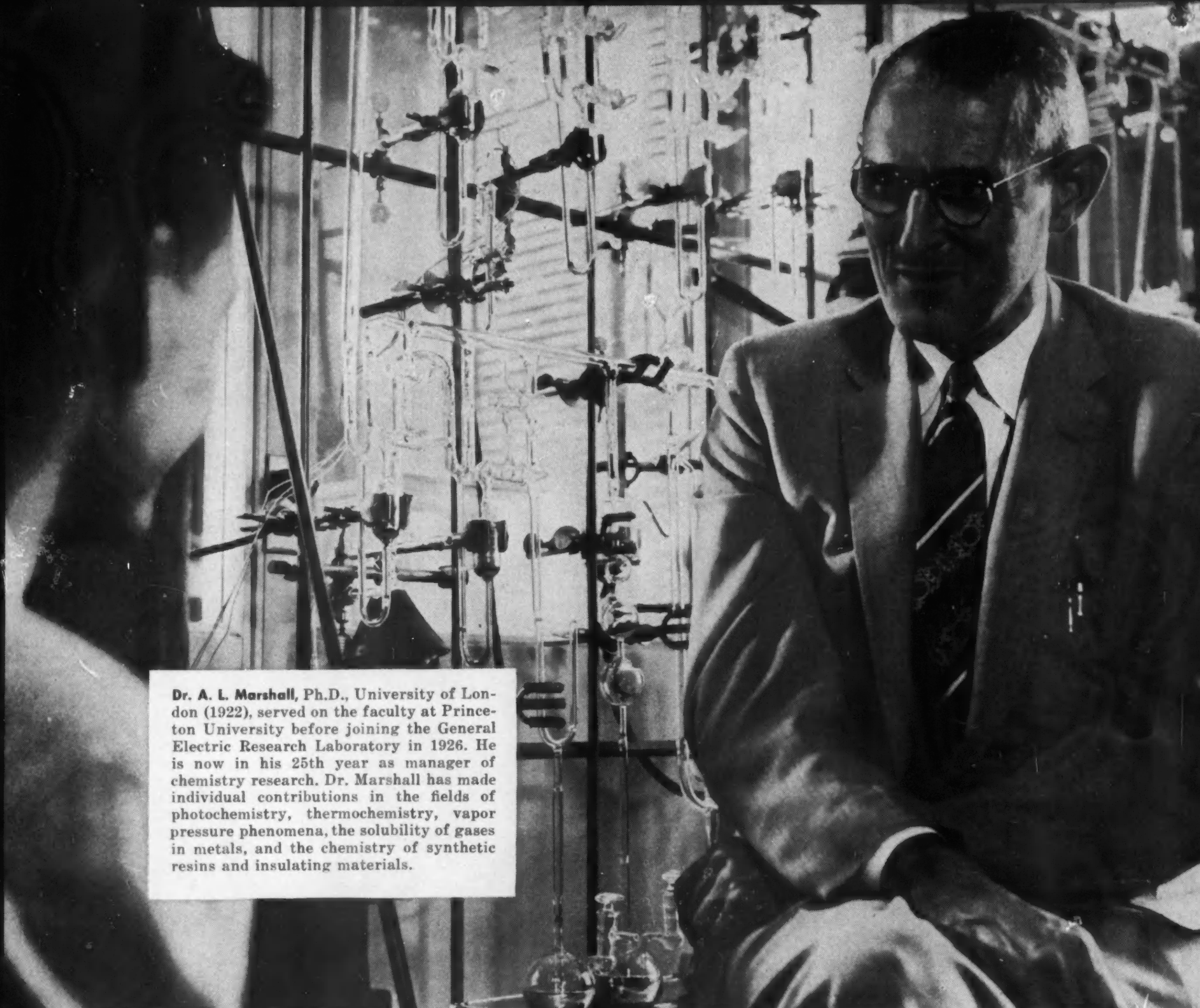
GENERAL ELECTRIC
Review
NOVEMBER 1957

Researchers in organochemistry, looking for a better insulating material, come up with a plastic so tough you can maul it with a heavy hammer, and . . .

Triple-Exposure Photo

A Newborn Synthetic Material Challenges Metals

PAGE 14



Dr. A. L. Marshall, Ph.D., University of London (1922), served on the faculty at Princeton University before joining the General Electric Research Laboratory in 1926. He is now in his 25th year as manager of chemistry research. Dr. Marshall has made individual contributions in the fields of photochemistry, thermochemistry, vapor pressure phenomena, the solubility of gases in metals, and the chemistry of synthetic resins and insulating materials.

Chemistry in the electrical industry

The work of Dr. A. L. Marshall shows why research in chemistry is vital to General Electric

The problems of *electrical insulation* prompted the electrical industry's earliest interest in chemistry. Dr. A. L. Marshall was among the first to realize that getting better electrical insulation would depend heavily on getting fundamental facts about polymers, and under his leadership the primary goal of chemists at the General Electric Research Laboratory has been a "*new understanding* of basic structures and basic reaction mechanisms."

New knowledge has led inevitably to new products: silicones, improved wire enamels, irradiated polyethylene, and many others. It has helped produce materials with potential for *structural use* as well as insulation. Dr. Marshall predicts that within a decade the electrical industry may have as much need for plastics as for steel.

He also has directed his philosophy of basic research toward other areas. In *superpressure, friction studies*, and *combustion*, for example, the eventual results from new scientific knowledge can be seen in such things as man-made diamonds, better bearings, and jet engine combustors.

Dr. Marshall's leadership in fundamental research is another reason why scientists at General Electric are uncovering new knowledge that can contribute to better living standards for people today and for generations to come.

Progress Is Our Most Important Product

GENERAL ELECTRIC

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Review

NOVEMBER 1957 VOLUME 60 NUMBER 6

The GENERAL ELECTRIC REVIEW is issued in January, March, May, July, September, and November by the General Electric Company, Schenectady, NY, and is printed in the USA by the Maqua Company. It is distributed to scientists and engineers throughout industrial, consulting, educational, professional society, and government groups, both domestic and foreign. . . . . The GENERAL ELECTRIC REVIEW is copyrighted 1957 by the General Electric Company, and permission for reproduction in any form must be obtained in writing from the Editor. . . . The contents of the GENERAL ELECTRIC REVIEW are analyzed and indexed by the Industrial Arts Index, The Engineering Index, and Science Abstracts and are available on microfilm from University Microfilms, Ann Arbor, Mich. . . . For back copies of the REVIEW—1903 through 1954—contact P. and H. Bliss Co., Middletown, Conn. . . . Six weeks' advance notice and old address as well as new are necessary for change of address. . . . Send communications to Editor, GENERAL ELECTRIC REVIEW, Schenectady 5, NY.

COVER

One of America's leading industrial photographic teams, the Burns brothers, executed this triple-exposure photo to dramatize the toughness of a newly developed plastic. Red streak of man's swishing arm was burned in during a several-second exposure inside a totally dark studio. Trade-marked Lexan, the new plastic is being produced in pilot-plant quantities (model, background). Its use for the radio cabinet pictured is purely developmental; General Electric's Radio Receiver Department cautions against hitting your own set with a hammer! Though developed for electrical applications, Lexan plastic may one day replace many die-cast metals. For its significance to the materials' outlook, see article on page 14.

Dr. Irving Langmuir spoke frequently of "the freedom that characterizes democracy and is necessary for making discoveries." His contributions to men everywhere should be measured both by the value of his scientific discoveries and by the extent of his efforts to maintain and enlarge the meaning of freedom. All of us who were honored to be his associates are shocked and saddened by his passing but sustained by the unparalleled legacy of knowledge and inspiration he has left us and all the world.

DR. GUY SUITS

Irving Langmuir

Dr. Irving Langmuir, world-famous scientist, died at Falmouth, Mass., on Friday, August 16, 1957, at the age of 76. A Nobel-prize winner, Dr. Langmuir was widely regarded as one of today's scientific geniuses. He worked on the scientific staff of the General Electric Research Laboratory from 1909 until his retirement in 1950.

During his long career at General Electric, the results of Dr. Langmuir's researches saved the American public nearly $1 billion per year in electric light bills, aided in establishing modern radio and television broadcasting, helped safeguard the lives of combat soldiers, and provided man with a key to weather control.

Little known to the layman—but considered of the highest importance—are his contributions to pure science . . .

- His studies on electron emission and on gaseous discharges are regarded as classics.
- His study of molecular films and surface chemistry films on water uncovered an entirely new branch of chemistry.
- Experimental techniques that he developed for studying proteins furnished a new and powerful attack on fundamental problems of the functions of the human organism and are now being used by biochemists and biophysicists throughout the world.

For his accomplishments, Dr. Langmuir received the world's top-ranking scientific awards. Both a chemist and a physicist, he was once described as one "who continually embarks upon mental voyages in regions so nearly airless that only the mind can breathe in comfort."

On such "voyages," he developed new concepts that resulted in many benefits: the gas-filled incandescent lamp, the high-vacuum power tube, atomic hydrogen welding, a highly efficient smoke-screening generator for the military that was referred to by the chemical warfare service as "one of the major triumphs of science in helping fight the nation's war," and methods for artificial production of snow and rain from the clouds.

The gas-filled lamp, further improved by Dr. Langmuir and others after its original development, increased many times the efficiency of electric lamps. It raised lighting levels in workshops, schools, offices, and homes, and made possible the development of the portable projector for home movies.

The high-vacuum power tube, which permitted use of high-voltage in radio sending and receiving for the first time, gave modern broadcasting its "heart" and is regarded as probably the greatest single development that has occurred in this field.

In recent years, Dr. Langmuir, together with his associates Dr. Vincent J. Schaefer and Dr. Bernard Vonnegut, discovered methods by which precipitation can be induced from certain types of clouds. Although proper evaluation may not be possible for many years, this work—conducted when the Research Laboratory had a joint program of weather research with the Army Signal Corps and the Office of Naval Research—could prove to be of great significance to mankind.

With the methods developed by the three scientists, rain may be produced or prevented, hurricanes and large snowstorms may be diverted to unpopulated areas, hailstorms and resultant lightning causing crop damage may be eliminated, and snow removal in congested areas may be lessened.

Among Dr. Langmuir's other major scientific accomplishments were the condensation mercury-vapor pump for producing very high vacuum and a series of highly effective submarine detectors used in World War I. These he developed in collaboration with Dr. William D. Coolidge, retired vice president and former director of research for General Electric.

As an outgrowth of his study of oil films on water, Dr. Langmuir devised a means for optically detecting viruses, toxins, poisons, and other tiny and invisible materials. This method has proved highly useful in biology and toxicology.

Recipient of many of the highest and most coveted of scientific awards, Dr. Langmuir served his profession in several capacities. A member, fellow, and honorary member of several societies, he was president of the American Chemical Society and president of the American Association for the Advancement of Science.

He received honorary degrees from many colleges and universities including Northwestern, Union, Edinburgh, Columbia, Princeton, Lehigh, Harvard, Oxford, Queens (Canada), Rutgers, and Stevens Institute of Technology where he taught chemistry before joining General Electric.

Dr. Langmuir attributed all his accomplishments solely to scientific curiosity and an ability to profit from the unexpected. Of his work, he said, "Whatever has come in industrial applications has come incidentally from experiments followed for their interest alone." Ω

What Is the Real Challenge of the Satellite?

Intensify effort on immediate projects, accelerate our over-all defense program, strengthen our educational system from grade through graduate levels—three important moves to reinforce America's scientific and engineering achievements.

By DR. RICHARD W. PORTER

In keeping with the REVIEW'S *continuing objective of helping its readers keep abreast of significant General Electric research and engineering activities, views, and developments, we present here Dr. Porter's statement of October 12, 1957. This is the Company's first authoritative comment on the news concerning the Soviet satellite.* —EDITORS

Man has for the first time stretched his hand outside the cradle in which he was born. The establishment by Soviet scientists and engineers of the first artificial earth satellite is a tremendously significant accomplishment—of which those responsible can justifiably be proud —both now and for all time. As a citizen of the United States, I naturally wish the accomplishment could have been ours. Since it was not, we should sincerely congratulate Russian scientists and engineers on a difficult job, well and quickly done. Now we should get down to work on our own program.

Serious Competitor

Aside from its obvious importance to scientists and engineers everywhere, this event has a very special significance to the United States. It has demonstrated in dramatic and absolutely unmistakable terms that the USSR must be regarded as a serious competitor in the world of science and technology. This idea is not new. Russian progress in atomic energy, aerodynamics and aircraft propulsion, guided missiles, and in many fields of basic science should have made it abundantly clear for several years that the United States can no longer expect to remain unchallenged in its position of leadership in the basic and applied sciences.

Actually, it has never been any secret that at least 12 years ago the USSR set out determinedly to equal and surpass the United States as soon as possible in all fields of science. There have since been a number of challenges, most of which we have foolishly disregarded or ignored. Today we have a challenge which cannot be overlooked unless we are completely resigned to taking the eventual role of a second-class nation.

The importance of the *Sputnik*, therefore, is not so much that it has come into being several months before, instead of several months after, the equivalent United States test satellite, but rather that its erection was accomplished in a manner indicative of broad skill and experience, and that this basic fund of ability has been acquired in a fantastically short period of time. The trend is clear. Although we have not yet been completely surpassed, we are being surpassed in many fields, make no mistake about it.

Strengthen Technical Curricula

I believe that if we want to reverse this trend, one of the important things we must do is to strengthen a large part of our educational system, beginning with the elementary grades and extending up through the most advanced work in our universities and institutes. Technical curricula will have to be strengthened and foreign languages added, beginning at an early year, so that the exchange of technical information can flow both ways instead of only one way as at present. Perhaps classes will have to run eleven months of the year, as they now do in Russia, instead of eight or nine months as is now common in the United States.

The economic status and prestige of the teachers must be enhanced, incentives provided to make the student do his best, and appropriate opportunities and rewards must be offered to those who can qualify as exceptional students. Better buildings and equipment must be provided. Of course, it will be expensive —but think of the cost of the alternative. We no longer have a choice.

Surely all of our engineers and scientists will understand the meaning of the message our Russian colleagues have sent us. They will really go to work, not just on missiles and satellites—for the next challenge may come in some unrelated field—but in all fields and disciplines, as if they were working for the very future of their families and their nation. For indeed they are. Ω

VANGUARD—A FUNCTION OF MANPOWER, MATERIALS, AND MONEY

Scientists and engineers in the United States have known for a long time how to put a satellite into an orbit around the earth, and tremendous progress has been made in view of the comparatively recent decision to go ahead with this project. (For a definitive article on the satellite's applications, see pages 10–16, September 1956 REVIEW.) General Electric, for example, has developed, built, successfully tested, and delivered to the prime contractor, the first-stage rocket motor that will launch United States's satellite *Vanguard* on its way.

Achievement and timing, as in many other things, is basically determined on how much manpower, material, and money is concentrated on any one project. Government leaders are constantly faced with decisions. And the effects of their decisions are often delayed as to what areas are most important—areas that give the most promise in solving future space problems, as well as providing adequate, immediate, national defense.

Nearly half of General Electric's scientists and technicians are devoting their talents to a wide variety of defense projects, missiles, rockets, electronic systems, jet engines, radar, research, to name but a few. In addition to work on specific defense contracts, General Electric spends a large portion of its own funds for research in the constant quest for fundamental knowledge that will contribute further to the security and progress of the nation. —EDITORS

Dr. Porter—Consultant, Communication and Control, Engineering Services, New York Office—began with General Electric on the Test Course in 1937. A national authority on guided missiles and past president of the American Rocket Society, he is now Chairman of the Technical Panel of the U.S. Committee for the International Geophysical Year of the National Academy of Sciences.

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Science — The Fabulous Pitcher

By DR. GUY SUITS

It is the great beauty of our science that advancement in it, whether in a degree great or small, instead of exhausting the subject of research, opens the doors to further and more abundant knowledge, overflowing with beauty and utility. —MICHAEL FARADAY

There is an ancient Greek fable which tells of a miraculous pitcher of wine that never emptied, but renewed itself of its own accord as fast as the wine was poured. This presents an enticing concept—one quite contrary to experience, which teaches that good things tend to run out or to run down. A good well may supply water for a long time, perhaps indefinitely, but no practical wine pitcher lives up to the one in the fable. Even the best mines finally give out and have to be abandoned.

I was reminded of this fable of the wine pitcher not long ago when a friend of mine expressed misgiving about the capacity of science to expand indefinitely. "Is it realistic to expect," he asked, "that the astounding avalanche of scientific discovery which the past half-century has witnessed can continue indefinitely into the future? And is it likely that the technological progress of the next half-century will equal the revolutionary technical achievements of the last 50 years?"

These are thoughtful questions. Possibly there are others who have wondered whether the magic pitcher of science is in danger of running dry. How does the fabulous vessel renew itself? Certainly not by any supernatural power as related in the fable, but by the infinite multiplication of human endeavor. Perhaps nature's storehouse of knowledge is truly an infinite source, and the real limit on what we draw from it is the human mind—its resourcefulness, its ingenuity, and, most important, its comprehension. In any event, science is a powerful attribute of modern life, and it seems that the more that its substance and its methods are employed to the benefit of man, the greater is the reservoir of "abundant knowledge, overflowing with beauty and utility."

FROM IDEAS TO ASSETS

Technological progress is based upon the translation of scientific ideas and concepts into practical assets. It is interesting to note that Michael Faraday —himself a researcher in pure science— emphasized *utility*. The practical benefits of science are more than a characteristic feature of American life today; they exert a profound influence on the national economy, on our society, and on our national defense. In the electrical industry our technology is based partly on classical researches of the last century and partly on a growing host of new physical phenomena that have emerged from modern researches and have more recently traversed the long path through applied research and engineering.

Through Fundamental Research . . .

The starting point is *fundamental research*, perhaps better described as *learning work;* it is a primary wellspring for creative ideas and innovations that eventually enlarge our tangible assets through subsequent applying work. No better example of the eventual utility of new knowledge and understanding which originated in learning work could be found than the researches of Michael Faraday himself.

Our present electrical technology derives directly from the ideas generated by Faraday and his contemporaries, Maxwell and Henry. The basic ideas of communication by means of electromagnetic waves are directly traceable to the fundamental researches of Hertz. The extensive medical and industrial uses of x-rays stem from the original idea of Roentgen in 1895 and the essential contributions of Coolidge in 1913. J. J. Thompson identified the electron in 1897; and the important work of many later contributors, including Irving Langmuir, brought it "to market."

From a relatively few basic original ideas may come an infinite variety of practical assets; at the time of the original idea the ultimate practical impact of the concept may be hard to predict.

. . . Engineering . . .

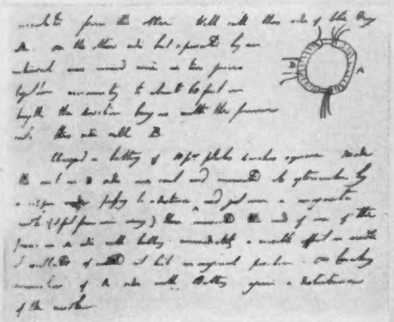
Adapting technological assets to human needs is the role of engineering. This is a vital phase in technological progress, and one that demands the close interrelationship of science and engineering. Although the original creative ideas in electricity and magnetism came from fundamental research, we owe our vast electrical resources to the application and continued improvement of engineering skills in the generation, distribution, and utilization of electric power. The great diversity of chemical products and processes that enrich our technology depend upon the happy wedding of chemical research and chemical engineering. Evidence of the important role of engineering in present-day technology is so impressive and so widely recognized that there is no need to review it here.

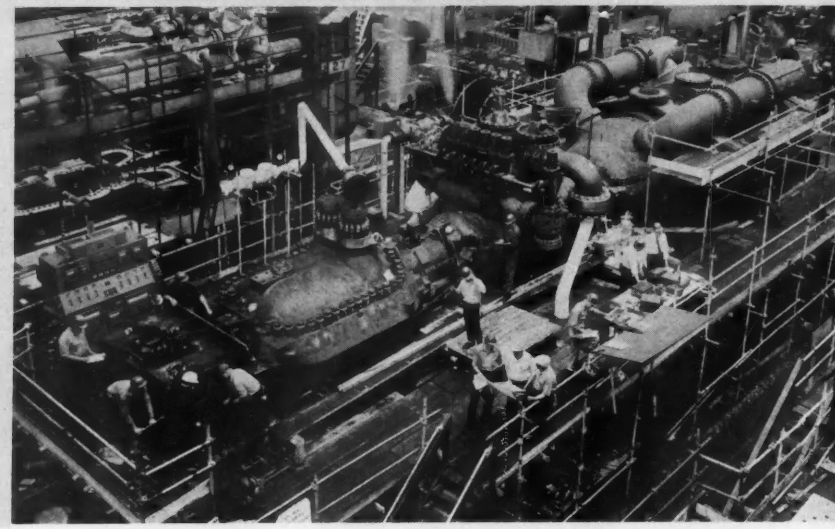
My objective in this paper is to emphasize the importance of the *combined impact* of scientific research and engineering upon the American way of life, both now and in the years ahead.

Throughout my professional life it has been my privilege to be associated with an industrial research laboratory whose primary responsibility is the search for new ideas. There is no more exciting quest than the pursuit of a new fact of nature, and one of the greatest sources of satisfaction for anyone closely associated with industrial research is the transition of ideas into assets.

During the 57 years of its existence, the General Electric Research Laboratory, in cooperation with engineers and scientists throughout the Company, has participated in a wide variety of technological enterprises of great public utility. In many of these the ultimate value of the original idea could not have been foretold with any degree of certainty. Looking back, however, it is not difficult to trace the development of an idea from its conception in research to its useful application through the manifold contributions of engineering.

Dr. Suits is Vice President and Director of Research, General Electric Company.





From the original Faraday concept of electromagnetism (page from his notebook) has evolved the complete steam-turbine-generator capable of producing 225,000 kw.

Take, for example, the fundamental researches of Irving Langmuir. Like Faraday, Langmuir was a scientist whose work in pure science—although motivated primarily by insatiable curiosity—was directly responsible for widespread practical benefits. And like Faraday, Langmuir was always alert to the utility of scientific knowledge. Speaking of his own work, Langmuir once said: "Whatever has come as industrial applications has come incidentally to experiments followed for their interest alone."

That practical benefits do surely derive from pure research is well demonstrated by Langmuir's own career. From his early researches on the conduction of heat in gases and related phenomena, we got the gas-filled lamp, which increased the efficiency of the incandescent lamp by a very large factor. Estimated savings to the American public resulting from the development of the gas-filled lamp amount to $1 billion annually—a spectacular example of the translation of ideas into assets.

Langmuir's basic researches on thermionic emission and electron space charge are now classic. They laid the foundation for manifold developments in electron tubes and, incidentally, won for him the highly coveted Faraday medal of the Institute of Electrical Engineers of Great Britain, an appropriate citation for a true disciple of Faraday. The industrial art of hydrogen welding grew out of Langmuir's studies of the dissociation of hydrogen, and the condensation pump was the result of his investigations in high vacuum.

This brief reference to Langmuir's work reminds me of a question that I am frequently asked: "Your elder scientists are firmly established in the hall of fame, but where are your Langmuirs and Coolidges of today?" To this challenging inquiry I reply unequivocally: "They are right here in the Research Laboratory." They are young. They are becoming recognized in the scientific fraternity, but their ideas have yet to be translated into generally recognizable assets. Forty years ago Langmuir's genius was recognized only by his immediate scientific fellowship. If, in 1915, my distinguished predecessor, Dr. Willis R. Whitney, had been asked: "Where are your Newtons and Maxwells?" would anyone have appreciated his probable reply, "We have Langmuir, Coolidge, Hull, and Dushman"?

Looking into Langmuir's laboratory about 1912 (photo, opposite), you would find his quarters somewhat more primitive than the modern laboratory today. But in these simple facilities some very important researches were accomplished.

What about the work he was doing? As typical examples, I've listed here the titles of several of Langmuir's early papers in technical journals:

Chemically Active Modification of Hydrogen.
Chemical Reactions at Very Low Pressures.
Effect of Space Charge and Residual Gases on Thermionic Currents in High Vacuum.
Vapor Pressure of Metallic Tungsten.
Dissociation of Hydrogen into Atoms.

How many of them would have been recognized outside scientific circles as portending great practical benefits? For that matter, would anyone thumbing through the pages of Faraday's notebook in 1825 have been able to predict that the ideas contained therein would change the way of life the world over? Look at a modern steam turbine-generator and then at a page from Faraday's notebook (photos), and you cannot help being impressed with the impossibility of predicting the eventual utility of fundamental scientific research.

The measure of a scientist is the originality and fruitfulness of his ideas. The great names of today are those with an accumulation of achievements through productive ideas. The great names of tomorrow will emerge from among the young scientists who are today pursuing their abstruse ideas in the seclusion of their laboratories. I cannot give you their names today, but they will be found in the scientific headlines tomorrow.

. . . Time . . .

Sometimes a long period of time elapses between the conception of the basic idea and its development into a practical asset. A case in point is the magnetron, the principle of which was discovered by A. W. Hull in 1925. The idea of controlling the flow of current in a vacuum tube by means of an external magnetic field was a new and promising one, but it was nearly 20 years before a device based on Hull's original idea, further developed and extended by others, was actually put to use.

The opportunity came during World War II, when the pulsed magnetron emerged as the best generator for the microwave radar, and the continuous-wave magnetron was developed as the most powerful means of jamming enemy radar. But it required the necessities of war and many important contributions by other scientists and engineers to complete the transition from idea to asset.

It is now likely that a modern version of the magnetron, still further developed and extended, will play a basic role in electronic cooking. None of these applications of the magnetron were dreamed of by the most imaginative scientists and engineers of 1925.

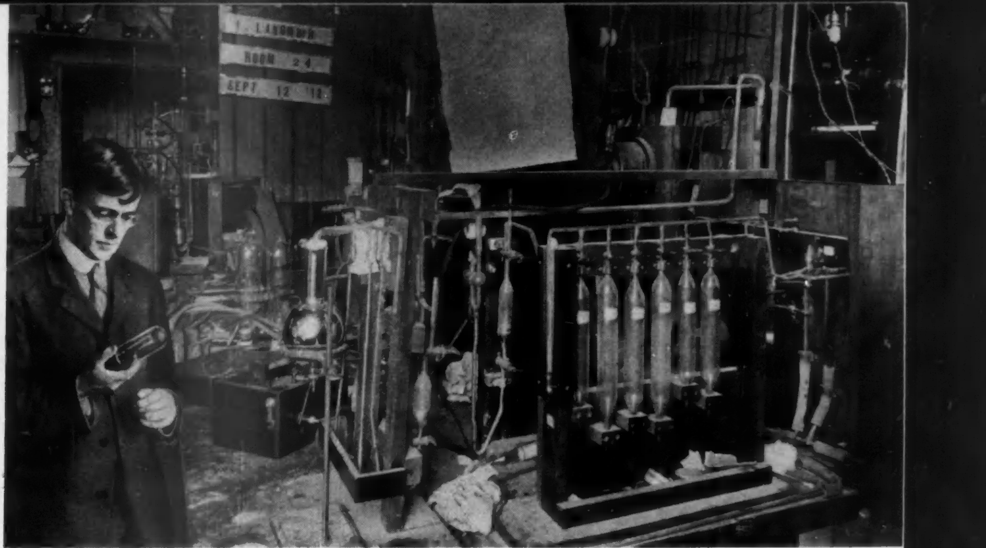
. . . and Team Effort

Important among new chemical products of the past decade are the *silicones*, polymers which have provided us with a large new family of synthetic rubbers, oils, resins, and varnishes for a great variety of applications. The crucial idea that gave impetus to a long and interlocking chain of developments which eventually brought silicone products to the market place was the discovery of a substitute for the *Grignard* reaction for producing methyl and phenyl chlorosilanes, the basic materials from which silicones are made.

The fundamental discovery was made by Dr. E. Rochow; and, as in much of present-day work, the important subsequent steps were the result of teamwork involving many workers. Incidentally, the team effort required in so much of modern research and the interplay of diverse scientific endeavors are factors that make it difficult to individually identify today's young Langmuirs, Coolidges, and Hulls.

Magnetic materials are of great importance to the electrical industry, and our Laboratory has been engaged in research in this area almost from its inception. For many years the performance of electric equipment was limited by the inherent magnetic properties of ordinary iron. In the 1930's a new idea—introduced and developed by our metallurgists under the leadership of William E. Ruder—culminated in a way to improve upon the natural magnetic behavior of iron by rendering it especially susceptible to magnetization along a given axis. The resulting "oriented" magnetic sheet provided an additional degree of freedom to the designers of electric equipment and increased the efficiency of the equipment significantly.

Only a few weeks ago, we announced another significant step along this line—a new magnetic sheet that is "doubly oriented;" that is, it has two lines of ready magnetization at right angles to each other. This new material, which will make possible many improvements in design, was the result of the cooperative effort of young theoretical and experimental metallurgists in our Laboratory.



IMPORTANT RESEARCH was undertaken and accomplished by Langmuir in this early laboratory.

CURRENT IDEAS—FUTURE ASSETS

It is easy to look back and recognize the birth of ideas that resulted in current assets. The evidence is clear that present technology is based on earlier science. It is not so easy to look ahead and fully perceive the future assets which will accrue from present ideas. However, there are some areas of active research today in which I believe it is possible to make some speculative predictions.

We are now well advanced in a metamorphosis in world technology that is so far-reaching in its implications as to be almost revolutionary. To an ever-increasing extent, technological progress depends upon scientific advances rather than upon the availability and variety of natural products. In a primitive technology, the essential raw materials are extracted from the earth's crust and used with little or no modification. Iron, copper, gold, coal, and petroleum are examples of such primary resources.

As technology advances in scope and complexity, the value of primary resources is enhanced by modifications of the raw material. Steelmaking, for example, represents an "added value" to primary raw materials that has had an enormous influence upon technological progress. The greater the complexity of technology, the more important are the added values contributed by science.

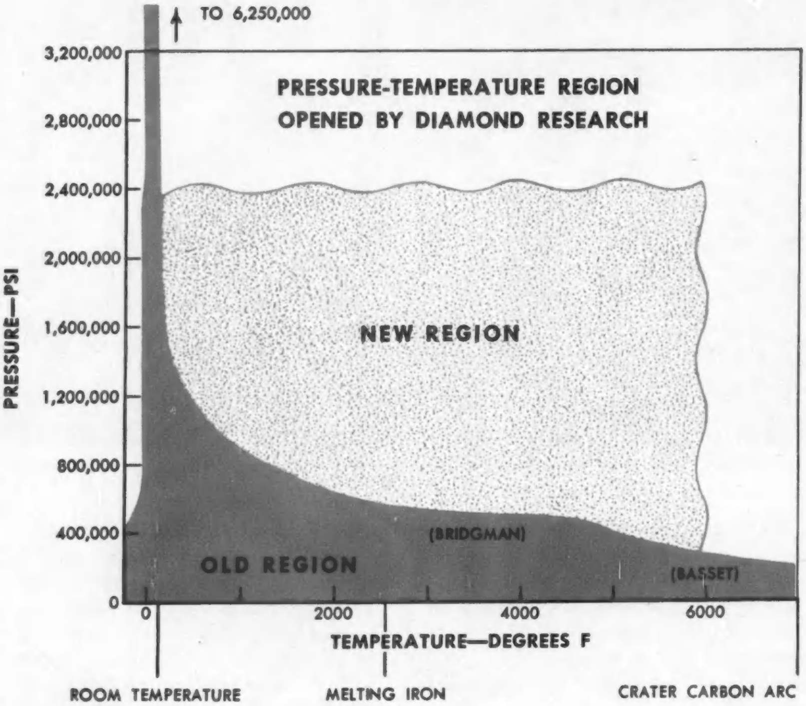
Natural products, of course, will always be of primary importance, but their utilization to meet new technological requirements will demand much more than merely extracting and refining. In developing new assets based upon the physical properties of natural products, scientific research serves as a bountiful source of new technology. To an increasing extent, the role of industrial research will be the enhancement of these added values, which contribute to technological innovations.

In the Area of Semiconductors . . .

A current example of the value of fundamental research as a source of new technology is solid-state physics. Just as the elucidation of the laws of gases in the last century led to unforeseen technological developments over a broad front, so the 20th-century study of the properties of matter in the solid state is advancing modern technology along new lines. In particular, the development of solid-state devices employing semiconductor materials, such as transistors and rectifiers, is adding a new dimension to electronics.

This technological area provides an excellent illustration of added values contributed by research and engineering. The common semiconductor materials, germanium and silicon, while plentiful and readily obtained, are, in the natural state, wholly unsuited to electronic applications. Not only is an unprecedented degree of purity essential, but once purified, they must be modified, or "doped," by the addition of minute and precise quantities of appropriate "impurities." An understanding of the physical role of these critical additives, as *donors* or *acceptors* of electrons, is one of the important objectives of fundamental research on this class of materials.

Ten years ago semiconductors were little known materials of scientific interest only; today semiconductor products constitute one of the most rapidly growing industries in America. An industry that was wholly nonexistent in 1950 is expected this year to gross over $140 million; and it is conservatively estimated that the figure will reach $1 billion in 10 years. Thus, a whole new industry was born in the research lab-



oratory and brought to maturity through the combined contributions of research and engineering. Moreover, the birth of this new industry has provided myriad opportunities for new business ventures —large and small.

It is likely that 10 years from now the annual numerical production of transistors and other solid-state devices will exceed that of vacuum tubes. Semiconductor devices will play an important role in the growing applications of computers, information storage systems, and automation. The transistor will invade the home to a much greater extent than the vacuum tube has done—in control devices for heating, air conditioning, and electronic cooking, and possibly in communication.

It is not unrealistic to expect that the autos of the various members of the family will be linked to home base through a communication system involving multiple transistorized signal receivers powered by miniature solid-electrolyte batteries. As new solid-state devices like the transistor become commonplace, it should be remembered that these working gadgets are the progeny of ideas born of pure science.

. . . Industrial Diamond . . .

Another area of pure research that holds great portent for the advancement of future technology is the superpressure, supertemperature field. This, too, is an example of a *learning* activity motivated by curiosity about a hitherto inaccessible region in nature. When this work was initiated in our Laboratory six years ago, some of the phenomena to be encountered in this region could be anticipated from the evidence of naturally occurring substances, such as diamonds; others could only be guessed at. The successful culmination of the attempt to find a reproducible method of making diamond was a confirmation of preconceived ideas based on scientific understanding. The potential value of a practical commercial process was, of course, fully recognized. The conversion of graphite into diamond is a striking example of added value derived from research and engineering. At the current market price of industrial diamond, the value of the primary raw material is multiplied several thousand times.

Only recently our Metallurgical Products Department at Detroit released the announcement that man-made diamonds are now on the market. Actually, they have been too modest in their announcement. The elapsed time between the date of the discovery of the basic process in the laboratory, to the first marketing of diamonds made by the process was about 2½ years, an achievement that reflects great credit upon the cooperative effort of scientists, engineers, and manufacturing specialists. In fact, this astonishing result in bringing a fundamental discovery to market must set some kind of a world's record. This prompt transition of new knowledge into practical benefits could hardly be done except by the close coupling that existed between the source of the new fundamental knowledge and the specialized engineering and manufacturing skills in the sponsor's own company—thus a quick, efficient transition from ideas to assets.

When we made the initial diamond announcement in February 1954, I expressed the opinion that scientific information gleaned from the exploration of this new region might, in the long run, prove more valuable than the ability to make diamond. If progress in the field since that time is a reliable indication, I am inclined to think I was not far wrong. The production of the entirely new material, *borazon*, is an indication of the potential riches to be found on this new frontier. In this case, a substance never observed in nature has been synthesized and found to possess properties more outstanding in some respects than diamond.

I predict that continuing learning work in this field will yield new assets more rare and more valuable than gems. With respect to man-made industrial diamond, it is entirely within the realm of possibility that eventually diamond, and perhaps borazon, will be commonplace in industrial abrasive applications.

. . . and Nuclear Energy

Nuclear physics is a 20th-century field of investigation that will have tremendous impact upon the technology of the future. The potential value of the fusion process as a source of power presents one of the foremost technological problems of the day. Incidentally, the separation of the fissionable isotope U-235 from natural uranium and the production of plutonium from U-238 are notable examples of added values from research in this new and complex technology. The utilization of nuclear energy is a very broad area of investigation—one that demands the mobilization of a wide range of highly specialized skills and technical facilities.

One aspect of the problem that holds the center of the stage just now is the possibility of utilizing thermonuclear reactions in a *plasma*, a concentrated atmosphere of ionized gas atoms, as a source of controlled power. In contrast to the *fission* process, which releases energy by the splitting of heavy atoms, the thermonuclear reaction known as *fusion* involves the combination of light atoms at extremely high temperatures—of the order of stellar temperatures.

The technical obstacles confronting science in this area are formidable and the path to victory is only vaguely discernible, but the potential assets are so great that we cannot afford to do less than our utmost to overcome these obstacles. I feel confident that the time will come when nuclear energy will become an invaluable tool in the hands of man instead of a sword of Damocles hanging over his head.

It is just possible, too, that the study of plasmas will yield assets in areas that now seem remote to the immediate objective. For example, there is some interest in plasma phenomena in connection with the production of electromagnetic radiation, possibly x-rays. When the temperature of a gas is raised, it first radiates visible light, then at higher temperature ultraviolet light, and at still higher temperatures x-rays or gamma radiation. Thus a thermonuclear plasma may become an entirely new source of radiation. Another unexplored possibility in the study of plasmas is chemical synthesis—the production of complex molecules by chemical reactions in a fully ionized gas at very high temperatures. These speculations take us far beyond the horizon that now stretches out before us, but we must constantly peer into the distant future if we hope to draw continuously from the fabulous pitcher of science.

LARGE-SCALE INDUSTRIAL RESEARCH

Industrial research is an investment in the future. Like other investments, it involves risks—often long-term risks. Not all research projects bear fruit; in fact, a relatively small number of highly productive research ventures must carry the burden of the great number of unsuccessful undertakings necessary for thorough "prospecting" to insure that hidden opportunities aren't missed.

The financial investment required to support a large-scale research program is very great, the risks are considerable, and the period before dividends are declared may be long. Here large industry has an important role to play. With extensive physical, economic, and human resources and with a great diversity of technological interests, the major industries are uniquely able to support the type of large-scale research effort necessary to guarantee continued technological progress. For these reasons, modern technological progress is dependent upon the research contributions of large industry—a role that is not always fully appreciated by the American public.

This is a good place to emphasize the importance of profits in large-scale industrial research. There is probably no aspect of American industry that is less understood and appreciated by the public than the vital role of profits in a free-enterprise system. The average citizen is inclined to have the somewhat vague opinion that profits are all right, provided they are not too big. On the subject of what is "too big," he is apt to be a bit hazy. He lives by the creed that the "laborer is worthy of his hire" and when he attempts to translate this creed in terms of business operations, his conclusion generally is that "some profit" is necessary and justifiable.

In our free-enterprise system, profits must be adequate to yield a reasonable return to the investors who supply the venture capital and also provide funds for the essential business investments necessary to keep pace in a progressive industry.

Research is an essential business investment—and a very costly one. The costs of carrying on a large-scale research program are subject to all the inflationary factors that are present in any business venture, exaggerated by the ever-increasing complexity of scientific work. It is unrealistic to assume that the research activity of private industry can be geared to the demands of technological progress without consideration of adequate profits with which to finance it. It is important that the American public understand that an adequate profit from the industrial enterprise will permit further investments in research and new technology with important benefits to all.

There are values in large-scale industrial research that are important to technological progress. Not the least of these is the *scope* of a large-scale research effort—the breadth and depth that result from the mobilization of a multiplicity of skills. Probably the chief characteristic of modern scientific research is the very high degree of specialization required in the various scientific areas.

The *depth* of a research effort depends upon the degree of specialization that can be focused upon the various technical aspects of the program; the *breadth* is determined by the range of specialization encompassed by the total effort. A comprehensive research program demands a multiplicity of technical skills and a diversity of scientific interests. Moreover, the productivity of the individual research worker is greatly enhanced by cross-fertilization taking place in a research environment that embraces a wide range of specialization.

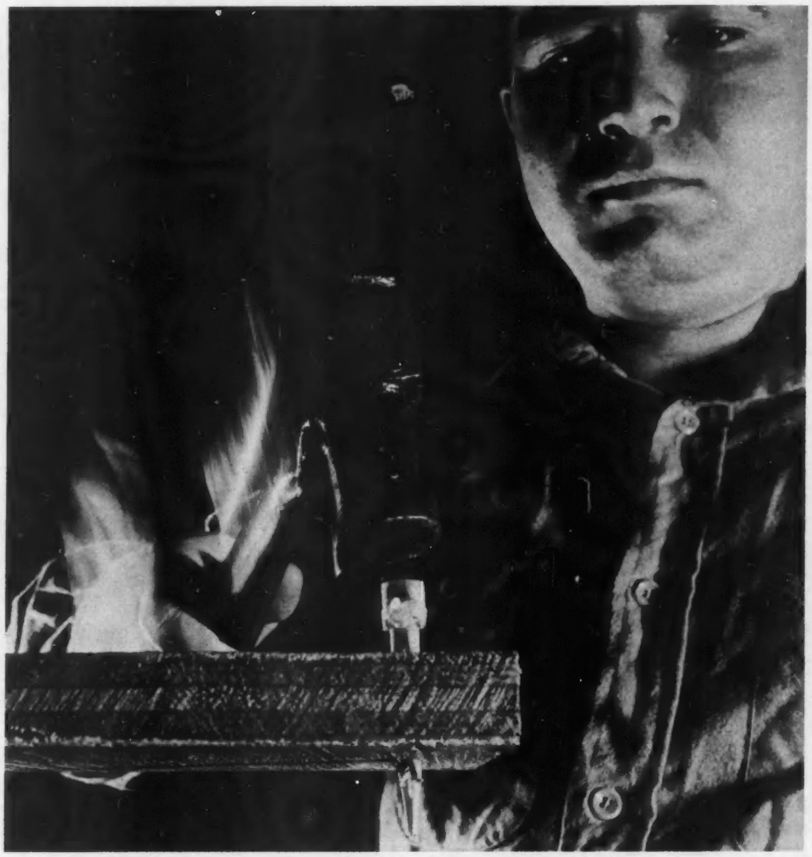
One of the prime values of large-scale industrial research is the fact that the transition from new knowledge to useful practice is greatly facilitated when the entire sequence of events—from research to end product—takes place within one sponsoring organization. The coordination of effort is more efficient when all participating components are parts of the whole than it is when the research results from one or more independent sources must be correlated with engineering carried out by another organization and with manufacturing practices in yet another. Prompt utilization of research results demands integrated effort all along the line.

Although large-scale research is relatively new on the industrial scene, its role in maintaining the flow of wine from the miraculous pitcher is already well established. Its importance to future technology is clear. When you are looking ahead a decade or two in science, you must calculate among your assets, in addition to present knowledge, new discoveries that are certain to be made.

At the pace of modern scientific progress, two decades is a very long time. The last two decades, for instance, encompass the whole of the atomic age, including atomic bombs and thermonuclear weapons, as well as microwave electronics including radar, semiconductors, sulpha drugs, antibiotics, and a host of other developments that we now recognize as technological assets. There is no evidence that this pace is slowing down. Natural limits to new discovery, if they exist at all, are not discernible. Hence, we may expect the miraculous pitcher to yield everything that our scientific competence and resourcefulness can draw from it.

In conclusion, I should like to state the following beliefs.

- Future technological progress will dwarf the achievements of the past.
- As we progress technologically, appropriate and substantial emphasis must be given to *basic* research, the learning activity that constantly adds to our greatest asset—knowledge.
- Science and technology will become an ever-increasing basic source of industrial growth.
- To an ever-increasing degree, America and the world at large will become a science-oriented society. Ω



No tricks involved, a plastic nail about a quarter inch in diameter—its point ground in a pencil sharpener—pierces plywood under repeated hammer blows. Parts molded of the material are practically unbreakable and highly stable dimensionally.

New Plastic Gains on Metals' Properties

With profits continually ploughed into chemical research, plastics will soon take a position alongside metals as materials in their own right.

By DR. K. B. GOLDBLUM and R. J. THOMPSON

"Tough as nails" is the description copywriters used in news releases to emphasize the toughness of a new plastic, called Lexan (registered trademark, General Electric Co.). Immediately and unexpectedly, a demand for plastic nails turned up from a lumber company.

The company straps their logs together and floats them downstream from forest to sawmill. Trouble began at the mill, however. For metal nails left in the logs when workmen remove the strips damage whirling saw blades. Lexan plastic nails (photo) tested in this application neither damaged nor dulled the blades.

And so, by a purely coincidental application, a new plastic proved a solution to a bothersome problem for the lumber industry. It's indicative of the larger role plastics will play in the future.

Coming into Their Own

Newly developed Lexan plastic is a good example of the progress you'll find being made in America's laboratories. Unmatched by any other thermoplastic—material that softens with increasing temperature—it has an unusual combination of properties: exceptional impact strength, dimensional stability, heat resistance, and good electrical characteristics. You can, in fact, pound Lexan plastic with a hammer, expose it to 140 C temperatures, immerse it in water and dilute acids, and subject it to strong electric fields; it withstands all.

The new plastic material yields to fabrication by the three main methods of molding—injection, compression, or extrusion. And you can solvent-weld it, seal it with heat, or machine it.

Lexan is but one of many exciting plastic products that, in the future, you'll see doing old jobs better while opening completely new fields of application. Because more than ever before America's chemical industries are ploughing back a larger share of their profits into research. The result: Plastics continue to gain stature as engineering materials in their own right. (See March 1957 REVIEW, page 20.)

Dr. Goldblum—Supervisor, Development Unit, Chemical Development Department, Pittsfield, Mass.—began with General Electric in 1940. His past experience with the Company has been with the Plastics Laboratory in Pittsfield. Mr. Thompson joined General Electric in 1954. Also with the Chemical Development Department, he serves as Specialist, Sales Development.

Thinking back to the material shortages of World War II, you'll recall that the plastics used in some applications then simply performed unsatisfactorily. And in their early uses for toys and housewares, the poor properties of some products gave people a generally unfavorable impression of plastics. Fortunately with the advent of new products, plastics are being accepted for what they really are: unique, versatile raw materials for industry.

By utilizing their unique properties and allowing for their limitations, you can replace metals with plastics—not as mere substitution but often for a better job at lower cost.

Research Leads to Discovery

Among many in the chemical industry, the laboratories of traditionally research-minded General Electric make manifold contributions to progress in plastics. Some of this progress is unexpected dividends from extensive research in the electrical insulation field. Lexan's development followed such a path.

By far, most of the insulation in electric equipment is organochemical in nature. Accordingly, you can appreciate an electrical manufacturer's abiding interest in developing new and better organochemical plastics.

This interest manifests itself in many products currently on the market. Some of these include a plastic wire covering with higher temperature resistance than natural rubber; an enamel wire coating that provides a thin, tough heat-resistant electric insulation; silicone coatings and rubbers that resist heat and the attack of atmospheric oxygen; and, most recently, an improved wire-insulating enamel that's still more resistant to heat. All these materials allow electric equipment to run at ever higher temperatures, under ever more severe operating conditions.

The basic requisites of course in all these developments are good electrical properties and resistance to atmospheric oxygen's attack. Additionally, designers of electric equipment also deem highly essential a material's strength and toughness at elevated temperatures.

An attempt to combine all these features in one material led to the discovery of Lexan plastic.

The Unexpected

For some time, researchers in the field of organochemistry knew that certain configurations of atoms are more stable than others to the effects of heat and oxygen. Certain atomic groupings increase the temperature that a thermoplastic will withstand before softening and, at the same time, stiffen the material of which they're a part.

Conveniently enough, these desired atomic groupings are combined in a relatively simple compound—one that you can buy commercially under the name Bisphenol A. Chemical hooking of these simple units together into large molecules with the aid of phosgene—the chemical known for its use in warfare—forms a material called Bisphenol A polycarbonate. Translated, this means that many units of Bisphenol A are united by a chemical linkage known as a carbonate.

So much for the chemistry.

Did the new plastic really possess the properties researchers hoped for?

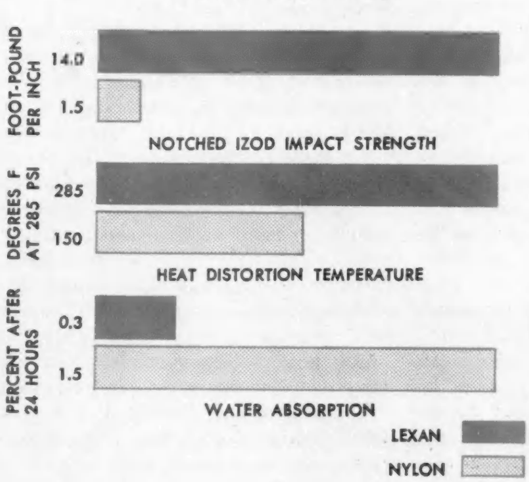
The first successful attempt to produce the plastic material, subsequently trade-marked Lexan, yielded a lump of tough resin about the size of your fist. It could be mauled with a heavy hammer, yet it did not shatter. Here was real toughness, a bonus property, that its discoverers hadn't anticipated.

Heated well above what the usual commercially available thermoplastic materials will resist, Lexan was thermally stable. The temperature needed to distort it under load, determined through standard tests established by the American Society for Testing Materials, was about 140 C (Table). Actually, this particular property wasn't totally unexpected. Because researchers knew from the start that selected groupings would give the material a higher melting range.

Neither was Lexan plastic affected dimensionally by moisture; it remained highly stable dimensionally, from bone-dry conditions to immersion in water. By contrast, you find that nylon—a well-established and widely used plastic—is greatly affected dimensionally by moisture and changes in humidity (illustration).

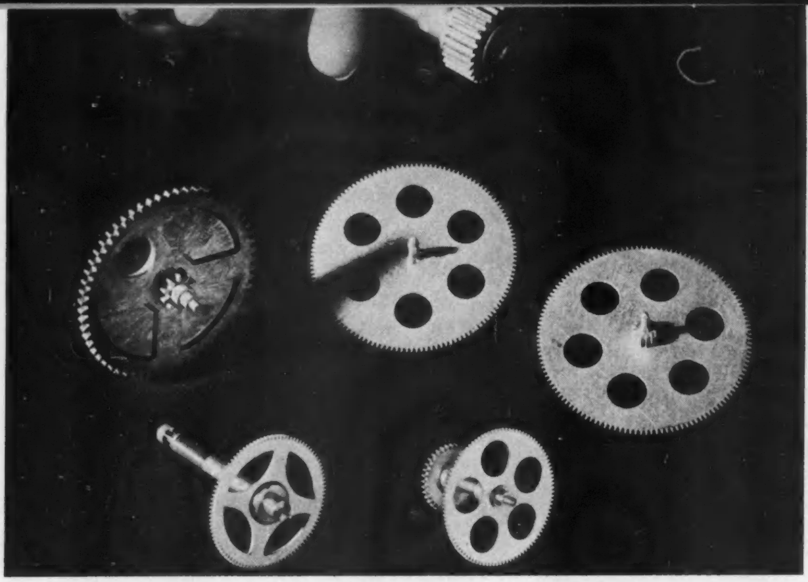
As researchers measured other Lexan properties, they found that, compared with other thermoplastics, it had excellent stability when subject to the effects of heat and atmospheric oxygen. Its electrical properties were also good.

LEXAN versus NYLON



PROPERTIES OF MOLDED LEXAN RESIN

Property	ASTM Number	Units	Value
Notched izod impact	D-256	foot-pound per inch notch	12–16
Ultimate tensile strength	D-638	psi	8–9000
Tensile modulus	D-638	psi	160,000
Elongation	D-638	percent	60–100
Water absorption, 24 hours	D-570	percent	0.3
Specific gravity	D-792		1.20
Heat distortion temperature	D-648	degrees F	280–290
Arc resistance, stainless-steel strip electrodes	D-495	seconds	10–11
Dielectric strength, short time, ⅛ inch thickness	D-149	volts per mil	400
Dielectric constant, 60 cycles / 10^6 cycles	D-150		3.17 / 2.96
Power factor, 60 cycles / 10^6 cycles	D-150		0.0009 / 0.010
Volume resistivity		ohm-cm	2.1×10^{16}



FUTURE GEARS, instead of metal, may be made of Lexan plastic. Unaffected by petroleum oil, Lexan can be readily molded to the precision necessary for such applications.

Applying the Discovery

What uses can you find for a new plastic tougher than any other known unfilled resin—one that has low moisture absorption, excellent dimensional stability, and good electrical properties?

First of all, gears came to mind. In clocks and business machines, for example, gears must be dimensionally stable, unaffected by petroleum oil. Lexan plastic embodies both of these features. What's more, Lexan can be readily molded to the precision necessary for gears in such equipment. In this field, Lexan should find a large market (photo).

Another fruitful combination of properties inherent in Lexan is needed in coil forms for various pieces of electric equipment.

A coil form, as you know, acts as a spool on which to wind wire, after which it actuates part of an electric mechanism. To withstand crushing and to maintain shape under tension of the wound wire, the coil form must be tough. To insulate satisfactorily, the plastic from which the form is molded needs good electrical properties. And with ever-increasing heat requirements of electric apparatus, the coil form has to be thermally and dimensionally stable at higher operating temperatures.

Lexan plastic enjoys a fine union of these properties. Already molded are a number of coil forms having different shapes and sizes; some of these are on developmental test.

Where are toughness and dimensional stability alone needed? This was another question Lexan's discoverers faced. The answer came quickly: in housings or cases for business machines, radios, electric equipment, and the like.

Such cases, if molded of Lexan plastic, would be thinner, lighter, smaller, and practically unbreakable—not just *impact* resistant. Likewise, clock and business-machine cases of Lexan could absorb many times the punishment that usually results in failure in these applications (Cover). Another thing you can't overlook: The dimensional stability of a housing made of Lexan plastic will insure that whatever is fastened to it won't be damaged or distorted by warpage of the case.

Metals Challenged

In a number of uses and applications, Lexan molded parts will certainly compete against metals—true especially of higher cost die-cast brass and bronze. And you can readily see why.

Certain of Lexan's properties aren't possessed by die-cast metals. For example, it has good electric insulating properties while also resisting liquid solutions of acids and salts. This means that Lexan plastic will prove useful as cases for storage batteries and flashlights, for photographic processing equipment, and for similar applications where metals can't compete because they neither resist chemicals nor the passage of electricity.

But this isn't all. The ease with which Lexan can be molded plus its toughness, heat resistance, and dimensional stability are all properties shared by die-cast metals. Lexan has advantages, however.

Take the example of the clock gears mentioned earlier. If you molded the gears of Lexan, not only would the clock be lighter, but it would be completely silent when running. Now consider for a moment a refrigerator door handle. A part popularly made of die-cast metal, it will be strong yet warm to your wife's touch when molded of Lexan.

Only the Beginning

You can see then, why Lexan's development promises to be a milestone in plastic's progress. Not considered a substitute for any particular plastic available today, Lexan will enable engineers to create totally new designs. Parts once made by assembling several small metal components can be fabricated in one piece of Lexan. Not only does this reduce your costs but in many instances it also provides even better performance.

This should come as no surprise. Plastics generally have arrived and are being accepted as full-fledged engineering materials. New products, typified by Lexan polycarbonate resin, are helping to remove the old stigma associated with plastics.

Some manufacturers even have programs aimed at developing conventional products made completely of plastics. Most major industries are investigating and adopting a greater number of plastic parts for their products. In automobiles, the amount used has been steadily increasing over the years. For the first time this year an all-plastic house will be built as a demonstration unit. And the aircraft industry, too, is keenly interested in applying new plastics to help solve the problems involved in jet flight.

Last year, all together, United States producers turned out about four-billion pounds of plastics. This year, a five percent increase in production is on the way.

Of these man-made materials, Lexan promises to be a leader. Remarkably tough, it's easily moldable, dimensionally stable under widely varying conditions of humidity and temperature, resistant to aqueous acids and salts, and resistant to oil; electrically, it can hold its own.

All these properties combined in one material give promise that plastics, properly designed and developed, will take their position as materials in their own right—not as replacements or substitutes for other materials. Ω

Do Your Reading Skills Need an Overhaul?

By THEODORE F. MARBLE

Effective reading ability is one of the most fundamental, but unappreciated, springboards for self-improvement that exists today. Few skills are so rare and yet so important in your personal life, as well as in your business efforts, as the ability to read well.

The professional man with a scientific, engineering, or financial background, whether in office or laboratory, may have a greater need for training in reading skills than the rest of the population. For instance, evidence indicates that the average engineer's careful attention to words and figures, learned in college as a professional tool, seriously slows him down in all areas of reading outside his own specialty.

Reading Training on the Increase

Both industrial and educational leaders are expressing an increased interest in the matter of reading training. Industry is picking up training methods developed in the universities, because reading is so important to so many of its personnel. They must read and quickly comprehend an enormous amount of internal memoranda, letters, instructions, publications, and reports.

Training in reading techniques thus seems to be expanding in industrial educational curricula. Among General Electric's many internal educational courses, it is becoming a more and more popular choice. Recognizing the particular significance of the reading problem to engineers, Purdue University has taken action in this direction. One of the first educational institutions to do so, it requires a reading course for technical-degree candidates.

Engineers Recognize Their Need

The industries are not alone in promoting training in reading skills. Their grasp of the dollars and cents value of reading skill is matched by a sound comprehension among a widespread number of people who feel the *need* for just such training. Talk with enough industrial executives, and you are bound to find a few who express a clear-cut wish for a reading tool to help in their own work.

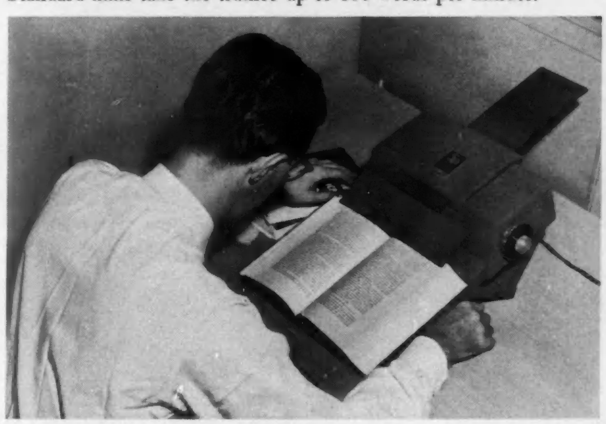
Consider your own situation if you are the average holder of one or more scientific degrees. The last time you had any training in reading probably dates back to the fourth grade. You were only about nine years old and may not have realized the full importance of the reading foundation you were so laboriously laying.

Chances are that your reading practice since those days has not helped you much. Records show that 15 percent of the adult population have failed to improve their reading skills to the fifth-grade level. Furthermore, fully 50 percent of the population reads no better than sixth- or seventh-grade students.

You probably conform to the rough average we have established for General Electric engineers and scientists, spending nearly three hours reading every day of your life. With your limited training for this activity, regardless of your professional

TACHISTOSCOPE—Numbers and words flashed on the screen for 1/100 second make staccato demands on nerve and muscle. Operator presses an ordinary camera cable release to operate the shutter.

TRAINING FILM—A training movie audience must try to keep up, as phrase after phrase of the story pops into focus and out again. Standard films take the trainee up to 550 words per minute.



PACER—The reading pacer may be set for any speed the student wishes from 100 to 2000 words per minute. Keeping ahead of the plate as it moves down the page teaches both speed and steadiness.

Mr. Marble—Specialist, Education and Training, Large Steam Turbine-Generator Department, Schenectady—began with General Electric on the Test Course in 1946. For the past five years he has been engaged in personnel-development activities.

competence, this much of your daily effort probably represents unskilled labor.

Compare your training in reading with your training in other fields. Again assuming that you are an average engineer, you did not stop with the apples-and-oranges arithmetic you learned in fourth grade. In all probability your mathematical training culminated in two or three courses in integral and differential calculus. The end result of this exhaustive training is that you use your calculus on an average of, say, 15 minutes every other day, or perhaps one twentieth the amount of time you spend reading.

A recent test points up the general difficulties that confront engineers and scientists in the reading area. When we tested a mixed group in Schenectady, a housewife and a seventh-grade student surpassed every engineer in the group. We gave the test to a number of engineers, members of the American Institute of Electrical Engineering, who brought their wives and other members of the family to an evening session on the subject of reading. The engineers recorded an average score of 220 words per minute in reading a package of test material while the housewives, grandmothers, and other nonengineers in the group registered an average score of 418 words per minute.

Furthermore, the subject matter of the reading tests given to each group covered two sharply different categories: geology and oriental art. In the rather technical field of geology, you would expect the electrical engineers to do better at reading this material than in reading about oriental art. The results surprised us: they registered an average of 70 words per minute slower on geology. One 14-year-old boy beat his father by a score of 410 to 254 words per minute. Another father was somewhat redfaced when his 11-year-old daughter came up with a score almost matching his own.

Unfortunately, the average engineer reads at the speed of 200 to 300 words per minute—no better than the average normal American male with less education. Reading with a comprehension of between 60 and 80 percent, the engineer could double his reading speed if he undertook the project first by informing himself about reading techniques and then by practice and self-discipline.

A number of General Electric departments, like many other industrial and service organizations, are trying to meet this widely recognized need. Reading training has come a long way since its start immediately following World War II. However, there is still considerable experimentation in training methods. We may still be uncertain of the best way to go about it, but we are certain of the results. For example, one of the pioneer industrial companies to try reading training for top-executive personnel announced that, because of the improvement in reading skills and the consequent speedup in completing their reading work, they had gained the equivalent of one extra executive for every seven who took the training.

HELPING PEOPLE REACH THEIR FULL POTENTIAL

A shortage of educated people may, in the long run, be the greatest limit to America's capacity to provide the good things everyone wants. Meeting such a challenge depends primarily on each individual's plans for his self-development, with the encouragement of parents and with the effectiveness of America's educational systems.

Businesses, too, are developing increasingly effective ways to help people further their education. At General Electric, for example, one person out of every eight is taking additional education or training. The Company helps young people set high educational goals and encourages all employees to achieve their full capabilities with increased personal satisfaction by . . .

- Awakening secondary-school students to future opportunities through such stimuli as the "House of Magic" show and career-guidance materials supplied to teachers
- Helping teachers through summer fellowships and through financial support of colleges
- Teaching new skills in more than 1000 factory courses
- Encouraging employees to continue part-time schooling at all levels
- Offering advanced professional development seminars and study in the work of managing, such as the opportunities available at the Company's Management Research & Development Institute.

For its employees alone, the Company spends $35 to $40 million a year on education and training.

Education must be a lifelong pursuit for every citizen. The more each person recognizes this, the more he will seek to develop himself to take advantage of America's expanding opportunities.

—EDITORS

Improving Your Reading Speed

If you are interested in improving your own reading speed, you can take a few simple steps in that direction. It will help to remember that nearly all engineers can raise their reading ability from 200 or 300 to 400 or 500 words per minute. These are conservative figures; once in a while a man will become so interested in the subject that he will read some materials at 2000 words per minute or more without sacrifice of comprehension. A few people can absorb printed matter at the rate of more than 6000 words per minute.

Typical companies and teaching specialists in the reading-training field employ three basic kinds of equipment. A tachistoscope, training film, and the reading pacer are used singly or in combination in most reading programs.

The tachistoscope (photo, page 17) flashes numbers, words, and figures before the trainee for brief intervals. This trains a student's eye to accurately and quickly absorb words and groups of words from the page.

Training films (photo, page 17) project a page of printed material on a screen but allow the student to read only according to a fixed pattern. Habits of proper eye movement can be established by following this pattern.

The reading pacer (photo, page 17) progressively moves a covering plate down a page of printed material, forcing the reader to keep ahead of it. In addition to these devices, a wide range of study books, material, and special equipment have reached the market in recent years.

Much of the effectiveness of these mechanical devices depends on stimulating the interest of technical people in the subject. Interestingly enough, all the methods give more or less equally significant results. This includes the training course that uses little or no equipment.

A prime factor in the improvement of reading ability appears to be an individual's inner, emotional motivation. You know from your own experience that every once in a while you'll be doing a little leisurely reading at home in the old arm chair. You may wander into the kind of reading where "You, too, are in her arms," and all of a sudden you'll reach the end of a chapter and discover that it's 2 am. Such concentration, or communion with the author, cannot be generated by any machine. Only a genuine desire to read effectively can initiate it.

Reading Training Courses

Aside from the equipment question, the experts differ widely on the proper

DON'T READ PAGE 19 WITHOUT CHECKING YOUR WATCH

TO TEST YOUR READING SKILL . . .

. . . time yourself as you read the text below at your normal pace. An average engineer would read it in about 3½ minutes; a really effective reader would require half the time without sacrificing comprehension.

(About 1075 words appear on the page.)

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length for a training course. Industry offers courses that range from one session to 36 and from 3 to 54 hours in total course length. Outside study requirements vary from none to 6 hours per week. Programs can be group or individually oriented, and with or without elaborate equipment. Despite their own recognized need for reading training, probably few of today's engineers and scientists would generate much enthusiasm for an opportunity to spend 54 hours, plus homework, in a reading course during the winter.

Teaching improved reading can be divided into three basic stages to represent levels of seriousness on the part of the student, which may be roughly compared with his attitude toward various illnesses. In the first, or superficial, stage a couple of aspirins will clear up the trouble; in the intermediate, or half-serious, stage he goes to the doctor for a prescription; in the advanced, or really serious, stage he realizes that drastic action is required and calls an ambulance to take him to the hospital.

Most reading courses treat the patient at three different levels simultaneously and somewhat indiscriminately. They give him a mass of detailed, specific information about reading; practice in specialized techniques designed to improve reading skills, both controlled—and free—reading practice; and the opportunity to discuss problems, both individually and in groups.

Nearly all engineers and scientists can benefit dramatically from treatment at the superficial and intermediate levels. Few of them will ever be interested in or qualified for advanced reading training. Consequently, we have simplified our training approach by eliminating some of the mechanical paraphernalia.

Without the determination of a strong and individual personal drive, not even the finest training can produce significant results. As our first move, we show the reader just how he stacks up against his contemporaries—both trained and untrained in the reading area—and not simply by statistics. First, we expose the individual to an exploratory session to help him determine whether or not he is interested in taking the slack out of his reading ability. Then we place him in a small class that creates a continuing competitive situation with his peers. Here he can compare his progress with theirs, his problems with theirs. The competitive atmosphere is heightened by a strenuous series of time tests with the results represented graphically for each individual. Running scores are also kept on comprehension; we do not sacrifice understanding for speed.

Building on this competitive tension, we then proceed with a little class work. By a little we mean 6 or 8 or possibly 10 hours—the probable length of an ideal course. Because we are assured of a strong interest in the subject of reading when we accept a student, much of the material we use for reading tests is *about* reading. While taking our reading tests a student learns about . . .

. . . *Eye Motion*—Contrary to popular belief, the eye does *not* move across a printed page of reading material in a smooth motion. Instead, it makes a series of fixations. The eye can "see" only when it pauses. The fewer the number of fixations required to cover a line and the fewer the regressions, the better the reader.

. . . *Speed*—The ability to read rapidly is one of the essentials of the effective reader. Not the end goal in reading training, speed is an important achievement, however. Different materials, interests, and objectives require different reading speeds. The person who can read rapidly can slow down when required, but the slow reader can never overcome his handicap.

. . . *Comprehension*—Every reading student has good comprehension as his goal, but 100 percent comprehension is not necessarily good or obtainable in all situations. Slowing down does not necessarily improve comprehension and may adversely affect it. Whole thoughts may be better understood when seen completely in fast reading. Comprehension usually increases when speed increases!

. . . *Concentration*—As in many skills, concentration is also a key factor in reading. Increased attention allows increases in both speed and comprehension. The ability to lose yourself completely in a book should be sought.

. . . *Vocabulary*—Your reading can be limited by your vocabulary. Each of us has a speaking vocabulary that we employ in our everyday contacts. But we should have a much larger reading, or passive, vocabulary. Many reading programs include vocabulary development.

. . . *Ability to Change Pace*—An effective reader acquires the ability to change pace. A poor reader plods along at a steady clip while a good reader *adjusts* his speed to both the level of difficulty of the material and to his personal interest in that material. Most engineers and other technical people skim and read at the same speed.

Practice Makes Perfect

Once equipped with a theoretical knowledge of reading technique, the engineer needs properly motivated practice. Much like the golfer who has struggled with so many golf books, he's all theory. He needs to pick up his clubs, go out on the course, swing away, and practice, practice, practice. From our brief experience in teaching better reading, it's surprising to see so many people well-versed in the ground rules, who can already swing their clubs. But they lack practice.

A small amount of training, combined with a large amount of interest and determination to improve reading speed, will help everyone capitalize on his opportunities in everyday reading.

Higher Reading Efficiency

Certainly you can appreciate the benefits to be gained from an improvement in your reading. The ever-increasing load of business reading that we now ask our key men to accomplish makes some form of training imperative. An engineer may spend from 3 to 4 hours a day in business reading. His subject material can range from textbooks and journals to letters and announcements. It's usually far more than he feels confident to handle. The results of such overloading appear when the homeward-bound briefcases start bulging and when men begin to skip reading the general or related materials so that they can partially keep up with essential reading.

A little arithmetic will convince you of the value of this training for yourself. If you're spending three hours a day in reading, and you succeed in the relatively modest project of doubling your speed, then you have, in effect, extended the length of every working day by 1½ hours. Looking at it another way, you can do twice as much reading as you formerly did. Either way, you increase your value to yourself and your work. Ω

NEW DIMENSIONS OF AMERICA'S ECONOMY—2

The Emphasis on Businesslike Methods to Build

***Review* STAFF REPORT**

Military observers, legislative leaders, and industrial teams closest to the overall problems of national security agree today that businesslike methods are necessary for an unassailable superiority in defense equipment. Production must be flexible enough to adopt a new design as quickly as it becomes available. Financial men must direct the money flow into constantly changing channels, avoiding the high-inventory weapons reserves that characterized World War II. Research and development men must continually strive to outpace themselves.

The success of the various approaches to defense superiority is the key to national survival. In the fiercely competitive world of the Intercontinental Ballistics Missile, there may be little or no time for prewar preparatory build-up. Quantity is no longer so critical; quality is. It's too big a job for any in our economy save our industrial teams.

Industrial organizations—composed of businessmen who daily deal with long- as well as short-range variables—have the experience, patience, and self-perpetuating steadiness to approach defense as a continuing, not an intermittent, activity. They know that the nation's need for electronic controls, high-energy fuels, and high-temperature metals will not decline with a hopeful shift in the political situation. They know too that tomorrow's weapons must be under construction today, in sufficient quantity to meet predicted needs without unduly straining the taxpayer's personal budget. In short, they know that a long-range plan is not only possible but also necessary. The nation's Armed Forces would be badly served by placing an order for aircraft here, an order for ground transport there, without integrating them into the latest image of the fluid technological picture. Clearly, our nation's business and industrial organizations are ready to play their full part in teamwork with the Armed Forces.

One of the most important techniques of private enterprise, capital investment in research and manufacturing facilities, finds increasing application today. Thousands of square feet of manufacturing area have been devoted to jet engine manufacturing, for example. Missile facilities will undoubtedly be expanded by business leaders to similar proportions.

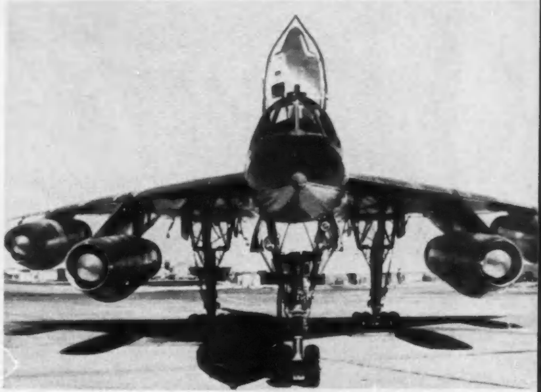
Manpower, in both technical and professional management fields, is another of private industry's increasingly vital specialties serving national defense. Such organizations as General Electric's Advanced Management Research Institute at Crotonville, NY, are already beginning to significantly advance the modern organization to match the modern weapon. Industry recognizes a new breed of scientist and engineer—men who have spent their entire careers in advanced work on defense systems and weapons.

The continual expansion of production facilities and modernization of both methods and organization must be accompanied by care in cost control. One answer: More thorough exploration of the cost-cutting ideas that always form part of sound businesslike operations. Through formalized programs—say, Gen-

TEXT CONTINUES ON PAGE 22

Obsolete bombs and bombers symbolize the quantity approach to defense. Today a handful of highly technical, highly ingenious, sensitive, and expensive equipment guards the nation against attack. Tools of quality defense include . . .

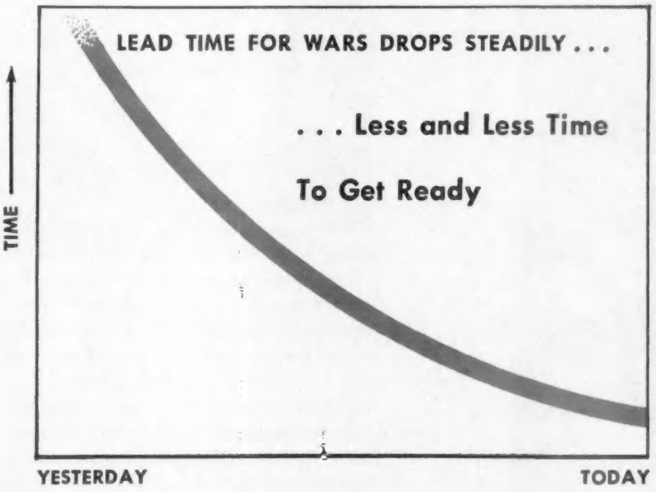
. . . Radar . . .

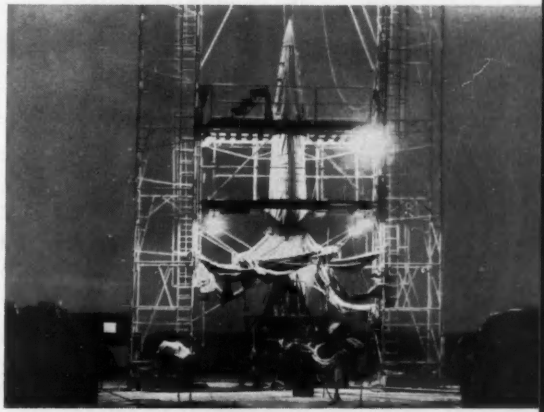


. . . Supersonic Aircraft . . .

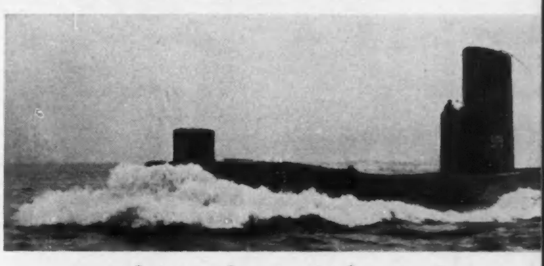
Defense Superiority

With the lead-time margin narrowing to a sliver, today's defense must be ready throughout the year, and from year to year. This means planning on a meaningful continuum, on a business basis.

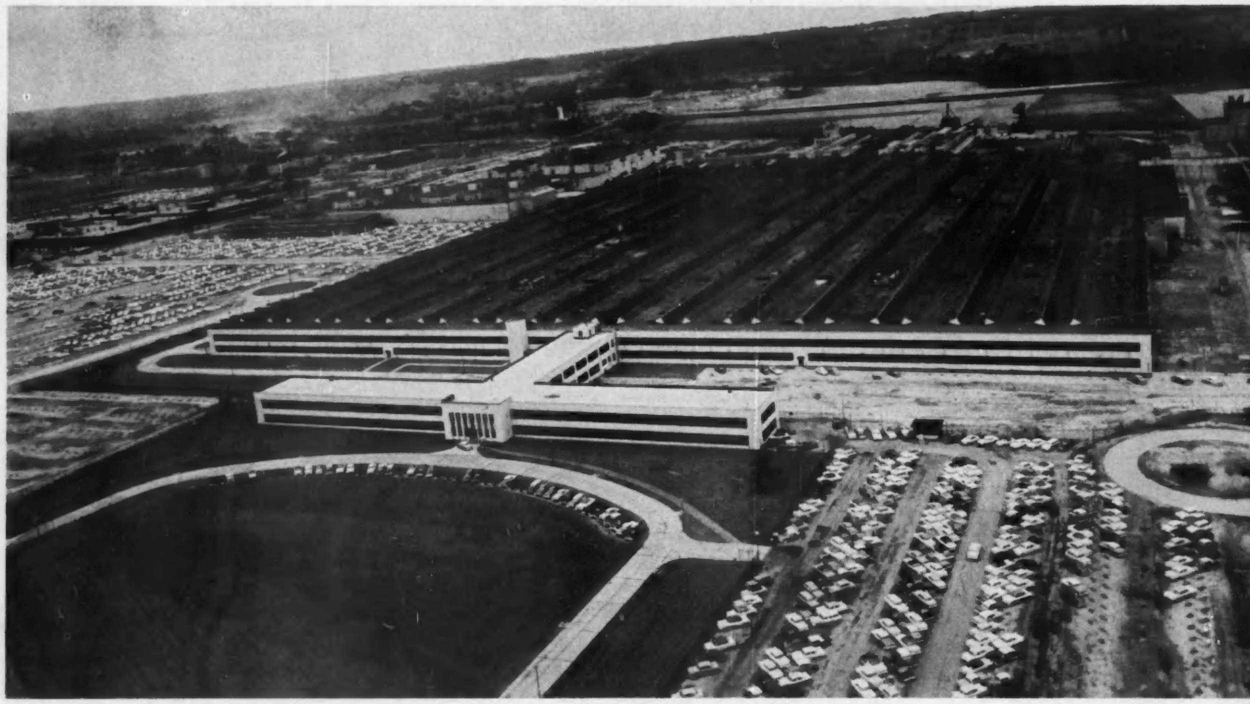




. . . Guided Missiles . . .



. . . and Nuclear Submarines



Private Investment in Facilities such as these extensive acres of space devoted to manufacturing operations, is one of the most important phases of today's increased application of private enterprise techniques to the defense requirements of our nation.

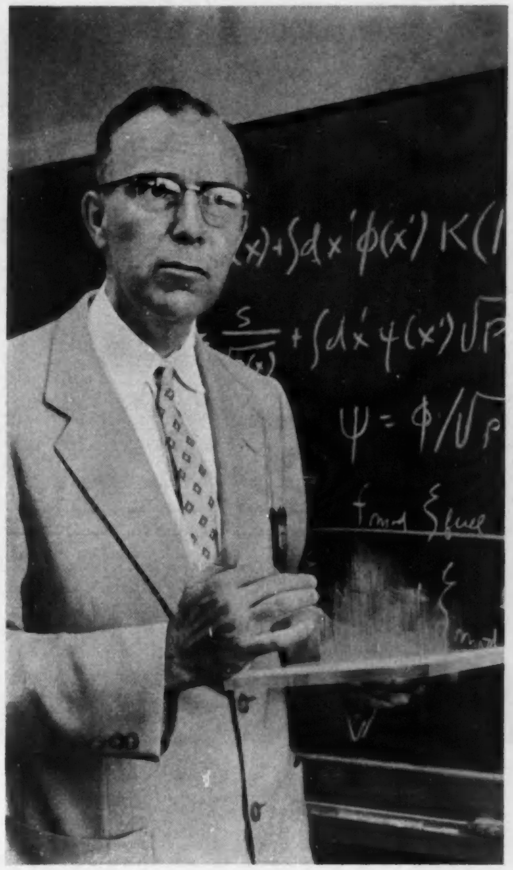
Professional Management men distil experience during seminar at the General Electric Advanced Management Research Institute.

eral Electric's Value Analysis where continuing comparisons of component design and costs are conducted by experts —cost-cutting ideas can be advanced more rapidly than ever before. Such programs should be encouraged in every defense industry, in whatever form they may take. They result in benefits for both defense contractor and taxpayer.

Eventually, though, all cost-cutting programs reach an area of diminishing returns. They have limits imposed by the nature of the product and the basic cost of raw materials and labor. When all costs have been brought under tight control, profits should be appropriate. Businessmen must rely on profits for incentive and also for continuing exploration of promising new development areas.

The important role of profits in large-scale industry is probably among the least understood and appreciated by the American public. In a free-enterprise system, profits must be adequate to yield a reasonable return to the investors who supply the venture capital and also provide funds for the essential business investments necessary to keep pace in a progressive society. Some profit from the industrial enterprise will generate important benefits for all. Ω

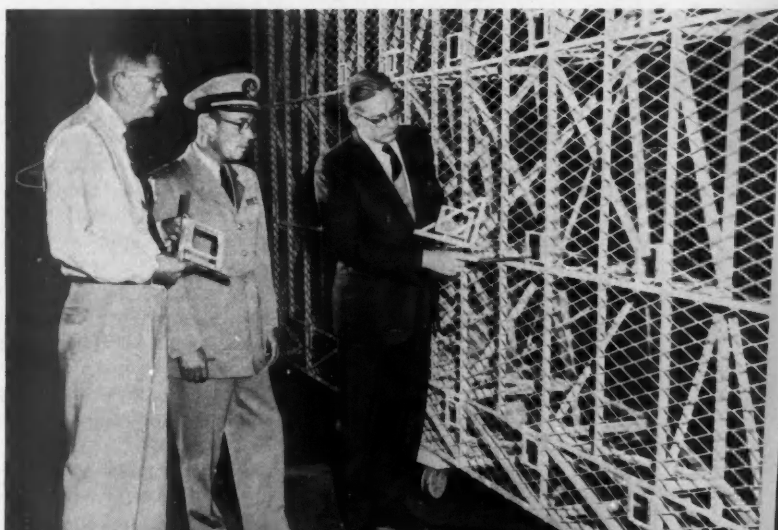
Technical Manpower includes a new generation of engineers and scientists making defense a career. Allen Bell, helicopter engineer at Defense Electronics Division's Flight Test Center, who has worked in defense almost since graduation, and Dr. William Kanne, scientist at Knolls Atomic Power Laboratory, devoting his entire career to nuclear energy, typify professionals in defense.

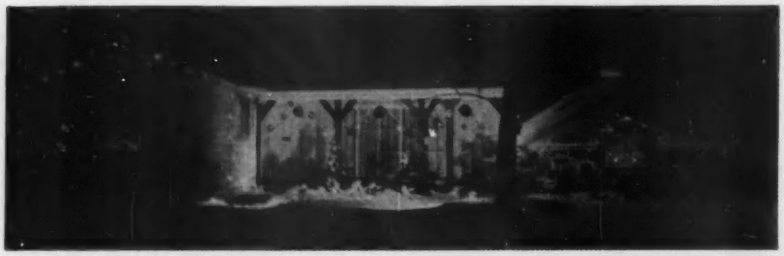


NEW DIMENSIONS OF AMERICA'S ECONOMY—2 (concluded)

Today's Defense Requires More Private Enterprise Techniques

Cost Reduction watchwords of the successful defense contractor, depends on thorough product analysis. Value analysts recently compared designs for the Navy on radar antenna dipole supports that form key links in the portable screen (below). Contract costs were reduced $11,571 through a more easily manufactured design.





Lighting engineers constantly improve the ever-changing decorative Christmas lamps to help you achieve new and different effects with your Christmas lighting as you plan ahead for the forthcoming Holiday Season.

The Year-Round Business of Christmas Lamps

By GWILYM F. PRIDEAUX

Christmas and decorative lamps have a long history—long, that is, for lamps. Advertisements appeared as early as 1901, and complete string sets were sold in 1903. During those early years when largely made by hand, lamps were produced in a variety of shapes and sizes—some in the forms of Santa Clauses, bells, and birds.

But automation reached the lamp industry at an early period. With the development of highly mechanized lamp-making processes, increasing costs of material and labor, the special lamps at premium prices were replaced by a rather standardized product which could be mass-produced and sold at a low price. These 15-volt lamps, designed to operate eight in series from the standard 120-volt residential-circuit power line, consumed a little under 5 watts each.

Series operation had some drawbacks, however. If one filament of the eight burned out or one lamp loosened in the socket, the entire string of eight lamps went out—an annoyance desirable to overcome.

Mr. Prideaux—Senior Specialist and Consultant, Miniature Lamp Department, Nela Park, Cleveland—joined General Electric 35 years ago. In 1933 he received the Charles A. Coffin award for his development of the photoflood lamp. A previous contributor to the *Review* and an authority on Christmas lamps, his most recent accomplishments are developing twinkle and lighted ice lamps.

A Larger Lamp

In 1934 the 120-volt multiple-type candelabra-screw-base lamp made its appearance; if one lamp burned out, the others stayed lighted. Of necessity, this lamp was a little larger than the series-burning lamp. The candelabra base was required for 120-volt service and also to make certain the public could not use the two types of lamps interchangeably. Moreover, a much longer filament in the lamp required several supports, making the accompanying bulb larger and, incidentally, about twice as expensive. Similarly, the multiple-string sets required larger sockets and nearly twice as much wire.

Although most of the string sets currently being sold and used indoors today employ 120-volt multiple-burning lamps, many of the series lamps and sets are still sold because people prefer their smaller size and lower price.

The outdoor 120-volt multiple-burning Christmas and decorative lamp was also introduced in 1934. This 10-watt lamp used the larger intermediate screw base. Lampholders for it are either intermediate screw-base string sets or pin-on holders. These present outdoor lampholders or sets incorporate special weatherproofing features approved by the Underwriters' Laboratories (UL) for outdoor use. The indoor strings also carry the UL approval label, which you should always look for. (A number of miniature light sets recently imported may not carry the UL label nor meet the UL's minimum safety requirements.)

Visual Sensation of Color

Christmas and decorative lamps, usually colored, primarily create a stimulating or exciting visual sensation by

direct viewing rather than by illuminating an area as with most lamps.

For this reason let's briefly inquire into the three separate and distinct aspects of color: physics, chemistry, and psychology.

The physics involved tells us that the primary colors of light are red, green, and blue with the dominant hues at 6400, 5300, and 4600 angstroms respectively. Red and green light together make yellow light; red and blue light produce violet; and blue and green combine to produce a blue-green. The combination of all three primaries—red, green, and blue—produces white light.

But light can be subtracted as well as added. Because the filaments generate white light, filters are applied to the bulb to color the light by a subtraction process—the chemistry aspect. In this area of chemistry, every artist also knows three primary colors—blue, yellow, and red, with dominant wavelengths of 4830, 5700, and the complement of 5300 angstroms respectively.

We encounter the psychological aspect in our study of what the eye perceives. Here, in addition to gray, four primary sensations are experienced as bluish, yellowish, greenish, and reddish. The dominant hues of these sensations are generally accepted to be 4760, 5820, 5150, and the complement of 4930 angstroms respectively.

Because Christmas lamps are used primarily for their lighted effect, you should wisely choose from lighted examples rather than only the cold appearance of the lamps because they will sometimes be different. Colors used for many years include red, blue, green, and orange, all in varied hues and shades. These have fluctuated slightly over the years because of the coating employed: outside spray coating on some, inside color coatings on others, and more recently ceramic enamel coatings on both indoor and outdoor lamps with greater permanence despite some disadvantages.

Our current red, blue, green, and orange lamps match four color chips in a hue circle made from the Ostwald color system, which recognizes 30 hues. The colors of the lamps are unevenly spaced in the hue circle and none complement the other.

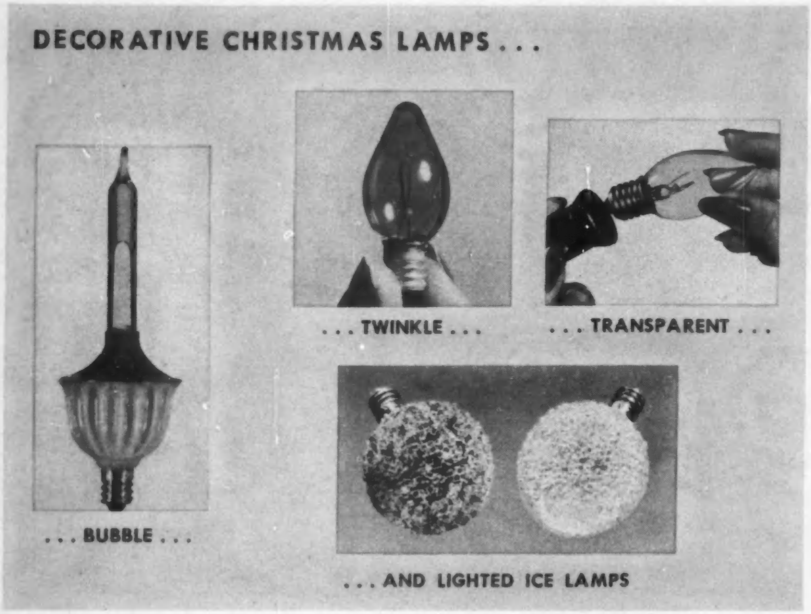
More recently we added four additional colors—exactly complementary to the four lamp colors now in use, making a total of eight hues. During the process, we experienced much difficulty in getting enameled bulbs to match the selected color chips.

Market Survey

About 1000 lamps of each of the different colors were submitted to a large market-survey organization. This firm distributed the samples to people known to have string sets that would accommodate the lamps. They received the lamps in plain unmarked cartons with each bulb numbered in excess of 10 to avoid a technicality in number preference. The 1000 selected families, scattered across the entire United States, made two choices: first their preference of the lamps unlighted, and then two weeks later, their preference of the lighted lamps (Table).

From the survey results we concluded that the colors of the translucent lamps might be modified and that the sale of the lamps should be made from lighted samples rather than the cold lamps. Some difficulties are involved in this method of selling; they will probably not be surmounted until enough customers demand to see the lamps lighted.

The color preferences for Christmas lamps should not be interpreted too



DECORATIVE CHRISTMAS LAMPS . . . . . . BUBBLE . . . . . . TWINKLE . . . . . . TRANSPARENT . . . . . . AND LIGHTED ICE LAMPS

broadly. For many other factors besides hue—the dominant one of the test—influenced preference. These same factors also affect other fields where color plays a vital role. Color specialists list some of the more important as. . .

Hue	Warm-Cold
Brightness	Mat-Gloss
Lightness	Volume-Depth
Saturation	Location
Insistence	Size
Texture	Luminosity
Hard-Soft	Glow
Pronounced Effect	
Opaque-Transparent-Translucent	

These attributes applied to the test in several ways: Unlighted, the lamps were opaque in color, the finish glossy. (Previous experience indicated mat finish as less desirable.) Lighted, the finish appeared translucent. Transparent lamps, however, are also now being introduced, but their brightness looks entirely different. The saturation as well as the pronounced effect or insistence may be greater. Colors may be warm or cold depending on the effect desired. In some of the novel lamps, texture, size, shape, and luminosity contribute importantly.

Novel Innovations: Bubble Lamps . . .

A radical novelty occurred in 1946 when bubble lights (grouped photos) went on the market. They introduced not only colored light but also a new ingredient—motion. Their glass vials contain a colored fluid of low boiling point. (In the past methylene chloride was used.) The base of the vial makes contact with or has close proximity to the lamp bulb: bubbles form from the heat of the lamp and rise through the fluid where they condense on top.

. . . Pink Lamps . . .

The history of color preferences also suggests some cyclic changes. In recognition of the public's desire for innovations in Christmas and decorative lamps, a pink color was added to the 15-volt series line and 120-volt multiple line two years ago. Since then a number of new or modified lamps with greater appeal to young and old have been introduced. And they lend themselves to more attractive displays.

. . . Indoor Twinkle . . .

In 1956 twinkle lamps were added to the line offered in four transparent colors—red, yellow, green, and blue—as well as clear glass. The 6-volt twinkle lamp incorporated a new bulb shape resembling that of a tight rose bud.

The development of this lamp with a built-in flasher stems indirectly at least from rather similar lamps with built-in flashers made by the Ontario Lamp Works of the Canadian General Electric Company for the Royal Air Force during World War II. These and more recent twinkle lamps flash because of the built-in bimetal strip similar to those used in thermostats. When the lamp lights, heat from the filament causes the bimetal strip to bend away from the lead-in wire. This breaks the circuit and the lamp goes out. As the bimetal strip cools, it bends back to its original position against the lead-in wire and lights the lamp. This cooling and heating cycle keeps the lamp flashing.

Inspection of the twinkle lamps presented an unusual problem. Normally, as lamps are produced, they come off the finishing machine, are inspected, and then are packaged at a high rate of speed. The twinkle lamps flash about 30 to 40 times a minute. Moreover, to warm up and start flashing originally takes a little time. Consequently the special inspection procedure devised takes much longer than for nonflashing lamps.

In the production of these lamps, automation again played its part. Naturally the first few samples were handmade. Product design engineers first developed a design that would lend itself well to automation. Then the precise machinery needed to make such Christmas lamps was developed. Pilot-plant operations were organized and run, and improved manufacturing techniques were developed.

The 6-volt twinkle lamp incorporates a miniature screw base and a ¾-inch-diameter bulb. Tests were conducted to determine the amount of radio and television interference, if any. Because of the low voltage, low power, and the filtering action of the transformer, practically no radio interference could be detected.

The transformer string sets utilizing the lamps were designed for indoor service, although this year we offer one for outdoor use. The lamps themselves give a relatively small amount of light so that they can be successfully used on indoor trees, particularly if other lights are on the trees in greater numbers. (Again, a word of caution: Some imported lamps employing the same miniature screw base as the domestic twinkle and the 15-volt indoor series lamps have the bimetal strip so connected that it shorts the lamp rather than opens it. If these are improperly used, as for example, insertion in a transformer string set or in a standard 15-volt series set, fuses may blow. If the transformer is not equipped with a fuse, it may burn up.)

. . . and Outdoor Twinkle Lamps . . .

It soon became apparent that people also desired twinkling lamps especially designed for outdoor use. To meet the demand, a 6-watt 120-volt version (grouped photos) was developed. It emits much more light, incorporates an intermediate screw base, and is manufactured with a clear bulb and four transparent coatings that create a sparkling effect.

The 6-volt twinkle lamp has a relatively small filament so that it becomes essentially a point source of light at a close distance. The 120-volt lamp, however, must use a filament many times longer—about 3/8 inch over-all. At a distance of 100 feet this represents one minute of visual angle, believed the smallest size that people can ordinarily see. So again, with the 120-volt lamp at its normal viewing distance, we have a point source of light that emphasizes color rather than filament.

The bimetal strip element in the outdoor twinkle lamp periodically opens and closes the circuit to the 6-watt 120-volt filament.

...Smooth Bulbs and New Coatings...

For many years the outdoor intermediate-screw-base Christmas lamp was fluted. A recent study indicated that at normal viewing distances the flutes on these lamps were indistinguishable and caused an uneven distribution of color. The enamel tended to be thin on the flute ridges, diluting the color with some white light. Slightly better colors will be obtained with the smooth bulb soon to be adopted.

Lamps with transparent coatings were tested last year by a market survey to determine people's preference for them versus the long-standard translucent coating of the outdoor lamps. The transparent coated lamps (grouped photos) give much more light than do the translucent coated lamps. Yellow transparent lamps substituted for orange translucent coated lamps now give half again as much light. It's the same with green transparent lamps. The red transparent lamps emit about twice as much light as the translucent, and the blue transparent slightly more than twice as much.

About one-million transparent coated 120-volt intermediate-screw-base lamps will be made for market testing this season prior to scheduling for full production. Last year, for instance, the United States public purchased nearly 400-million domestic and imported Christmas lamps. This number about equals all lamps purchased for residential use. With such quantities involved, manufacturers want to be reasonably sure that the public's needs and fancies have been adequately anticipated.

MARKET-SURVEY RESULTS ON CHRISTMAS LAMPS

Color	Preference Unlighted	Preference Lighted
Royal Blue	2	5
Red	1	1
Green	5	8
Orange	7	7
Yellow	3	3
Fuchsia	8	2
Peacock Blue	4	4
Turquoise Green	6	6

The first group comprises the standard translucent colored lamps.

. . . and Lighted Ice Lamps

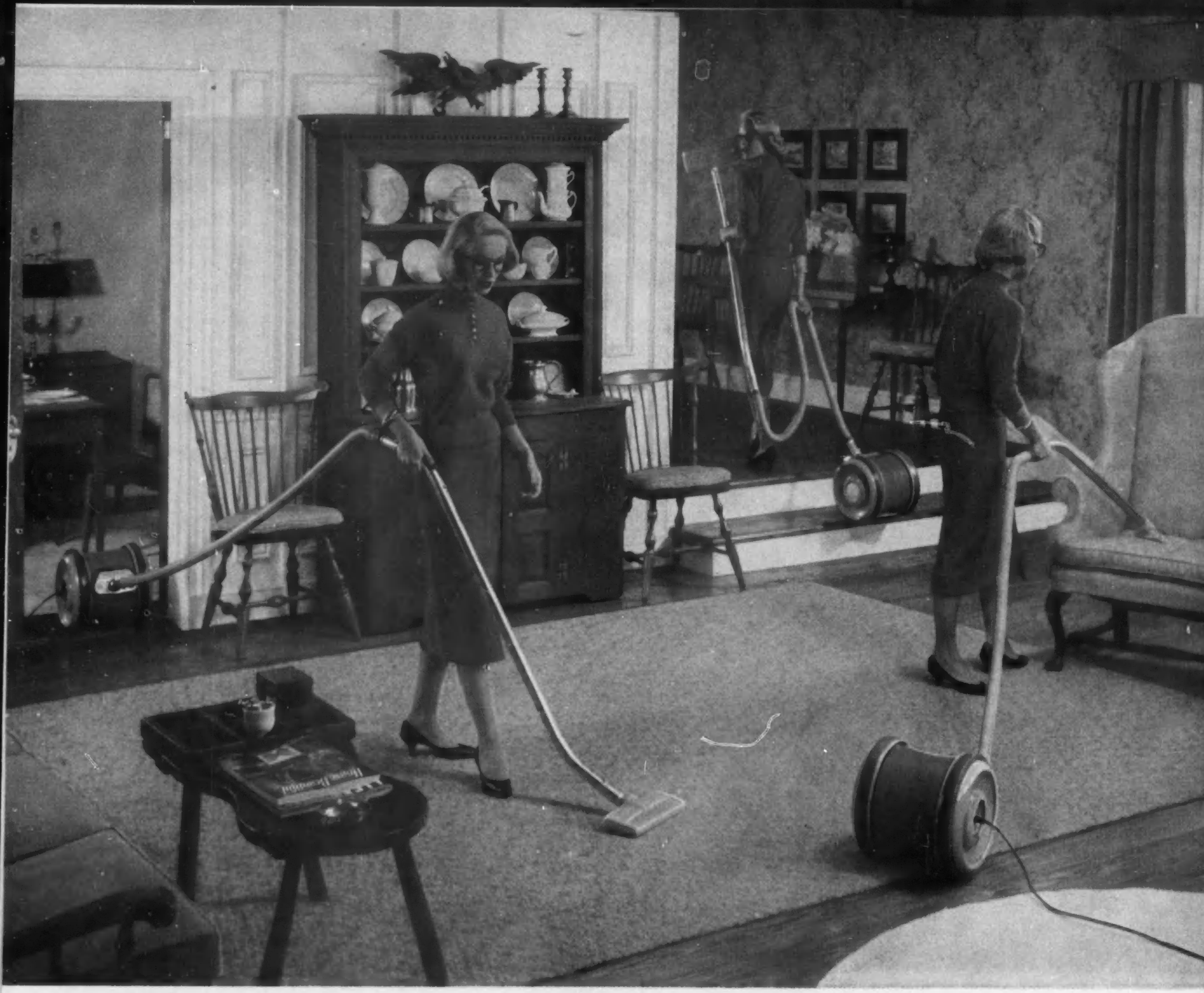
General Electric's latest development in the decorative lamp line is an unusual lamp called lighted ice because of its cool operation and crystal coating (grouped photos). It will be offered in six colors: pearl, topaz, emerald, turquoise, garnet, and ruby. The crystal coating diffuses yet transmits the sparkle of the filament located near the center of a spherical bulb about 1¾ inches in diameter. The light is colored first by the film applied to the lamp and then modified by the light transmitted through the crystals. Both prismatic action and reflection of the light occurs so that the entire bulb serves as a luminous colored disk around the filament—liberally sprinkled with brilliant spots of light. The lamp, about 2¾ inches high, is designed for use on 120-volt service, either indoor or out, in appropriate candelabra-size multiple strings or other candelabra decorative sockets. Being spherical, it is eminently satisfactory for use either base up, base down, or for horizontal burning. This year the lighted ice lamps will be manufactured on a limited basis so that consumer acceptance can be evaluated.

Problems of Merchandising

The merchandising field poses some peculiar manufacturing, distribution, and sales problems. Sales to the consumer are generally concentrated in the three or four weeks immediately preceding Christmas. To manufacture economically, however, these lamps must be produced, insofar as possible, on a year-round basis. This requires the best market forecasting possible. And these lamps further require extra warehousing for long periods of time; they don't usually move out into retail channels until shortly before the Christmas season.

You can see that Twelfth-night doesn't mean the end of the Christmas season to the manufacturer. For our product designers plan new and revised lamps for the following year. Our market researchers ask questions to obtain customer preferences. Manufacturing orders materials and schedules production. And advertising and promotion plan and prepare for the coming season.

Christmas and decorative lamps are a year-round business. Ω



Smooth-Rolling Cleaner Traveled a Rough Road

Now housecleaning is easier because engineers spotted a good idea, sold it to manage opinion, carried out a strenuous design evolution, and then they refused to be

By JAMES P. HUNTER

"I stub my toe every time I work the switch."

"The handle dents my woodwork. . ."

Mr. Hunter—Manager, Engineering, Vacuum Cleaner Department, Cleveland, for the past seven years—joined General Electric on the Business Training Course in 1941. His experience with the Company includes engineering positions in the Ship Fittings Division and the Wiring Devices Department, Bridgeport.

"Can't you make the cleaner lighter?"

Housewives testing an early prototype of General Electric's new Roll-Easy vacuum cleaner in their homes eagerly criticized it. Much of their criticism resulted in improvements, which our engineers designed into today's production model. Like many modern home appliances, this vacuum cleaner was not conceived in its complete final form; many minds contributed to its formation. Laborious trial, study, and much compromise went into the cleaner's over-all development.

A few years ago our Vacuum Cleaner Department, riding comfortably along with our swivel-top cleaner, anticipated optimistic sales results. And Marketing saw a clean-cut plan for effectively selling the cleaner in the foreseeable future. Manufacturing was engaged in a practical and rewarding cost-reduction program based on experience and increasing volume. Our engineers were

New mobile vacuum cleaner rolls easily through a housewife's daily cleaning. Simplicity of production model is deceptive; months of design effort lie behind its development.

d to Market

ge ment, listened to housewife be atisfied with the result.

planning many minor variations and additions to the product to carry it along through coming years.

But we recognized the danger signals of self-confidence and self-satisfaction. Although we had never ceased our attempts to develop improved cleaning devices for the home, the danger signals actually increased our efforts on new product development.

During this paradoxical period of good product acceptance and fear of complacency, we embarked on the Roll-Easy development. And just then an element of luck intruded.

Every year the Company considers hundreds of letters from customers, friends, potential customers, General Electric employees, readers of our advertisements, and many others who have product ideas to present. Most suggestions are rejected because they cost too much to develop, lack originality, or are unsuitable. For instance, people have proposed special dandruff-removing attachments or cleaner nozzles equipped with magnets to pick up hairpins. These ideas—while good—don't add enough value to the cleaner to justify the additional manufacturing cost. But buried in this torrent of suggestions, we occasionally find an idea of real value to our business.

A member of our Vacuum Cleaner Engineering Section had an idea: "Make the body like a barrel, with big wheels on the ends." He put this idea into a sketch; the sketch went into a patent docket (Box, next page). A patent docket review and subsequent search of issued United States patents, however, disclosed that this basic idea was not novel.

Though the sketch presented no details on the internal arrangements, it clearly stated the general idea. Further study showed that this concept had real potential. And recognition of this potential represents some of the most important duties of the engineer: filtering out the good idea from the mass of poor ones, carefully evaluating it, and then supporting it enthusiastically.

But this new idea couldn't be effectively presented to management and marketing in the form of a rough and incomplete sketch. Good ideas must be displayed in a favorable and realistic light; a poor presentation can kill a good idea.

Selling Top Management

We formed an engineering team to develop the idea for presentation to management. Our first move: Preparing a demonstration model. To clarify the idea, we set about making a wooden dummy incorporating color styling and good appearance. A common clay model would not withstand the punishing demonstration. The interior layout for the cleaner soon crystallized into a detailed sketch of the tentative arrangement of the motor, dust bag, and other parts. We took no chances on having the whole idea misunderstood and thwarted in the conference room.

To demonstrate how easily the large wheels roll up and down, we built a set of wooden steps—complete with carpeting. This feature could be effectively demonstrated visually, say, to a television audience.

Then to complete our preparations for selling the idea to top management, we prepared a chart listing some of the proposed cleaner's advantages . . .

SMOOTH ROLLING—Large wheels easily cross door sills, scatter rugs, cords.

SHORT TURNING—Cleaner swivels in its tracks because wheels turn independently.

NO LIFTING—Cleaner rolls up and down stairways.

EASY PUSHING — Extension tube, inserted in a socket on the body, becomes a steering handle.

Our engineering team was now ready for the presentation to management. At the appropriate moment, we rolled our carefully polished wooden model into the conference room and banged it up and down the artificial steps.

After witnessing the demonstration and listening to our story, our general manager decided to go ahead. "How soon can we get it in production?" was the big question.

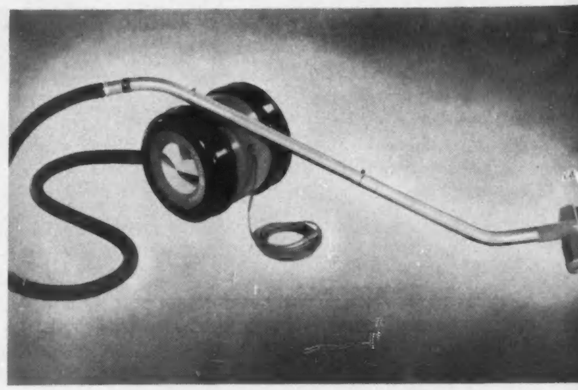
Tackling the Problem

Almost at once we struck a snag. Because of its basic barrel shape, it was extremely difficult to provide the cleaner with a pleasing and practical appearance. Industrial designers, consulted shortly after the management conference, wanted to make the cleaner look less bulky. Their solution: Spoked wheels to lend a feeling of lightness. The idea looked good at first, but the spoked wheels proved too costly.

Returning to the solid-wheel concept, the industrial designers worked out a compromise retaining some features of their previous design: a richly embossed center hub that reflected in the bright metal wheel disc; and the special die casting with carrying handle, hose inlet, and tube socket all formed in one piece.

Even that small detail, the tube socket, had undergone evolution during this period. On the original wooden model, we had created this socket with a simple bracket attached to the cleaner hose coupling. The extension tubes could be inserted into the bracket. The tubes then served as a steering handle for directing the cleaner from one room to another. When we replaced the early bracket with a socket formed in the solid casting, the arrangement proved stronger and easier to use.

As designers sifted ideas for the new vacuum cleaner, combinations crystallized in successive wooden dummies. Housewives, supplier representatives, engineers, industrial designers, sales personnel, and management—all added fuel to the chain reaction. Their efforts culminated in the working unit (far right), revealing first results of actual service. These photos depict the cleaner's evolution...



First Dummy helped sell management on development project when engineers dramatically wheeled it into meeting.

The steering-handle idea could also be applied to the swivel-top cleaner: We mounted a bracket on the caster frame that holds the steering handle without necessity of removing the rug tool. This improvement in the swivel-top cleaner was a by-product of our concentrated development work on the Roll-Easy model.

The new rolling cleaner, in turn, benefited from early development work on the swivel-top model. For example, we had determined the length and shape of the swivel-top extension tubes by asking a large number of women to try several tube sets of various lengths and curvatures. The tubes used with the new cleaner resulted from the choices made by these women. Previous home testing during 1948 and 1949 also determined the length of the cleaner hose.

Providing cleaning attachments for the cleaner was easy; we simply used our existing standard attachments. The power unit needed no design work, because we were already building our own motor and precision ball bearings.

Supplier Pitches in to Help

One of the most difficult design jobs associated with the new cleaner occurred in the development of a disposable paper bag. The bag needed the right degree of porosity to pass enough air while retaining dust. Further, it had to fold readily into pleats for flat storage and open into a horseshoe shape to fit in the space between the cleaner's motor and cylindrical casing.

In this problem, as in so many involving materials purchased from suppliers, the engineers of the supplier's company readily furnished aid.

We were determined to develop a proper disposable bag, even though our cleaner operates effectively with only its permanent cloth filter.

We finally found the right combination—but only after trying 20 grades of paper and an uncounted number of pleating techniques.

As we completed various phases of development, a mounting pile of engineering drawings reflected the results. Altogether, it took 262 individual drawings to fully describe the cleaner. And despite this mass of detailed preparation, the cleaner was still a long way from the customer.

Tests Bring More Changes

After completing the engineering drawings, we built prototype models. A long and strenuous course of testing lay ahead, both in the laboratory and in the homes of selected housewives.

Home tests consisted of two types . . . Do-It-Yourself—After a brief demonstration, we left the cleaner with a housewife for a short trial period. She

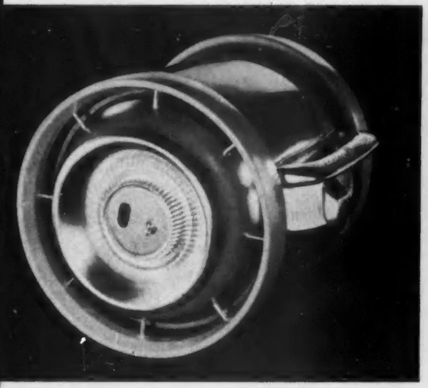
BENEFITS OF GENERAL ELECTRIC'S PATENT PROGRAM

General Electric's patent program played an important part in the development of the Roll-Easy cleaner. "In designing for sales" the development engineer doesn't always fully appreciate the vital role of legal protection of the fruits of his labor.

In the case of the new cleaner, the basic idea of a large-wheeled barrel-shaped vacuum cleaner turned out to be old in a legal sense; but because of the stimulus of our patent program, the idea was presented in a patent docket and thus demanded attention. This indicates the importance of actively pursuing a patent program and fostering a prompt docketing of ideas. And it also shows that even though a patent may not ultimately be obtained, the incentive provided by the patent system frequently results in the production of a commercially successful product.

During the design metamorphosis of the new cleaner, we reviewed the development frequently to avoid any adversely held patents and to detect potentially patentable subject matter. The results: The filing of numerous patent applications on various improved structural aspects of the cleaner.

When a patent application is filed in the name of a General Electric employee, he receives a $100 patent bonus. When the patent issues, he receives publicity that helps enhance his reputation among his professional associates. The man sees his achievement mentioned in publications that range from his home-town newspaper to the U. S. Patent Office *Gazette*. And managers and their associates in the patent field actively promote all three: publicity, patent bonus, and actual patenting. They know that engineers function best in the climate of recognition of their accomplishments.



Second Dummy used spoked wheels to make bulky cleaner body appear lighter.

Compromise Dummy retained most practical features of both earlier packages.

Working Model provided valuable design information in early performance tests.

then described her reactions on a questionnaire, which she returned to us for evaluation.

COMMAND PERFORMANCE—We called on the housewife, handed her a cleaner, with no prior instruction, and asked her to clean with it. A trio of General Electric vacuum-cleaner representatives —marketing, engineering, and management—took notes as they followed her while she cleaned. Though ponderous, this test produced valuable insight.

Our designers made several improvements as a result of these home tests. For example: The cleaner's protruding handle, made of a heavy casting, whacked the woodwork and furniture when the cleaner rolled by. We replaced the casting with a flat-handled plastics assembly.

The control switch was hard to snap by anyone wearing soft slippers and toeless shoes. An electrical components engineer came up with a sensitive toggle switch that worked in any position.

An intensive program of laboratory testing was also carried out. Of all the laboratory tests conducted, the rug-cleaning efficiency tests are probably the most elaborate. The basic ingredient for this testing is a standard "dirt" to yield valid consistent results (Box, next page).

During such a test, the cleaner is operated by a testing machine over a carpet in definite movement patterns, at fixed rates. The amount of standard dirt collected is then weighed. Comparison with the amount laid down provides the cleaning-efficiency percentage. Percentages measured on other models provide relative cleaning-efficiency figures. We run similar cleaning-ability tests with specially prepared threads of various lengths, lint from long- and short-staple surgical cotton, cracker meal, and bicarbonate of soda.

We conduct noise tests, dedicated to the housewife's peace of mind, in a silent room—a 10-foot cube mounted on rubber springs, heavily insulated with sound-deadening materials. Operating the cleaner on a medium-pile carpet in this room, we collect noise frequency and intensity figures. Knowing the pitch of the loudest noise on a particular test machine, an engineer can often locate and reduce the noise source. We record these tests results for long-term comparison.

Other tests include vacuum measurements under various conditions—made with an ordinary water manometer—and wear tests such as those for wheel and bearing life.

In the stairway test, crudest of all, a husky man walked up and down a flight of stairs 100 times, pulling or pushing the cleaner. This test provided important conclusions: It taught us much about human endurance values—it also indicated that the cleaner was too heavy! Because this test proved too much for our test man, we replaced him with a suitable testing machine.

"Weight doesn't matter, because the cleaner is so mobile," we had declared earlier. Consequently, we had formed the main parts—barrel and wheels—of steel, to cut cost. We were wrong!

Because the stairway-test results confirmed the housewives' reaction to the weight, we specified aluminum for the body and several internal parts. Costly heavy steel wheels gave way to plastics wheels so strong that you can drive an auto over them without squashing them. We actually subjected the first plastics wheel samples to this treatment. To test impact resistance of the wheels, we dropped them from a second-story office window onto a concrete slab. They bounded without breaking.

Selecting the Colors

As the final step in design, we called in a home fashion consultant to substantiate our color choice and to achieve an over-all appearance to harmonize with current trends in the home furnishing field.

Before the final color scheme could be decided upon, many various color proposals had to be examined and evaluated on actual models.

Two-tone turquoise in combination with copper-finished metal parts was the final choice. This choice was made because research confirmed the trend toward high interest in these colors.

At last the testing and redesigning had ended; our production model was approved. Tooling and pilot production were completed soon after. The pilot run went smoothly. The time had come to announce the cleaner to our dealer and distributor organizations and then to the general public.

Salesmen Enthusiastic

We scheduled a meeting with our field sales force for May 1955. Until that time, our engineers had been careful to keep word of the new cleaner from leaking out. Vendors and General Electric salesmen alike had been barred from the engineering laboratories and offices. Headquarters personnel, mindful of the dangers of premature disclosure, were also careful to say nothing.

The cleaner's reception at the May meeting was as favorable as anyone could wish for a promising new product. The salesmen were enthusiastic, filled

"Successful business demands steady, continual product development."

with confidence, and "ready to set a new sales record for the industry." Department store and syndicate buyers and distributor and dealer representatives, who saw the new cleaner a short time afterward, shared the salesmen's confidence.

The general optimism, while based primarily on the merits of the cleaner itself, was reinforced by marketing plans for the product. We planned a heavy schedule of television advertising, because you can grasp the advantages of the new cleaner best when you actually see them demonstrated. The advent of widespread television viewing had occurred at just the right time for our vacuum-cleaner business. Now we could use television to bring actual cleaner demonstrations into millions of American homes.

Beginning the Redesign

The machine we placed on the market back in 1955 has already been reengineered extensively. The engineers who developed the cleaner continued development work after their initial product went into manufacturing. For a successful business demands steady, continual product improvements.

Made early last year, the first major improvement was a two-inch reduction in the cleaner's width. We accomplished this by partial redesign of the machine's internal components. It allowed a return to less expensive steel in place of the aluminum barrel, with little weight increase and a reduction in manufacturing cost. It also improved the cleaner's appearance considerably.

A change in the shape of the barrel further improved the cleaner's appearance. We constricted the midsection slightly, making the cylinder wall concave instead of convex. This created an optical illusion of lightness and removed the beer-barrel appearance of the earlier models. The color scheme was brought up to date with a new combination: the turquoise was retained, but pewter replaced the copper.

Today's cleaner weighs a full three pounds less than the first test models. We have also redesigned the blower and exhaust air system. Manufacturing cost has been trimmed down by $2.03 so far. These cost reductions directly benefit today's consumer: our price has been reduced by about 15 percent.

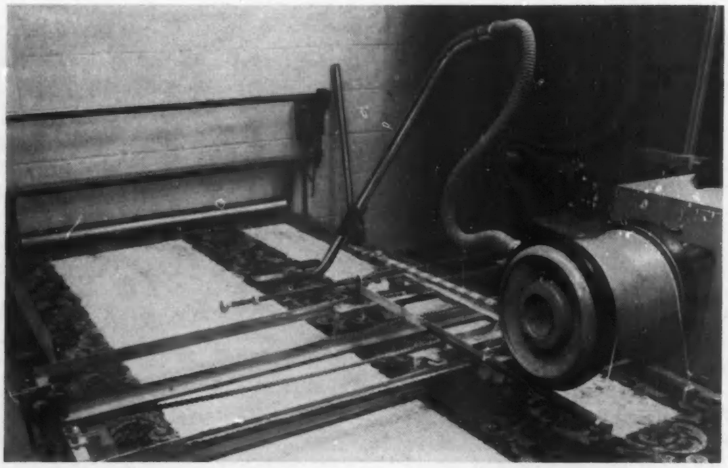
This improved product has recently been honored by being chosen as one of the few American exhibits at the Undicesima Triennale Industrial Design Exhibit in Milan, Italy. This exhibition, which takes place every three years, is a collection of significant new products and designs from the entire free world.

Our Real Boss

Design improvements such as those described will continue to appear on successive models of the cleaner. Today's product is being reshaped for tomorrow's customer.

But designing a good appliance that performs well for the customer's dollar isn't enough. More and more, a device for home use must look good; it must appeal to the image in the housewives' minds. It is for this reason that we will always be investigating new concepts in cleaners: to improve their function and consumer acceptance, because the customer—Mrs. Housewife for us—is our real boss. As long as we keep this concept before us at our drawing boards and test benches and conference tables, we'll always have a new project coming up. Because somebody always wants a job done a little better, a little faster, with less effort, at a lower cost.

That's why our vacuum cleaner rolls along so smoothly today. Ω



STANDARD DIRT TEST . . .

To measure the cleaner's efficiency in removing dirt from rugs, we developed our own tests. A special machine moves cleaner over standard rug at a fixed rate and collects a measurable amount of standard material such as this mixture . . .

STANDARD DIRT RECIPE

- Sift a few pounds of white silica sand through a No. 50 and No. 30 sieve.
- In a clean container, mix 140 grams of the strained sand with 210 grams of commercial talc.
- Gently pour the mixture into an electric vibrator.
- Using the vibrator, spread the mixture evenly over a clean living-room carpet.
- Roll this mixture well into the carpet for 8 minutes, using a 150-pound roller.

Now the standard dirt mixture is ready for testing.

Test section at NACA's Lewis Flight Propulsion Laboratory indicates advanced state of wind-tunnel technology. Tunnel's sidewalls (background) adjust for varying throat area.

Wind Tunnels Bolster America's New Sky Defense

By M. D. HORTON

The decision last June by the United States Department of Defense to switch emphasis from manned aircraft to a mixture of manned aircraft and missiles well illustrates the tempo of flight technology. Yet in a vital area of our nation's overall defense program, it's but another forward step.

As part of this program, industry during the last five years has cooperated with government in constructing major wind-tunnel facilities (photo) for aeronautical research and development. These cost the taxpayers hundreds of millions of dollars. America is being equipped with a variety of tunnels through which winds hurtle at subsonic and hypersonic speeds—driven by an assortment of electric motors and equipment capable of delivering more than one-million horsepower.

With the unusual size and type of these new laboratories of aeronautical research, complex engineering problems arise. For it's not just a matter of increasing power input to get a bigger, swifter breeze.

Some of the questions most frequently asked about wind tunnels: Why is it necessary to build so many? isn't there a duplication of facilities? why shouldn't a few tunnels of each type be sufficient? To answer these questions you must first know something of the several types of wind tunnels and the range of speeds in which they operate.

Mr. Horton—Systems Application Engineer, Apparatus Sales Division, Schenectady—has been with General Electric for the past 13 years. His present assignment is concerned with wind tunnels and other specialized testing equipment.

Primer on Speeds

Commonly, air speeds in wind tunnels are compared to the speed of sound for a moving body behaves differently at speeds below, equal to, or above that of sound.

Pressure waves—which sound waves actually are—move through air at a velocity that depends on the square root of the absolute temperature.

Sound traveling through the air at a temperature of 60 F, for example, moves with a speed of 760 mph. As this temperature decreases—and it does so from sea level to about 36,000 feet—the speed of sound also lessens. From 36,000- to 100,000-foot altitudes, the speed of sound remains approximately the same because of a constant temperature in this range.

A plane or missile traveling at subsonic velocities—less than the speed of sound—transmits pressure waves ahead of itself. Causing the air molecules to move in an orderly fashion, these pressure waves prepare them for displacement by the onrushing body.

But if the body hurtles along at supersonic velocities—above the speed of sound—it can't transmit advance warning to the air molecules ahead. It strikes them with great shock and violence.

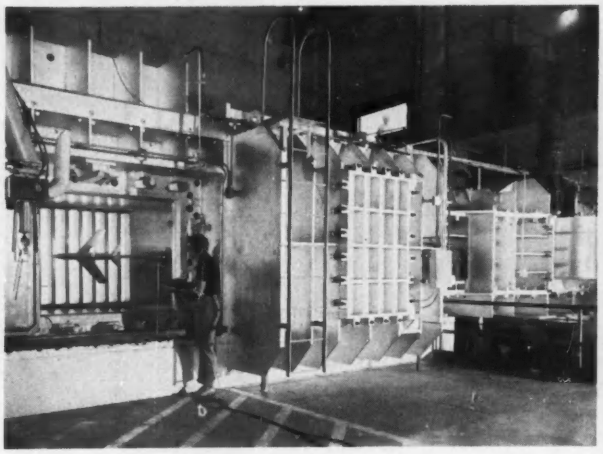
What about a body moving at exactly the speed of sound? It combines both of these conditions. The air velocities over the object's entire surfaces vary, depending on its shape. Some portions of the body's surface experience subsonic flow, while simultaneously supersonic flows blast other surfaces. Under such conditions the air behaves neither as pure subsonic nor supersonic flow. This troublesome region is called *transonic*.

You can classify the major types of wind tunnels, then, by their relationship to the speed of sound—or their Mach number. This is the ratio of a body's actual speed to the speed of sound. For three conditions of air flow, the common range of Mach numbers is . . .

- Transonic—Mach 0.7 to 1.3
- Supersonic—Mach 1.3 to 5.0
- Hypersonic—Mach 5.0 and above.

The value of wind tunnels is that engineers can test a stationary missile or plane, or one of their components, under controllable conditions. Because the model remains stationary, it can be instrumented to measure thrust, drag, lift, stresses, and pressures at critical points and temperatures. When designing a high-performance aircraft, human lives needn't be risked flying under actual conditions, and weather can't delay tests.

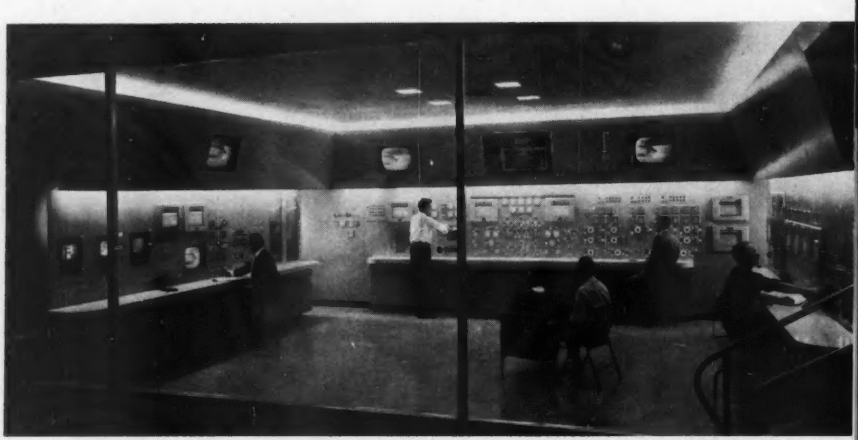
A model of the missile or aircraft can be constructed at a fraction of the time and expense required for the full-scale craft. By using plastics or other moldable



Nation's most extensive facilities are centered at NACA's laboratory at Langley Field, Va. Supersonic wind tunnel operates at velocities from 1.5 to 5 times the speed of sound.

Langley Aeronautical Laboratory

At Cleveland, Ohio, Lewis Flight Propulsion Laboratory operates the world's most powerful supersonic propulsion tunnel for engine testing.



Lewis Flight Propulsion Laboratory

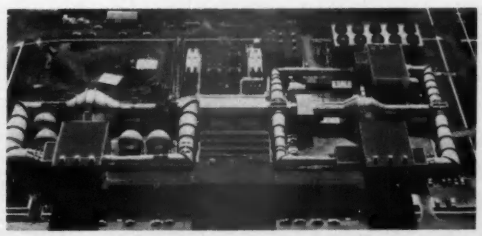
Observers view the tests via television in supersonic-tunnel facility's main control room. Data signals from the tunnel are fed to an encoder (below) and, in turn, to a push-button-controlled computer.

WIND TUNNELS (Continued)

materials, engineers can readily change the model's configuration. To simulate performance of proposed prop-driven aircraft, some models are even equipped with propellers driven by miniature high-speed electric motors.

Several of the newer tunnels accommodate full-size jet engines, rocket motors, and ram jets. Under accurately controllable conditions, engineers can

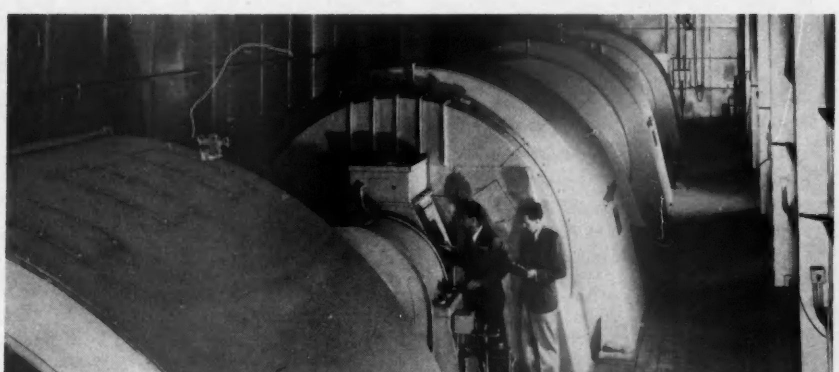
Four-by-four-foot test section of Langley's supersonic tunnel (left) is operated from an elevated control room (above). In the tunnel's second test section (right) a missile model is readied to furnish data for aeronautical studies.



Huge supersonic wind tunnel, one of several facilities at Moffett Field, Calif., handles large aircraft and missile models. Having three circuits, it's actually three tunnels in one.

Ames Aeronautical Laboratory

Four motors on a shaft—world's largest single drive—power supersonic tunnel's 11-stage compressor.



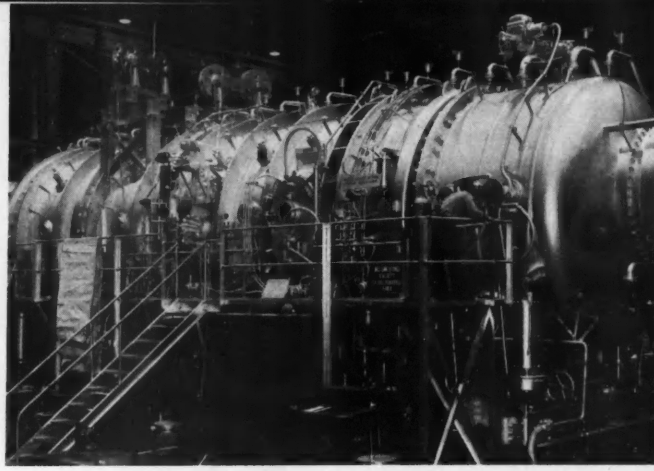
run these power plants at full load—precisely instrumenting them for overall performance to determine stresses, temperatures, and pressures.

In the design of a single fighter plane, many wind tunnels are employed. Engineers test its power plant alone in a special wind tunnel. To find out how the aircraft will perform at speeds above sound, models of the plane are tested in a supersonic wind tunnel. For determining its characteristics during transition from subsonic to supersonic flight, engineers test it in a transonic tunnel. To ascertain landing and take-off characteristics and to determine its flying characteristics at high subsonic speeds requires investigation of the model in a subsonic tunnel. If changes are necessary to obtain satisfactory subsonic characteristics, the design may have to be retested at transonic and supersonic speeds.

Before the model is ready for construction in a full-scale fighter plane, it may undergo tests in a half-dozen wind tunnels and, because of necessary changes, perhaps return for several retests.

The four basic types of wind tunnels —subsonic, transonic, supersonic, and

USAF's wind-tunnel center includes an engine-test facility (arrow), where air-breathing propulsion systems are tested inside sealed cells (right).



Arnold Engineering Development Center

Supersonic tunnel (lower, left), part of gas-dynamics facility, has speed range to Mach 5.5. In another tunnel, actuators "flex" walls of supersonic nozzle.

hypersonic—aren't all inclusive, however. Just as the engineer himself has become specialized, so have wind tunnels. These include . . .

. . . *Full-Scale Tunnels*—NACA has one such tunnel whose test section measures 40×80 feet and another of 30×60 feet.

. . . *Propulsion Tunnels*—full-scale engines, ramjets, and rockets may be operated loaded.

. . . *Spin Tunnels*—a model is made to spin under control and observation of an operator in an uprushing column of air.

. . . *Gust Tunnels*—a model in free flight is subjected to a sudden blast of air.

. . . *Ice Tunnels*—models are flown under actual icing conditions.

. . . *Heat Tunnels*—for aerodynamic heating research on aircraft and missile structures.

Who Has Wind Tunnels?

Government laboratories, universities, aircraft-industry manufacturers, and private laboratories operate wind tunnels. The automotive industry uses wind tunnels too, but of course not for aircraft applications.

Because of large initial and operating costs, most organizations find it impractical to possess complete wind-tunnel facilities. As a result, several aircraft companies may subsidize construction of a wind tunnel at a university so that each can utilize the facility when needed.

Because the largest wind tunnels cost more than most manufacturers can wisely afford to spend, the United States government builds the larger facilities. The National Advisory Committee for Aeronautics (NACA) operates major wind-tunnel facilities as do the Air Force and Navy.

NACA—the world's largest and most completely equipped flight-research organization—was established by an Act of Congress in 1915. To the Advisory Committee the President of the United States appoints civilian and military members who serve without pay. They supervise scientific study of flight and conduct research and experimentation.

A renowned physicist and former president of Massachusetts Institute of Technology, Dr. Karl T. Compton, has described NACA this way: ". . . unique among our federal scientific agencies, its controlling body . . . has been composed of men of such high character and distinction as to render it completely free of political influence."

NACA's three major laboratories—situated at Langley Field, Va.; Cleveland, Ohio; and Moffett Field, Calif.—each possess extensive wind-tunnel facilities devoted to specialized fields. Staffed by civilian scientists, they aren't affiliated with any branch of the military.

The Langley Aeronautical Laboratory of NACA has the largest number and variety of tunnels. The more than 20 facilities include a full-scale tunnel with a test section of 30×60-foot area plus high-speed, transonic, supersonic, and hypersonic tunnels. Some spin and gust types mentioned are also situated there.

A 100,000-hp constant-speed electric-motor system drives the Langley Unitary Plan Tunnel (photos, pages 34 and 35)—the largest in horsepower requirements. Two other tunnels have 60,000-hp adjustable-speed drives; one of these will soon be increased to approximately 100,000 hp.

The Lewis Flight Propulsion Laboratory at Cleveland (photos, page 34), the newest of NACA's three major laboratories, has a wind tunnel with a 10×10-foot test section—the world's most powerful supersonic propulsion tunnel now in operation. At top-rated load it takes 300,000 hp from two adjustable-speed axial-flow compressors. For testing engines it is run as an open-circuit atmospheric-pressure tunnel—that is, with fresh air sucked in from the outside. Where exhaust gases aren't present to contaminate the air, the tunnel operates closed-circuit at controlled pressures. In this instance the tunnel's air continuously recirculates.

Other facilities at the Lewis Flight Propulsion Laboratory include an 87,000-hp transonic-supersonic tunnel, an altitude tunnel, an ice tunnel, and a propulsion systems laboratory. In fact, so large is NACA's Cleveland laboratory that its peak electric power demand from the utility company presently reaches 350,000 kw. This represents a power bill of $3500 per hour if you assume a rate of one cent per kilowatt-hour.

Several large wind tunnels operate at the Ames Aeronautical Laboratory, Moffett Field, Calif.—the third of NACA's major facilities.

Not one but three electric motors on a single shaft drive the mammoth three-stage axial-flow compressor for a 14-foot transonic wind tunnel. The motors reach a peak output of 132,000 hp for one hour, or a continuous output of 110,000 hp. Speed of the electric drive system adjusts automatically. It's so simple to run that the engineers can remotely control all normal operations.

Building the compressor for this tunnel made unusual history; it typifies the excellent team play between industry and government-sponsored agencies. Because of the compressor's large size plus the heavy workload in factories of major equipment builders at the time, NACA engineers did the aerodynamic design. General Electric then built the rotor, shaft, and bearing at its Schenectady plant; the Pittsburgh Des Moines Steel Company built the stator; and a California plant fabricated the blades to NACA specifications.

Then came the job of getting all these components to Moffett Field. Major parts of the compressor were so large that they were finally shipped by boat, via the Panama Canal, from East Coast factories. (For a picture story of the rotor enroute, see March 1954 REVIEW, page 27.) Assembled into place on its foundation, the compressor immediately went into service. Since that time it has operated most successfully with only negligible maintenance.

Ames Laboratory's second major wind-tunnel facility, the Unitary Plan Tunnel (photos, page 35), began operating in 1955. Four electric motors—the largest adjustable-speed electric drive ever built on a single shaft—supply 180,000 hp continuously, or 216,000 hp for one hour.

Comprising two compressors and three wind-tunnel circuits, this facility is actually three wind tunnels in one. While model changes are taking place in one section, engineers can use its motors and compressors in another test section—a good way to economize on these expensive items.

Other facilities at Moffett Field include a 40×80-foot full-scale tunnel and several smaller tunnels.

The USAF, another major operator of wind-tunnel facilities, has laboratories at the Wright Air Development Center near Dayton, Ohio, and at the Arnold Engineering Development Center (photos, page 36), Tullahoma, Tenn.

Not yet complete, the Tullahoma facilities will include three major laboratories . . .

- Propulsion Wind Tunnel, consisting of two large tunnels, one transonic and the other supersonic, each having a 16-foot-square test section
- Gas Dynamics Facility, comprising a group of supersonic wind tunnels for development-testing models of aircraft
- Engine Test Facility, with three test chambers and a test bed for operating turbojet, turboprop, and small ramjet engines under simulated flight conditions.

Much Data Accumulated. . .

Large wind tunnels employ automatic pressure, temperature, and force transducers to accumulate data in a short time. To effectively use them, you must employ large-scale computing machines for data processing (photo, page 34).

With such processing machines, the time between taking data and the return of calculated results to the engineers comprises several minutes or less, depending on complexity. This way, engineers know the test results almost immediately, and they can take more data or make adjustments based on the knowledge obtained. The productivity of a wind tunnel may be increased many fold by these techniques.

. . . And Much Electricity Needed

Wind tunnels consume individually several hundred thousand kilowatts of electric power. Obtaining such large amounts requires careful and considerate teamwork with the electric utility serving the tunnel.

The laboratory must always limit the rate of rise and fall of power to reasonable values so that the utility can control its generation, while maintaining system voltage and frequency. When the utility has a large percentage of hydroelectric generation, such that generators may be started and loaded in a short time, the laboratory need not give advance warning when it starts.

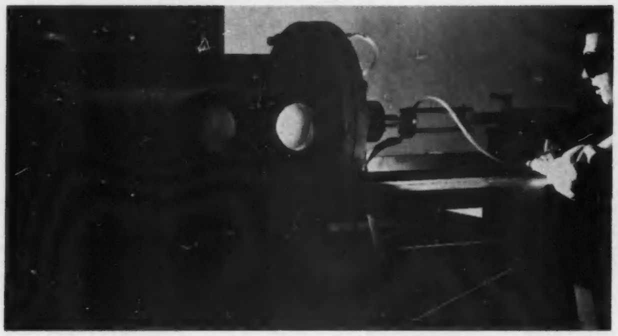
When steam-turbine electric generators supply most of the utility's power, the situation changes, however. Here it is more difficult to add additional power generation on sudden notice. To cope with this situation, the aeronautical laboratory maintains a power dispatcher with a direct telephone line to the utility's power dispatcher. Several hours in advance of starting a tunnel, he notifies the utility to put extra generating capacity on the line.

Sometimes engineers can operate major wind tunnels only during the night when the power company's loads are low and there's sufficient generating capacity available. Then the electric utility doesn't have to add extra generating capacity.

Research Rapidly Advancing

Through research programs, technical societies, and free interchange of technical papers, the work done in many wind tunnels is coordinated. But even with these precautions, engineers require a large number of special wind tunnels for urgent work.

Engineers use certain tunnels for highly advanced research, others for development and performance-testing of current aircraft and missile models. The transonic range, particularly, requires much work because modern aircraft are currently invading this region. As mentioned earlier, actual tests of models at transonic speeds are essential because the theories applicable to subsonic and supersonic flows aren't applicable in this "no man's land."



Fluid-Stabilized Arc Tunnel

Electric arc within the core of the spinning fluid vortex produces a high-temperature plasma for the investigations of missile nose cones. By evaporating and disassociating the fluid, jet-core temperatures of 13,000 C have been produced.

What's more, planes and missiles today exceed even supersonic speeds. And the demand for supersonic and hypersonic tunnels increases accordingly. The techniques that go into these newer, advanced facilities call for much imagination, and the higher and higher tunnel speeds sought require large investments in equipment.

Hypersonic Blow Down

Engineers often power a hypersonic tunnel with a minimum of costly equipment by using a blow-down system. Compressors pump up a large system of pressure vessels from which the air is suddenly exhausted.

The Arnold Engineering Development Center at Tullahoma maintains a vessel 700 feet long that engineers can pump up to a pressure of 4500 psi. While the pumping operations take several hours to reach the desired pressure, they require relatively little power. During a test the stored air discharges through the tunnel so rapidly that it exhausts the storage tanks in a few minutes.

Engineers thus obtain the large peak power needed for hypersonic wind blasts through the tunnel in a short time. If they heat the air as it enters the tunnel, its velocity further increases. For this purpose oil- or gas-fired heaters are frequently employed.

Hot-Shot Tunnel

Another more recent development also situated at the Arnold Engineering Development Center is the hot-shot tunnel—a high-temperature short-duration hypersonic facility. Here, a metal membrane separates a small pressure vessel from a nozzle and the test section.

As before, engineers pump air into the vessel to the pressure wanted. Then they discharge a high-energy electric arc through the pressurized air. Heat from the arc increases the air's temperature and pressure, causing the metal diaphragm to burst. The resulting torrent of hypersonic air through the nozzle and past the test model lasts sufficiently long to obtain data by specialized techniques.

Energy for the electric arc comes from a large bank of capacitors. At the Tullahoma hot-shot tunnel, the capacitor bank stores approximately one-million joules of energy—released through the arc in a fraction of a second.

Hypersonic Shock

General Electric presently uses a unique arrangement of a hypersonic shock tunnel. In it, hydrogen, oxygen, and helium are ignited in a driver tube to produce a chemical explosion.

Rupturing a metal diaphragm, the explosive gases are propagated down a long driven tube. At the driven tube's end, another diaphragm momentarily stops these gases and bounces them back on themselves to cause greater pressures. They then burst the second diaphragm, producing a distinct shock wave. While lasting only microseconds, the shock wave provides essential information in developing missiles to withstand speeds at high Mach numbers.

Fluid Stabilized Arc

Almost certain to extend the frontiers of wind-tunnel technology is the high-temperature high-velocity fluid-stabilized arc—new use for moderately old concept.

A high-power electric arc confines itself within the core of a spinning fluid vortex (photos). To produce a high-temperature plasma, the arc's temperature evaporates and disassociates the fluid. Ejected through a hole in one of the arc's electrodes, the resulting stream of high-temperature high-velocity plasma flows over the test model. For the fluid, engineers can choose water, liquefied air, or other liquids, depending on the desired content of the plasma.

Today engineers operate fluid-stabilized arcs with electric power inputs of several thousand kilowatts, and they are seriously considering the use of stabilized arcs requiring 100,000 kilowatts of electric power. With an experimental system now operated by the University of Chicago and General Electric, engineers have produced jet-core temperatures on the order of 13,000 C at near sonic velocity.

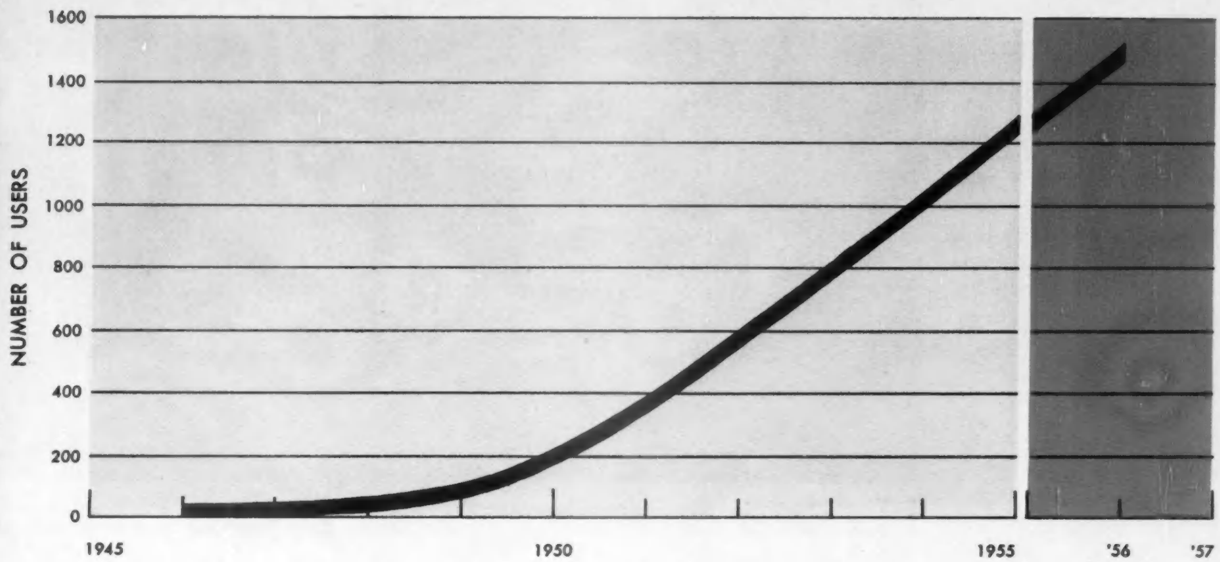
Much Ahead

From what has been said you can see that, despite the large number of wind-tunnel facilities already existing, the field is by no means saturated. In fact, it's just the opposite. Engineers are continually developing plans for new tunnels and modernization of existing tunnels.

Not only in high-performance aircraft but also in missile development, activity proceeds at high tempo. Judging from the government's recent announcement, spending for guided missiles alone will increase almost twofold in the next four years—from $1.2 billion next year to $2.2 billion in 1961. Specialized wind tunnels are needed to help solve knotty technological problems. The design and development of nose cones for missiles probably constitutes one of the best-known problems. These cones must withstand searing heat generated by a flight vehicle moving through the atmosphere at hypersonic speeds.

The nation that pioneered powered flight cannot afford to lag behind in modern flight research and development. And wind-tunnel facilities play an important part in advancing this science. Today the United States is equipped with the best facilities to do the job. It must remain so in the future. Ω

GROWTH IN NUMBER OF U.S. INDUSTRIAL USERS OF RADIO ISOTOPES



Radioisotopes Take on a Bigger Role in Industry

Now cheaper and more plentiful, radioisotopes save industry millions of dollars on expensive time-consuming tests and open new avenues of development.

By DR. ROBERT S. ROCHLIN

You might be surprised to see how the use of radioisotopes has grown since the early postwar years (illustration).

According to estimates by the Atomic Energy Commission (AEC), last year American industry saved about $400 million using radioisotope techniques. And in the years ahead you'll see radioisotopes cut industrial costs by a considerably wider margin as knowledge of their many applications spreads and men become more specialized in their use.

Frequently radioisotopes accomplish tasks previously considered impossible. They already perform invaluable service in diverse fields: manufacture of electric blankets, curing bearing trouble in air conditioners, developing better plastics, producing neon glow lamps, locating flaws in castings, and controlling production quality of transistors. They even help your wife get the family wash cleaner!

These are only a few of their present applications; the horizon of their future use is ever widening.

What Are Radioisotopes?

Radioisotopes—radioactive forms of elements—emit alpha, beta, or gamma radiation. You can, for instance, make ordinary materials radioactive by bombarding them with neutrons in a nuclear reactor.

Each individual radioisotope has a specific half-life—that is, the time it takes a given amount to decay to half its initial radioactivity. Just how long depends on the material. Among the more than 1200 known radioisotopes, half-lives vary from fractions of a second to millions of years.

Based on three major properties of their radiation, radioisotopes' diverse applications can be divided into three groups . . .

- Because radiation can be detected with extremely high sensitivity, radioisotopes are useful as tracers.
- Ionization and excitation effects of their radiation make possible such uses as: dissipating electrostatic charge, improving operation of electronic gas tubes, and exciting phosphors to produce light.
- Radiation emitted by some radioisotopes penetrates many inches of solid material—a steel casting, for example—opening an immense field of gaging, radiography, density measurements, and the location of hidden objects.

Quick, Cheap Measure of Wear

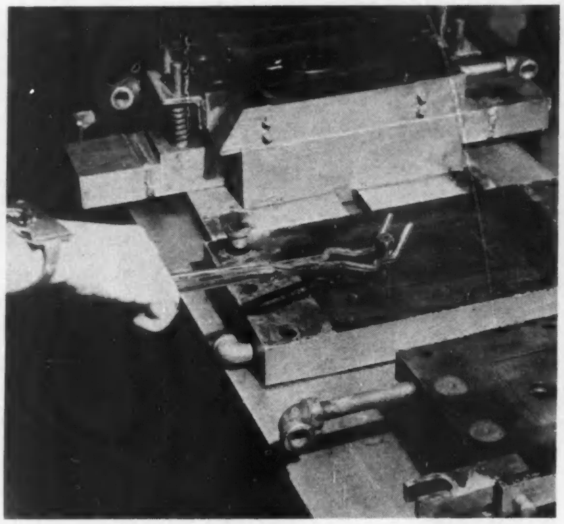
Recently radioisotopes solved a baffling problem in bearing lubrication.

The main sleeve bearings of a new type refrigeration compressor failed prematurely. To pinpoint the operating conditions or design factors responsible for the failure, engineers radioactivated a bearing for testing. Placing it into operation, they then monitored for the presence of worn babbitt material in the lubricating oil with scintillation counters highly sensitive to gamma radiation. Within minutes they could measure the effects of various operating conditions on bearing wear. And based on these data, the bearing was redesigned to eliminate the high rate of failures.

Each of these measurements would have taken months instead of minutes

Dr. Rochlin—nuclear physicist, General Engineering Laboratory, Schenectady—came with General Electric in 1951. He has developed specialized instruments for measuring nuclear radiation and frequently advises engineers in other Company departments on the use of radioisotope techniques.

Development of a new plastics molding compound illustrates the value of radioisotope techniques. Problem here was to determine molding compound's wear on steel mold . . .



1 Test of plastics molding compound's erosive effect begins with insertion of radioactive bushing into steel mold.

2 Mold assembled, engineer mon activity level, then forces compour

without radioisotopes. And for each measurement you would have painstakingly disassembled the compressor. Furthermore, the old methods could yield no information on the bearing's transient wear during its ON-OFF cycling.

Another project that illustrates the value of radioisotope techniques is development of a plastics molding compound (photo sequence) for radio and television cabinets. The problem: Minimize wear on expensive steel molds that form the plastics' compound.

Investigating the steel mold's wear by conventional methods was long and costly because each compound under investigation had to be formed thousands of times before engineers could detect a change in weight or appearance of the steel mold. A radioactive tracer method eliminated these difficulties.

First, part of a steel mold was made radioactive in a nuclear reactor and used to mold plastics disks of many different compounds. By simply monitoring each disk with a sensitive scintillation counter, technicians measured the amount of radioactive steel removed from the mold in forming that single disk—even though it might be as little as one part of steel to 20-million parts of plastics. In a few minutes this technique yielded an accurate measure of wear. As a result, engineers formulated a plastics compound having highly improved mold-wear properties.

Radioisotopes as Tracers . . .

Radioisotopes have proved a sensitive tool in analytical chemistry.

By using a technique known as *neutron activation analysis*, the analytical chemist can sometimes detect and identify impurities as small as one in 100-trillion parts. The process consists of irradiating the sample with neutrons to make its impurities radioactive (photo, lower, opposite page). The chemist identifies the impurities by noting their energies of radiation and half-lives.

Because of the extremely high sensitivity of radiation-detection equipment, it's possible to measure an amount of sodium in silicon, for example, as small as 50 parts per trillion. Sensitivity depends on the nuclear properties of the impurities and bulk material. But you can greatly extend the versatility of this technique by combining it with conventional methods of chemical separation.

Where superpurities are required, this extremely sensitive method of chemical analysis proves of greatest value—for example, in germanium and silicon for transitors and in especially pure metal samples for metallurgical research.

Going from the scientific realm of pure metals to the more mundane problem of washing clothes shows the versatility of radioisotope techniques. Radioactive tracers are used to test the efficiency of washing machines in removing bacteria from clothing.

Blending powdered materials at one time presented a problem—testing the efficiency of the mixing operation. To provide a safety factor and erase any doubt, large industrial mixing machines were run two or three times longer than necessary for each batch of powders. The result: Extra dollars wasted in processing and manufacturing costs. Introducing a small amount of radioactive material into one component and comparing the radiation from different samples of the mixture indicates quickly and easily how long it takes for thorough mixing.

Some recent studies of aging in fluorescent lamps illustrate radioisotope tracer methods.

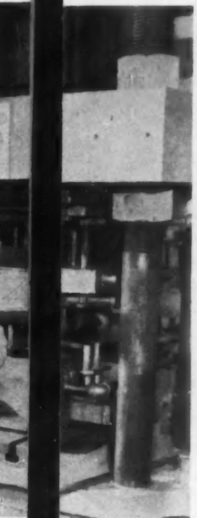
At one time lamp designers thought that blackening of fluorescent lamps might be related to chemical action of the mercury. To test their theory, they placed some radioactive mercury inside the lamps. They were then able to follow the mercury's migration while the lamp operated and determine how it was related to the blackening.

In the field of metallurgy, radioisotopes are used extensively as tracers. Engineers employ them to trace one metal component in relation to another and to study the mechanism of luminescence, corrosion of aluminum, vapor pressure, and a host of other applications.

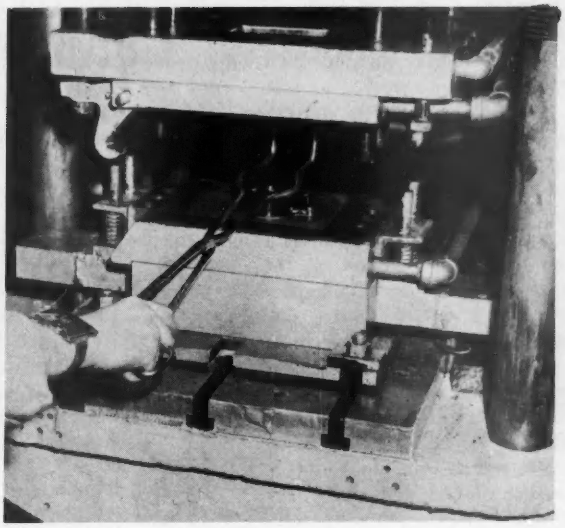
. . . Atom Exciters . . .

As we've already mentioned, radiation excites and ionizes the atoms of material through which it passes. You can utilize this effect of radioisotopes in many ways.

One example is in a gaseous discharge tube. Typical of these are the small neon glow lamps in electronic computers and the glow switches in fluorescent-lamp starters. An abundance of ions in the gas is needed to fire tubes quickly



rs for radio-
rough bushing.



3 Enroute to cavity in mold, the compound erodes the steel particles from the bushing. Plastics slug is then removed.

4 Placed in scintillation counter, slug's radioactivity —proportional to plastics' abrasiveness—is recorded

and dependably at their rated starting voltage. To obtain this condition simply, safely, and cheaply, you just add a trace of radioactive hydrogen or krypton to the gas during manufacture.

Electrostatic charge often accumulates on fabrics or sheet plastics. To eliminate this troublesome condition, you simply ionize the surrounding air with a radioactive source. Such sources, for example, are used in the textile industry to prevent fog marking caused by the electrostatic attraction of dust particles to threads left in the loom overnight.

Where flammable solvents are employed, dissipating electrostatic charge to prevent sparks is also useful.

Closely related to the ionizing properties of nuclear radiation is its ability to excite phosphors and thus produce light—a phenomenon familiar to all engineers. Radium-dial watches are a common example. But because of radium's high cost and hazardous nature, it hasn't been used as a source of light on a large scale. As other radioisotopes become available at low cost, however, it will be more practical to produce cheap, long-lasting luminescence for highway markers, instrument dials, and house numbers.

For ionizing applications, you can obtain beta and gamma radiations from strong radioisotope sources produced in nuclear reactors. These sources, along with x-ray and electron-beam generators, are being used to improve properties of plastics; catalyze chemical reactions; kill insects in stored wheat; retard sprouting in stored potatoes; and to sterilize meat, bandages, and drugs. Of course, many problems must still be solved before all these uses become widespread. But future prospects in these fields do seem promising.

. . . And Penetrating Radiation

As a source of penetrating radiation, perhaps the most widespread use you'll find of radioisotopes in industry today is in the noncontacting thickness gage.

Here the material to be measured—say, a sheet of metal foil—passes between the radiation source and a detector. By indicating how much radiation the material absorbs, the detector measures the material's thickness.

These gages prove invaluable in a steel or paper mill—wherever the material is a moving sheet, or soft, fragile, sticky, or freshly painted. Beta-ray

LUBRICATING-OIL SAMPLE is removed from linear accelerator by author. Bombardment by accelerator's neutrons render the oil's trace-impurities radioactive for identification.

thickness gages are now used in hundreds of plants in the United States. And according to an AEC estimate, more than 10 times as many could be profitably used.

A common gaging application involves measuring a film of constant thickness coated onto a base sheet of varying thickness. One source and its detector are placed where the sheet enters the coating bath, and another where the sheet leaves. Detector outputs are connected to give a difference signal that's fed back for automatic control of the coating operation.

In a related application of radiation absorption, air density is continuously measured at the inlet and outlet ports of a gas-turbine compressor to measure efficiency. So effective is this technique that it has proved more flexible and reliable than conventional pressure gages.

Other modifications of the radiation-absorption principle include determining density of a mixture inside a pressure vessel, stability of emulsions, the amount of air in lubricating oil, presence of steam bubbles in water, and the points at which freon gas is liquefied in a refrigerator.

Probably one of the best known uses of penetrating radiation is detecting hidden flaws in metal castings. While x-ray machines are employed for this application, radioisotope sources are usually smaller, more flexible, and less costly. And you can place them in small cavities where x-ray machines just won't fit. One drawback: These sources usually have lower beam intensities than standard x-ray tubes, requiring longer exposure times. But hundreds of firms use radioisotopes for flaw detection.

The manufacture of automatic electric blankets gives you a good idea of radioisotopes' value in locating hidden objects.

The heating wires that go inside these blankets are wrapped with nylon. Next a protective coating of polyvinyl is extruded over them. Maintaining a continuous flow of wire through the wrapping and extruding machines speeds manufacturing. When a reel of bare wire becomes empty, the operator splices on a wire from a fresh reel. So far, so good. But after the wire is wrapped and coated, the splices are hidden from view. Electrically unsatisfactory in finished blankets, these splices must be found and removed before the wire goes to assembly machine.

To facilitate automatic splice detection, the operator paints a small amount of radioactive phosphorus onto each splice before insulation is applied. Later, passing through a radiation detector, the spliced regions are automatically removed before the wire is assembled into the blanket.

In this typical example of radioisotope methods on a production line, equipment and set-up costs were less than \$5000—savings totaled about \$32,000 a year on manufacturing costs.

Principal Concerns

Two questions often asked by prospective users of radioisotopes are: How expensive are they? how dangerous?

For a few dollars you can purchase radioisotopes for most applications from the Oak Ridge National Laboratory or other AEC installations. As the market for radioisotopes becomes larger, many of them will cost even less than they do today. Instrumentation will often cost less than \$1000.

Handled carelessly or without proper precautions, radioisotopes *are* dangerous. Not only do potential hazards arise from external radiation emitted by the radioisotope but also from the possibility of introducing contaminated material into the body—through eating, drinking, breathing, or through cuts in the skin.

But when you take proper precautions—under direction of specialists competent in radiation protection—these hazards are negligible for many industrial applications. Safety precautions for handling radioactive materials are prescribed by law in regulations of the AEC and many individual states. (For a description of radiation protection in AEC laboratories, see November 1956 REVIEW, page 12. Most industrial uses require much simpler protection measures, however.)

Coming of Age

Radioisotopes in industrial applications are carving out a niche of their own. Already, consulting services for their use are being set up throughout the United States. And, in fact, many larger companies employ their own specialists in this new technology.

Information on the valuable potentialities of radioisotopes should be more widely disseminated. They are no longer a postwar by-product of the atomic age, merely of academic interest. And, as industry grasps their importance to advancing technology, you'll see a continually rapid increase in applications.

Speaking in Houston recently, AEC-member Willard F. Libby prophesied, "In three to five years, United States industry and agriculture will be saving \$5 billion annually through the use of radioisotopes."

Radioisotopes *are* coming of age. Ω

ANNUAL INDEX VOLUME 60 1957

Authors and Titles

Annual Index (continued) — Subjects

How General Electric tries to do its part

A SHORTAGE of educated people may, in the long run, be the greatest limit to America's capacity to provide the good things everyone wants.

Meeting such a challenge depends primarily on each individual's plans for his self-development, with the encouragement of parents and with the effectiveness of America's educational systems.

But businesses, too, are developing increasingly effective ways to help people further their education. At General Electric, for example, one person out of every eight is taking additional education or training. On these pages are some of the ways the company is trying to help young people set high educational goals—and to encourage all employees to achieve their full capabilities with increased personal satisfaction.

Education must be a lifelong pursuit for every citizen. The more individuals recognize this, the more they will seek to develop themselves to take advantage of America's expanding opportunities.

Progress Is Our Most Important Product

GENERAL ELECTRIC

WORKING WITH SCHOOLS TO

Awakening students to future opportunities. General Electric's science show, "House of Magic," is one of many ways we try to stimulate secondary-school students to tackle their studies with enthusiasm and appreciation. Each year 700,000 young people see the show.

PROVIDING OPPORTUNITIES FOR MEN AND WOMEN AT GENERAL ELECTRIC TO DEVELOP TO

A chance to acquire new skills. General Electric conducts 1,000 courses in factory skills to train or retrain employees. George Du Pont (above), a welder witn 14 years' experience, recently completed 3 weeks of full-time schooling in new techniques.

Encouragement to continue schooling. Plans for college-level studies are worked out with hundreds of General Electric people. Paul Gagnon (above) recently graduated as an engineer from the U. of New Hampshire as a result of a 6-year work-and-study program.

Expanding opportunities for technicians. General Electric offers people with aptitude (but not necessarily a college degree) a chance for responsibility as technicians. For example, Winifred Balz (above) is taking advantage of our Technician Program.

in helping people further their education

ENCOURAGE YOUNG PEOPLE TO FURTHER THEIR STUDIES

Providing career-guidance materials. General Electric furnishes teachers, at their request, with materials that point up to young people the value of further studies. Above, a teacher counsels students with a G-E guidance booklet, "Why Study English?"

Helping teachers to be even more effective. Through G.E.'s summer fellowships, over 1,900 math and science teachers have had graduate study and seen firsthand how their subjects are put to use in business. Above, teachers see the "insides" of giant turbines.

Financial help to colleges. To help employees "pay back" their colleges for the education from which they and the company are benefiting, the General Electric Educational and Charitable Fund matches alumni support payments made by employees.

THEIR FULL ABILITY

Programs for college graduates. Education doesn't stop with the end of college. Robert Erskine (Minnesota, '56) gains more knowledge and experience in the G-E Manufacturing Training Program—one of 11 professional programs offered to recent graduates.

Advanced professional development. In advanced courses at General Electric, qualified men and women can study in many different fields under the leadership of experts. Above, Professor C. R. Christensen of Harvard leads a seminar in Marketing.

Study in the work of managing. Education continues for people in management, too. Above is a seminar at General Electric's Management Research & Development Institute. The work of managing is also being studied by 6,000 people at plant locations.