. Smith, LCDR R. L. Simon, LTJG B. H. Whiteaker.



Second Annual Nuclear Science Seminar

News Items from Units are Welcome

The Reserve Section of Research Reviews is intended as a medium for exchange of information between the Washington Office and Research Reserve units scattered throughout the country. Some of the units, however, have been unduly modest about reporting on their activities and plans. We therefore wish to remind all CO's that the editors of the Reviews are interested in receiving material for articles on any activities in progress or in prospect. Accomplishments of individual members are also of interest.

Remember that other units are interested in hearing about what your group is doing. Such information may be useful in helping newly organized units to plan projects or in giving groups engaged in similar activities the benefit of others' experiences.

Pictures to accompany news items are especially welcome; even snapshots are often usable. All material will be returned (on request) after it has been used. It should be addressed to:

Director, Research Reserves
Office of Naval Research
Washington 25, D. C.

Items to be published in a particular issue should reach this office by the first of the previous month; otherwise printing deadlines preclude their use.

Visual Education: From this studio at the Special Devices Center, a lecture on a jet engine is being telecast to naval bases and to units of the fleet which are in port. This is one of the Center's many activities to which Reservists on training duty there may be assigned. In this connection members of VNRR units are reminded that two-week courses, starting on the first Monday of each month, are now available at the Center. The first two days of the course cover the background of synthetic training, the history, mission, organization, and functions of the Center. During the remaining time trainees participate in actual work. Since facilities are limited, it is necessary to screen applications carefully to make sure that training is assigned to Reservists who will derive the maximum benefit from it. To facilitate the screening the Center provides a Reserve Officer questionnaire, Form 3ND-SDC-7-13, which must be submitted by the applicant with the request for duty.

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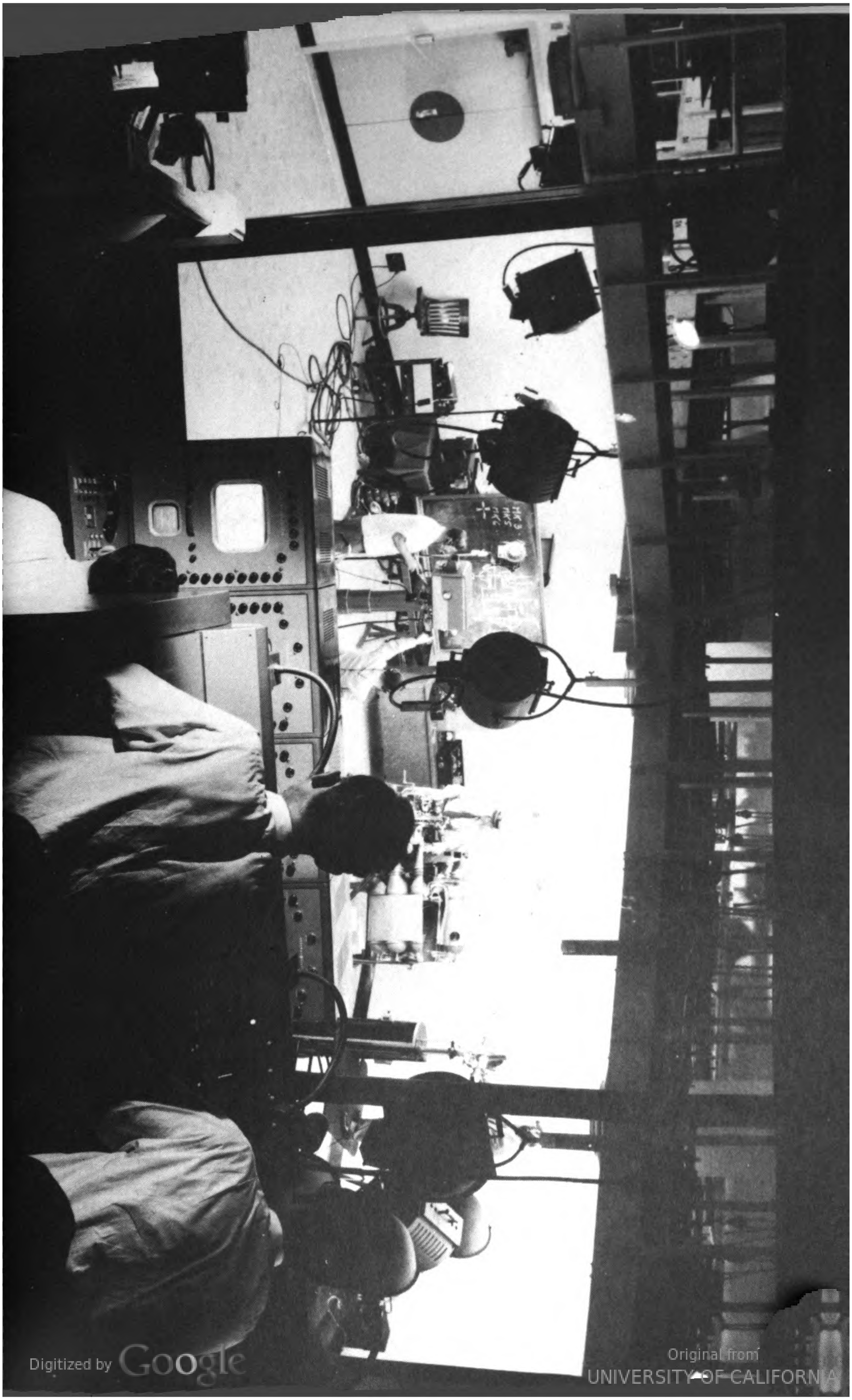

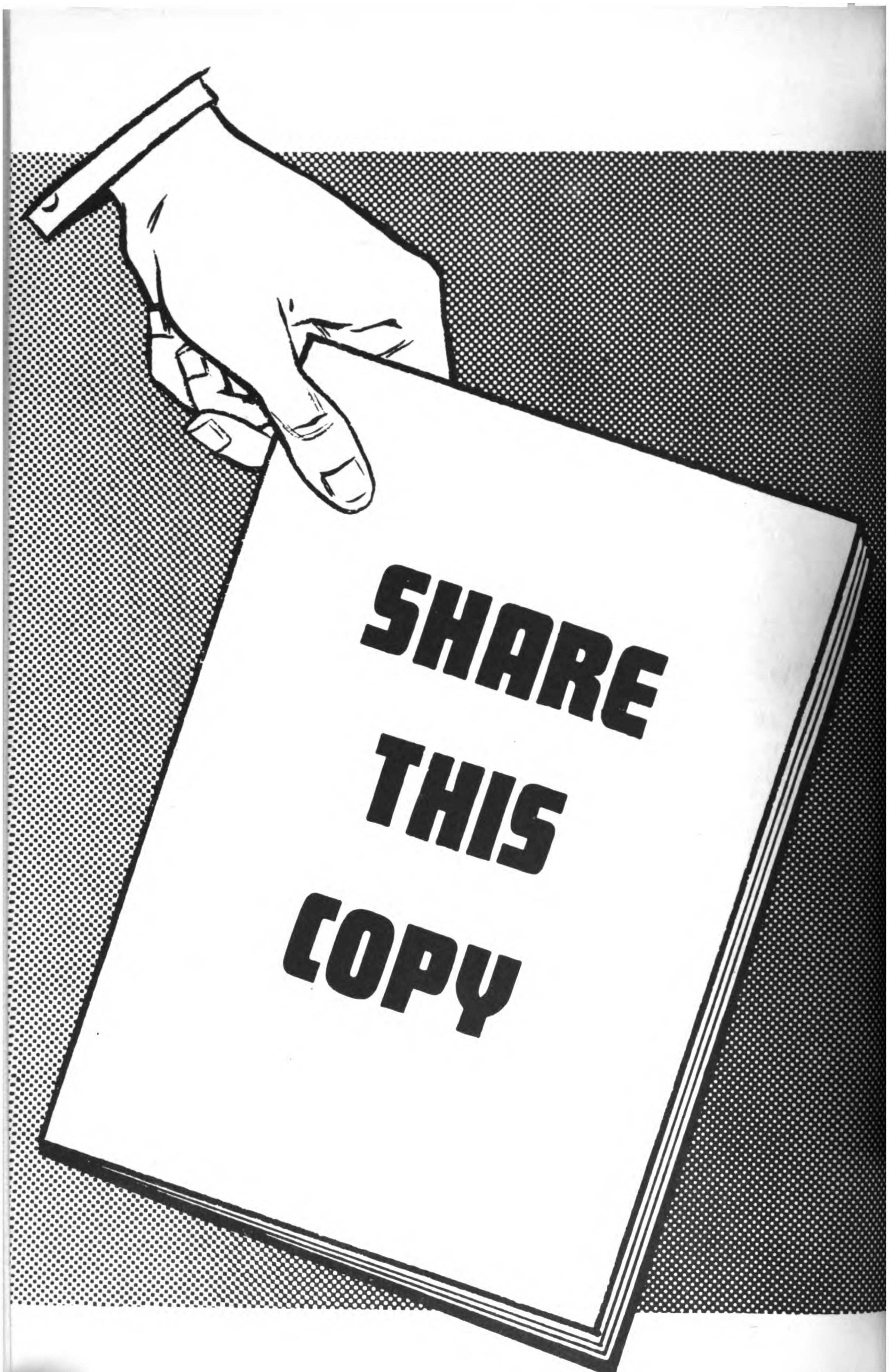
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