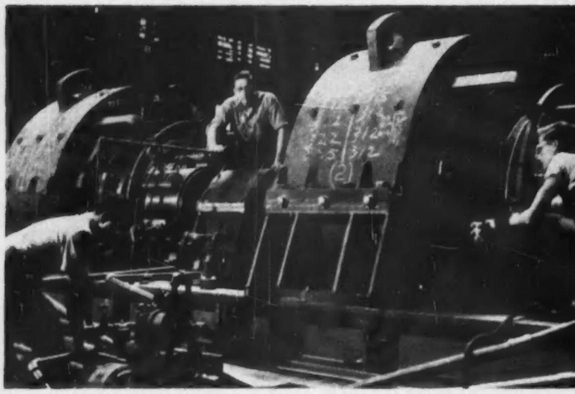
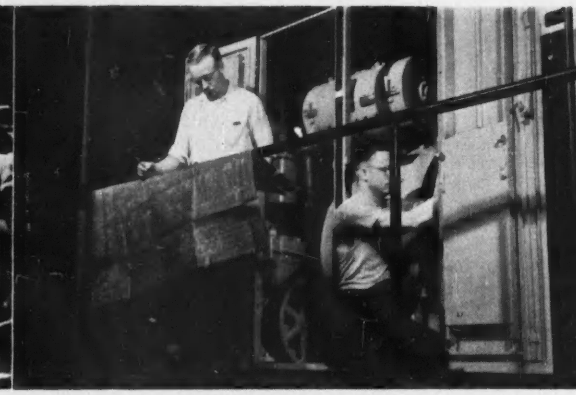
GENERAL ELECTRIC Review

NOVEMBER 1953



CHARLES SNYDER, R.P.I., (center) adjusting 5250 triple-unit d-c mill motor for use in a steel mill.



Engineers RICHARD RENK, IOWA STATE, (left) and ALLEN FRINK, CATHOLIC UNIV., make last-minute check on 1600-hp diesel-electric switcher before it is moved to test track.

THEY'RE "GOING PLACES" AT GENERAL ELECTRIC

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If you are interested in building a career with General Electric see your college placement director for the date of the next visit of the General Electric representative on your campus. Meanwhile, for further information on opportunities with General Electric write to College Editor, Dept. 2-123, General Electric Company, Schenectady 5, New York.

Test engineers F. K. VON FANGE, U. OF NEB., (left) and R. E. LOVE, U. OF TEXAS, work on stacker and stapler built by them for homework project.

Physicist ROGER DEWES, BROOKLYN POLY., working with scintillation counter in G.E.'s Engineering Laboratory.

ANTHONY TERZANO, PRATT INSTITUTE, checks connections on direct-current rectifier which charges 7,500,000-volt impulse generator in G.E.'s new High-voltage Laboratory.

GENERAL ELECTRIC

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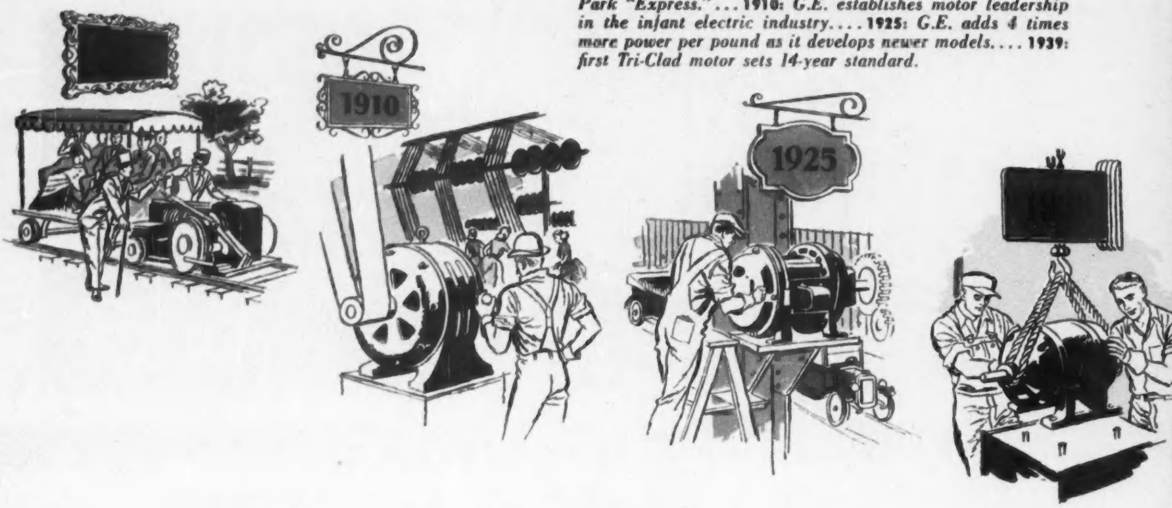
GENERAL ELECTRIC Review

EVERETT S. LEE • EDITOR PAUL R. HEINMILLER • MANAGING EDITOR

COVER—Better white light is achieved by mixing "green" and "pink." While green fluorescent phosphors give off more light than any other color, too much of it in white fluorescent lamps make people look ghastly. Pink phosphors must be added to produce a critical balance of green for light output, and pink for looks. For the "why" of white fluorescent lamps, see page 15.

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 U.S.A. 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 CONTENTS OF THE GENERAL ELECTRIC REVIEW ARE ANALYZED AND INDEXED BY THE INDUSTRIAL ARTS INDEX, THE ENGINEERING INDEX, AND SCIENCE ABSTRACTS. . . . SIX WEEKS' ADVANCE NOTICE, AND OLD ADDRESS AS WELL AS NEW, ARE NECESSARY FOR CHANGE OF ADDRESS. . . . ADDRESS ALL COMMUNICATIONS TO: EDITOR, GENERAL ELECTRIC REVIEW, SCHENECTADY 5, NEW YORK.

1878: *Thomas Edison builds an electric motor for his Menlo Park "Express."* ... **1910:** *G.E. establishes motor leadership in the infant electric industry....* **1925:** *G.E. adds 4 times more power per pound as it develops newer models....* **1939:** *first Tri-Clad motor sets 14-year standard.*



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The General Electric Tri/Clad '55' is an important milestone in motor history. For this is a *completely new motor*. Born out of thousands of engineering man-hours, the Tri/Clad '55' incorporates design improvements that go far beyond mere modifications. Many years of pure research, the discovery of new, better materials, the knowledge of how to make better use of present materials, and improved manufacturing processes all make the Tri/Clad '55' motor the new leader in the motor field.

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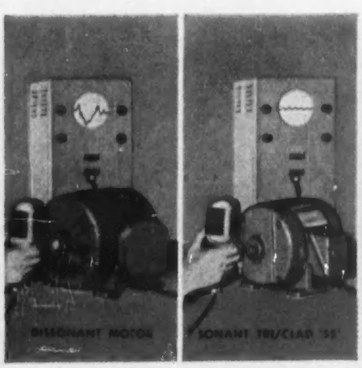
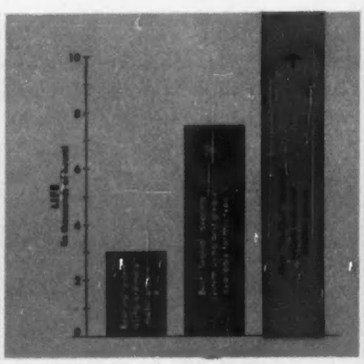
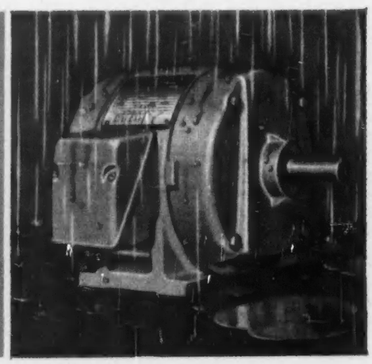


DESIGNED FOR BETTER PERFORMANCE: Tri/Clad '55' has a low noise level ... runs cool ... gives up to 53% increase in shaft output per pound...has higher full-load speeds.



ENGINEERED FOR LESS MAINTENANCE: 10%-life tests (such as the one shown) prove the Tri/Clad '55' bearings last longer without regreasing than any other bearing system.



BUILT TO LAST LONGER: cast-iron strength . . . more fully enclosed dripproof construction . . . water-shedding stator windings... polyester film insulation 8 times stronger.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TRI 55 CLAD
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WE'VE HAD A BIRTHDAY

Everybody loves a birthday. It commemorates the beginning of a life—the most precious thing in God's great universe. And it marks the renewal of a life—a time for looking back; a time for looking ahead.

This year we in General Electric have had a birthday—the renewal kind. We've been looking back over the 75 years to that day in 1878 (October 15, to be exact) when the friends of Thomas A. Edison provided the capital to form a company so that he could carry out his experiments to realize his dream of an incandescent electric lamp. That was American enterprise.

Hundreds of experiments took place. Then on the historic evening of October 19, 1879, Edison placed in circuit a crude experimental lamp with a filament of carbonized sewing thread. For the next 40 hours Edison and his assistants anxiously watched the bulb as it burned with a bright continuous glow.

One can easily imagine what a nerve-racking period it was for them. That tiny glass globe with its slender filament contained their hopes of harnessing electricity—that wild, mysterious force—and setting it to work for the benefit of mankind.

At the end of 40 hours, Edison declared the lamp a success. He then applied ever-increasing voltage until the lamp burned itself out.

The news of Edison's accomplishment spread like wildfire, stimulating the imagination of everyone. A tremendous demand for the new electric light was created, and Edison immediately set about supplying it. He began the first commercial manufacture of electric incandescent lamps in October of 1880. Later he established shops for the manufacture of dynamos, underground conductors, sockets, fuses, switches, meters, fixtures—everything necessary for a complete system.

On September 4, 1882, Edison began the operation of the first commercial central station for incandescent electric lighting in this country. It was located at 257 Pearl Street, New York City, and supplied 59 customers with power for a few hundred incandescent electric lights. (And 10 years later, in 1892, the Edison General Electric Company and the Thomson-Houston Company combined to form the General Electric Company.)

In Edison's story we find the fundamentals for the development of every product we have. Always the story begins with a man. He has an idea of something new. Capital provides the means for the developmental work that follows, usually long and hard, but culminating in gratifying attainment. Then follows the design of the product and the setting up of manufacturing facilities to produce it, together with the development and production of the necessary components to make the product useful. Finally, sale and use.

To the engineers of today the essentials of that picture are just the same as they were in Edison's day.

And what a parade of names there has been since that day! Would that we had the space to list them all. For, as each one lifted on his shoulders his younger associates that they could see and go further, so have they built a structure and a superstructure of service on the firm foundation established in those earlier days. This is our heritage as we look back on our 75th birthday.

And what do we see as we look ahead? Greater opportunity for even more service. For the electrical world is a glorious world—just as magnificent as the lightning in the heavens, and just as forceful. And as God put electricity into the universe of Nature, where the scientists discovered it, so have the engineers and their associates in industry made it available to Man for his use. And so will they continue to make it useful in even greater abundance, thus returning to God's people the power which He placed in Nature for them to have and to use.

This is our beholding thought on our Diamond Anniversary.

EDITOR

WHAT'S AHEAD IN ENGINEERING EDUCATION?

They're not teaching the same things in the same way as they were when you went to engineering college.

In many cases the four-year curriculum—the backbone of engineering education today—has been drastically altered; in other cases it has been but slightly modified.

The five-year course has been adopted by some colleges, and one of the newest approaches—the unified engineering curriculum—has made its appearance on the West Coast.

To determine the significance of these various approaches—particularly as to how they will aid the training and development of better engineers for tomorrow—the REVIEW asked three leading authorities to present their ideas on recent trends in engineering education.

J. F. Downie Smith is the Dean of the Division of Engineering, Iowa State College, Ames; S. C. Hollister is Dean of the College of Engineering, Cornell University, Ithaca, NY; and L. M. K. Boelter is Dean, College of Engineering, University of California, Los Angeles.

—EDITORS

I. Four-Year Engineering Program

By DR. J. F. DOWNIE SMITH

Perhaps we ought to define what is meant by a four-year engineering program. Such a program accepts students with specific entrance requirements, and if they are able to complete satisfactorily a prescribed course of study, it is possible for them to graduate in 12 academic quarters, or eight academic semesters, or four academic years. This might be called "par" for the course. Golfers realize that a few break par, more approximately equal it, and many more aren't quite that good.

Actually, the percent of students finishing in four academic years at some engineering schools is quite small. However, the term is readily understood.

In this country at present the great majority of engineering colleges operate on a four-year plan.

That only a small percentage of those who start the course finish in the specified four years has been used as an argument for the five-year program; and it has been urged that if it takes more than four years for the average student to finish anyway, we might as well be honest and say that it is a 4½- or five-year plan. But as soon as anyone sets up a five-year plan, the program becomes crowded each year, and the slower students would take still longer to complete the work.

Many educators, including myself, believe that the engineering program for many students should contain more than four years of training beyond the high school level; but there is a question whether this more-than-four years should finish at the bachelor's level. At the present time, for example, many of the four-year schools offer graduate work leading to the master's degree, and some to the doctor's degree. The master's degree generally requires a minimum of one year beyond the bachelor's degree, and the PhD, or equivalent, at least three years beyond the bachelor's degree. Thus, in such schools it is possible for a student to take any number of years that he needs to get the education he wants. Also, in some colleges the advanced work may be pursued by the student who expects to go into the practical aspects of industry, as well as by the student who is training for research.

College Analogous with Business

For our purposes let's consider a college, to some extent at least, as a business. Perhaps we might illustrate by a greatly oversimplified simile.

A department store may have the most modern salesrooms, the best-looking and most efficient salesgirls, and excellent merchandise and still be a failure as a business. What really determines its success *as a business* is the ability to sell goods at a profit. Some stores may be staffed by men with vision, who see what the public *should* buy, and who can see that what they recommend and have in stock would be better in the long run than what the public actually buys. And in the end the public may realize the wisdom of these men in foreseeing the demand. But this is of little consequence to the company if it has gone bankrupt in the meantime. The lesson may be appreciated, of course, by other stores.

Fortunately, engineering college administrators are a sensible group of people who keep their feet on the ground remarkably well. There are a few colleges with new approaches to the training of engineers. I am personally very strongly in favor of such programs, and believe that they should be encouraged by engineering educators and by industry. Some of them may be outstanding successes, some only so-so, and others outright failures. We all ought to profit from the results. But the large majority of engineering colleges cannot be of an experimental nature—too much depends on the output; and, until something more satisfactory is developed, most colleges must stay with a system which has been demonstrated over the years to be reasonably satisfactory. Of course, this does not mean that changes in courses, or curricula content, or methods of instruction cannot be modified or changed completely. Such changes are frequently desirable and even necessary. Certainly, at the present time major improvements are called for in the curricula of several engineering departments, but within the scope of the customary length of four years.

Of course, it would be disastrous to have all colleges tend towards a dull uniformity in curricula—and there actually is a tendency in this direction. On the other hand, there is an awakening of the realization of some stagnation, and efforts to change this are being made.

Also, it might be argued that colleges are not a business, and thus business criteria cannot be used. But that really is just a matter of definition. If the student studying in a college acquires the ability to think clearly and can, and will, apply his knowledge of the fundamentals of engineering and other subjects in a satisfactory manner, technically and morally the college will have been successful, and its product can be sold. If, however, the student acquires a distorted sense of values and has not been tested intellectually at a reasonable level, it might be difficult to convince industry that they want him—especially if something more to their liking is readily available. There are such institutions, but to my knowledge, fortunately not in engineering.

Thus, as I see the picture, there ought to be a few colleges where the approach may be quite different than in the others. These more or less experimental colleges might have longer or shorter curricula than the conventional ones, may teach from a totally different viewpoint, may emphasize more fundamental and less practical subjects or vice versa, may stress more of the pure science and less of the engineering phases, and so on. Some of the experiments will be failures, and others complete or partial successes. Because of the natural desire to be on a winning ticket, other colleges would tend to emulate the successes, and thus change can come about. But there will probably be several successful experiments, thus tending to eliminate the trend towards complete uniformity.

Emphasis on the Fundamentals

It is evident that, because of the increasing complexity of engineering devices and rapid advance in science, future engineers will have to be better trained to handle the more difficult engineering problems that will be assigned to them. Thus, it is my conviction that more and more engineers will spend more than four years in college; but again I should ask: "Does this mean at the bachelor's level?" It seems to me that there is sufficient flexibility in the four-year program to permit the study of advanced engineering at the graduate level.

The changes that have taken place in our society during the past 50 years have been such as to decrease the age at which a man retires and to increase the age at which he starts productive employment; this in turn means a constantly decreasing period that he is productive in industry. Industrialists recognize that the sooner the engineer can be made available to them, the more productive life he can offer them. Because much of the technique used can be obtained in industry at least as well as in college, there is a growing feeling that engineering colleges should stick to the so-called fundamentals and leave the applied material to industry.

We realize that everyone's idea about the meaning of the fundamentals is different. Nevertheless, the broad picture is clear. Many applied courses taught in engineering colleges are not in themselves actually used by the engineer in practice but undoubtedly help in his training.

Although it does seem as if some progress can be made in eliminating applied courses, this can't be carried too far. After all, there is a distinction between an engineer and a physicist—a distinction that lies to some extent in the engineer's training in economic design, production, and construction.

Some steps in the direction of streamlining programs can be achieved by the elimination of duplication. For example, in the physics course that most engineers take there are several sections including heat, optics, electricity and magnetism, statics, and others. Some schools think there is needless duplication in having electricity and magnetism taught in the physics department and then repeated, with somewhat different emphasis and perhaps different symbols, in the electrical engineering department.

Similar comments have been made regarding the duplication of the teaching of heat in physics, and thermodynamics and heat transfer in mechanical engineering or in chemical engineering. Duplication is also evident in the teaching of statics in physics and later in theoretical and applied mechanics. Of course, repetition may be necessary to ensure that the student really understands and retains the subject matter.

Planning with High Schools

To me another profitable prospect for conserving the time of the students would be to make an analysis of the complete program from the beginning of high school through the four-year engineering college program. Since engineering colleges get a very small percentage of high school graduates, the problem would not be too easy for the many small high schools in rural areas. But some progress can be made. Some steps already taken in this direction show a distinct possibility of saving time if proper co-ordination could be obtained. Some states have made definite efforts to improve the situation; it is my opinion that in the long run this will be necessary if we are seriously to consider the welfare of the student and the cost of education to the individual, to society, and to the state.

Social Humanities

A strong argument for increasing the length of the engineering program is to broaden the engineer's viewpoint of civic, national, and international affairs so that he may more actively participate in such activities. After watching the progress of many undergraduates in college, I question whether undergraduates below the junior level are mentally and emotionally prepared for a serious consideration of many of the social humanities. In my opinion a graduate student is more likely to be interested in the social humanities than the undergraduate engineering student. It takes maturity to develop that interest. Thus an alternate suggestion having considerable merit is to offer additional social humanity subjects *after* the student has graduated in engineering. At least one college is proposing this seriously. Of course, during the undergraduate period the student would also have to take some of these social humanities.

With the present scarcity of engineers and scientists, this is probably an unwise time to increase the length of the average engineer's formal training. It is quite possible that if we had teachers with the proper viewpoint and breadth of training, they could interject social humanities at the same time they are teaching technical subjects. If that were done, I believe the undergraduate engineer would be more receptive of the various humanities to which he is exposed. But such teachers are not too plentiful.

As time goes on I am convinced that professional engineers will require a higher degree of technical training and greater knowledge of physics and chemistry than are now ordinarily required for a BS in engineering. In addition, I am convinced the engineer should not only take a specified number of courses in the social humanities, but he should also have a greater appreciation of what the teachers of those subjects are trying to do. At the moment, there is a question whether the average undergraduate really does appreciate them. Where outstanding teachers are available, there is considerable stimulation to the student, but this situation is not universal.

Attaining Professional Level

The engineer should not stop his training at the bachelor level if he expects to go into the higher branches of technical achievement. Among those higher branches we might consider engineers engaged in design, research, college teaching, consulting work, and a few other categories; but it should be remembered that far more engineers are used in positions that do not require a knowledge of the more advanced phases of engineering. Thus, unless the engineer's objectives are changed, a fairly large percentage of engineers will limit their training to a four-year period. Those who are scientifically able and so inclined should carry on to graduate degrees and should be encouraged to do so, even though this might sometimes involve subsidization through scholarships or fellowships.

Nor should the training of the engineer stop when he gets to industry—to industry falls the responsibility of continuing the engineer's training so that he can become the real professional that he is not at graduation. Some 200 companies in this country have training programs, and the number is increasing rather rapidly.

Technical Institutes

Because of the increasing amount of subprofessional work now being done by engineers, a proper screening of the utilization of engineers is definitely in order. Many engineers in industry are presently engaged in work that could be done by a technician. In my opinion this percentage is larger than most people realize, creating a crying need for more technical institutes to train those men who do not expect to become professional engineers. If such men were now available in sufficient quantities, I believe that there would not now be a scarcity of engineers, although there would still be a serious need for very competent engineers to handle the difficult engineering problems that confront industry.

Industry has the responsibility of utilizing the engineer to his maximum effectiveness and ability. It is quite possible that to achieve this end engineering colleges may have to develop more work of the graduate nature in the engineering extension services throughout the country. A good start on this has been made, but a large amount still has to be done.

New Approaches

Engineering education in this country is in a state of flux: several new approaches to the teaching of engineering are being proposed, and some are under way. I am heartily in favor of new or different methods and techniques, and I'm encouraging them in my own college. But a change away from the traditional four years for the average undergraduate engineer would require more convincing arguments than have yet been put forth.

For the better students or for those who expect to go into the higher branches of engineering, additional time can and should be spent at college, either at the graduate level or in study of nontechnical subjects. The present needs of the country are for more technicians who can handle some of the subprofessional work of the engineer, for the large majority of engineers to be trained in four-year undergraduate programs, and for a growing percentage of engineers to go into the more complex phases of engineering, trained at the graduate level.

Also, steps should be taken to achieve closer co-ordination in the eight years of high school and college with the thought of better utilization of the time.

II. Five-Year Engineering Program

By DR. S. C. HOLLISTER

In 1938, Cornell undertook an innovation in undergraduate engineering education by adopting an integrated five-year program leading to a first degree. This program began in chemical engineering only, but six years later the engineering faculty voted to extend it to all branches of the profession that offered undergraduate curricula. Prior to 1938 some schools offered combinations of liberal arts and engineering, often leading to two degrees; but in these programs the engineering content was not more advanced than in four-year curricula. Optional five-year programs leading to a professional degree were taken by a few students, the great majority, however, electing the shorter programs.

Weaknesses of the Four-Year Program

The main reason for the adoption of this program at Cornell was one growing increasingly more evident: The current four-year programs in engineering were not adequate in our opinion to provide the professional education required of the new generation of practitioners in the expanding field of engineering technology. A number of industrial companies whose businesses depended on good engineering put into operation technical training programs calculated to elevate the level of engineering education of its technical staff.

These were not aimed at the research staff alone but were applied to the entire engineering force. Companies that tried them concluded that such programs pay off—in benefits both to the individuals and to the company. The fact that industries engage in basic technical education indicates to educators the inadequacy in the typical college engineering program.

Different ways to strengthen the educational program were reviewed. The obvious one—involving a BS after four years and an MS after a fifth year—was considered. Every engineering student could not be compelled to take the needed fifth year—and four years was not enough.

But inherently, another weakness existed that would be less apparent to the entering student or to most parents. Four-year programs are designed to terminate in four years. The amount of basic science and mathematics is thus limited; this in turn limits the nature and depth of the subjects that can be taught in the last two years. If the subjects that could not be covered in the four-year program were added in a fifth year of graduate work, the scientific and mathematical foundation would not be strong enough to support the level of these subjects. Another year would be required to provide the sequence necessary for both prerequisites and advanced courses—the reason why the master's degree usually cannot be earned before the end of the sixth year in the stronger schools. A program of desired strength involving two degrees could not therefore be given short of six years, unless the whole operation could be integrated and streamlined in the interest of saving the student's time.

Program Possibilities

The plan commonly referred to as the "three-and-two" program—three years in liberal arts (including mathematics, physics, and chemistry) followed by the last two years of a four-year engineering program—was another possibility. The engineering content is no different in the last two years than in the four-year program; and three years are used in presenting the work normally given in the first two years in engineering. If the work is divided between two institutions, such a plan puts the basic training in the liberal arts school where frequently it is better taught but where motivation towards engineering and engineering methods is likely to be lacking. Further, advanced-level engineering-science preparation cannot be set up in the liberal arts college in this pattern without specially designed curricula.

Still another advocated plan is to make all engineering a graduate program. Its many admirable features include the maturity of the student, the broader general educational background, and the natural elimination of the indifferent or incapable student. Such a radical departure is not feasible at present, however, because it's too costly in both the student's time and money. Moreover, any student who wants this program can follow it under present curricula. But the profession has not yet arrived at the point where such an educational pattern may be required of all engineers.

Affecting a choice of educational pattern at Cornell was the necessity of preserving a broad background in the arts and humanities. If such education is to be effective, it must be gaged to the advancing maturity of the student. It is not appropriate, for example, to give a course in banking or labor relations to freshmen or sophomores who have not had an adequate preparation in economics or psychology. To us this precluded an effective two-year pre-engineering course followed by technical work. It indicated, instead, a sequence of courses that could be given with due regard to prerequisite subjects and to the growing ability and experience of the student.

Broad vs Specific Training

Why not give a more specialized program in the last two years, thus making room for growing requirements at the basic level? This is the "option" system followed now by so many schools. In electrical engineering, for example, one would select either the power, electronic communications, or illumination option. Again, our faculty was unable to accept such a pattern: experience told them that no junior could say with certainty he was going to devote his professional life to any one of these fields, and they were convinced that these options strengthened each other if taken together in producing a well-rounded education for an electrical engineer.

Permeating the entire atmosphere of the faculty's consideration was the conviction that engineering education should consist of thorough mastery of a broad range of principles rather than training in specific types of computing and formula application. The student in college today will reach his prime 20 years after graduation; surely by that time many of the problem-solving and handbook techniques will be obsolete. The only certain sustaining potential in technical education therefore lies in a thorough grounding in the sciences—both basic and applied.

The Five-Year Program Evolved

Thus the faculty concluded that for a sound professional engineering program in which both a strong technical content and general education background would be maintained the curriculum would have to be lengthened to five years in such a way as to preserve maximum educational effectiveness and minimum expenditure of time for the student. Two parallel stems were thus set up—one technical, the other nontechnical—and each of these was carried through the five years.

Some surprising results came from the streamlining of the curricula: Undesirable overlaps inherent in four-year programs because of restrictions on sequence of courses were eliminated with a saving in time. And the sequential arrangements improved the pedagogical character of subject presentation. An extension of both technical and nontechnical content was thus possible.

An engineering curriculum is divisible into four main parts . . .

- Basic sciences—chemistry, physics, mathematics, biology, and others.
- Applied sciences — thermodynamics, fluid mechanics, electric circuit theory, mechanics, properties of materials, electronic theory, and others.
- Engineering applications — radio, servo-mechanism, high-voltage techniques, machine and structural design, and others.
- Nontechnical courses — English, economics, public speaking, history, languages, and others.

Curricula of different colleges emphasize these four components in varying degrees and widely varying depths. In the training of engineers for the future technology, emphasis on basic and applied sciences is essential. At Cornell basic science extends through the first two years, with calculus available in increasing degree. All students get some physical chemistry, and most get organic chemistry. Dynamics is taught using vector analysis and differential equations. Mathematics at this level is also available for fluid mechanics and thermodynamics, studied by students in all curricula. Likewise, nearly all students take work in electronic tubes and circuits. The main point is that usually the fundamental background in the basic and applied science field is in all curricula, occupying most of the time in the first three years. This recognizes that the principles behind different branches of engineering are much the same; and broad, solid training in them increases the ability of the engineer to work on problems overlapping and interlocking among various fields.

Functions of the Engineer

It is not possible to write a job classification for an engineer in the same way that it would be for a specific craft function: he deals primarily in ideas, and his job is to take certain ideas and bring them into effective form so that others may accurately produce a useful structure, machine, or process. In this respect engineers' ideas differ from those of men in other fields—they are based on physical sciences and mathematics, and must meet certain functional and economic requirements in a manner that maintains safety to life and property. The function of the engineer is essentially the initiation and prosecution of a detailed conceptual process, followed out with such precision that when the operation is begun the performance will be in accordance with forecasts, both technically and economically. Some call this integrated conceptual process *design;* others call it *development.* Whatever the name, it's the heart of the engineer's function.

Building a curriculum to enhance creative imagination is necessary to develop a truly professional engineer, one who can "engineer" structures, machines, systems, or processes into existence. But the necessary ingredient is not so much the title or subject matter of a course as it is that quality of the staff that vitalizes and inspires the student. The beginning may be made in freshman drawing where routine drafting techniques are abandoned in considerable measure for spatial visualization, followed by problems requiring projections of visualization or creativity. Problem courses throughout the curriculum may be so slanted that each solution can be thought of as a method of attack and a process of synthesis leaning upon previous basic knowledge.

In some schools of architecture there is no course in drafting as such. The student acquires this during a course in design in the same manner that slide-rule techniques are learned during computations of problems in engineering courses. Also in architecture there is a sequence of design throughout the full curriculum.

Faculty Requirements

A curriculum with such objectives requires a faculty with qualities beyond those of routine training and methods beyond those of repetition. It must be an inspired and inspiring faculty who believe in the great future need for strongly trained professional men, mentally vigorous and capable of stimulating the students' best efforts. It requires balance and blending between scientific attainment and practical engineering experience.

Clearly, it would be a mistake for all schools to undertake immediately a more advanced educational program of this type. Only those equipped with the necessary staff and facilities and having experience in high-level engineering and science training should undertake it. After watching the performance of the graduates in the field it is equally clear however that such a program fills a widening need in the profession—a need that in time will require schools intent on supplying men of high engineering ability to adopt advanced undergraduate programs.

Frequently we hear that four years is as long a time as can be spent in obtaining an engineering education. This all depends on what kind of an education one wants, and whether 25 years from now it will meet the needs of a man dealing with the problems of our rapidly expanding technology.

Future Educational Programs

Education is an investment in the future. One invests well or poorly and reaps the corresponding harvest. Medicine, law, and architecture have had to extend their training beyond four years to meet professional needs. In 1925, Cornell initiated the move to lengthen the architectural training program to five years; now all accredited schools are on this type of program. It is believed that perhaps over a 25-year period a group of the leading engineering schools will lengthen and strengthen their programs. Still there will be a need for the four-year schools where emphasis would be more on operation and maintenance functions than would be true in the more professional schools.

The guiding element in the educational growth is the profession's needs—that in the engineering schools must be judged not in terms of the present but with a sensitive awareness of the expanding professional requirements over the quarter-century ahead.

III. Unified Engineering Curriculum

By DR. L. M. K. BOELTER

The engineering baccalaureate program is a part of the training and education of the professional engineer that begins in high school and continues for a period of years after the award of the bachelor's degree.

Considerable evidence has been presented that leads to the conclusion that specialization in engineering can be postponed until after the completion of the undergraduate curriculum beginning with an internship program in industry or through a carefully planned professional graduate program.

A unified undergraduate program has been found to be adequate for employment in both the large company that often provides the opportunity for on-the-job specialized training and the small company where the young employee is asked to solve a great variety of problems for which a broad basic training is necessary.

Fundamental Background

The essential task that faces the student in an undergraduate engineering curriculum is to prepare himself to handle specific elementary problems immediately upon graduation and to have acquired the background to proceed most expeditiously in the direction that his employment opportunity presents. The former can be provided by several courses in the senior year that serve to introduce the student to the language, the status of knowledge, the state of the art, and specific applications of the general methodology in a branch, or specialty, of the various engineering fields. The acquisition of the engineering methodology can be accomplished through a strong unified educational program that includes the disciplines common to the different branches of engineering.

The present engineering curricula, as well as the professional activities of the engineer, must be studied to determine the common disciplines and to establish the differentiating characteristics, if any, of the several branches of engineering. I tentatively conclude that the difference between the activities in the several branches of engineering rests only on the different engineering systems normally included in the separate branches.

Differences of technical language and nomenclature have developed around the several systems that can be generally classified as structures, machines, circuits, processes, earth, and combinations thereof. These differences of language and nomenclature should be continuously reduced or eliminated. The unified curriculum will aid in this process. In addition, the state of the art differs not only for each system but may differ greatly with respect to the several members of a given class (say the low-speed reciprocating steam engine in contradistinction to the gas turbine or the jet engine). The unified curriculum can contribute somewhat to the education of the student in the art; however it is the considered judgment of many educators that this segment of the professional engineer's training can be accomplished more effectively by industry as a part of the industrial experience of the engineer.

Content of Curriculum

The outline, right, may lead to the formulation of the essential and common disciplines of professional engineering. It reveals a division of the engineering curriculum in accordance with the bases, the physical and biological sciences, and their applications to engineering. The outline is not presented in terms of subject material but rather in terms of the framework of science and of engineering.

The study of the present curricula in terms of this outline, as well as in terms of an outline based on subject material, will greatly illuminate the present state of engineering education.

The unified curriculum has been developed with the content in mind as presented in the outline.

A cardinal principle of the effective utilization of knowledge is the recasting of segments thereof into other immediately useful subdivisions. To place the entire responsibility of recasting knowledge upon the student or the engineer-in-training proves to be an excessive burden. The formulation, generalization, and integration of fragments of knowledge as made available either through scholarly work in the university and college or in the industry is one function of the engineering faculty.

In a new curriculum the content of all courses should eventually be changed. These changes can be effected slowly. For instance, strength of materials (the mechanics of materials) and analytic mechanics have been combined reminiscent of an earlier day. An attempt is also being made to place mechanics on an experimental experience basis and to reduce the present emphasis on "problem solving." The mechanics of fluids and solids are presented more intimately than is possible if their segregation in different teaching units exists. Heat-power illustrations of thermodynamics have given way to the presentation of

CONTENT OF AN ENGINEERING CURRICULUM

Division by bases and their application

1. **Physical sciences**
   - Chemistry and physics
   - Geology (Insofar as it is not descriptive but represents an extension of chemistry and physics)

   Content
   - Ideal systems, experimental basis of science, and symbolic description of phenomena
   - Observation and description (verbal and symbolic) of physical phenomena
   - Properties of substances and materials
   - Concept of matter and energy; conservation and transformation principles
   - Experimental method—mensuration
   - Problem solving

2. **Biological sciences**
   - Physiology, psychology, bacteriology, biology, biochemistry

   Content
   - See (1) above

3. **Languages of communication**
   - Native tongue } oral and written
   - Foreign tongue } oral and written
   - Symbolic (arithmetic, algebra, calculus, and others)
   - Pictorial (graphics)

4. **Properties of materials and their sources**

5. **Application to components of engineering systems, that is, the engineering sciences**

Division by force field

- Mechanical—fluids, solids
- Electrical
- Magnetic
- Thermal

6. **Methodology**
   - Methods of reasoning—logical processes; inductive, deductive, analogy
   - Modes:
     - Mechanical (utilizing all physical laws except 2d and 3d laws of thermodynamics)
     - Thermodynamic (introducing 2d and 3d laws)
     - Humanic (introducing man)
     - Economic (introducing cost)
   - Analysis and synthesis
   - Evaluation and maximization
   - Experimental and analytical bases

7. **Application to engineering systems**
   - Structures
   - Machines
   - Processes
   - Circuits
   - Earth
   - Or combinations thereof

   Utilize techniques of systems analysis (operations analysis), that is, synthesis

8. **Professional engineering**
   - Engineering as an art supplemented by engineering as a science
   - Ethical, moral, and aesthetic content
   - Industrial functions
     - Design
     - Development
     - Research and others

9. **General education**
   - Socio-humanistic
   - Literature and history as past solutions to man's problems
   - Impact of technology on society

"The student must be capable in the experimental method. . . ."

thermodynamics with emphasis on the mode of reasoning introduced with the second law. The techniques of circuit analysis are applied to systems other than electrical.

Considerable attention is being given to the continuity of student experiences, thus no time gap exists between the instruction in mechanics in the physics courses and the introductory course in mechanics as administered in engineering.

Several experimental additions are being made to the engineering curriculum. The base upon which engineering instruction is being built is being extended to include the life sciences as well as the physical sciences, particularly physiology and psychology. A one-year course in biotechnology is available in which the laws of physics, chemistry, and biology are applied to man, and the interaction of man with the environment created by the engineering system (machine, process, circuit, structure) is studied. Thus the engineering student will be partially grounded in the behavior of animates, particularly man, as well as in the behavior of inanimate objects and systems.

These biotechnologic course experiences are, and must be, followed by their application in subsequent student activities and courses. Knowledge of the basic considerations relative to man provides a setting that increases the meaningfulness of latter courses and experiences that revolve around supervision, management, labor relations, and sales problems.

A one-year course in the statistics of engineering has been introduced as an elective. Most engineering students complete this course which allows the analysis of systems not amenable to those techniques included in the orthodox courses in mathematics. It is to be noted that this course is not an introductory course in statistics, nor is it a problem-solving experience. The background acquired by the student leads to the graduate operations-analysis offering in which typical engineering systems are analyzed and synthesized.

Engineering works are wrought in materials. The properties and uses of materials receive concentrated attention. The several materials are studied; their properties are observed separately and in place. That is, the mechanical, electrical, magnetic, thermal, and other properties are brought into focus and then their interrelations noted. Again the properties and behavior of living tissue and bones are presented together with those of the usual "engineering" materials.

Analytic and Experimental Approach

Solutions of engineering problems are found through the use of analytic methods (derivations and calculations) or the use of experimental methods, or the judicious use of both. The student must be capable in the experimental method upon graduation. The parallel learning of the two methods (analytic and experimental) by the student is important.

The laboratory exercises then become more than demonstrations of the behavior of physical, chemical, and engineering systems; they become a workshop in the applications of the methodology of experimental solution. In brief, the experimental basis of engineering is brought into relief. The laboratory course activity also includes experiences in management, communication, and semantics.

The laboratory courses will provide experiences in mensuration and instrumentation, properties of materials, unit operations, and engineering systems, with the major emphasis on each of the subdivisions noted above in the freshman, sophomore, junior, and senior years respectively, but with each of the four subdivisions being represented in the other three years.

The term unit operation implies experiment stations describing a particular physical- or bio-phenomenon—for instance, flow of a fluid through a channel or over a surface; behavior of a circuit containing inductors, capacitors, and resistors; or absorption, transmission, and reflection of radiant energy. On the other hand, the engineering systems will be complete replicas (models or prototypes) of actual industrial systems. Complete power plants (steam and diesel), a production system in which a small pulley is produced, an irrigation system, a sewage reclamation plant, and a radio station are listed as examples of engineering systems already available or in the planning and construction stage.

The production system will be illustrated. Strap iron and bar stock are subjected to a cutting and punching operation (punch press) and to a turning, cutting, and drilling operation (automatic tool) respectively; assembly is accomplished and the parts are brazed together, forming the pulley. The accuracy of the product is established through the use of appropriate gages, and manufacturing tolerances are met. An economic analysis is made of the process and another is proposed and subjected to economic scrutiny by each student group.

Other Unifying Courses

Several other unifying courses will be introduced in the senior year at an early date. The first will include a discussion of natural resources, their availability, depletion or accretion rates, and the associated processes. The resources considered are air, soil, water, minerals, sea, plants, and animals (excluding man who is presented in the earlier courses). The second will be a course in systems engineering that will be taught by the case method and in which the synthesis of components and the maximization of a production (or construction) sequence will be illustrated. In this course the student will obtain his first glimpse of the activities of a professional engineer. A course in modern physics that will be required of all seniors and that will replace in unit value certain of the freshman-sophomore physics course material is also in the planning stage.

Many more details could be given relative to the teaching methods employed, recasting of courses, and future plans, but these will be omitted.

The extensive engineering correspondence and engineering extension activities, as well as graduate work, are planned to bring the materials of an engineering education to the engineer-in-training and the professional engineer employed in the industry. Many of the courses are designed specifically to meet the needs of the engineer in industry, and the instructors more often than not are experienced professional engineers.

The graduate program leading to the MS and PhD degrees consists of courses on and near the campus, both day and evening, as well as work leading to the MS degree at two off-campus stations located at Inyokern and San Diego. Again, a segment of this program is designed for the employed engineer. Upgrading through engineering education is a conservator of technical manpower. Ω

MODERN STORES NEED MODERN LIGHTING TO ENHANCE THE APPEARANCE OF THEIR MERCHANDISE AND THEREBY INCREASE SALES APPEAL.

The Why of White Fluorescent Lamps

By C. N. CLARK

Why are there several different "white" fluorescent lamps? And why are lamps marked Standard Cool White, Soft White, and Deluxe Warm White?

Modern white fluorescent lamps are designed to meet specific application requirements. In doing this, two variables are taken into consideration by the lamp designer. In the first place, the degree of whiteness selected will determine the "atmosphere"—warm or cool—the light tends to produce in a room. Second, the distribution of energy throughout the visible spectrum will determine both the degree to which specific colors will be emphasized or subdued and the luminous efficiency of the source.

How White is White?

Your impressions of whiteness are influenced by environmental conditions. To illustrate, let's take the familiar example of the headlights of an approaching automobile at night. They usually appear brilliantly white, with no hint of being colored. Yet in the daytime when you meet a car with its headlights on, you usually see them as a pale yellowish-orange light. The reason is that you become "color-adapted" to the color of the prevailing light by means of a mechanism that suppresses the eye's sensitivity to the predominating hue of the light. The result is that it tends to look white. At night you're usually adapted to incandescent lighting. Then the headlights have the same color as the lighting you're adapted to, and they appear white. In the daytime you're adapted to a mixture of sun-and-sky light that is relatively rich in blue energy. The auto headlights are rich in red and yellow wave lengths, as are all filament lamps. They seem, by comparison, to contain an excess of these colors, and thus appear yellow-orange. So both natural daylight and filament lamps are "white," given the proper viewing conditions, although they cannot both be seen as white at the same time.

In this case the contrast between the headlights and daylight occurs simultaneously. Similar contrast may also occur successively—as, for example, when you enter a building lighted by filament lamps in the daytime. At first they seem yellowish. Gradually, your eye adapts to them so that finally they look white, and any daylight present seems bluish. Under usual conditions then, any one of a whole series of colored lights, ranging from yellowish to bluish, can look white. Nevertheless, your color-adaptation is never quite complete so that the lighting usually retains some of its yellowish or bluish character, as well as its emphasis of the warm or cool colors in the surroundings.

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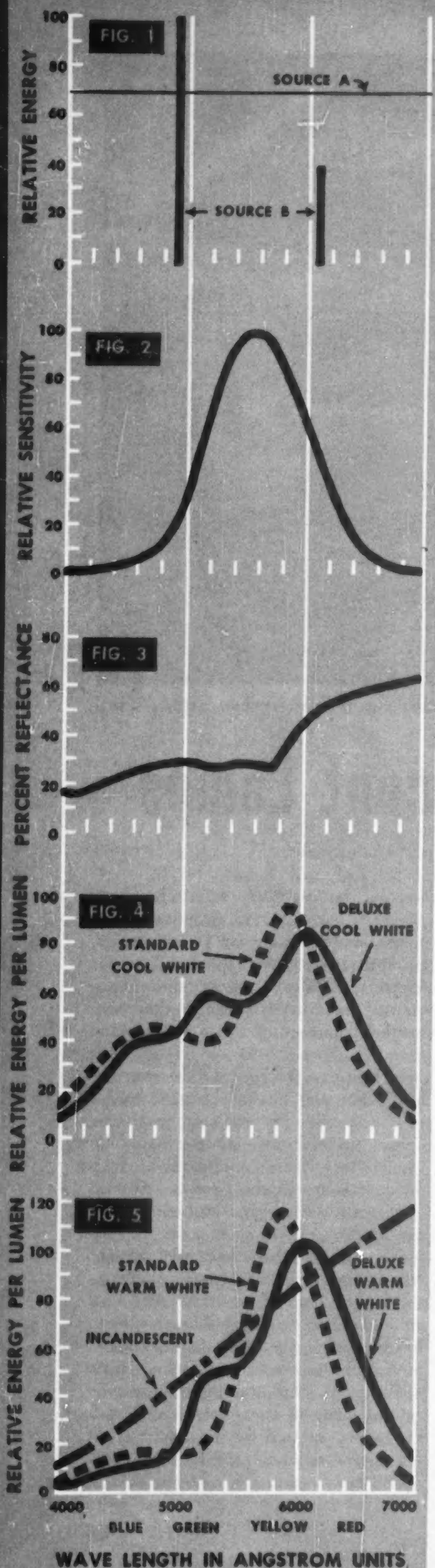
In 1949 Mr. Clark joined GE's Lamp Division at Nela Park, Cleveland, where he is a member of the Lighting for Selling Section of the Application Engineering Department. His activities include study of the application of color in lighting and development of new uses of lamps in stores, theaters, and restaurants.



Throughout the centuries man has lived under two main kinds of light—natural daylight and flame sources, ranging from firelight to incandescent lamps. The atmosphere associated with natural daylight normally is neutral to slightly blue (cool), while that associated with incandescent lamps is usually slightly yellow (warm).

Early White Lamps

It is interesting to note that the early white fluorescent-lamp designs (1938) took into account the warm and cool aspects of lighting. The lamp named Daylight was patterned after a typical phase of natural daylight, while the one called White was designed to produce a yellowish light, yet not quite as yellow as typical incandescent lamps.

The Daylight lamp was an almost exact duplicate, colorwise, of a typical sun-and-sky light, which rarely gives an impression of being too blue. Despite this, when Daylight lamps were used indoors at illumination levels that were a small fraction of those outdoors, the effect was often chilly, blue, and even gloomy.

A new "white" that simulated the appearance of natural daylight at the illumination levels commonly encountered indoors was introduced in 1945. This lamp (now known as Standard Cool White) is intermediate between the White and Daylight lamps in appearance, and under usual conditions appears the whitest of all fluorescent lamps. About the same time a fluorescent lamp was introduced that was a more exact match for typical filament lamps in appearance and atmosphere produced than the earlier white lamp. A similar color is now known as Standard Warm White.

In answer to the specific requirements for lighting displays at meat counters, a Soft White color was developed in 1940. It was also complimentary to people's complexions. Later improvements in the spectral distribution changed its appearance from a "purplish white" to a "pinkish white."

FIG. 1. SPECTRAL ENERGY distribution of hypothetical light sources that to the average person would match in color, but would have a completely different effect on the appearance of colored materials. Source A emits equally at all wave lengths; Source B at only two.

FIG. 2. INTERNATIONAL standard luminosity curve of relative brightness sensation induced in the normal human eye by a unit amount of energy at each wave length indicated.

FIG. 3. SPECTRAL REFLECTANCE of the average Caucasian facial complexion.

FIGS. 4 AND 5. SPECTRAL ENERGY distribution of 40-watt cool white and 40-watt warm white fluorescent lamps. Fig. 5 also shows a typical incandescent lamp.

Efficiency vs Color Rendition

The phosphor coating on the inside of fluorescent lamps converts short-wave ultraviolet energy, generated by a low-pressure mercury-arc discharge, into visible radiations of longer wave length. By varying the ingredients and combinations of the phosphors, a great variety of spectral energy distributions may be produced.

Many different spectral distributions can give the same impression of whiteness: our eyes integrate combinations of energy at various wave lengths into a single composite sensation. An extreme example of this phenomenon is shown in Fig. 1 where a hypothetical light source emitting at only *two* wave lengths will, to a normal observer, appear the same color as a source emitting equally at *all* wave lengths. The Standard Warm White and filament lamps shown in Fig. 5 represent a more practical example. When we look at these lamps or their light reflected from perfectly neutral surfaces, they appear practically identical in color.

For each white fluorescent lamp color there is a wide choice as to the particular combination of phosphors used to produce the required degree of whiteness. But lamp efficiency will vary, depending on the relative amounts of energy emitted by the phosphors in the various spectral regions. Fig. 2 illustrates why this is so. It shows the relative sensation of brightness induced in the eye of a normal observer by a unit amount of energy at each of the wave lengths indicated. The human eye is "tuned" to the yellow-green wave lengths, and its response falls rather rapidly to zero at the blue and red ends of the spectrum. (In general, animals, insects, and plants do not have sensitivity curves peaking at the same wave length as people.) Thus, by using phosphors rich in yellow-green and relatively weak in red and blue, maximum luminous efficiency may be attained for a given degree of whiteness.

If we lived in a black, white, and gray world, such a lamp design for

COLOR EFFECTS OF WHITE FLUORESCENT LAMPS

Conditions	Simplified Line: *Standard Cool White	Deluxe Cool White	*Standard Warm White	Deluxe Warm White	Daylight	Older Colors: *White	Soft White
†Lamp Appearance; effect on neutral surfaces	White	White	Yellowish white	Yellowish white	Bluish white	Pale yellowish white	Pinkish white
Effect on "atmosphere"	Neutral to moderately cool	Neutral to moderately cool	Warm	Warm	Very cool	Moderately warm	Warm pinkish
Colors strengthened	Orange, yellow, blue	All nearly equally	Orange, yellow	Red, orange, yellow, green	Green, blue	Orange, yellow	Red, orange
Colors grayed	Red	———	Red, green, blue	Blue	Red, orange	Red, green, blue	Green, blue
Remarks	High efficiency; blends with natural daylight	Best over-all color rendition; simulates natural daylight	Highest efficiency white lamp; blends with incandescent light	Excellent color rendition; simulates incandescent light	Usually replaceable with Standard Cool White	Usually replaceable with Standard Cool or Warm White	Usually replaceable with Deluxe Cool or Warm White

* Before 1949, White was called 3500 degrees White; Standard Cool White, 4500 degrees White; Standard Warm White, Warm Tint. The numerical designation indicates "color temperature"—the temperature in degrees Kelvin of a theoretical thermal radiator whose color is an approximate visual match to the fluorescent lamp. Because of differences in spectral distribution between the two, color rendering properties are different. Color temperature ratings of fluorescent lamps tend to be misleading, and were dropped in favor of more descriptive names.

† For simultaneous viewing. When lamps are used separately, color adaptation minimizes differences in whiteness, but strengthening and graying of colors still takes place in the manner indicated, as does effect on atmosphere.

maximum efficiency would be ideal, because maximum visibility of objects would thus be obtained. Happily, though, we live in a colorful world. Indeed, the color of objects is often the main factor in our decision to buy, in our concepts of beauty, and in conveying information. It is therefore important that attention be paid to the effect of spectral distribution of light on the appearance of colored materials.

A colored surface common to all visual environments is the human complexion. Because it is so familiar, deviations in its appearance are easily detected. Fig. 3 shows that the typical complexion reflects red wave lengths most strongly. So it generally appears as some shade of pink. If it is viewed under a light source lacking in red radiation (mercury vapor lamps, for instance), it cannot have its normal pinkish color, for there is no red present in the source to be reflected.

A similar statement could be made for materials of any hue. Therefore, to give all hues a natural appearance, all colors must be emitted in substantial amounts by the light source; that is, the spectrum must be balanced. This necessarily results in lower efficiency, because the eye doesn't see red and blue efficiently. Thus, in the design of white fluorescent lamps, a compromise is necessary; a balance must be made between phosphors yielding highest luminous efficiency and those necessary to give the most natural appearance to all colors.

When the earlier fluorescent lamp colors were designed, there were no practical phosphors emitting long-wave red light. So, of the five white lamps commonly available in 1949, all except Soft White were relatively high in efficiency but lacked the balanced spectrum necessary for rendering *all* colors well. It's true, though, that their color-rendering properties were satisfactory for many applications, and their use grew tremendously. As pointed out, Soft White was specifically designed to compliment complexions and foods, but it tended to make greens become grayish and often to give an undesirable pinkish tint to the areas where used. Clearly what was needed, particularly for color-critical applications, was *white* light that would render *all* colors well.

Deluxe Lamps

Such a lamp design was made possible by the development of improved red phosphors. In 1949 these were used in the design of two new fluorescent lamp colors. One, called Deluxe Cool White, closely simulates the color-rendering effects of natural daylight. The other, called Deluxe Warm White, simulates the color-rendering effects of incandescent lighting.

These two deluxe lamps combine excellent color-rendering qualities with reasonable efficiency. One has the degree of whiteness that experience indicates to be most useful in creating an atmosphere suggesting the coolness of natural daylight. The other suggests the warmth of incandescent lighting.

Two older designs—Standard Cool White and Standard Warm White—provide the same impression of coolness or warmth in the environment as the respective deluxe lamps. But in the standard lamps emphasis is on the production of higher luminous efficiency at some expense of color-rendering properties. Their color quality is acceptable, however, in a wide variety of noncritical color applications.

In the appearance of the lamps themselves or of neutral surfaces illuminated by them, the Deluxe Cool White and Standard Cool White are designed to match each other. The same is true of Deluxe Warm White and Standard Warm White lamps. Figs. 4 and 5 show that the standard lamps, although high in efficiency and emitting radiation of all colors, are relatively weak in red and green, while containing large amounts of yellow-green. In each deluxe lamp the spectrum is better balanced by adding substantial amounts of red and green so that all colors illuminated take on a much more familiar, hence, more "natural," appearance.

These four colors—two standard and two deluxe—are called the "simplified line" of white fluorescent lamps. By making the proper choice, you can easily find the right lamp color for practically any application requirement.

Choosing the Right White

With this simplified line, the choice of an appropriate white fluorescent lamp color is determined by answering two basic questions. . .

- Which is more important—highest lighting efficiency (standard lamps) or best appearance of colors (deluxe lamps)?
- Should the lighting contribute toward the cool, crisp atmosphere associated with natural daylight (cool white lamps), or the softer, warmer atmosphere associated with incandescent lighting (warm white lamps)?

For applications where black-and-white seeing tasks are the prime consideration—where the best appearance of colors is not of great importance—the standard fluorescent lamp colors are the logical and preferred choice, because their higher light output produces greater visibility.

For installations where appreciation of the full richness and beauty of color in complexions or certain materials is involved, where accurate discrimination of color is important, or where visibility depends on color contrast, the color advantages of the deluxe fluorescent lamps can often more than offset their approximately 25 percent lower light output. Because they contain more radiation in the red and green regions of the spectrum, these colors appear relatively brighter and stronger when seen under deluxe lamps. And because the lamps have better-balanced spectra, visibility by color contrast is also improved, with all colors taking on added depth and richness.

To illustrate how this works in practice, here are a few examples of preferred lamp colors for various applications, based on the experience of Lamp Division application engineers concerned with the specific fields.

In the work world—factory, office, school—seeing tasks often involve fine detail, requiring high illumination for best visibility. Appearance of colors is not usually critical, so the high-efficiency standard colors are the logical choice. Standard Cool White is most commonly selected, because the cool atmosphere it creates appeals to many people. In addition, its color-rendering qualities are generally considered better than those of the other white lamps, except deluxe. Standard Warm White is slightly higher in efficiency than the Standard Cool White. It is used where only highest light output is required.

However, in some working areas, particularly offices, many employers are using deluxe lamps for better appearance of employees and work spaces. Also, for tasks requiring accurate color discrimination—such as industrial color grading or inspection and art classrooms in schools—the light source having most uniform color-rendering properties is required. Deluxe Cool White meets this need. Deluxe lamps are also appropriate in such places as lounges, rest rooms, and cafeterias to improve the appearance of complexions and decorative schemes.

Deluxe fluorescent lamps are almost always chosen for stores and other commercial establishments. The color of merchandise is an important factor in its sales appeal; appearance of customers and environment are important, too. The choice between Deluxe Cool and Deluxe Warm lamps is most often made on the basis of the use to which the merchandise will finally be put. For instance, home furnishings stores may select Deluxe Warm White because their customers want to judge the appearance of merchandise as it will look at home in the evening, usually under incandescent lighting. Food stores, on the other hand, tend to select Deluxe Cool White. One reason is that this white brings out the rich red appearance of meats while still keeping fats white, and without tinting the white display trays. Deluxe Cool White also emphasizes the fresh appearance of fruits and vegetables, and blends well with natural daylight in open-front stores.

Additional Factors

Under some conditions other factors may be dominant in the choice. Northern exposure may lead to the selection of Deluxe Warm White to "warm up" the room, or Deluxe Cool White may be used to "cool off" rooms with southern exposure. Similarly, the warmth or coolness of a room's color scheme may be emphasized by the appropriate lamp color. Climate also has a bearing, for cool tints of light are more widely used in southern parts of the United States.

Deluxe lamps are accelerating the acceptance of fluorescent lighting in all areas of the home—earlier fluorescent lamp colors were often felt to be uncomplimentary to complexions and interior decoration. The usual choice is Deluxe Warm White, because it simulates and blends with the incandescent lighting usually present. In warm climates, or where relatively high levels of illumination are provided by mainly fluorescent sources, or for certain color schemes, Deluxe Cool White is often used. An intensive study has been made of the effect of each of the lamp colors in the simplified line on the appearance of typical colors used in home decoration. For workshop, laundry, and garage Standard Cool White is usually selected.

Deluxe white fluorescent lamps have gone a long way in expanding the beauty and utility of fluorescent lighting by providing good color rendition at efficiencies much higher than other light sources of comparable color quality. Past progress is both a challenge and a promise of future gains. For just as surely as the engineer will find ways to improve the efficiency of fluorescent lamps, he will also discover how to narrow the gap in efficiency between the standard and the deluxe types. And he will seek new materials and new techniques that will enable the design of lamps having even better-balanced spectra, with resulting further improvement in color rendition.

The language of color in our environment is an expressive one, but we cannot yet fully interpret or translate it into words or numbers. Indeed, one of the more pressing problems in the application of lighting is the need for a system to express the relative color-rendition characteristics of fluorescent lamps. This need is recognized, and development of such a system is being undertaken by various national and international technical groups.

While the recently developed white lamps discussed here continue to meet current requirements very well, we can look forward to the day when the nearly infinite range of color effects can be described and predicted. Then we'll have color at our command. Ω

IN DEVELOPMENTAL COLOR TELEVISION STUDIOS, EQUIPMENT IS BEING READIED FOR NEXT YEAR'S COMMERCIAL COLOR TELECASTS.

Color Television—Today and Tomorrow

By DR. W. R. G. BAKER

Color television has such a major potential impact on the entire industry, and there seems to be such a welter of somewhat confusing statements that an objective statement of the situation may be helpful.

Technically, color television is highly involved. In terms of production, color television receivers offer new and complex problems that will make our black-and-white manufacturing problems look simple in comparison.

Marketing Problems

The problems of marketing at all levels—the factory, the distributor, and the dealer—will be complicated.

In the first place, color television, like black-and-white or monochrome, must be a system; that is, all elements and equipment used in broadcasting and receiving must function together according to a basic set of principles or specifications—each must be tied in and work with the other.

To protect the public investment in receivers and to prevent complete chaos in broadcasting, such a system must be legally approved by the government. This duty and responsibility has been delegated to the Federal Communications Commission (FCC).

In 1950 the FCC approved a field sequential system of color television. The principal objection to this system lay in the fact that it was not "compatible" to the system under which black-and-white television was operating. This meant that black-and-white receivers in American homes could *not* receive color broadcasts either in color or black-and-white without extensive alterations and expense to the owner.

The importance of that major shortcoming is evidenced and magnified today because the public has invested over

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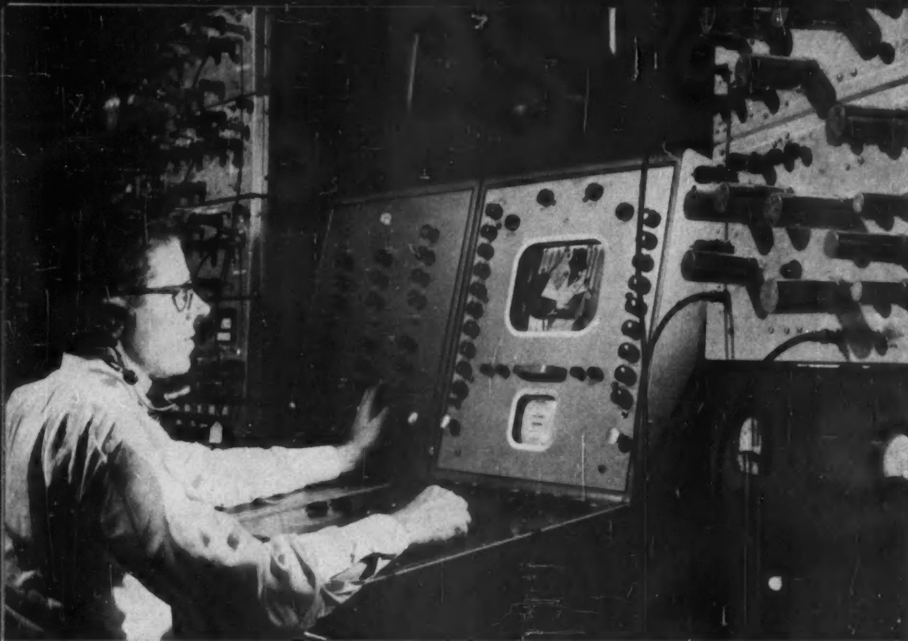
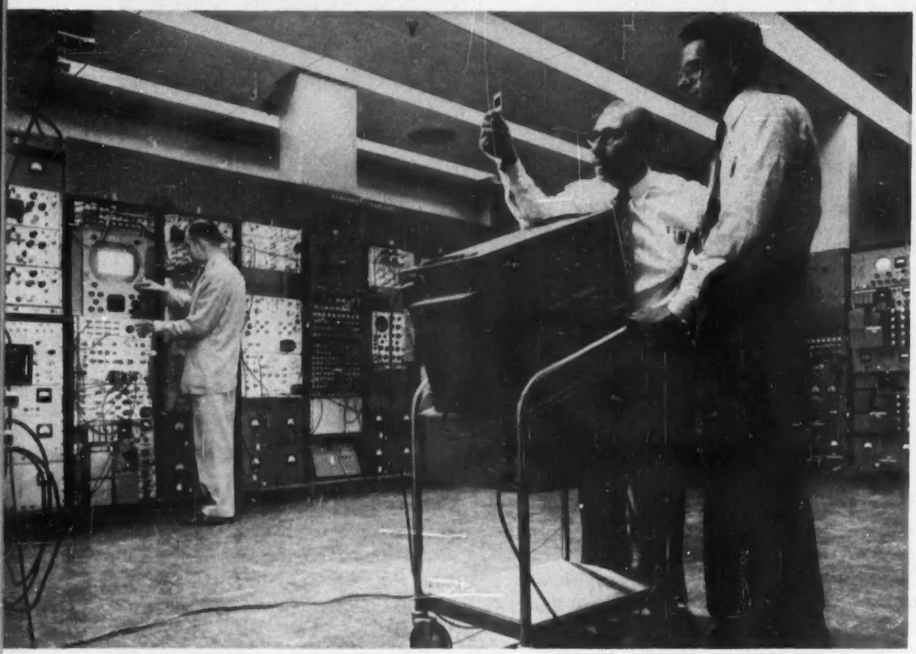
Dr. Baker—a Vice President of the General Electric Co., and General Manager of the Electronics Division—was awarded the 1953 Medal of Honor by the Radio-Television Manufacturers Association for his outstanding contributions to the advancement of the industry. He is chairman of the National Television System Committee.



LABORATORY SETUP for color TV includes developmental transmitter control, multiplexing equipment, pulse generator, and flying-spot scanner for presenting slides.



CONTROL AND MONITORING EQUIPMENT used in GE's Electronics Laboratory, Syracuse, for the operation of the TV color camera and the processing of color signals.

seven-billion dollars in some 25 million black-and-white receivers that would not be able to receive such color broadcasts in black-and-white without expensive alterations.

Obviously, the solution of the problem lay in the possibility of developing an all-electronic system that would be compatible—a system that would make it possible for any and every black-and-white receiver in the home to receive future color broadcasts in black-and-white, without any alteration or expense.

The development of this electronics system was the task undertaken by the National Television System Committee (NTSC), formed under the auspices of the Radio-Television Manufacturers Association.

In the development of the standards for a compatible color system, the NTSC had the full and complete co-operation of the companies comprising our industry. The source of an idea was completely disregarded. The only questions were: Is this the best idea? Is this the best way to do the job?

Toward the color assignment 91 companies in the industry contributed the skill and services of over 200 leading scientists and engineers.

The NTSC has now been in operation the better part of two years. It has produced a number of significant contributions not only on a system basis but also in details.

What does the NTSC system of compatible color television do?

First, it fulfills its primary function: the transmission of excellent pictures in full color to color receivers. The detail of these images is equal to that of monochrome telecasts. In chromatic quality—that is, fidelity of color reproduction—the color television images match or excel color movies.

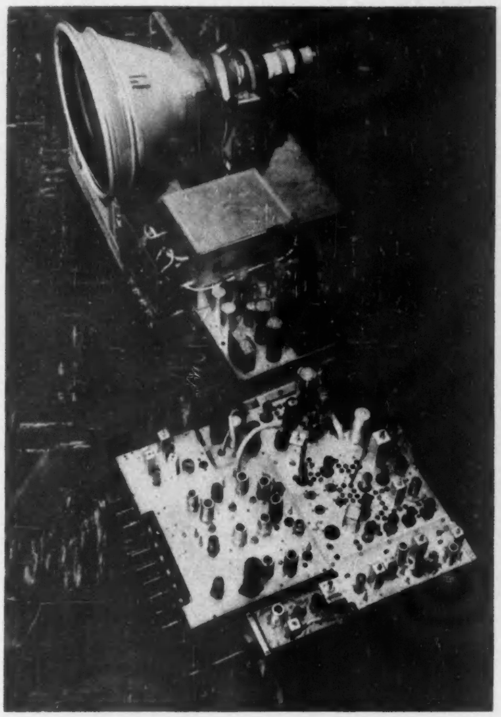
Second, the NTSC system fulfills the compatibility requirements. It produces the program on black-and-white receivers, producing images in monochrome which are virtually indistinguishable from those provided by standard monochrome broadcasts. No modification of the receivers is required; in fact, no adjustments whatever are needed except the normal operation of the front panel controls used in monochrome reception.

Reception by the present-day audience has been checked, for example, by transmissions over Channels 4 in New York, 3 in Philadelphia, and 2 in Syracuse.

Reports from viewers are overwhelmingly favorable. Many say that the color broadcasts, viewed in black-and-white on present-day standard television receivers, are superior in pictorial quality to the regular broadcasts. These reports are not imagination. The broadcaster's equipment, "spruced up" for color programs, can actually do a better job of rendering the shades of the gray in the monochrome picture.

The NTSC System

How does the NTSC compatible system work? The standard black-and-white television transmitter sends out two signals—one carrying the picture, the other the sound. The picture signal



COLOR TV RECEIVERS REQUIRE MANY MORE TUBES THAN BLACK-AND-WHITE SETS BUT ARE DESIGNED TO FIT IN A STANDARD CABINET.

is produced in the television camera that views the scene in full color and transforms it into a representation in shades of gray. In so doing, the camera removes the "color" aspect of the image.

In transmitting a full-color image, then, it is necessary to take into account the missing elements of hue and saturation. In the NTSC system these are transmitted by a third signal, known as the color carrier, that is fitted into the channel between the picture signal and the sound signal.

The NTSC color system is thus founded on the principle that a color image may be reproduced from two signals, one of which carries a monochrome version of the image in shades of gray, while the second superimposes on the monochrome image the missing hues and saturations.

This principle is well suited to compatible operation of monochrome receivers. It is merely necessary to so arrange the transmissions that monochrome receivers respond only to the monochrome signal, ignoring the color signal.

Color receivers, on the other hand, are designed to accept and make use of both signals.

Simple as this principle appears, it was a major task to develop a system based on it. The principal problems were...

- To fit all the information, both monochrome values and hue and saturation values, into the standard television channel without overcrowding.

- To assure that monochrome receivers would ignore the color information for which they have no use. (If this distinction were not made, the surplus color information would interfere with the monochrome reproduction and so degrade the image that the system would not be fully compatible.)

The first problem was solved with the discovery that the monochrome aspect carries the essential pictorial detail of a full-color image. Once the monochrome portion is available in full detail, the hues and saturation can be superimposed in a relatively coarse manner, "painted with a broad brush," so to speak. Thus, the color carrier need not occupy as much channel space as the picture carrier, and overcrowding of the channel is avoided.

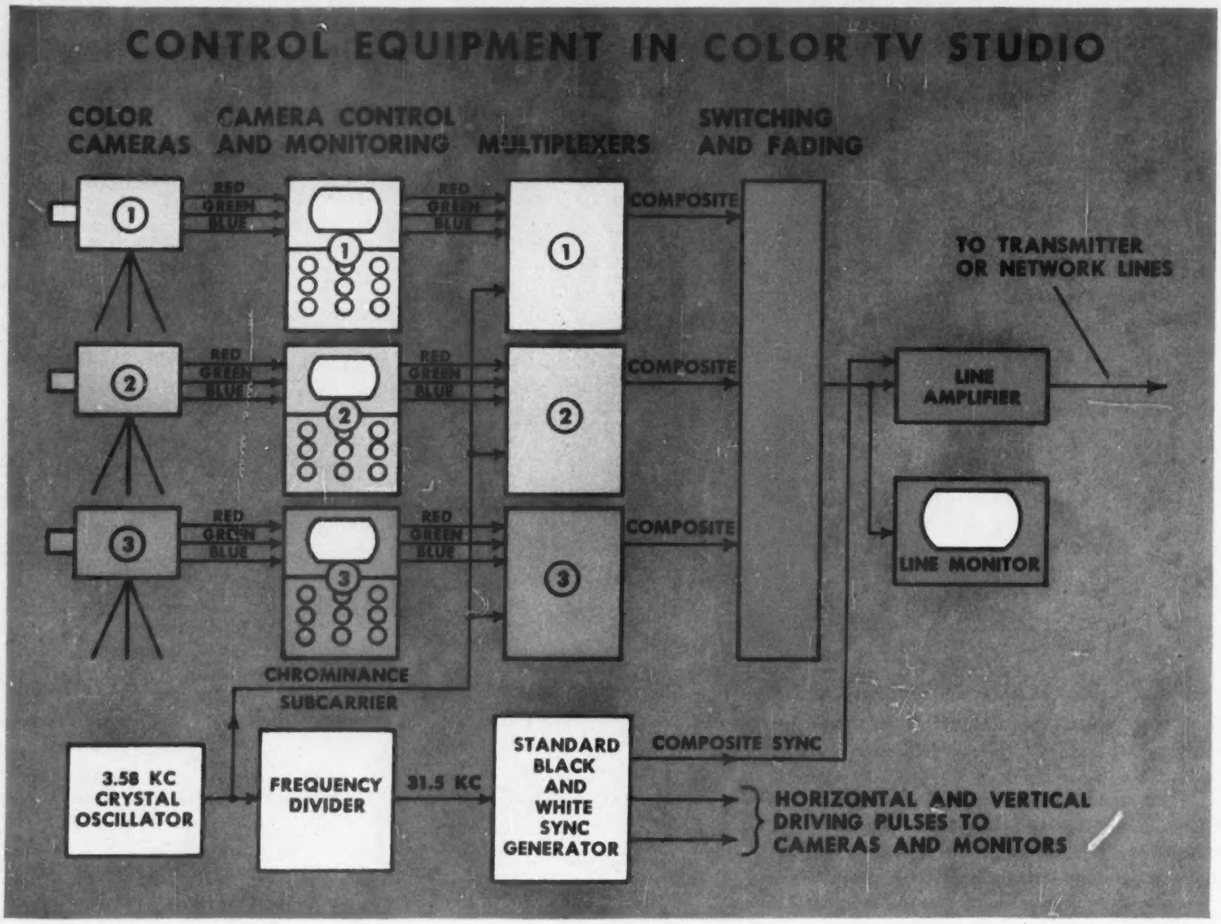
And the second problem was solved by assigning to the color-signal carrier frequency a precise numerical value relative to the picture-signal carrier frequency. When this exact frequency relationship is maintained, the monochrome receiver retains its full sensitivity for the picture signal but finds itself virtually blind to the color signal. Mutual interference between the signals is thereby avoided.

In summary, the NTSC system achieves compatible color transmissions by building on the existing monochrome system. No basic changes are required in the existing FCC regulations governing black-and-white broadcasting beyond tightening of tolerances, and that has the effect of improving the performance of receivers now in the hands of the public, and making a minor addition to the synchronizing pulse. To these regulations must be added a group of supplementary standards which set up the color signal, specify its frequency, and outline the techniques by which the hue and saturation values are transmitted.

Successful Demonstration

This NTSC system was formally demonstrated by RCA on April 14, 1953, to the Wolverton Committee of the House of Representatives and to the industry on April 16, 1953. It was acclaimed as highly successful.

A television transmitter broadcasting a monochrome signal will accommodate



the color signal without change. Precautions necessary to insure satisfactory monochrome transmission are usually the only precautions necessary to insure proper color transmission, although misadjustment will be more objectionable in the picture when transmitting color.

Transmitters that will take color signals from the network will probably be required to utilize an additional piece of equipment, known as a *synchlock*, to insure the adequacy of the received synchronizing pulse. Fortunately this is a rather simple and inexpensive piece of equipment and could be supplied quickly to any station then on the air with black-and-white.

Signals have been satisfactorily transmitted over the Bell Telephone System's networks. Their engineers have taken an active part in the affairs of the NTSC and are thoroughly familiar with the NTSC proposal.

These factors mean that a color program originated at a key network station and put on the network could, for a minor capital investment and at practically no extra operating expense, be taken off the network and rebroadcast by any local station.

Color programs on a national basis could thus be available a few months after the system is approved. This could be an important advantage in our merchandising problem.

Studio Changes

It is in the color television studio that the most extensive changes will be required. Initially a three-tube camera will be used, although development is now intensively under way on an improved single-tube camera. It is expected that further development will materially reduce the bulk and complexity of the color camera.

Providing the necessary studio equipment for hundreds of stations across the country is a substantial technical and production job. But this need not necessarily preclude the possibility of originating a national color television signal quickly.

Enough studio gear, much of it now only in prototype stages, is available to equip at least several key network stations. This equipment could be used however to put a small percentage of color programs through the networks in parallel with the standard black-and-white programs.

One of the three important elements of the NTSC color television signal is that it employs the same monochrome signal as used for today's black-and-white television. This, of course, is the feature of the system which makes it fully compatible. This feature in the NTSC system does simplify to some degree the design of color television receivers. The fact remains, however, that to incorporate in one chassis and in one picture tube the ability to receive at the turn of a switch either color or black-and-white programs is a complex problem in engineering and a costly one in production.

"... standard sets will still outsell color ... four to one in 1955."

Tube Requirements

A large number of proposals have been advanced for all-electronic tricolor picture tubes, but up to the present time only one of these that has been extensively demonstrated has produced satisfactory pictures. Such a condition will probably not endure for long. Various types of tubes are under intensive development in several laboratories, and it is almost inevitable that results will be forthcoming shortly.

All the tricolor tubes have in common the requirements that the phosphor surface utilize not a homogeneous deposit, as in monochrome, but three separate phosphors for red, green, and blue, deposited as hundreds of thousands of dots or as fine vertical or horizontal stripes. Here the similarity ends and development is progressing in two general directions.

The first category of tubes are those using a single electron beam with a change in beam direction at the front of the tube to provide color selection. Usually these tubes are simpler and cheaper than those in the next category, but they depend on complicated chassis and require greater circuit precision to insure color fidelity. Furthermore, the beam-bending operation requires an appreciable amount of power at high frequency, which raises the problem of interference radiation.

The second general category of tubes comprises those utilizing three separate electron beams whose possible paths are so restricted physically that the green gun, for instance, can only reproduce green, and so on.

The use of these tubes permits a reduction in chassis and circuit precision and complication, but the tube complexity and cost is increased. The radiation problem, of course, does not exist. Several laboratories are known to be working in this direction.

The industry thus seems to have two choices . . .

- Build the precision into the tube, thus permitting simpler chassis circuits with the assurance that when a given color is called for, only that color can be reproduced. The radiation problem does not exist.

- Build the precision into the chassis. This alternative possibly will result in lower-cost tubes. It involves the hazard of radiation and probably puts more of the responsibility for reliable operation into the hands of the customer.

Factors Affecting Cost

If the three-gun type is used, and if current price estimates of $150 to $200 prevail, it is obvious that the picture-tube component alone in the receiver might add $325 to $350 to the list price. Just adding this difference in picture-tube price to the price of an average good-quality 21-inch console would bring the total cost to $750 or more.

Further, a color receiver will probably use 45 to 50 receiving tubes, more than twice that of a black-and-white set. Add the cost of these tubes and necessary circuitry and it becomes evident that the first color receivers will have to be priced at $800 or more. When color receivers go into mass production, the cost will come down of course; but because of their complexity they will remain more expensive than standard monochrome receivers.

Predictions

When will color television be available to the public?

Any timetable depends on one fundamental—the official FCC approval of the NTSC color system.

The NTSC petitioned the FCC on July 28, requesting adoption of the NTSC standards. This could mean that the NTSC system could be approved by March 1, 1954. RCA and CBS have announced they would begin limited broadcasts using the NTSC standards this fall.

Also, by March 1, 1954, the color tube output could possibly attain a monthly rate of 2000 to 4000 tubes. Assuming that this is accomplished, it may be anticipated that a model or two of color receivers will be included in the 1954 fall line of many manufacturers.

Available quantities will be limited, but there should be enough receivers available to permit the public generally to see color television in comparison to black-and-white in the fall of 1954.

I believe that color television will come as an evolution and not a revolution.

Color will prove to be a supplementary service and will not quickly, or perhaps ever, completely replace the monochrome service.

I am also confident that the standard black-and-white receiver will continue to be the backbone of television sales for at least five years into the future.

But there will be a critical period in sales while the public appraises the value of color against black-and-white, becomes educated to the true facts of the actual advantages of color television, evaluates the programs that will be available, considers how much color adds to the programs, and ascertains what they would have to pay over and above the cost of a good black-and-white receiver.

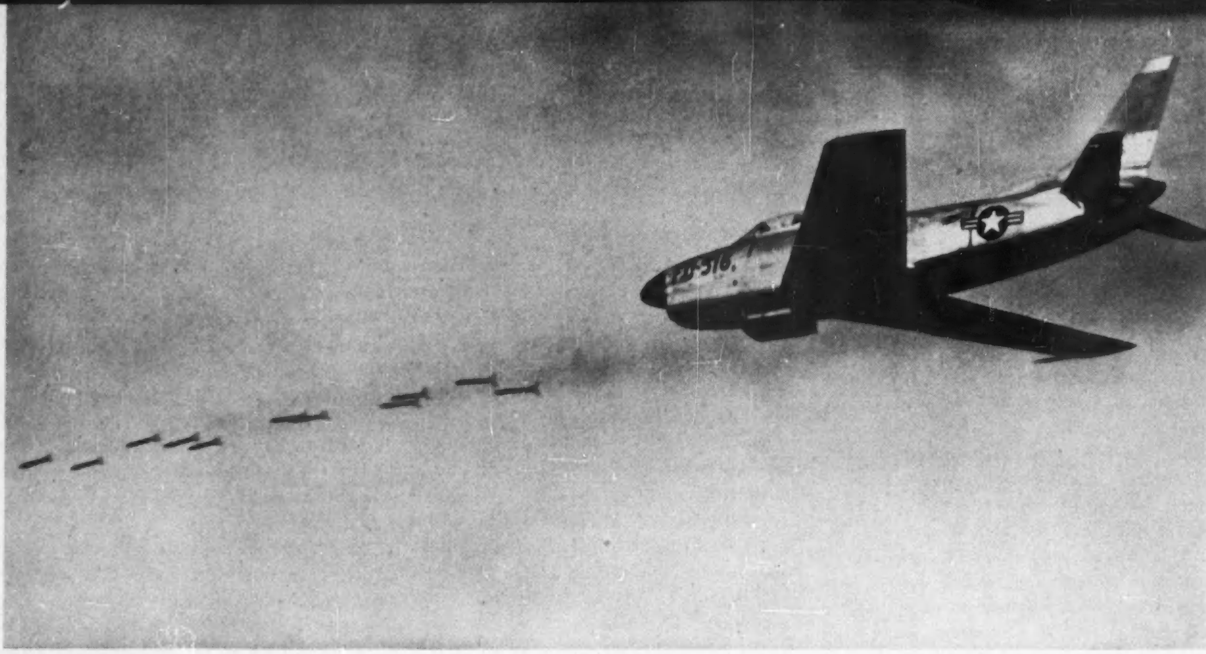
The quicker we can give the public the opportunity to make this side-by-side comparison and appraisal, the shorter will be the period of indecision and hesitancy to buy a black-and-white receiver.

During 1955 the number of hours of color programs will gradually increase. At the same time, perhaps by the fall of 1955, color receivers will come down somewhat in price as the volume of production increases. We will then be entering the real period of evolution, with color gradually bettering its service and lowering its cost to the consumer. The ratio of color sales to black-and-white will increase, but I predict that standard sets will still outsell color receivers four to one in 1955.

By that time the industry will be oriented to a pattern where it will be offering the public both types of television receivers as a matter of course, and the public will be making its individual choice purely on the basis of what each service offers at the price it has to pay.

And I am convinced that under such circumstances and realistic comparison a high percentage of purchasers will continue to favor the standard black-and-white receiver. Plain economics will dictate this choice for millions of families, particularly when they know that such a receiver will bring them all the programs on the air in excellent black-and-white.

That is the great asset of the NTSC system. Every black-and-white set sold—every such set sold this year, next year, or five years from now—will continue to give its full measure of service for every dollar of cost, without added expense or any reduced quality of performance. Ω



THE F86D *SABREJET*—VITAL ENGINEERING MANPOWER WAS CONSERVED WHEN ITS CONTROL SYSTEM WAS DEVELOPED WITH . . .

Analog Computers—Successor to Cut and Try

By C. E. BRADFORD and W. M. GAINES

Nowadays, analog computers are essential in developing many kinds of control systems — autopilots, missile-guidance systems, and gunfire controls, to name a few. And there are a lot more in other fields. For it's a considerable advantage when you can evaluate a control system in the laboratory using a computer to simulate the device under control, or even part of the control itself.

The General Electric J47 turbojet engine with afterburner that powers the F86D *Sabrejet* (photo, above) is a case in point. While a jet engine is basically simple in principle, it isn't in operation. True, a slight movement of the throttle at the pilot's fingertips and the engine responds with a burst of power. But to make this possible, a sensitive and complex array of control equipment had to be developed. Acting as a nerve center, it regulates the engine's functions just as our own nervous system regulates our body functions.

The Problem . . .

The control problem has two main facets—static accuracy and transient response.

Accuracy is extremely important because for maximum thrust the engine must operate at its highest permissible temperature and rotational speed. Yet a continued overtemperature of 100 F will reduce its life 10-fold, while overspeeding it by a few percent may cause serious damage or even destruction. Response, on the other hand, is the pilot's need for rapid and sensitive control of the engine's thrust: when coming in for a landing, a few seconds delay caused by a sluggish control can easily be the difference between his life and death.

A control system must accordingly be capable of allowing the engine to accelerate at its maximum temperature and speed.

Also, arrival at a new power setting shouldn't be accompanied by any "hunting" of the engine—that is, the system should settle rapidly and stably. For thrust oscillations are reflected throughout the airframe, giving the pilot an extremely rough ride.

It's not enough that the engine perform satisfactorily at sea level. In modern aircraft, where the sky's the limit, it must give top performance over a wide range of altitudes and flight speeds. And operating characteristics of the engine vary widely with altitude. For example, the amount of fuel needed to maintain a given speed at 50,000 feet is only one-tenth that at sea level, and the engine's acceleration is proportionately lower. This variation in flight makes control a difficult problem.

All factors affecting operation of the J47 turbojet engine and its control (illustration, top, opposite page) are mutually dependent. Again for example, the introduction of afterburner fuel will tend to slow down the engine so that the speed control will have to momentarily introduce more fuel to maintain correct speed. This increase in fuel flow in turn causes the gas temperature within the engine to rise and—through the action of the temperature control—make some other changes on the engine.

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Mr. Bradford and Mr. Gaines began their G-E careers as test engineers and both completed the Advance Engineering Program. They are development engineers in the Aeronautic and Ordnance Systems Division, Schenectady. With GE since 1949, Mr. Bradford is concerned with analytical work in developing turbojet engine-control systems. Mr. Gaines joined GE in 1947 and does analytical work on fire-control systems.

Obviously, development of a control system that will constantly ensure the engine's maximum performance under all conditions—while meeting the requirements of speed and temperature mentioned before—means extensive testing at all altitudes. And such a program would be prohibitive from the cost and time standpoints alone, if it weren't for the analog computer.

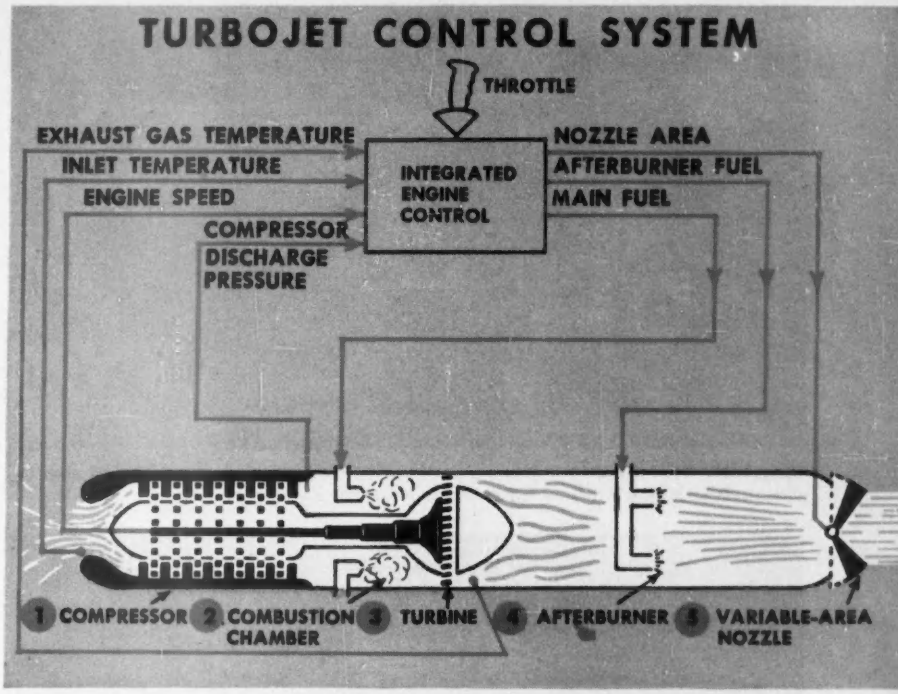
. . . And the Tool

An analog computer takes many forms—the slide rule is one. In a dynamic system, the analogy is between the computer's electric or mechanical circuit and the system under study. The latter might be electric, mechanical, or hydraulic in nature, and might also be represented by differential equations. For this reason you sometimes hear of an analog computer referred to as a "differential analyzer." (A simplified example of how such an analogy is set up appears on page 27.)

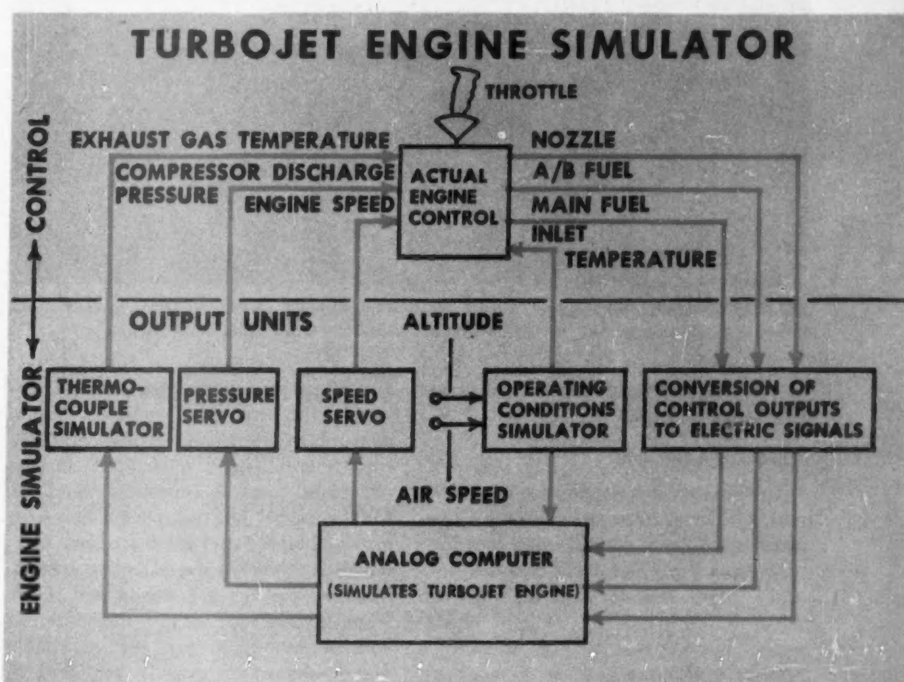
For control-system applications an analog computer is used strictly as a device in which the analogy of the engine and control is set up—or, it is used to simulate the engine alone while evaluating the actual control system. In the latter case, the control (illustration, right) has outputs of nozzle-actuator position and main- and afterburner-fuel flows. Since the computations are most conveniently made by electronic means, the control outputs are converted to electric signals. Similarly, outputs of the computer-simulated engine are converted into the proper type of signals.

An important portion of the analog is thus concerned with conversion of information into electric signals and back again. Physically, this portion may be larger than that duplicating the actual engine characteristics. But since conversion units add nothing to the actual analog, they should introduce no time delays or spurious effects. This requirement presents severe design problems.

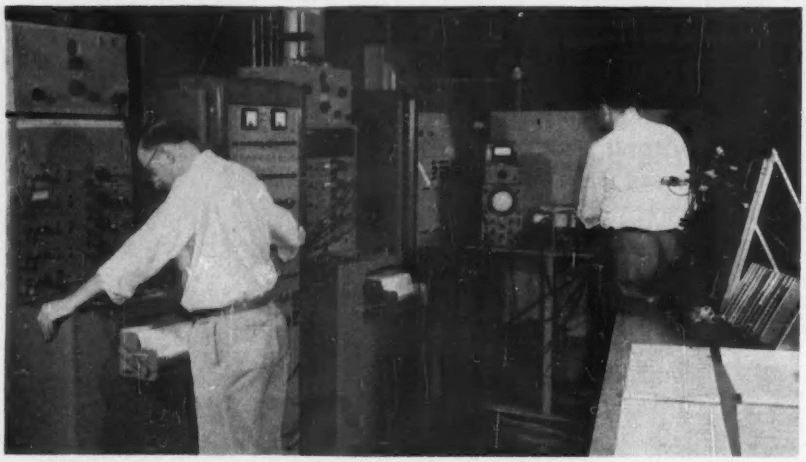
While the computer illustrated would no doubt be a complex, expensive machine, this isn't necessarily true of all analogs. For by fully appreciating the characteristics of the device under study, and by intelligently interpreting results, you can build and successfully operate inexpensive analog computers. Many simple dynamic processes, such as the flow of fuel through a system of pipes, can easily be represented by a resistance network. (For a more detailed



ACTUAL TURBOJET operates as air, sucked in and compressed at (1), enters combustion chambers (2) where it is sprayed with fuel and ignited. Swift-moving gases drive the turbine (3), powering the compressor. For added thrust, more fuel is sprayed into the gases, and the mixture is ignited as it passes through the afterburner (4), while proper operating pressures in latter are maintained by the variable-area nozzle (5).



COMPUTER-SIMULATED TURBOJET duplicates engine conditions at the various flight speeds and altitudes. But to do this, its input and output functions must be converted to the proper type of signals and back again. Because such conversion units may be physically larger than the actual turbojet-simulator and cannot introduce time delays or false effects, they play a highly important part in the over-all analog.



TRANSIENT RESPONSE of proposed control system for a jet engine is recorded in a matter of seconds by author Bradford (*left*) with an electronic analog computer.

MAGNETIC-AMPLIFIER control system is tested by author Gaines with JEAC (*center*) simulating turbojet engine. On the workbench are actual control-system components.

discussion on this subject, see the article on page 60.)

Control Philosophy

In the early development work on the control for a turbojet engine with an afterburner and variable-area nozzle—or on any other similarly complex control system—one of the first things you must determine is the control philosophy. Because they provide means for rapidly evaluating several alternatives, analog computers have proved of great value in this phase of development.

Evaluation of transient performance, or stability, of the control is of prime importance during these early studies. For it shows, among other things, the speed with which the proposed system responds to new power settings. Stability studies are usually made first for the individual control functions—such as the main-fuel control or variable-area nozzle control—and these are later combined to represent the complete system. Showing any adverse effects that result from interaction among the different control functions, the studies enable you to determine quickly how best to eliminate these effects. They also provide vital data for the specification of control components.

Often this initial work is done with incomplete performance data because the production model of the engine has not yet been built. However, an analog computer permits study of the control over a range of engine characteristics varying widely from their originally estimated values. At the same time, operation of the system is studied at various simulated altitudes to determine the effect of the changed characteristics.

All this computer-study work is done with standard electronic computers (photo, left) before any pieces of the proposed controls have been built.

Turbojet Analogy

After the engineering prototype of the control has been built, the analog computer still plays an important role: its use now is more as a simulator than strictly as a computer. Connecting to the prototype, it takes the place of the engine while the simulated system undergoes study.

At this stage of development some of the prototype's components may not behave exactly as they were represented in the initial computer study. And so the simulated system may exhibit different transient behavior. These differences may even be great enough to require slight alteration of the prototype. At this time additional and more accurate data may become available from the engine, requiring modification of the simulator, and in turn of the prototype.

The use of an analog computer as an engine simulator was considered essential to development of the integrated electric control for the J47 engine. So much so, in fact, that a special one was constructed for the job. The Jet Engine Analog Computer—JEAC, as it is called—simulates the J47 engine under all important conditions of speed and altitude. Providing a constantly available means of testing new ideas, it has proved itself an invaluable aid throughout development. By continual improvement of engine representation on the simulator, excellent correlation has been obtained between actual engine tests and simulator results. And because of such checks, the respect for simulator results has grown to the point where engine testing of control modifications becomes a matter of routine. On more than one occasion the JEAC (photo, left) has predicted control difficulties in advance of field tests.

Still, there's no substitute for the actual engine testing. Each series of engines has peculiarities that don't seem predictable; thus, as much actual testing of the control as possible is done.

Money Saver

During engine tests, and particularly during flight tests—where cost of one hour of test time approaches the cost of a computer—analog computers are worth their weight in gold. They enable you to predict the change in performance expected of a given control-system modification, and to readily evaluate many such modifications before recommending them for testing on the engine.

For example, considerable use was made of the National Advisory Committee for Aeronautics (NACA) wind tunnel at Cleveland while the control was being tested on J47 engines. To speed and guide this work, an electronic analog computer was made available to engineers conducting the tests.

Even after the J47 control system was put into production, the JEAC continued to be a valuable piece of equipment. Many times it was used to check out modifications found necessary as a result of field tests.

To illustrate, a report came in one Saturday morning describing the difficulty engineers had in starting the turbojet's afterburner. That weekend, simulator tests were made using the JEAC, and by Monday morning the necessary circuit changes were ready for field testing.

Another example of the well-proved usefulness of the JEAC as an engine simulator is the development of a magnetic-amplifier engine control. This control was completely developed in the laboratory using the JEAC. When it was tested on an actual engine, satisfactory operation was obtained with no adjustments of the laboratory settings.

These are but two examples—and there are many more—of how a computer costing in the order of $20,000 has saved many times that amount in engine-testing expense.

Not a Cure-all

Analog computers have allowed testing and development of a turbojet control system even before the engine itself had completed the development stages. Where schedules were short, this was extremely important.

Even where it isn't necessary to develop the engine and control concurrently, the use of analog computers makes for better control systems. They augment the limited test time and relieve you of complete dependence on the test vehicle—often subject to breakdowns that can seriously hamper a development program.

HOW AN ANALOG COMPUTER SIMULATES A TURBOJET ENGINE . . .

A turbojet engine involves thermodynamic processes ideally represented by complex and lengthy equations. But since the control engineer isn't concerned with the intricacies of these processes—only with the end products of speed, temperatures, and pressures—he can look upon the engine as merely a black box exhibiting certain over-all characteristics.

In general he is concerned with repeatability and precision in the analog and not absolute accuracy. Thus, he can simplify the equations necessary to describe the engine's characteristics.

The simplified basic equation describing engine speed in terms of fuel flow over the important operating range is a first-order nonlinear differential equation—

$$J\frac{dN}{dt} = K[W_f - \Phi(N)]$$

where,

J is the engine-rotor inertia

N is engine speed

K is the acceleration constant of the engine

W_f is fuel flow

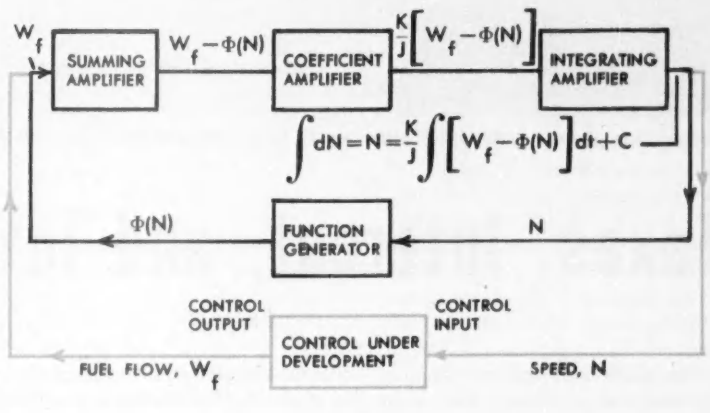
$\Phi(N)$ is steady-state fuel requirements of the engine as a function of speed.

This equation states that the difference between actual fuel flow and the steady-state fuel flow required to maintain a given speed is proportional to the engine's acceleration.

Integrating the equation yields—

$$\int dN = N = \frac{K}{J}\int [W_f - \Phi(N)]dt + \text{Constant of Integration}$$

The analog computer allows you to mechanize these equations as shown below



Solving the equation continuously, the above analog will—within limits of the original equation—exhibit the same characteristics as the engine. The blue line indicates how the control undergoing study would be connected.

Similar equations can be derived for the important controlled temperatures and pressures within the engine. For a more complete cycle, however, nozzle-area and afterburner-fuel-flow factors will enter into the equations. In actual practice when mechanizing both the engine and its control, 17th-order nonlinear differential equations have been encountered and solved.

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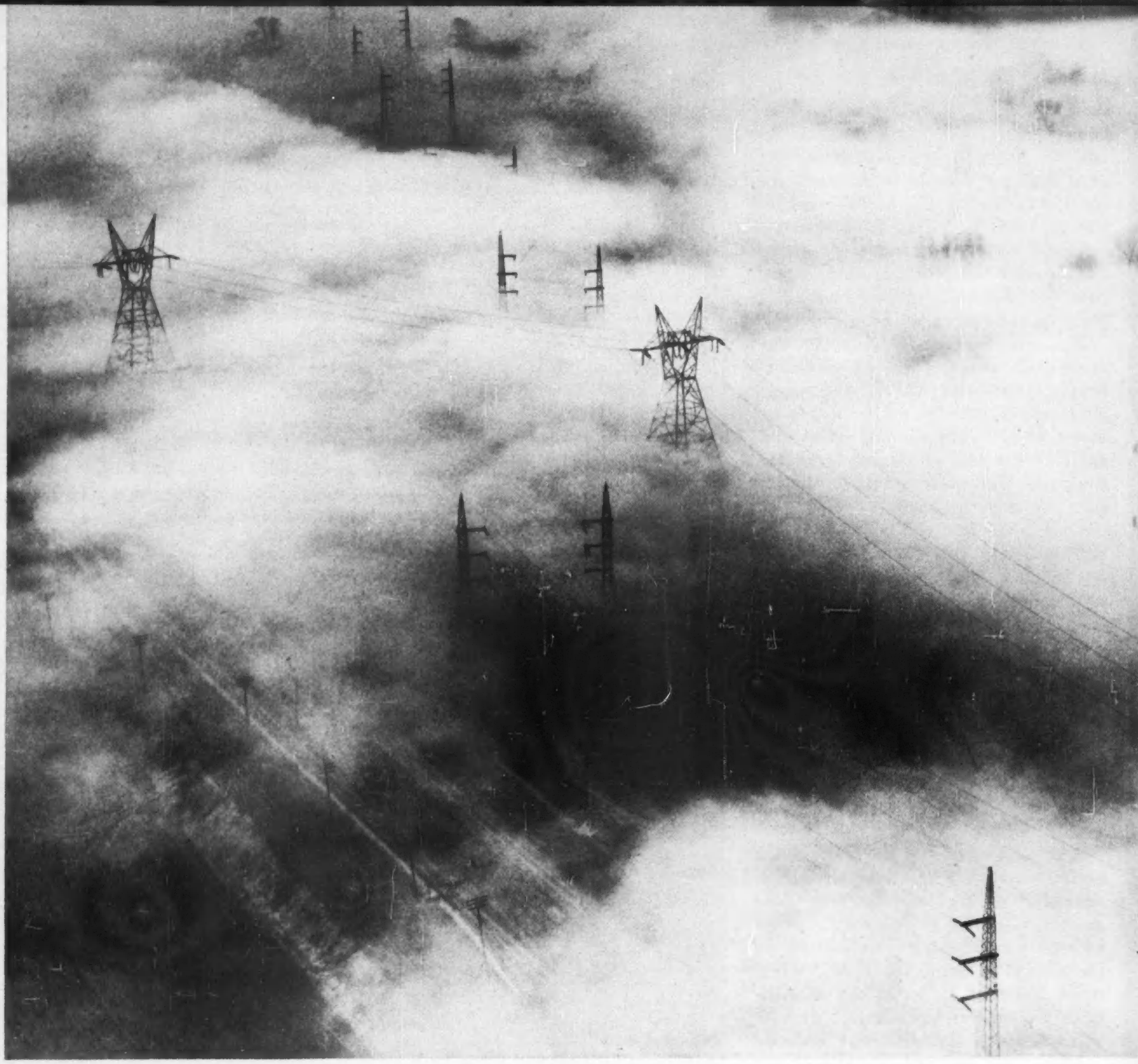


FOG-DRENCHED TRANSMISSION LINES AND TOWERS FORM INTERCONNECTIONS BETWEEN TWO MIDWEST UTILITIES. SUCH SYSTEMS ARE POSING

Taxes, Interest, and Interconnections

By EUGENE L. HOUGH

Electric utility systems in the past usually operated as closely knit units that took good care of their own areas, seldom exchanging kilowatts with neighboring utilities.

Today, interconnections among utilities to obtain economic and operating benefits have become more and more important.

As the chief engineer of one utility remarked recently, "For a great many years we had a nice tight little system that we operated and controlled directly. If we had any connections with neighboring power companies, it was for the purpose of providing power to them, because we were the most efficient producer of electric power in the territory and we were a preferred source for our smaller neighbors. But this nice peaceful existence was shattered by the necessity for reaching out to contact our neighbors."

He went on to say that in 1950 another utility constructed a steam-electric generating station near enough to one of its major load centers to make it desirable for them to interconnect. And they did it by a relatively simple rearrangement of the system. In 1952 an interconnection was completed to the west that provided a reliable supply to another large utility and permitted interchange of about 75,000 kw with still another power company.

Also in 1952, as an integral part of the job of supplying electric energy to

NEW POWER ENGINEERING PROBLEMS IN . . .

an important atomic energy installation, interconnections were completed with three other utilities to the south. "This whole job arose so quickly that we weren't able to provide all of the facilities before placing equipment in service. Just now we're finishing our communications and load-control systems," he concluded.

Early Interconnections

Tie-ins between the systems, as described, are one of the most common forms of interconnection today. Edison used a similar idea with his central-station system, the original electric utility designed for and operated with complete interconnection of all units, so that full advantage was taken of diversity in loads and other factors. This made it much more economical to provide service from a central station than from an independent or isolated plant. As long as direct current was the only method for supplying power, it never occurred to anyone that the system should be operated in any way other than fully interconnected.

The advent of the alternating-current system changed the picture. The wide range of voltages and the rash of frequencies proposed by the exponents of various systems practically precluded parallel operation to any degree. However, it was rapidly recognized that the parallel operation of units within any power plant was highly desirable, and efforts were made to accomplish this objective. From our vantage point today it's hard to realize the difficulties of some of our predecessors. But their problems *were* solved and success was achieved.

The next logical step in the development of interconnections was, of course, to interconnect the plants of a single system. But this development took much longer than is usually recognized, primarily because the electric utility business developed first as a series of small operations. Later these operations were grouped into larger ones; but in the zeal to build large groupings, the aggregations of systems became rather hodgepodge. And the interconnection between parts of a given system often became a rather expensive job and frequently was postponed for a good many years.

Because of this, connections between systems were slow, even though the electric utility business has long been noted for a high degree of co-operation among various companies.

Advantages

It's fairly well agreed that the reasons for the interconnecting of generating units within a plant, plants within a system, and between systems are all the same. Briefly, interconnecting provides an opportunity to take advantage of the diversity of loads between the various groups, permits a reduction in the reserve requirements, and does many of the other things that help to make electrical service more reliable and less expensive.

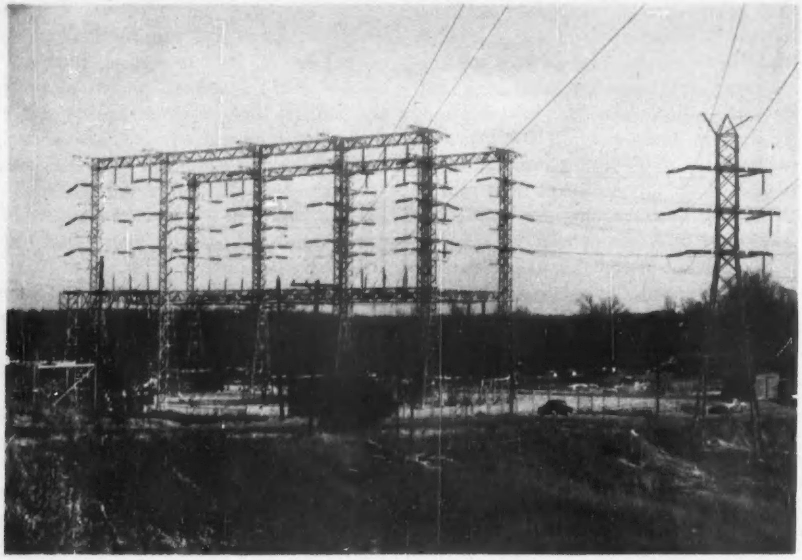
It's obvious that if two systems have loads with materially different characteristics, they will find it possible to reduce the total capacity needed to supply the load.

For example, in southern Illinois there's a large coal-mining load. The peak load of this operation normally occurs in the morning, and as a result the utility that supplies the territory must face a morning peak. Because our utility's load is chiefly in St. Louis and vicinity—thus predominantly a metropolitan load—its peak is the result of high lighting loads. Customarily, we will therefore have a peak in the afternoon. Interconnecting these systems not only improved the load factor on both but also reduced the total kilowatts of generating capacity required to supply these loads.

Electric power systems have an obligation to supply a service that is sufficiently reliable for the needs. Because electric machinery and equipment require overhauling and are subject to accidental damage, provision must be made for spare capacity. Also, system-planning engineers and load dispatchers are sometimes unable to predict loads accurately. True, they do a remarkably good job, but nonetheless they occasionally miss their estimates. To carry the load that is expected of it, a power company must have in reserve sufficient equipment to cover overhauling and accidental needs, as well as to make provision for errors in load estimates.

The percentage of reserve required is a function of a number of factors, including the size of power units used in relation to the size of the load. For example, let's assume that the load on the system is 100 kw. A 100-kw generator will carry this load as long as it doesn't exceed 100 kw, but it's obvious that this unit can fail. If we're to supply service during the failure of the unit, it will be necessary for us to put in another unit of the same capacity—100 kw. In this circumstance the reserve requirement is 100 percent. This is pretty hard to take, so it would promptly occur to anyone that if we had smaller machines the reserve required would be smaller. We would therefore attempt to carry the load with two 50-kw machines, and the provision for outage for one of them now would require a reserve of 50 percent. This is a considerable improvement; it can be continued until reserve requirements are probably determined by error in load estimate rather than by outage of generating units.

It's likely that interconnected systems will never be able to operate safely with reserve equipment much below six or seven percent of their peak loads. At present it is doubtful if there are many



OSAGE SUBSTATION of the Union Electric Company in Missouri—point of origin for transmission lines that connect with the Kansas City Power and Light Company.

interconnections that normally plan on having less than 10 to 15 percent of reserve capacity available to cover all contingencies.

If power systems are properly interconnected, an opportunity is afforded for economical use of generating capacity. In earlier days this took the form of more effective utilization of power from hydroelectric plants. Today the use of low-cost steam-produced energy often makes the use of interconnection attractive. With tie-ins provided for exchange of reserve and for emergency operations, the use of the facilities for economical loading of generating stations is a foregone conclusion. These facilities also permit the co-ordination of overhauling power system schedules and thereby allow carrying loads with smaller capacities than might otherwise be possible.

Power Plant Design

Another important saving that results from adequate tie-ins relates to the design of facilities, particularly power plants. It's a well-known fact that the cost-per-kilowatt of a power plant decreases as the size of the individual unit is increased. On the other hand, there's an upper limit to the size of a power-generating unit permissible on a given system—it's doubtful if the individual unit should ever be larger than 10 percent of the system peak load. If two adjacent systems are properly interconnected, the system becomes effectively larger and thus makes possible the use of a much larger generator in the power plant. This effects an important saving and is often a major reason for providing interconnection in the first place.

Interconnections sometimes provide further economy in construction by means of "staggered" installations; that is, System A puts in the capacity in 1953, and in 1954 System B puts it in. This permits a desirable leveling off in expenditures by the different power systems and results in over-all economy.

As interconnections are worked out, many other advantages come to light. For instance, a tie-in requires lines connecting the two systems. These lines frequently pass through territory that is too thin for development at the time. But experience has proved that a transmission line through a territory is an inducement to figure out ways to use the power so close at hand. The interconnection therefore frequently brings uses that were not originally contemplated. It's a mixed blessing to tap an interconnecting line—although it reduces the capacity of the line from end to end, it also gives two-way feed to the intervening load and provides a means of furnishing quick supply for new loads in unusual places. It's an item that's kept in mind when power companies route their lines.

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As Chief Engineer of Union Electric Company in St. Louis, Mr. Hough is responsible for system planning. Currently he is supervising an extensive expansion program for his company. He began his career with GE and recently returned as guest seminar speaker before members of the Power Systems Engineering Course in Schenectady.

The Major Problem

There's a tremendous amount of detailed information on the economics of interconnections. Much of this is concerned with how to divide the savings. Because interconnection are usually between power systems under different management, it's necessary to provide accurate breakdown of the savings so that the right group receives the right check. Apparently people are satisfied with their interconnections and make a profit from them—to the degree that the major problem is one of dividing the profits.

In the over-all picture of system tie-ins, certain economic considerations must be considered.

For example, college textbooks state that transmission lines should be sized according to Kelvin's Law. But operating men will tell you that Kelvin's Law, as detailed there, is totally inadequate to provide a proper selection of conductor for an interconnecting transmission line.

Stanley Stokes, vice president of the Union Electric Co. of Missouri, recently said:

"The economic size of conductor is one of those pretty calculations which engineers love to make, using Kelvin's Law, which says that when fixed and variable costs are equal you have just the one correct size. However, there are a few little things that may be a bit annoying. You . . . guess at the number of years before the line will be loaded; . . . the line is initially a tie-line for interchange with an unknown load factor guessed to be 20 percent, but later you guess it will become a regular transmission line at 50 percent load factor or perhaps better. Then you hesitate a moment over that little matter of evaluation of energy losses. This interchange is for reserve, and since it is low load factor, probably the power comes from high-cost old stations whose energy is high and capacity charge low. Later this whole thing will be reversed. You now wonder whether perhaps 'pool cost of power' might be the answer. You guess that it is.

"Now, having guessed at everything that goes into the equation, you work it out to the last circular mil. The answer comes out 500,000 CM but since nobody had in mind spending that amount of money anyway, you decide on 400,000 CM. Then the fellow at the other end of the line who is paying half of the cost will insist that 350,000 CM is all he can recommend. By this time you, yourself, are a bit concerned about the cost, since prices have gone up 10 percent since you made the preliminary estimate, so you agree with him that 350,000 CM is the economic size.

"The scientific way to do it is just to guess at the size of conductor to start with. Having done this, the only trouble is that a few years later it becomes evident to everyone that the correct size should have been 500,000 CM instead of the 350,000 CM you guessed. There is one conclusion to draw from this scientific discussion—that no one ever yet put in a conductor too large for sound economics. If he did, he must have built the line in the wrong place. But a funny thing about this is that we never learn."

The inference seems to be that after conductor size has been determined, someone not too familiar with all the details of Kelvin's Law should take a look at the over-all proposition and then increase the conductor about three sizes.

One other factor should be noted. If two systems propose an interconnection, and neither system is adequately and reliably serving its own load, it's not likely that an interconnection transmission line will improve things too much.

A SIMPLE PROBLEM DEMONSTRATING ECONOMIC FACTORS

Assume that the new facilities will require an investment of one-million dollars financed by bonds, preferred stock, and common stock. The arbitrary figures used here aren't unusual for this kind of setup.

Total investment		$1,000,000
Percent of investment		
Bonds (50%)	$500,000	
Preferred stock (20%)	200,000	
Common stock (30%)	300,000	
		1,000,000
Annual savings resulting from investment (assuming a 15% return on $1,000,000 investment)		150,000
Less cost factors		
Maintenance (3% of total investment)	$30,000	
Property taxes (1½% of total investment)	15,000	
Depreciation (3% of total investment)	30,000	
Bond interest (3% of $500,000)	15,000*	
		90,000
Net savings		60,000
Less 50% state and federal taxes		30,000
		30,000
Less 5% dividend on $200,000 preferred stock		10,000*
Money to be distributed as common stock dividends (This is a 6.7% return on the $300,000 investment.)		$20,000*

*A 6.7 percent return probably isn't enough to assure an adequate flow of common stock money to the utility; the actual money returned on the investment isn't $150,000 as would appear at first. Instead, it is the sum of the bond interest (3% of $500,000) plus the preferred and common stock dividends—$45,000, or 4½ percent.

Economic Factors

As mentioned before, there is plenty of information on how to split up the savings that you get from interconnections. Much of this material glibly points out that the annual costs of the investment should be balanced against items A, B, and C. Perhaps the authors of these papers know what they're talking about when they dismiss the annual costs on the proposed investment. But too often this has been one of the major stumbling blocks to clear thinking on the subject. The impact of the income tax on possible savings accruing from system installations is so substantial that it must be carefully considered. By referring to the problem in the Table you'll see how these various factors operate.

The figures definitely show that unless savings amount to substantially more than 15 percent, as assumed, the job will prove unprofitable. Perhaps you'll say that the rates used for bonds and preferred stock are out of line, but it's well to note that this past spring the federal government placed on the market a bond issue carrying an interest rate of 3¼ percent. The issue sold below par, a situation that indicates 3¼ percent isn't high enough to attract investors in long-term government securities.

Another example is the State of Maine and its Turnpike bonds that are exempt from federal tax. These bonds were issued bearing an interest rate of four percent at such a price as to return four percent to the investor. It's obvious that if bonds such as these issued by state governments require an interest rate as high as indicated, the electric utility companies are going to find it necessary to pay materially higher interest rates for bond money than they have in the past.

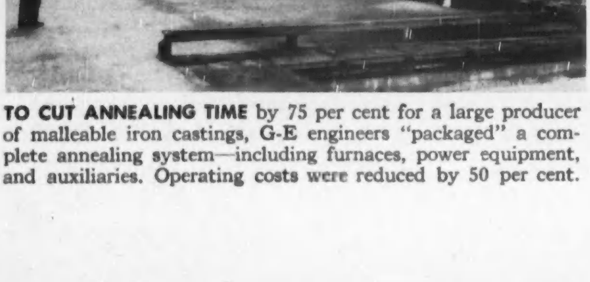
The point of all this is that no engineer worth his salt has the right to assume a return on the investment without adequate consideration of the rates for sale of securities and the impact of income taxes.

It's also necessary to point out that the costs of an interconnection must be covered completely in the estimate. This includes the cost of the transmission line, together with river crossings and other special features, and the cost of substations at both ends, plus any other special facilities required at near-by substations. In addition, it is also necessary to include the costs of providing the communication system, the telemetering system, the load control system, and the many other things that are required to make an interconnection work. Furthermore, line losses must be given proper consideration if a correct economic balance is to be drawn.

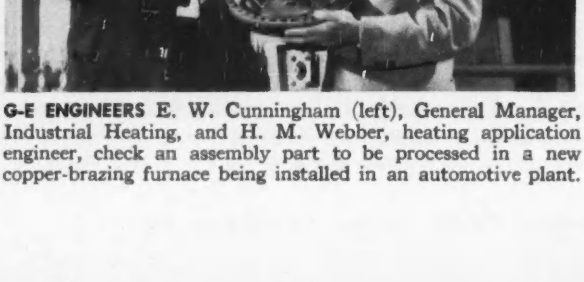
Interconnections serve a variety of functions profitably, and they certainly shouldn't be installed on too parsimonious a basis. How the profits are divided and how the transformer size is figured are important. But just as important are considering all interconnections in full light of all the economic facts. Ω

TO SPEED OUTPUT of steel strip, G-E engineers co-ordinated this huge G-E electric furnace with the drive system for a continuous cleaning and annealing tinplate line. This system approach helped operators get 30-tons-per-hour production.

Engineers "turn on the heat" to



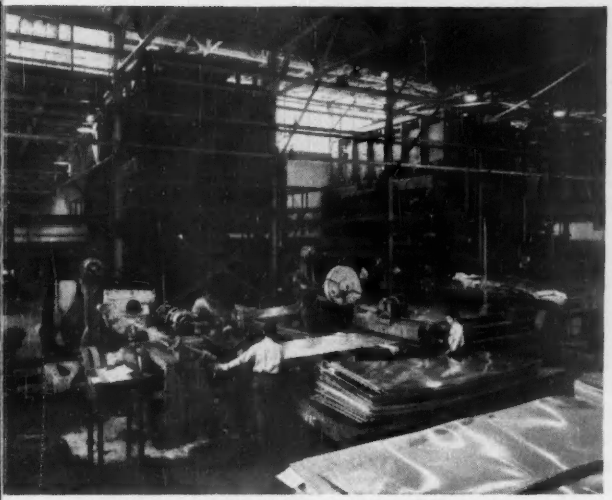
TO CUT ANNEALING TIME by 75 per cent for a large producer of malleable iron castings, G-E engineers "packaged" a complete annealing system—including furnaces, power equipment, and auxiliaries. Operating costs were reduced by 50 per cent.



G-E ENGINEERS E. W. Cunningham (left), General Manager, Industrial Heating, and H. M. Webber, heating application engineer, check an assembly part to be processed in a new copper-brazing furnace being installed in an automotive plant.

TO SAVE PROCESSING TIME for a manufacturer of textile-shrinking machinery, G-E engineers used Calrod* heaters for easier installation, more precise temperature control.

*Reg. trade-mark of General Electric Company



TO PROMOTE PRODUCT QUALITY, G-E engineers apply furnaces with protective atmosphere for better finishes.

TO IMPROVE WORKING CONDITIONS, G-E engineers concentrate heat required to treat these axle housings, reducing radiation.

shorten your processing cycles

Electric heat is another example of how G-E system engineering helps you cut production costs

Electric heat in many forms—from 5-story continuous furnaces to tiny heating devices—is one of the many tools used by General Electric application engineers to help you solve production problems. In almost every industry using annealing, galvanizing, enameling or brazing, G-E engineers have applied electric heat to eliminate processing steps, cut production costs.

G-E engineers have co-ordinated electric furnaces into steel-mill drive systems to anneal strip continuously—at 1000 feet per minute. In metal-working plants, they have applied induction heaters to improve product quality—often cutting processing costs up to 80 per cent. And they have helped hundreds of machinery manufacturers build a variety of heating devices into equipment for greater reliability, faster operation.

You can put this engineering skill to work for you by specifying "G.E." when you buy electrical systems. G-E application engineers will draw on this engineering leadership in working closely with you and your consultants. Contact your local G-E Apparatus Sales Office early in the planning stage. General Electric Co., Schenectady 5, N. Y.

672-11C

Engineering Leadership gives you better electrical systems from—

GENERAL ELECTRIC

American Institute of Chemical Engineers

By DR. JOHN H. PERRY

"The chemical engineer is a comparatively recent product of our industrial development; a couple of decades ago we find but little mention of him. When the American Institute of Chemical Engineers was organized, the conception of chemical engineering was rather hazy. What was actually realized was the fact that those engaged in industrial operations needed to supplement the results of the purely chemical research worker in order to adapt these results to use by the manufacturer. . . . The acceptance and adoption of chemical engineering in the family of applied science has been perhaps the most important factor in expediting the application of scientific development to the improvement of living conditions." This statement was made by Charles M. A. Stine in 1928.

The rapid growth of chemical industries since that time has accelerated the demand for chemical engineers and, as said by Arthur D. Little, ". . . the chemical engineer is the recognized connecting link between the laboratory and the plant, and one of his most important functions is that of converting laboratory findings into terms of plant operation on the commercial scale."

Early Organization

The American Institute of Chemical Engineers was organized in 1908 through the persistent efforts of Richard K. Meade—chemist, engineer, and founder of *The Chemical Engineer*. Preliminary and organizational meetings were held in 1907 and 1908 in New York City, Philadelphia, and Atlantic City. Many eminent chemists and engineers vigorously promoted these meetings and assisted in the AIChE organization until finally in December, 1908, the first Annual Meeting of the AIChE was held in Pittsburgh. Those who were prominent in the early history of the Institute included A. D. Little, W. H. Walker, S. P. Sadtler, H. P. Talbot, W. M. Booth, R. K. Meade, J. C. Olsen, E. G. Acheson, M. T. Bogert, J. A. Alexander, M. Toch, C. F. Chandler, H. Frasch, Thorn Smith, W. M. Grosvenor, C. F. McKenna, W. R. Whitney, M. C. Whitaker, to name only a few.

At the first Annual Meeting, Samuel P. Sadtler was elected the first AIChE president. For many years it has been the custom to elect a president and vice president each year. Usually the vice president has been a director for one or more terms. The organization structure of the AIChE is shown in the Table.

The secretary-executive secretary and treasurer are continuing positions, although AIChE membership annually nominates and elects these officers.

At the present time the AIChE headquarters is located at 120 East 41st Street, New York City.

Committees

Almost from its inception the AIChE recognized the need for Standing Committees. Some of the early ones that have functioned throughout the years include Admissions, Chemical engineering education, Finance, Publication, Chemical engineering catalog, Ethics, and Patents. In the late 1920's and early 30's standing committees were added under the name of Student chapters, Professional legislation, Public relations, Symbols and nomenclature, Constitution and bylaws, Local sections, Professional guidance, and Executive. Then in the middle 1940's came the need for still more committees—Program, Equipment testing procedures, Awards, Industrial waste disposal, Nuclear energy, and Publication board. The two most recent committees—Membership and Research—were established in 1950.

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Dr. Perry, Chairman of the AIChE History of the Institute Committee, is editor of the CHEMICAL ENGINEERS' HANDBOOK *and a member of the Development Department of the DuPont Company, Wilmington, Delaware.*

In addition to the standing committees there are many other council-appointed committees for special studies. Many of these are intracouncil committees.

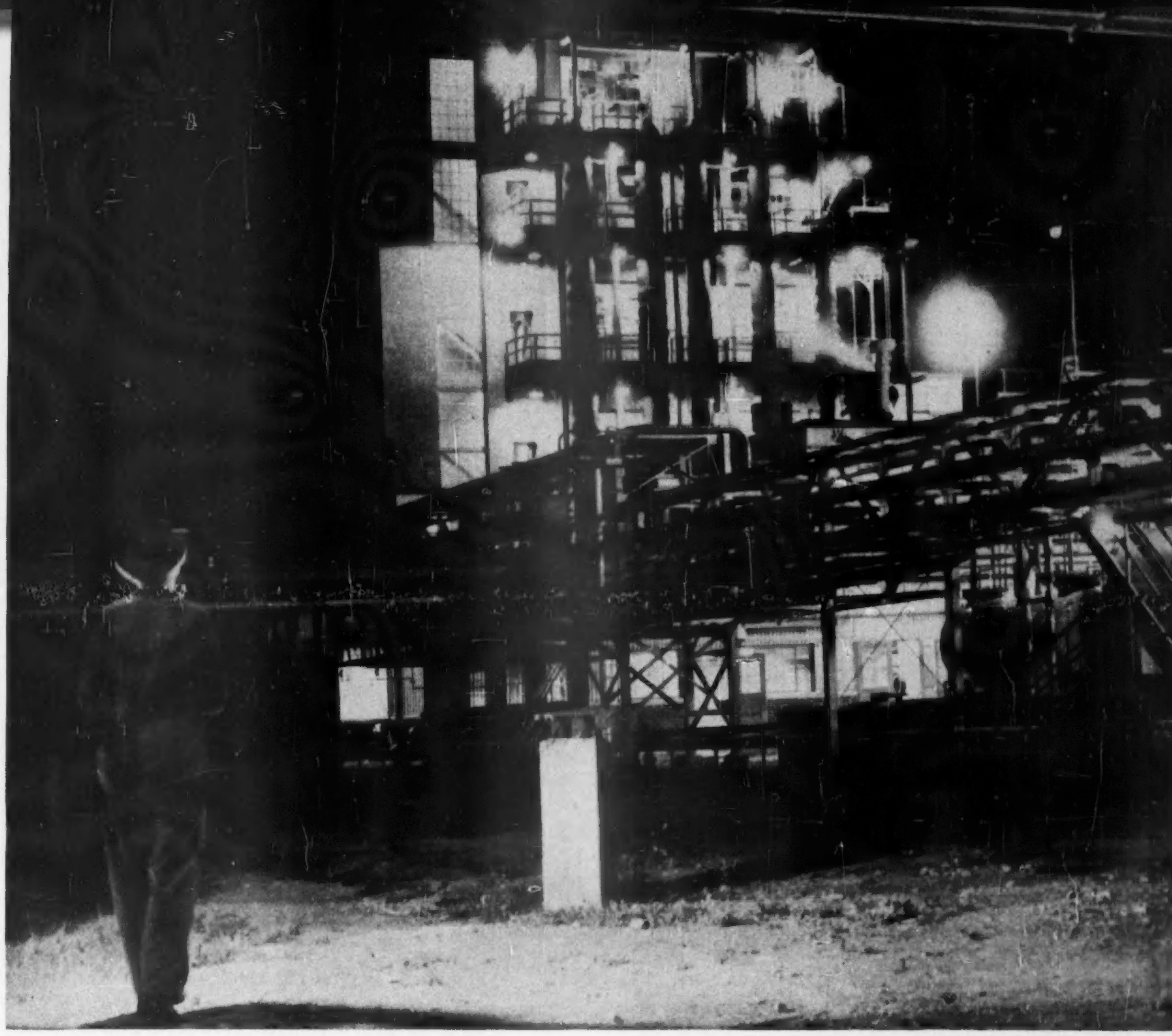
Besides the work of the standing committees there is Institute representation with other Societies. The AIChE works actively with such organizations as the Engineers' Council for Professional Development, American Documentation Institute, National Research Council, National Safety Council, American Society of Heating and Ventilating Engineers, American Society of Mechanical Engineers, American Society of Refrigerating Engineers, American Society for Engineering Education, American Standards Association, Engineers Joint Council, and others.

Meetings

The first Annual Meeting in 1908 set a precedent—one has been held each year since that time. Until 1945 there were two nationwide Institute meetings each year. The following year inaugurated the custom of three regional meetings, plus an annual meeting each year. The regional meetings are now known as national meetings. Last year in September the 100th meeting of the Institute was held at Chicago. These meetings have been held in most of the major cities of the United States; occasionally, meetings are held at resorts—such as Virginia Beach, French Lick, Swampscott, and White Sulphur Springs.

Each Local Section has its monthly meetings for the transaction of current business. At these meetings a talk is also given—usually by a nationally known chemical engineer. Frequently, several geographically adjacent Local Sections assemble for a meeting that sometimes sponsors symposia on chemical engineering and related subjects.

At international meetings the AIChE has entertained, and been entertained by, its brother institution, the Institution of Chemical Engineers of England: at Niagara Falls in 1928 and at London



CHEMICAL PLANT TYPICAL OF THOSE THROUGHOUT INDUSTRIAL AREAS, DEVELOPING AND PRODUCING MYRIAD NEW CHEMICAL PRODUCTS.

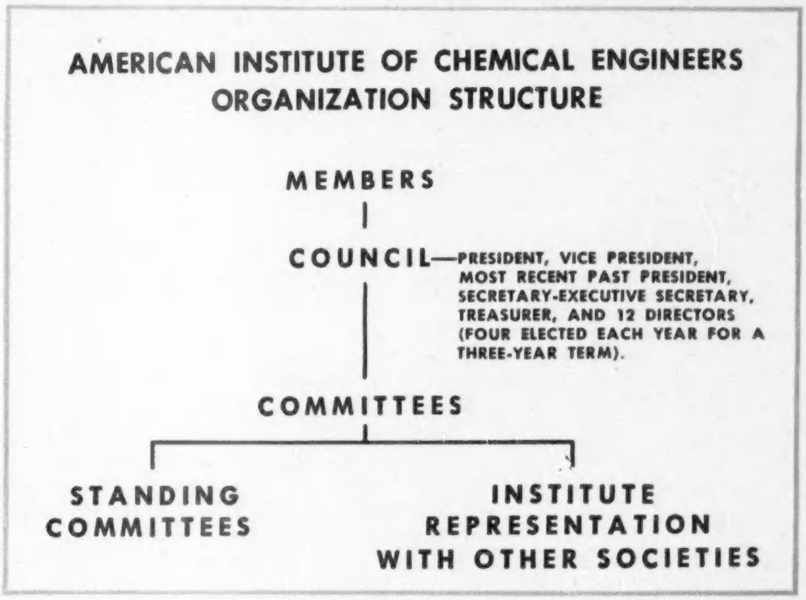
in 1925. Some meetings of the Institute have been held in Canada.

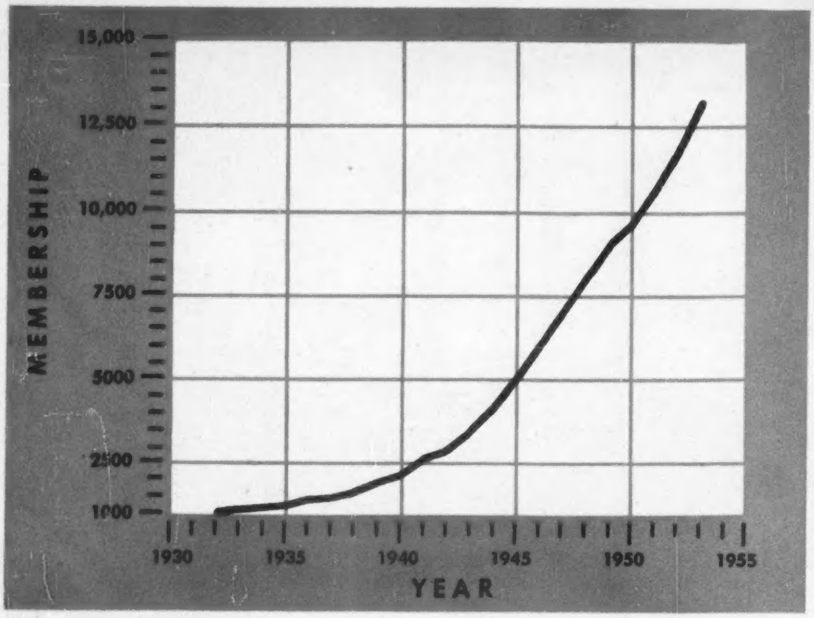
Meetings are held frequently by each Chapter at the 97 colleges and universities having Student Chapters.

Membership

Each of the grades of AIChE membership—Active, Associate, Junior, and Student—has well-defined requirements. In this way a high professional standard is maintained for its members and for the profession as a whole.

The membership of the AIChE, composed of the first three grades, has had a rapid growth since 1937, as indicated by the graph. Part of this growth rate is due to the relative youth of the Institute compared to the other major engineering organizations. But most of it is undoubtedly the result of the very rapid growth of the chemical process and chemical engineering industries in





MEMBERSHIP CURVE SHOWING RAPID GROWTH, ESPECIALLY DURING THE LAST DECADE.

the present Chemical Age. And this has called for greatly increasing numbers of chemical engineers and chemists.

Today the AIChE is made up of 14,890 members (including 1752 Student Members) in 45 Local Sections and 3000 Student Chapter members, or a total number of members and affiliated students of 17,890.

Sections and Chapters

As the AIChE grew, the need for localizing became apparent. It was recognized that a local Institute organization would increase the frequency of the members' professional, as well as social, contacts and would permit them to hear and to participate in the discussion of professional subjects more frequently than the two national meetings held each year. The first Local Section formed was at Chicago in 1925; others followed rapidly. There are now 45 such groups that meet monthly except during the summer. These meetings are the grass roots that nurture the national organization.

The AIChE has always been conscious of the need to educate and assist the student chemical engineer. In 1922 the first Student Chapter was established at the University of Michigan. The following year, Chapters were formed at the University of Wisconsin, University of Illinois, and Polytechnic Institute of Brooklyn. Today, Student Chapters are functioning in 97 universities and colleges.

Awards

Achievements of chemical engineers are recognized by annually conferring the following awards. . .

- William H. Walker Award—for excellence in contributions to the chemical engineering literature.
- Junior Member Award—for excellence in contributions to the publications of the AIChE by Junior Members.
- Professional Progress Award—for outstanding progress in chemical engineering and sponsored by the Celanese Corporation of America.
- Student Contest Problem Prize Award—for the best solution of a specific problem in chemical engineering.

Publications

One of the objectives of the formation of the AIChE as stated in 1908 by Dr. Sadtler, the Institute's first president, was "to publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity." This undertaking continued to be a major objective of the Institute.

A Publication Committee was formed in 1908 and the first of the annual volumes of the *Transactions of the American Institute of Chemical Engineers* was issued that year. In some of the succeeding years it has been necessary to publish two volumes. In 1947 a new Institute magazine, *Chemical Engineering Progress*, made its initial appearance. It includes the transactions, plus the news, and maintains a full-time staff.

Supplemental publications include two major items, the Symposium Series and the Monograph Series.

The AIChE *Student Chapter News* was established to serve as the official publication of the Committee on Student Chapters and is published four times yearly.

Accreditation

The AIChE began its Accrediting Committee activities in 1922. The Engineers' Council for Professional Development was founded in 1932 and its accrediting program was started soon thereafter. The Institute Committee reinspects the staff personnel, equipment, and curricula of the accredited schools as continually as is compatible with the personnel available and the time they can give to this work. In addition, this Committee devotes considerable time to investigating other institutions that want to be accredited. This work is one of the Institute's most important contributions to the profession of chemical engineering, to the institutions having chemical engineering departments, and to the industries served by the profession.

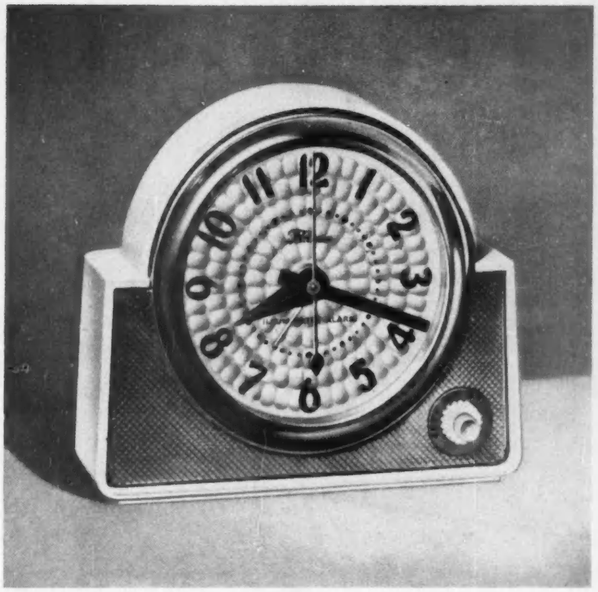
The first chemical engineering curriculum was accredited in 1925. This activity has grown until at the present time there are 77 accredited institutions.

Advancing the Profession

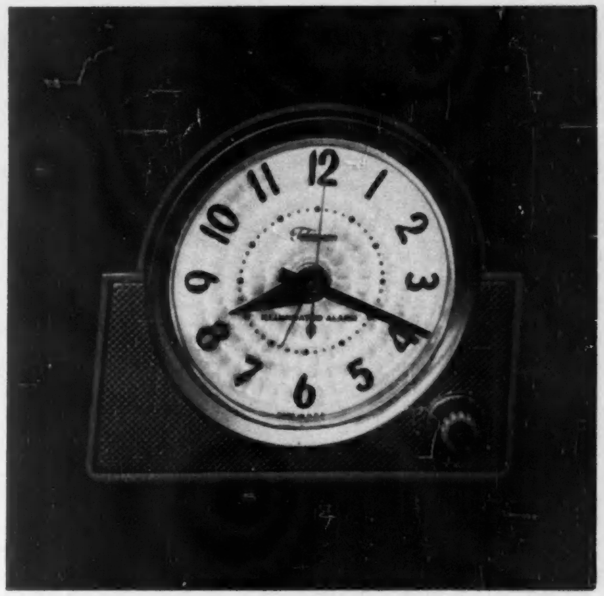
The contributions of the AIChE to the advancement of chemical engineering and the engineering profession as a whole, as well as to the general progress of civilization, have taken many forms. Among its major contributions are: 1) the improvement of chemical engineering curricula; 2) the development of personal and professional qualities of students and young graduate engineers; and 3) the contributions resulting from its publication programs.

In addition, the opportunities for all members to meet old and new friends and to talk with the leaders of the chemical engineering profession are important factors in the development of all chemical engineers. National and Local Section meetings and committee work offer many opportunities for maintaining and developing professional contacts.

The meetings also provide opportunities for presenting and discussing papers. And the Standards developed by the Institute are regarded as being especially useful. Ω



DAY Appearance of the new Telechron illuminated alarm clock in daytime. Knob at lower right adjusts brightness of the dial.



NIGHT Shadowless contrast in a darkened room between the clock's hands and dial is unique feature of illumination.

ILLUMINATED CLOCKS— NO MORE SQUINTING IN THE DARK

By C. B. MARBLE

Do you ever try to read a telephone book in a dimly lighted telephone booth? You have trouble because your eyes are "dark-adapted"—that is, their pupils are dilated to accept a maximum amount of light. In this condition the eyes' defects are greatly magnified; hence, their resolving power—or ability to distinguish fine detail—is reduced a good deal from normal. The older you are the more pronounced the effect.

When you view an illuminated clock in a darkened room, the effect is much the same. And for best visibility, it's important that the clock's dial be uniformly lighted to get maximum contrast between it and the hands. At the same time, illumination mustn't be so bright that it disturbs your sleep.

Materials Problem

Simple as it might seem, designing an illuminated clock to completely overcome these visual effects wasn't economically feasible until new materials and methods become available.

During development of the new General Electric and Telechron (photos, above) illuminated alarm clocks, we found: 1) the minimum acceptable brightness for a clock on a bedside table is five-thousandths of a footlambert—or the approximate brightness of radium-treated clock dials, and 2) a clock on a bureau across the room requires about 10 times this amount—or illumination several times brighter than moonlit objects.

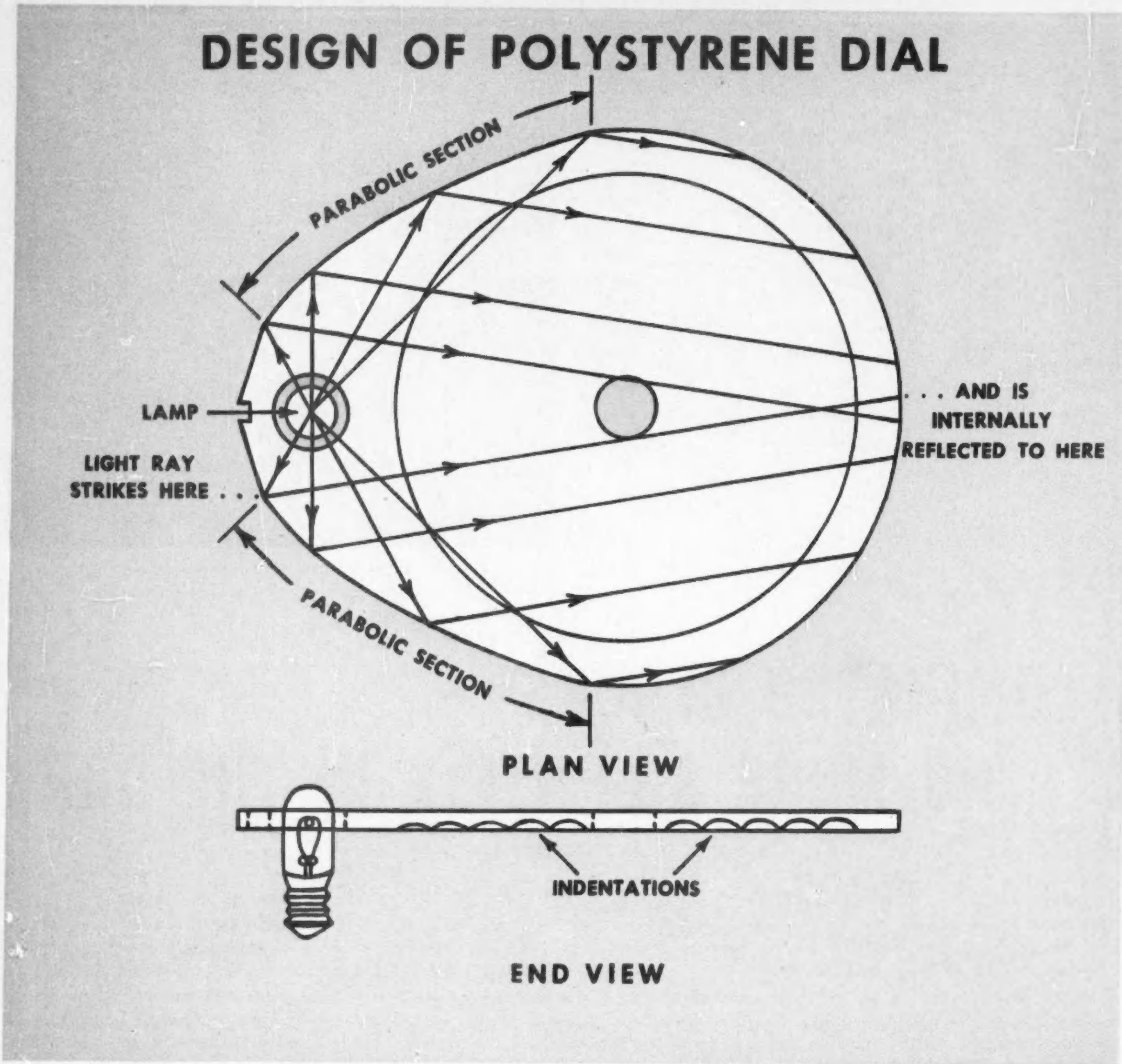
These requirements were satisfied with the use of a transparent polystyrene dial illuminated through the *edge* by a miniature tungsten-filament lamp. Based on the refraction-of-light principle, this method evenly illuminates the plastic dial which in turn silhouettes numerals and clock hands for maximum contrast. Brightness of the dial can be varied from a level high enough for counter displays or night-light use to any lesser value.

(From practical considerations, a brightness level of about one footlambert was provided so that the clock could be demonstrated by a clerk in a store with average lighting. This requirement, plus the knowledge that people vary considerably in brightness preference, made the use of variable illumination necessary.)

Bending Light

Key to design of edge-lighted dials is the material's *critical angle* of internal reflection. For example, you can cause light to travel within clear polystyrene, glass, or even water by simply controlling the angle at which internal light strikes the surface.

As Manager of Clock Engineering, Telechron Department, Ashland, Mass., Mr. Marble is responsible for engineering Telechron and General Electric clocks. With GE's Telechron for 19 years, he is a specialist in the performance and design of synchronous electric timing motors.



LIGHT RAYS internally reflected from two parabolic sections of the transparent dial fill in light beyond the clock's movement sleeves. The indentations—indented to an increasing depth—are staggered slightly so that all radial areas of the dial will receive light.

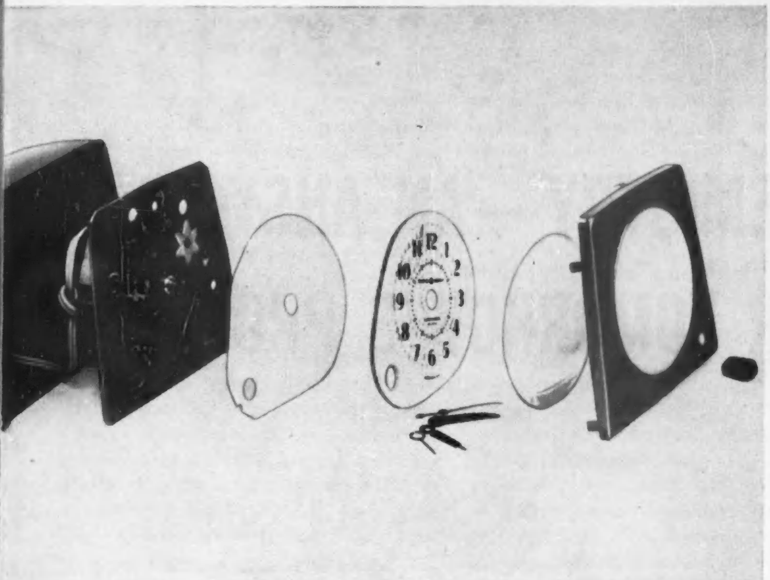
With polystyrene, the critical angle at which this occurs is 39 degrees to the perpendicular, or 51 degrees to the surface. Light within the polystyrene is therefore reflected internally if it approaches a polished surface at less than 51 degrees. This principle allowed us to arrange the edge contour of the clock dial so that light is directed around the movement sleeves in the dial's center. Such an arrangement was made by adding two parabolic sections (illustration, top portion), to the circular portions of the dial. These sections direct essentially parallel rays of light across the dial to "fill in" light beyond the movement sleeves.

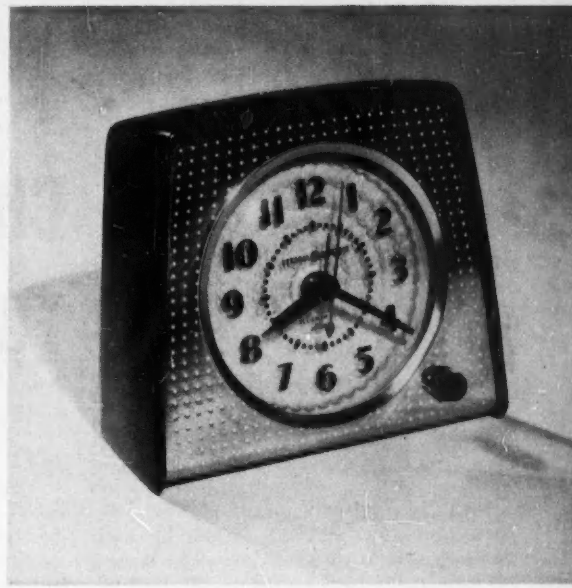
So effective is this method of directing light that many people, looking at the clock, think the lamp is located at the 1:30 position while it's actually at the 7:30 position.

Scattering Light

To illuminate the dial, you have to interrupt one or both of its polished surfaces. This interruption may be an indented pattern molded into the surface, or it may be a pattern printed on the surface. Either way, you obtain best illumination when the pattern does not cover the entire surface; otherwise, most of the light illuminates that part of the dial nearest the lamp, and the area farthest from the lamp will not be as brightly lighted. Obviously, for even lighting, design of the pattern is critical.

Best results for our design were obtained by molding a series of small spherically shaped indentions into the back surface of the dial. These scatter and direct light forward. Indented to an increasing amount, the pattern (illustration, lower portion) has a minimum





CREAM-COLORED REFLECTOR, THIRD FROM LEFT, PROVIDES A BRIGHT BACKGROUND FOR DIAL OF THE GENERAL ELECTRIC ILLUMINATED CLOCK.

depth at the lamp and a maximum depth opposite the lamp.

By molding a slightly rough surface on the spherically shaped indentations, light rays are scattered forward from the dial in all directions to provide uniform brightness from all angles of view. In addition, the spherical pattern is so arranged that each impression is staggered slightly from those in the adjacent circle. Otherwise, unlighted radial areas similar to shadows would appear on the dial. (These could be confused with silhouettes of the clock hands and make the clock difficult to read at night.)

Because the spherical indentations also direct some light toward the back of the dial, we've used a cream-colored reflector (photos, above) to provide a bright background. The reflector also provides the polystyrene dial with its daylight color. Numerals are heat-stamped on the dial's front surface for sharp contrast.

Light Source

The use of 110-volt lamps wasn't feasible because of the temperature rise involved. For a clock shouldn't feel unusually warm to the user, nor should it be so warm that it is detrimental to the life of the clock motor. The illumination feature is therefore limited to a maximum of 0.65 watts.

A standard miniature lamp, similar to a flashlight lamp, is used for the light source. It has a 2½-volt rating and is supplied with power by a transformer winding added to the clock motor's field coil. To extend the life of the lamp we've reduced the voltage supply from its 2½-volt rating to a maximum of 1.6 volts. This way, it should operate continuously for 10 or 15 years, because lamp life is in approximate inverse proportion to the 13th power of lamp voltage.

The dial is designed so efficiently that even the reduced lamp voltage provides more than adequate light for clock illumination. Also, because of the low voltage employed, inexpensive wiring is safely utilized.

So that a user can easily vary the level of illumination, we developed a miniature form of a carbon-pile rheostat arranged in series with the lamp. Actually, it's an assembly of three carbon washers. When the knob on front of the clock is rotated to increase dial brightness, these washers are squeezed together: electric resistance of the assembly is lowered and more current flows. Conversely, decreasing the pressure decreases the lamp's brightness. And when the pressure is fully removed from the carbon washers, the lamp is off. This simple design, as you can imagine, resulted in a more compact and lower-cost assembly than was otherwise obtainable.

The lamp itself is of such shape and size that only a portion of its length is contained between surfaces of the transparent dial. But light escaping from the base portion of the lamp could produce undesirable lighting of the plastic clock case. And to avoid this, we placed a small tube of black kraft paper over the lamp's back portion to act as a shield. Similarly, light escaping from the portion of the lamp extending in front of the dial is also shielded.

Customer Courting

A clock is a jewelry-type product, and so no feature can be successful without combining it with good appearance. To this end our appearance-design people have come up with two distinctly new and attractive styles, giving each clock a character of its own. At the same time, they've carefully located on the front of the clock in a conspicuous place the knob used to vary illumination. This was done partly for the user's convenience and partly to call attention to the fact that these aren't ordinary clocks. We feel that prospective customers may become sufficiently curious to inquire about them and encourage retail-sales personnel to tell the clock's story.

Although several types of illuminated clocks have been on the market for the past 25 years, the new illuminated clocks, with their evenly scattered light and adjustable brightness, are a big improvement over the old. For they provide the sleeper with an alarm clock equally suitable for use at his bedside or across the room—a clock he'll never have to squint at in the dark. Ω

CHEMISTRY—AN ANSWER FOR TOMORROW'S PROBLEMS

By DR. HARRY F. MILLER

What will be the role of chemistry in the world of tomorrow?

It would be easy to look at the many accomplishments that have been made in the past 25 years in the fields of plastics, fibers, medicinals, and insecticides and merely state that by 1975 we are going to have still more advances. But a straight-line projection is not often accurate; new products undreamed of at present will come out of research.

In 1925 the antibiotic industry—with such products as penicillin, streptomycin, and many others—wasn't even in existence. Yet last year antibiotics provided 40 percent of the income of leading drug firms.

So rather than try to predict new products yet to come, this article will discuss some basic economic problems and indicate how chemistry can help solve some of them.

The Basic Problem

From a broad view the fundamental problem in 1975 will be to feed, clothe, house, and transport 192-million people in this country—32-million more people than at present. If the job is to be done successfully, these people must possess good health and have leisure-time pursuits that make life worth living.

We have the means at hand to solve this problem, but it's necessary to say that we must show the rest of the world how to do it too. For by 1975 there will be at least 2½-billion people living in other parts of the world. If two-thirds of them are hungry and have a wretched standard of living then, as is now the situation, pressures will inevitably force us to divert production to items that will lower *our* standard of living.

Food is basic, and it's fortunate that the land is available to raise enough food for the 192-million people expected in 1975. As a matter of fact, right now America is raising food sufficient for 200-million people. But it should be noted that this country is exporting surplus food to other countries, both in normal channels of trade and in give-away propositions. Stopping such exports, while making it possible to easily feed the 192 million, would increase the pressures and the unrest in other parts of the world.

It seems to follow that the first problem for the chemist and the engineer is to show the rest of the world how to increase land productivity. This will undoubtedly take longer than the next 25 years, so we must assume that food exports will continue. And because it takes about two acres of land to feed each individual a proper diet, about 80-million more acres of land in this country will have to be reclaimed to feed the population increase of 32-million people.

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With GE for 17 years, Dr. Miller is Manager of the Advance and Development Engineering Services Dept. of the Company's Engineering Services Division. Before coming to Schenectady in 1952, he was Manager of the Transformer and Allied Products Laboratory, Pittsfield, Mass. In 1948 he received the Coffin Award for his work in capacitor paper research.

Food Sources

Some of this extra land can be obtained by irrigation and some by diverting to food production part of the 15-million acres now in cotton. And the equivalent of a good many of these needed 80-million acres will probably be obtained by increasing the yields of crops. Since 1918 there has been a 34 percent increase in the average yield per acre of such crops as corn and wheat.

It is estimated that at present there are about 100-million acres of worn-out land in this country. Bringing this land back to productivity is one of the major tasks that must be undertaken. The question may arise as to why we haven't felt a greater need for these 100-million acres. The answer, simply enough, is that the horse has been replaced by the tractor! At the turn of the century there were 20-million more horses than we now have, and each horse required food from land that would feed 4½ people. In other words, the disappearance of these 20-million horses has made available 180-million acres for food for human consumption so that in the balance we have gained more usable land in the past 50 years than we have lost through the wearing out of farms.

Bringing back these 100-million acres to productivity will require vast quantities of the nitrogen-, phosphorous-, and potash-type fertilizers. But apart from this, recent discoveries have shown that it is possible not only to alter the chemical composition of soil but also its physical composition — characteristics such as porosity, density, texture, and moisture retention. Small quantities of organic materials—the "soil conditioners" as they are called on the retail market—are capable of doing many of the things that only humus in the soil could formerly do.

In the next 25 years the need will also arise for other chemical additives needed for the soil to support the growth of the mold or the fungi now present in humus. There is conjecture that soil molds and bacteria play a great role in transferring nutrients from the soil to the roots of the growing plants. This is a chemical industry—not now in existence—that could be breath-taking in scope.

With the proper soil structure, plants may become so healthy that they will be much more resistant to insects, and the synthetic chemical insecticide industry could conceivably suffer. However, this is based on very indirect evidence. (One survey indicates that in 1975 we'll probably have to produce one-quarter-billion dollars worth of insecticides, or about four times the amount that is being produced now.)

Before leaving the subject of unproductive land, let's assume the worst: the rest of the world will not be able to raise the productivity of their land because of political inaction, religious beliefs, poor distribution of population in terms of land resources, and other reasons. If that is so, the population of the world could conceivably be greater than 2½ billion in 1975, because studies indicate that populations with an insufficient protein diet tend to be the most fertile. Those countries in which the population eats at least 60 grams of needed protein per day have the lowest birth rate; but countries such as Formosa and Malaya that average only 4.5 to 7 grams of complete protein per day have the highest birth rate in the world.

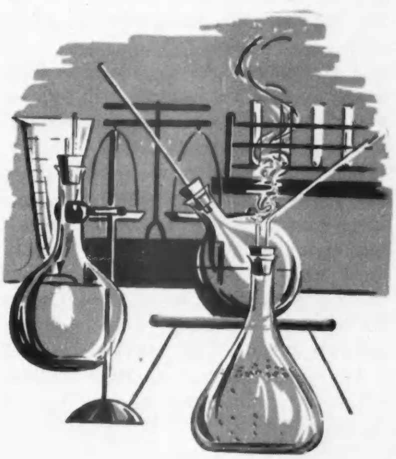
In regard to protein starvation it is interesting to note that no new food sources have been developed since neolithic times. The origins of such plants as potatoes, corn, wheat, and rice are lost in the mists of antiquity. And there have been no new major food animals developed that were not known in 3000 BC.

One way, then, to help feed the hungry masses of tomorrow would be to develop new food sources. During the recent war much work was done on the growth of torula yeast on molasses. Yeast yields a nucleoprotein with a good protein content. In the past few years tests have shown that the sugars obtained by the acid hydrolysis of waste wood products, or from the waste sulphite liquor from paper mills, are possible food sources for torula yeast.

Farms of Microscopic Plants

One suggestion along these lines would be to start raising large quantities of microscopic plants in the future, and to feed them on waste organic products and necessary minerals in vast tanks in food factories. A small plant of this nature is operating now on the island of Jamaica, but it's only producing a few tons of protein a day to aid in building the diet of the native population. Another plant is operating in Wisconsin, with a second to be built to furnish diet supplements to cattle.

Another possibility, providing that we use microscopic plants in food factories, is to develop a food source for them through photosynthesis. Studies are now going on to determine the proper use of Chlorella Algae as a food source for yeast. This is a large one-cell plant



that can be grown in tanks in the presence of sunlight, if ammonia, minerals, and carbon dioxide from the air are present. The yeast that is fed on this plant is rich in both fat and protein and could be a major source of food in the future.

This outlook may not be particularly palatable, but neither is a spoonful of bleached wheat flour. The skill of the cook or the baker will be a most useful intermediary.

Another suggestion has been made to combat protein deficiencies. To easily double the amount of protein that could be used by the body, small quantities of essential amino acids could be added to foods, such as cornmeal or whole wheat flour, that contain incomplete proteins.

There are 21 amino acids present in one protein or another that are needed by the human body to build tissue. Eight of these amino acids cannot be made by the human body and must be included in the diet. Four of the amino acids—methionine, lysine, tryptophane, and threonine—are often missing from vegetable products, but they're always found in the so-called complete proteins in meat, milk, and eggs. The essential point is that if these amino acids are not present in the food that is ingested into the body, then many of the other amino acids that are present in the protein that has been eaten are not able to be used by the body and are excreted.

One solution would be to set up synthetic organic factories to make the four essential amino acids. The cost would not be more than one cent per amino acid per person per day. For instance, 0.2 percent of lysine added to bread at a cost of perhaps a dollar a year per person would enable the body to use the incomplete protein in the bread more completely, to the extent that the over-all protein addition to the food supply for that person would be equivalent to 27 pounds of meat or 300 eggs in the course of a year. Only 15 tons of each amino acid per day would be sufficient to supplement the diet of 100-million people. It is a little discouraging to note that the only amino acid supplement being used today is synthetic methionine; it is being added to cattle feed so that they can use the protein in grain more effectively. Our cattle are being better fed than some of our children.

A more nutritious food supply should mean improved health for the 192-million people. But if it is not made available, the Stanford Economic Institute has predicted that the sale of medicinal chemicals—most of them organic—will amount to three billion dollars in 1975. This figure is six times the present sale of such chemical products.

Antibiotics

Because the entire field of antibiotics is so new, it is probable that many more will be found that are useful in combating disease. However, an application of antibiotics that is equally interesting is the addition of an agent such as terramycin to the food of young animals. Piglets can now be taken away from their mother immediately after birth and raised on milk supplemented with terramycin. The interesting thing about such a process is that the animals grow much faster, as described in John L. Davenport's article on antibiotics in the March 1952 REVIEW. Pigs that are fed terramycin often weigh 180 pounds, whereas others of the same age that are fed what was once considered a complete and adequate diet weigh only 150 pounds. Although this may be one way to get that needed food supply for the other 32-million people, it does raise some fundamental questions.

A Race of Giants?

Who will be the first doctor to put terramycin into infant's milk, and what is going to happen when he does? Are we going to have a young race of disease-free giants, or will such a process make humans susceptible to new virus infections that are not now on the scene? Also, are we going to be able to make more and more of these antibiotics synthetically? If past history repeats itself, by 1975 there will be large synthetic organic-chemical industries turning out antibiotics.

A specter that haunts many researchers is the possibility that there is already a chemical on some laboratory shelf that will cure cancer or other diseases. Sulfa, you may remember, was first synthesized in 1908, and DDT was on the shelf for 40 years before its usefulness was realized. And when a replacement for quinine was needed at the beginning of World War II, 14,000 possible compounds were systematically checked. At least 10 of them were found to show promise, and two of the compounds were so good that there will never be a quinine shortage to treat malaria in the future.

Dr. E. J. Crane, Editor of *Chemical Abstracts*, magazine, has estimated that approximately half-a-million compounds are known and that 30,000 new compounds are synthesized every year. But only a very few of these substances have ever been checked for their medicinal characteristics.

And Dr. Benjamin Miller, at the Harvard Medical School, has estimated that if eight-million dollars were spent yearly for 10 years, all known compounds could be checked as specifics against cancer. He missed the point somewhat in that many thousands of these compounds are no longer on the shelf and would have to be resynthesized at considerable expense. But he has suggested that if such a program were set up, the efficiency of such materials could also be checked against other diseases, against rodents and insects, against plant life, and also as plant-growth promoters. Many worthwhile

applications undoubtedly would be found, and these discoveries would be the basis of many new chemical industries.

A population with an adequate food supply, and in good health, will require a multitude of construction materials for shelter and transportation.

A Stanford Economic Institute survey has predicted that the business in synthetic plastics in 1975 will be at an eight-billion-dollar level, which is roughly eight times the present volume, and that the synthetic fiber industry will be at $4.7 billion, which is 4½ times the present volume. The synthetic rubber industry should grow to $650 million, which is 2¼ times the present level of production.

These three categories alone will probably amount to over half the dollar volume of the whole chemical industry, both organic and inorganic; and the Stanford predictions indicate that they will amount to two-thirds of the organic chemical industry, if fuels are excluded.

Future Synthetics

New plastics, new fibers, new rubbers are being developed every year. By 1975 economical resins, with improved properties, should be available for forming good laminates without the high-pressure multiplaten presses that are used today. Such laminates will find increasing uses in furniture and in the inside finish of houses.

The experience just now being accumulated on high-strength cold-setting adhesives will eventually accelerate the application of such materials in housing, because it will be possible to use them without nailing them in place.

Although synthetic fibers have somewhat replaced one fiber of animal origin—silk—they have not yet really made much of a dent in the cotton and wool business but undoubtedly will do so. During the next 25 years there will appear a new fiber that will be sufficiently hydrophilic to transmit the moisture from the body to the outside air in the same manner that cotton and wool do. Rayon does this, but it loses mechanical strength when moist; perhaps some day a rayon with excellent wet strength will be developed.

The people who raised the 7½-billion pounds of cotton last year in this country and converted it into cloth won't stand idly by. Synthetic resins and other organic chemical-treating agents to modify cotton and wool fibers will be developed so that cloth will hold a crease, will shed water, and won't shrink. Already on the horizon is the beginning of such an industry.

Laminates combine resin with some fibrous material, usually cellulose in the form of paper or thin sheets of wood. The laminate that is going into the house or factory of the future will, in many cases, contain glass fiber, either as cloth or monofilament. The glass-fiber industry should really be a major one about 20 years from now.

Still, at that time there is likely to be plenty of cellulose fiber around. The sources may be different, however. The easily pulped conifers, such as Douglas fir, are being depleted, but even today there is an industry in pulping hardwoods. Gumwood in the South is being extensively converted, and pulping is being done on Northern hardwoods. Agricultural wastes, such as wheat straw and sugar cane, can be pulped. The tropics have hardly been tapped as a source of cellulose, even though it is a region where it grows most lushly. Tropical woods are generally too dense to pulp, but there are more than 14-million acres of semiarid land in the bulge of Brazil covered with the caroa plant, a very good source of fiber.

"...by 1975 eight new chemical industries may be...part of our life."

The major raw material sources for most of 1975's products will be coal, oil, and gas. This country has used less than five percent of its coal, about six percent of its oil, and the gas has hardly been tapped. There are shale deposits in Colorado that contain more than six times as much oil as we have ever used, and the Athabaska tar sands in Canada contain possibly even more. The pattern of the future thus evolves: the chemical plant will sit beside an oil or gas well or a coal mine. The organic materials made by cracking and distillation serve as the starting point for most of the synthetic products of the future.

Mining the Sea

The earth has been gradually drying up since the last Ice Age. This has created vast deserts in Arabia, North Africa, Australia, and even in the Southwestern part of this country. The soil in all of these deserts is very rich and can be made to produce plentiful crops, if only the simple chemical H_2O is added. Many of these deserts are close to the sea, and one of their great technical problems that needs to be solved is how to recover potable water from the ocean. Many attempts have been made—usually involving solar energy—but none of them have been particularly economical or successful.

Last year we heard of an approach using synthetic, organic, permeable membranes, but the Department of Agriculture recently turned out a rather pessimistic report. It's possible that this membrane method is closer to the answer than anything to date; the possibility exists that by 1975 the researchers may have figured out some synthetic product that would transmit water at a high rate and hold back the salts.

Mining the sea offers many interesting possibilities. There are 320-million cubic miles of oceans, and each cubic mile contains about 166-million tons of dissolved salts. Much of this, of course, is unwanted. For instance, there is no need for the sodium chloride or the calcium sulphate. But the magnesium chloride and magnesium sulphate present do account for about 15.6 percent of the dissolved salts, and the potassium sulphate for about 2½ percent. Each cubic mile therefore contains about four-million tons of magnesium. By 1975 this metal, with its many useful properties, should be a common product in homes and factories, with a large chemical industry in existence, recovering magnesium from the sea.

What about all the other elements present in the sea? For instance, a cubic mile of sea water contains about 2.7-million troy ounces of gold worth about $95 million, and about 12-million troy ounces of silver worth about $8½ million. It's difficult to think of any good reason for going after such metals, since the only thing that happens to them is that they are put back in the ground at Fort Knox, and may sometime leach back into the sea.

How many of the other elements do we actually need? It's true that a ton of sea water contains a small quantity of nearly all the elements, but they're present in such small amounts that even now they are being detected with difficulty by very sensitive analytical methods.

It's quite possible that a new chemical industry of truly breath-taking scope could be built up if researchers could figure out how to use ion-exchange resins to capture these elements from the sea. True enough, elements such as magnesium or calcium wouldn't need to be claimed, but think of what the plants and animals in the sea do now in claiming the elements. Common seaweed at one time was the major source of iodine for the world. The sea cucumber contains an appreciable amount of vanadium in its structure. Lobsters have recovered both copper and cobalt from the ocean, and nickel is easily detectable in mollusks. These plants and animals are functioning in the same fashion as semipermeable membranes and ion-exchange resins; the only thing now is for the chemist to figure out how they do it.

Tomorrow's Chemical Industries

There's a possibility that by 1975 eight new chemical industries may be an integral part of our life . . .

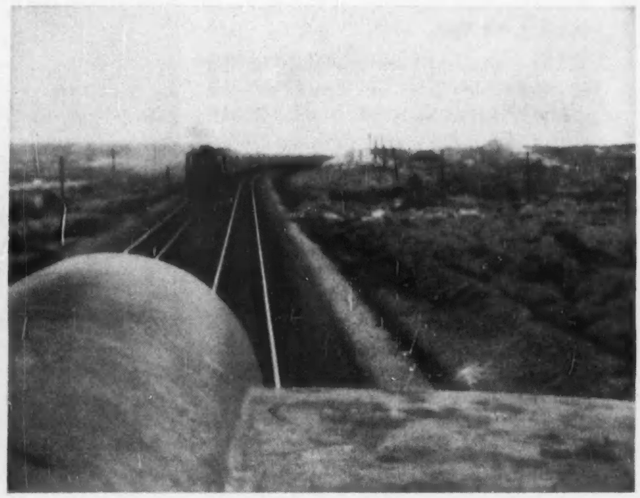
- Soil modification and improvement
- Protein and fat factories
- Synthetic amino acids
- New antibiotics by synthesis
- Other new synthetic medicinals
- New synthetic plastics and fibers
- Making sea water potable
- Mining the sea for metals

Political leadership of the world by our country—a leadership into a world worth living in—will be difficult unless some of these technical problems are solved. Ω

1 Castle Rock and bluffs tower over the town of Green River. Railroad Street in foreground; Nick's Cafe at far left.

2 Part of UP's "fleet" at Green River. *Los Angeles Limited* (left), *City of Los Angeles*, and *City of San Francisco*.

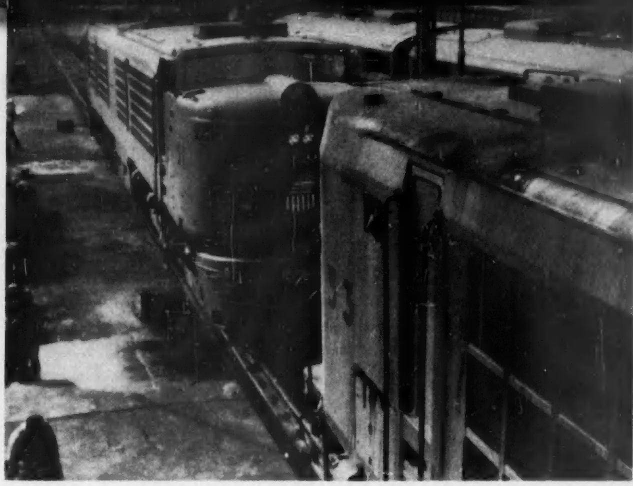
5 With a "clean stack," No. 52 leaves Green River on trial run. Picture taken from cupola of caboose behind locomotive.



6 Westbound *Los Angeles Limited* meets No. 52 east of Green River. Picture taken from engineman's side of cab.

9 "In the hole" west of the Continental Divide. Three "Streamliners" kept No. 52 on the siding for half an hour.

10 On the pit at Green River, No. 52 gets a routine check. An hour later it was working a heavy freight to Ogden.



3 General Electric gas-turbine-electric locomotives Nos. 51 and 53 on the pit at Green River. UP mainline at far right.

4 Turbine No. 53 on departure track at Green River heads into setting sun with 5000 tons for Ogden, 175 miles away.

7 "Divide of the Continent," 7104 feet. East-facing side of sign is more legible; gets less battering from weather.

8 No. 52 leaves Rawlins station for Green River with an ACB—*Advance Council Bluffs*—a "symbol" freight of 3888 tons.

The Trial of No. 52

***Review* STAFF REPORT**

In the lower left-hand corner of Wyoming, a few semiarid miles north of where the boundaries of Colorado and Utah come together, is the town of Green River. Tall bluffs overlook its many frame houses, and the lives of its 4000 people center around the Union Pacific Railroad.

Green River (the water actually is green from passing over oil-bearing shale) was a famous location on the Overland Trail, and it's getting a second—although somewhat less-spirited—chance at history by being the main terminal of runs for the first production units of gas-turbine-electric locomotives.

The new locomotives work heavy tonnage the 175 miles to Ogden, Utah, and back again. The 65-mile eastbound grade out of Ogden through the Wasatch Mountains, while not the most formidable in America, is one of the longest, and provides a brisk workout for motive power.

By the end of this year 10 production units will be in operation on the UP, and starting in January an order of 15 advanced models will begin leaving General Electric's Erie Works. When the UP has all 25 locomotives, it will have about $14 million invested in them.

There's no attempt by the Union Pacific to conceal the fact that the gas-turbine-electric locomotive has made a definite impression—not only with road crews but with management as well.

"We're always on the lookout for better locomotives, and the gas turbine fills the bill for certain service," a UP official said recently. "We're getting 80 percent availability, and for the first production models that's fair enough."

How the gas-turbine-electric locomotive will fit into the over-all motive-power picture of today's railroads is a subject that's discussed with a good deal of energy in some quarters of the trade. (A G-E spokesman has carefully stated that it wasn't developed to supersede the diesel-electric locomotive.) But everyone agrees that the outcome, whatever it may be, can result only in more efficient motive power for the railroads of tomorrow.

One bright noontime last summer I arrived at Green River on the Union Pacific's No. 1, the westbound *Los Angeles Limited*.

After checking into the Tomahawk Hotel, I met C. J. "Pat" Kline, an amiable young-looking engineer from General Electric's Omaha Office, who is liaison between the UP headquarters there and GE.

As we walked from the hotel to the UP's Back Shop on the other side of the mainline tracks, I learned that Kline's responsibilities weren't confined to Omaha. They also included Green River and at times extended—usually via the tenuous and abrasive medium of long-distance telephone—to the UP Shops in Los Angeles and GE in Erie and Schenectady.

He told me something about gas-turbine-electric locomotive operation on the Union Pacific. The units were all operating in the regular freight-locomotive pool, he said, and the dispatcher was showing them no grace in scheduling; they were working as strenuously as any diesel. The time it took a gas-turbine-electric locomotive to arrive on the pit after a run until it was serviced and ready to go again averaged about 45 minutes. Under pressure it had been done in 20 minutes.

The high horsepower-per-axle designed into the locomotive—it has the same horsepower as a three-unit diesel-electric, yet it has only two-thirds as much weight and two-thirds as many traction motors—has proved very satisfactory because it permits freight train operation at higher speeds.

Kline said that there were the usual nuisance items of any new development —reminiscent of the early days of steam locomotives and diesels. Irritating to dispatchers and operating crews because they occasionally tie up the motive power, they're usually small items, more or less readily fixed.

"An availability record of 80 percent is good, but we want it even better," Kline continued. "We're making improvements all the time. Just now there's some modification work being done on No. 52 that I think you'll be interested in. It should be ready in a day or so for a test run. We'll see that you get aboard."

A short time later we crossed the footbridge that spans the UP tracks and went to the Back Shop, a long, gloomy shed-like structure that has a spur track running inside it for two locomotives. We entered, and at the far end I could make out the yellow hulk of No. 52. Side panels were off, parts of the roof superstructure were scattered about, and the nose cab door was open.

After a look around, Kline took me into a large cluttered office where I met several of the G-E service representatives who are assigned to the gas-turbine-electric project. They're all young, aggressive, and confident. Five are stationed at Green River, and one at Ogden. Also, engineers from the Locomotive and Car Equipment Department at Erie, or the Gas Turbine Department in Schenectady, are sometimes on hand.

I also met Leonard P. Zeiler, the special representative from the staff of the Assistant General Superintendent of Motive Power of the UP who was assigned to the project. He has a boyish face and speaks evenly with a firm tone.

Kline turned me over to Newman MacDonald, a good-natured redhead who's in charge of G-E service activities at Green River.

I asked him more about No. 52, so we left the office and walked to one end of the Back Shop where the gas turbine for the locomotive was on a skid. It was small and brutish, and about the size of an MG sport car. It could, MacDonald said, and I found it difficult to believe, put out 4500 hp, with the possibility of considerably more if the conditions were right.

"Here's the story on the modifications," MacDonald said, pointing at some of the work that was being done. "In the first place, we've dropped in a new turbine wheel and it should give us more horsepower." The turbines are two-stage and operate at 1400 F.

Then we walked around to the other side of the unit and MacDonald pointed to the combustion chambers. "Here's an odd thing," he said. "A little while ago we noticed that the combustion chamber life of No. 52 was quite a bit longer than we had ever experienced before. We checked around and everything was in good working order until we found that the temperature gage on our main fuel pump was in error about 50 to 60 degrees. This meant that the oil was being fed into the combustion chambers at a somewhat higher temperature than was normal.

"But that was only half a blessing. I forgot to mention that previous to discovering the faulty temperature gage, our main fuel pumps weren't lasting as long as they normally do. So knowing these things we concluded that if we put a heat exchanger between the fuel pump and the combustion chambers, the increased temperatures might give us higher performance. That's what we're trying now.

"We're also doing some work on the control system, but I think you'd better meet the man who's in charge of that," MacDonald said.

Alongside No. 52 I met Russell M. Smith (his article, "Slip," is in the Sept. 1952 REVIEW), a young engineer with a quick grin and a crew haircut from GE's Locomotive and Car Equipment Department. He explained how the amplidyne control system for the four 1125-hp main generators operates, and about some of the changes he was making. The changes, again, were to

FANCY NAMES . . .

. . . for the gas-turbine-electric locomotive, undoubtedly fabricated in a moment of desperation for publicity purposes, probably sound romantic to outsiders. Fortunately, the road crews on the UP speak in more intelligent terms.

To an engineman or fireman, it's a "gas turbine," or merely, "a turbine," and very rarely a "gas-turbine-electric locomotive," or some other colorful name. (Around GE's Locomotive and Car Equipment Department in Erie there's a fine of 50 cents for every mention of the gas-turbine-electric locomotive that omits the word "electric.")

On the UP, the gas-turbine electrics are also referred to by their numbers —52, 54, and so on, as are steam locomotives. Diesels are called "Alcos," or "EMD's."

The townspeople of Green River look vague when you mention a gas-turbine-electric locomotive. To them they're just another source of noise and smell.

get still more horsepower from the locomotive.

Smith went back to his work, MacDonald and I watched some more of the operations, and then we left.

By that time it was late in the afternoon, so MacDonald drove me over to the hotel, and he returned to the Back Shop.

Checking in at the office the next morning I found that No. 52's turbine had been put in during the night. But there was still no definite word as to when it would be fired and sent on the trial run.

That afternoon I had time to observe firsthand some more details of gas-turbine-electric locomotive operation.

Firing, for instance, is an interesting procedure. The turbine is cranked to firing speed—the pitch goes higher and higher, reaches a peak, and then blasts forth with a lusty roar as the fuel is ignited in the combustion chambers.

Cranking the turbine (through one of the main generators acting as a motor) is a 250-hp diesel-driven generator located at the rear of the locomotive. With the turbine shut down, this auxiliary furnishes enough power for starting and moving the locomotive through the yards.

Close by, a gas-turbine-electric locomotive sounds somewhat like a giant jet airplane, or like a few hundred home oil burners going at once. The roar isn't as throaty as I had expected, but it's quite different from the throb of a diesel.

From a distance, a gas-turbine-electric locomotive sounds like a long freight train crossing a trestle. (That statement is not as muddled as it sounds. For in the early days of jet airplanes their noise was usually likened to that of a long freight train crossing a trestle.)

The locomotive's gas turbine is essentially a constant-speed device, which is fine for operating tonnage trains at high speeds; but it's a little bearish on fuel consumption when the locomotive is on a siding, in a yard, or running downhill. Cutting the turbine speed back to idling doesn't help too much; idling speed is only 1000 rpm less than the rated 6900 rpm.

Fuel consumption at full load is about twice that of a three-unit diesel electric, but as the fuel (Bunker C) costs only about one-half as much as diesel fuel, the fuel economy is about a standoff. (The UP owns more than 600 producing oil wells in the West, and in 1952 netted $33.6 million from them, compared to $35.6 million from their rail operations.)

On the 15 new locomotives, the auxiliary diesel engine will furnish power for dynamic braking on long downgrades when the turbine can be shut down, and should further help cut fuel consumption.

Another idea proposed to ease the heavy hand of high fuel consumption is a heat exchanger between the compressor and the combustion chambers of the gas turbine. Exhaust gas that is presently vented sky-high through the roof would be used to heat the air in the exchanger. "Theoretically, it sounds good," a G-E engineer said recently. "The only drawback is that at present a heat exchanger would be far too bulky."

Late that afternoon there was still no word as to when No. 52 would be ready for a test run, although MacDonald said a good guess would be that they would fire around midnight and be ready to put some tonnage behind it, "Maybe around 3 or 4 am."

As there was nothing further doing, I left. Jim Prendergast, a lanky, slow-talking engineer from Erie, promised to call me an hour before No. 52 was due on the pit.

I had supper, caught the early show at Green River's lone movie, walked around the town, and went to bed.

Shortly after sunrise the phone rang. My watch said 5 am. Prendergast was on the phone and told me that No. 52 was due at 6 o'clock. "Better get some breakfast and we'll see you over here in an hour. By the way," he continued, "we're not going to Ogden. We're scheduled for Rawlins; I'll explain later why the plans were changed."

I dressed, had breakfast at one of the all-night diners on Railroad Street that faces the UP mainline, and arrived at the pit a little before 6 o'clock. The sun was up, the sky was high, and the day was already beginning to warm up. There was no sign of No. 52.

I walked over to the Back Shop, and found No. 52 on the turntable headed for the track that led to the pit. The turbine had already been fired. No one was around, so I went over to the office and found Zeiler and the General Electric engineers who were going to make the trial run.

Prendergast explained that they decided to go the 130 miles to Rawlins instead of Ogden because eastbound they could get a train of heavier tonnage.

By 6:30, No. 52 was off the pit and on its way to the yards about a mile away. We coupled onto the train a few minutes later. Immediately behind the locomotive was a special caboose where service engineers could do their figuring and make their calculations. Because a locomotive can't accommodate many men, such facilities were necessary.

According to Zeiler, whom I passed on my way to the caboose, our train was an OVE (Oregon Valley Express)—mixed lumber and other freight—of 5000 tons.

I climbed into the cupola of the caboose and waited. A cupola has few of the attributes of a Vista-dome.

At 7:10 engineman Floyd Nickel checked the air brakes and three minutes later we departed.

After we left Green River, Smith came into the caboose wearing a sheepish grin and announced, "Well, I guess my job is over. All the fuses on one of the control devices just blew and the spares are the wrong size." Zeiler asked him about the size, and when Smith told him, he said that particular fuse happened to be standard on diesel-electric locomotives, and that he'd get some for Smith when they got to Rawlins.

Satisfied, Smith climbed up into the cupola opposite me. He had been on the job more than 24 hours and was beginning to look it.

A few miles east of Green River, while snaking through a cut, the gas turbine lost its thunder and began to unwind. Plumes of oily black smoke shot from the roof exhaust. Zeiler hurried forward. The train hadn't been moving fast and it soon slowed to a crawl. With a roar, the auxiliary diesel automatically cut in. The train stopped. Engineman Nickel "whistled out his flag" to protect the rear of the train, and Smith said, "Well, I'm not going up front. Enough guys are up there already to find out what the trouble is."

Moments later, the auxiliary diesel opened up, and I heard the low whine as the turbine began to get up speed. It caught, the smoke thinned out until the stack was "clean," and the heartening roar of the turbine reverberated through the narrow cut.

Nickel whistled in his flag, allowed him time to return to the rear caboose, gave two blasts on the air horn, and got under way. Zeiler soon came back to the caboose and told me about the trouble. The lubricating-oil pressure had fallen below a safe point, and this had automatically shut down the turbine. The fault was due to a new oil filter being tested in the system. The filters were taken out, cleaned, and the turbine was started without difficulty. Delay was a little less than 10 minutes. "Every time anyone goes past one of the filters," Zeiler said to a couple of the engineers who were near by, "give it a turn."

Throughout the trip to Rawlins, G-E engineers with clip boards under their arms and slide rules in their pockets came and went from the caboose to the locomotive. From them, in bits, I received a running account of some of the tests. So far, they reported, things were indeed favorable. They all had a general air of optimism.

At Bitter Creek, about 45 miles east of Green River, there was a train inspection and I took the opportunity to go forward to the locomotive cab. Nickel, the engineman, had few comments about the operation of the locomotive, although he felt that the noise level and riding qualities were about the same as those of a diesel-electric. I thought it rode a little better, but I did agree with him as far as the noise went.

The longest eastbound grade was the 12 miles leading to Creston and the Continental Divide—7104 feet. No. 52 settled back for the pull, and Prendergast started a series of readings. Instruments were on the floor at the rear of the cab, and more were located at various points down the passageways on both sides of the turbine. To get simultaneous readings at all points, Prendergast would flash the passageway lights from the cab, and the engineers reading the instruments would jot down the results.

During the climb to the Divide the speedometer read 18 and the throttle was at the 20th notch—the limit. The slip indicator flashed occasionally, but Nickel kept the sander in operation and there was no slowdown.

On the downgrade from Creston the block signal went red, and a workman with a flag was soon visible as we eased out of a gentle curve. Two torpedos exploded under the front trucks.

The train stopped and Nickel said to the brakeman, "See what the gandy wants." He clambered down and soon reappeared in the cab. "Nothing much. There's some track work ahead and he wants us to go slowly past the construction."

The rest of the trip was routine, as was the landscape—semiarid and desolate, and largely populated by sagebrush and antelope.

"This is the beginning of another Grand Canyon," a native of Green River had told me the evening before. He was referring to the high bluffs of a grayish buff color that rise immediately behind the town and all along the mainline tracks. The bluffs are made up of sedimentary deposits that range in thickness from that of a knife blade to many feet.

Shortly after noon, No. 52 entered the yards at Rawlins, the regular train crew left, and a yard crew took over. The locomotive and caboose were cut off the train and sent down the mainline where they were Y'ed.

We ate at a restaurant behind the station at Rawlins, and at 1:47 were on our way home.

Smith was furnished fuses that had been rustled from a near-by diesel-electric, so he went forward to install them.

In the caboose, Zeiler was looking over the details of our train. It was an ACB—*Advance Council Bluffs*—and was known to the trade as a "symbol" train. "The dispatcher wasn't fooling on this one," he said. "This is hot stuff and we'd better get through on time." The tonnage was 3888 and there were 88 cars.

The day was getting progressively warmer—moving into the 80's—and the caboose was getting progressively dirtier. From scattered reports I gathered that the turbine output was better than anticipated.

West of the Divide we were hung up on a siding for half an hour while three "Streamliners," as they are called on the UP, passed by. During that time I had an opportunity to talk to the engineman. He was an older man, and enthusiastic. "The turbines are doing a great job," he said. "We'll run the diesels right off the railroad. To give you an example, coming up to the Divide I did it four miles per hour better than I've ever done with a three-unit diesel."

At five o'clock, about 40 miles from Green River, the sky began to cloud over and there was a scattering of rain. The temperature dropped from 83 to 65 F.

Because of these conditions, Prendergast said, there would possibly be some increase in turbine output. With the lower outdoor temperatures, and the rain acting somewhat as water injection, the weight-flow of air through the compressor would be increased. (The technique of injecting water into the air inlet of a gas turbine isn't new; jet aircraft have used it for a number of years to get short bursts of power. You've probably also noticed that your automobile engine performs better on damp days. I later learned an interesting fact: Locomotive No. 57 had been shipped directly to the UP Shops in Los Angeles. There it had been converted to burn propane rather than Bunker C oil. Test results on regular runs between Los Angeles and Las Vegas were encouraging—the gas is clean and there's no ash problem. Water injection is also a possibility because the propane is carried in a tank car behind the locomotive, and the fuel tanks of the locomotive are filled with water for ballast. It might be possible to use this water for injection purposes when short periods of high power output are required.)

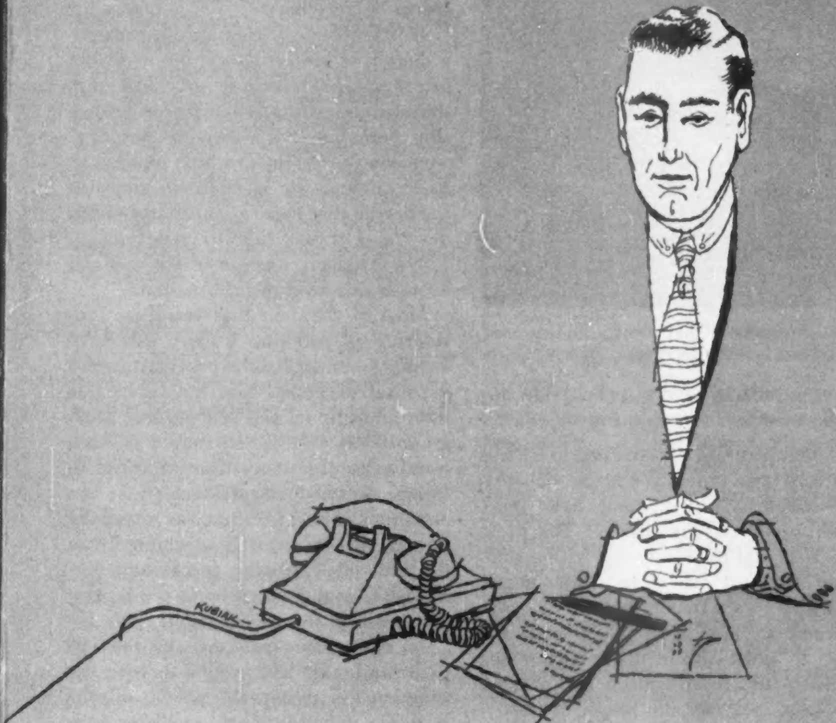
Prendergast later told me that the power output had been increased slightly because of the rain and the low temperature.

At 6:10 pm we hit the Green River yards, uncoupled at 6:17, and were on the pit at 6:30.

Later, with MacDonald in Nick's Cafe, a fluorescent-lighted chrome-tipped restaurant on Railroad Street, I had a chance to talk with some UP enginemen and firemen about how they liked the gas-turbine electrics.

As one expressed it to me, "They're faster on the flat than any diesel and I like them better because there's only one unit to handle instead of three.

"I remember one time out of Ogden, we followed a turbine. He had more cars and more tonnage than we did, and he walked right away from our three diesels. When they get all the bugs out, you won't be able to beat 'em." —PRH



Developing the Qualities of Leadership

By GEORGE C. HOUSTON

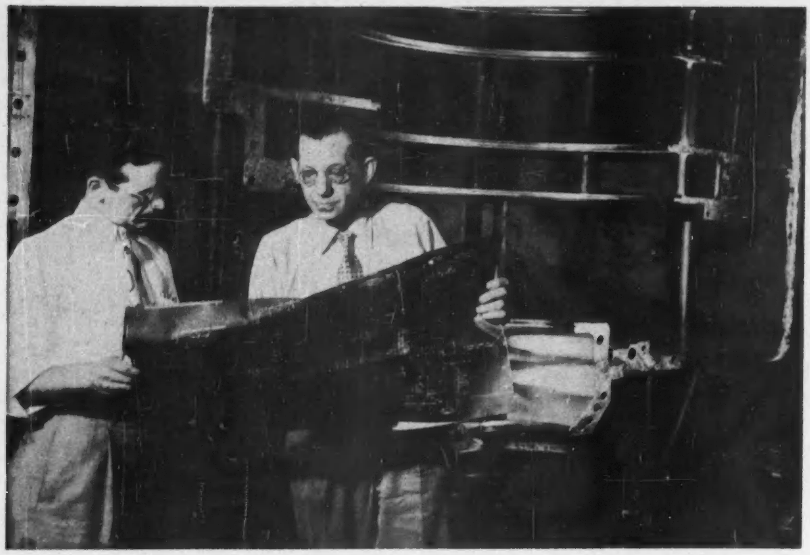
The increasing complexity of present-day business, together with the recognition of the responsibility of management toward its employees, share owners and customers, and to the community at large, calls for a higher degree of leadership ability than was recognized in the earlier stages of industrial development. It is not enough to have capable leadership in the top management group of a business. If your business is to be successful, it must have capable leadership at all levels of operation—from first-line supervision to the president of the company.

Top management develops, almost without exception, by growing from job to job. Providing adequate leadership in all functions and at all levels of the organization is one of management's most important jobs.

Under these circumstances it's essential that a progressive business organization have definite plans and procedures for selecting and developing men to fulfill the responsibilities of leadership, and to build a foundation for the future growth and development of the enterprise. Without such plans any business can be seriously handicapped.

Let's consider how we can approach this problem of developing effective leaders.

You have often heard the remark: "John is a natural leader." To be sure, there are certain basic qualities that an individual must have in order to fulfill leadership responsibility. Nevertheless, there is a vast difference between the type of leadership that might be effective in social or political organizations, or at the level of campus or fraternity life, and the exacting demands of leadership in the business situation. If you are to develop capable leaders in your busi-



ROTATING ASSIGNMENTS help provide the broad background that today's leaders need. Trainee is working directly with a supervisor in a typical factory operation.

ness operations, you must first seek out men who have the fundamental qualities that indicate leadership potential. Then you must develop these qualities to permit their most effective utilization. The demand for leadership ability today is too great, and the need too important, to expect that an adequate number of capable leaders will develop by themselves—or that you'll ever have a sufficient supply of the so-called natural leaders.

Traits of a Leader

Before discussing what can be done to develop leadership ability, let's first examine the fundamental qualities you should look for in the individual to whom you are willing to assign the responsibilities of leadership. In addition to the normal educational and work experience background requisite to a specific position, it is generally agreed that you look for the following 10 characteristics or *qualities* . . .

- Sound character and personal integrity
- A well-balanced personality
- Real interest in and understanding of people
- Well-developed ability to think clearly and logically
- Imagination and vision
- Common sense and good judgment
- Persuasiveness
- Initiative
- Clear-cut objectives or sense of purpose
- Abundant energy to provide the drive essential to achieving objectives.

You might well say that this looks like a pretty large order. We agree that it is. Nevertheless, many people have these qualities in varying degrees. The problem is to find the individual with a sufficient amount of these fundamental qualities—even though he may not have learned to use them effectively—and then to assist him in using or applying these qualities to acquire the abilities essential to leadership responsibility.

What are the primary *abilities* that you expect of men you are willing to place in positions of leadership? We might list them as . . .

- Willingness to accept responsibility.
- Ability to command the respect, co-operation, and confidence of others.
- Ability to get at the heart of a problem and come up with sound plans or decisions.
- Ability to sell ideas, plans, or decisions.
- Ability to organize men—and facilities—to translate plans and ideas into action.
- Ability to see ahead and understand the implications of decisions or actions.
- Ability to make decisions and to stand behind those decisions.
- Flexibility, or the ability to adjust to new trends or circumstances, and to honestly recognize and admit mistakes when necessary.

Selection Methods

As mentioned, before you can proceed with any plan for the development of leadership qualities and abilities, you must first do an intelligent job of selecting the proper men for such training. This is so, particularly if you expect results commensurate with the degree of responsibility for which these men are to be developed.

This problem of selection is primarily a matter of collecting all the available information concerning an individual that will indicate whether he has leadership potential. By leadership potential we mean the extent to which he has the basic qualities we have listed, and also the degree that these qualities have been developed or may need to be developed. There are many ways in which you can acquire this kind of information.

Most of the men that you'll be considering as potential leaders will have already been part of the organization for a period of years. You have available their educational and professional backgrounds, as well as the record of such training as they may have received in formal or informal programs; you can obtain additional information by talking to persons who are well acquainted with the individual. Rating sheets and performance-evaluation reports are of real assistance in the investigation.

In some cases you may be familiar with the family background or with the individual's activities outside of the business situation, such as clubs, civic organizations, and church activities. His college record may indicate leadership ability during his undergraduate years. Reports that he has written may indicate whether he has obtained all the essential facts, analyzed them clearly and logically, and presented sound conclusions or recommendations.

In addition to obtaining as broad a pattern of information as may be available, it is also possible to develop further information and to form conclusions based on well-conceived interviewing techniques. Finally, you have available a variety of reputable testing services through which you can administer a properly planned group of psychological and aptitude tests. This way you can gain further insight into the personality of the individual, his emotional balance and control, the quality of his thinking, and the degree to which he possesses other desired qualities. The results of such tests, properly interpreted, can further add to the available information on which a decision can be made.

"Leadership ability is not developed by attending lectures . . . ."

Development Program

Once you have done a thorough job of evaluating the available information and have decided that the individual meets your requirements, you can proceed with a definite plan for his development. Leadership ability is not developed by attending lectures or by reading, even though such activities may be helpful in stimulating thinking and developing a higher degree of understanding. We believe, without qualification, that the only sound way to acquire and develop these abilities is through the process of learning by doing. Consequently, any well-conceived leadership development program is built around these principles . . .

- Provide opportunities in the work situation to practice doing those things required of men in positions of leadership responsibility.
- Associate with proved leaders.
- Adequately evaluate performance and give sound guidance and counseling along the way.

Each of the individual's assignments in his work situation should be supervised by a man who has already proved his leadership ability, who is genuinely interested in developing others, and who is familiar with the objectives of the assignment in relation to the needs of the candidate. The assignment should be planned to provide experience which will not only increase the candidate's know-how, but which will also provide an opportunity to strengthen his weak points or further develop his specific abilities.

The number and variety of assignments will, of course, depend on the kinds of experience that the individual needs in relation to the immediate objective. For example, if you wish to provide experience in analyzing a specific business problem, he may be assigned to a special study or project, where he can be judged not only on the basis of his ability to come up with sound conclusions and recommendations, but also to effectively present and sell his ideas. His ability to think clearly, deal with others effectively, and to adjust himself to new situations can be appraised on the basis of his performance in conferences and staff meetings. He can gain experience in organizing men and facilities by assignment to projects or jobs involving the organization of a new unit or the reorganization of an existing unit. His ability to command the co-operation and respect of others can be observed in many ways, including the manner in which he handles those who report to him, as well as in his dealings with his associates at the same level or those in positions of higher authority.

These are but a few examples. There are many ways in which opportunities for experience can be provided. There is no stereotyped pattern in this field. The differences in background and needs of each individual require that his course of development and the planning of his assignments be handled on an individual basis, taking advantage of all available opportunities to provide the required types of experience.

Role of Supervisor

Finally, if you are to measure the results of such experience, it is essential that each assignment be of a nature that will permit measurement of performance. It is equally essential that the supervisor or individual in charge of the assignment follow the performance of the candidate closely and provide counsel and guidance as needed during the assignment. Finally the supervisor should prepare a complete and thorough evaluation report on the candidate's performance, to serve not only as a measure of his progress but also as a guide in planning future assignments. Such evaluation reports should, of course, be reviewed with the candidate so that at all times he is aware of his progress as well as his deficiencies.

Adequate guidance and counseling require not only genuine interest and a constructive attitude on the part of the counselor, but also a willingness on the part of the candidate to take an honest look at himself and to accept criticism in the spirit in which it is given—with the determination to profit from the experience. The objectives of counseling should always be to assist the candidate in understanding his difficulties and to help him see what he can do to correct them.

Emphasis should be placed on motivation or encouragement of the candidate to take the steps that are necessary to improve his own effectiveness. You do not develop leaders by holding their hands or by making their decisions for them. Consequently, look at counseling as helping the individual to help himself.

Additional Aids

In addition to adequate supervision, well-planned assignments, and effective counseling, there are many other things that can be done to assist in the development of leadership qualities. Those who need assistance in more effective oral or written presentation of ideas can be given additional instruction in report-writing, or they can be provided with opportunities for public speaking or conference leadership. Courses in business management may be available within the company or through colleges and universities. Conference series can be planned to provide an opportunity for studying specific case problems that will provide the members of the group with real experience in analyzing specific business situations, and in making decisions based on their analyses.

A Continuing Process

The process of developing leadership ability is a continuing one, as men advance from one level of responsibility to another. Consequently, the over-all plan of leadership development should be organized in relation to the needs of the business as a whole. Finally, it should be made a responsibility of the operating organization, so that each member of the business team will recognize and assume the responsibility of developing his own successors. By contributing to the development of others, he will at the same time be developing himself.

In the last analysis, this matter of developing leadership is more of a philosophy than a program. You must first understand the needs and objectives, establish a plan for achieving them, and then intelligently utilize sound and proved methods to gain the desired results. There is no more rewarding experience than the realization of the fruits of a well-conceived approach to leadership development. Ω

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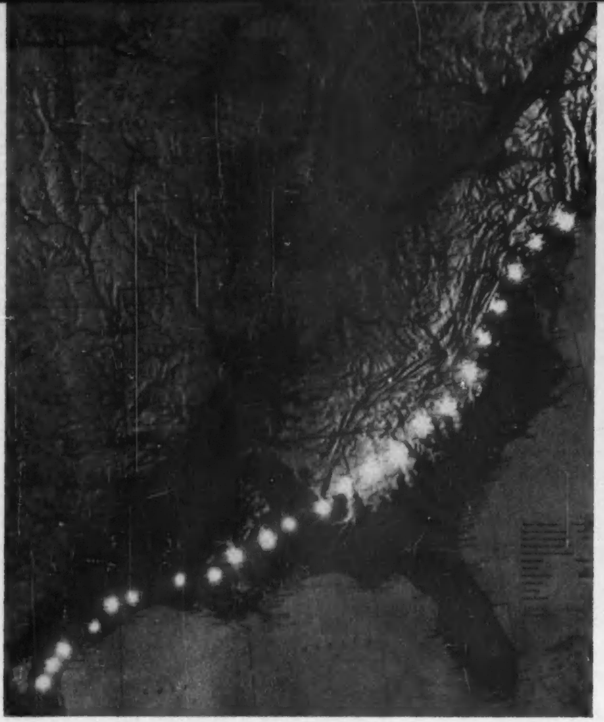


1840 MILES of 30-inch pipeline carry natural gas—500-million cubic feet of it daily—from oil fields in Texas and Louisiana northward to domestic and industrial customers along the route. Lights indicate pumping stations.

DISPATCHER in headquarters office at Houston—fifth light from bottom on map—supervises pumping operation over world's longest private system of microwave radio. Towers along route are spaced an average distance of 30 miles.

Microwave Radio's Longest Private System

By C. M. HEIDEN

More than 500-million cubic feet of natural gas are pumped each day from the oil fields of Texas and Louisiana to New York City's homes and industries. It journeys the 1840-mile distance—from the lower Rio Grande valley northward through the foothills of the Appalachians—in a 30-inch pipeline owned by the Transcontinental Pipe Line Corporation.

The gas is pushed along at pressures as high as 900 psia by 22 compressor stations. (Internal-combustion engines operating from natural gas drive the individual compressors; at some stations, steam turbines are used.) Connecting these with the chief dispatcher's office in Houston, Texas—and with each other—is the longest private system of microwave communications in existence.

Every hour compressor-station superintendents along the 1840-mile route call in data—such as gas pressures and temperatures, the number of units on the line, and weather reports—via a party-line telephone circuit. With this information the chief dispatcher at Houston then directs them to increase or decrease pumping so as to keep the gas moving at a desired rate. And on separate private circuits he transacts other business directly with offices in Corpus Christi, Baton Rouge, Atlanta, Culpepper, Va., and Newark, and with the metering station in Linden, NJ (photo sequence).

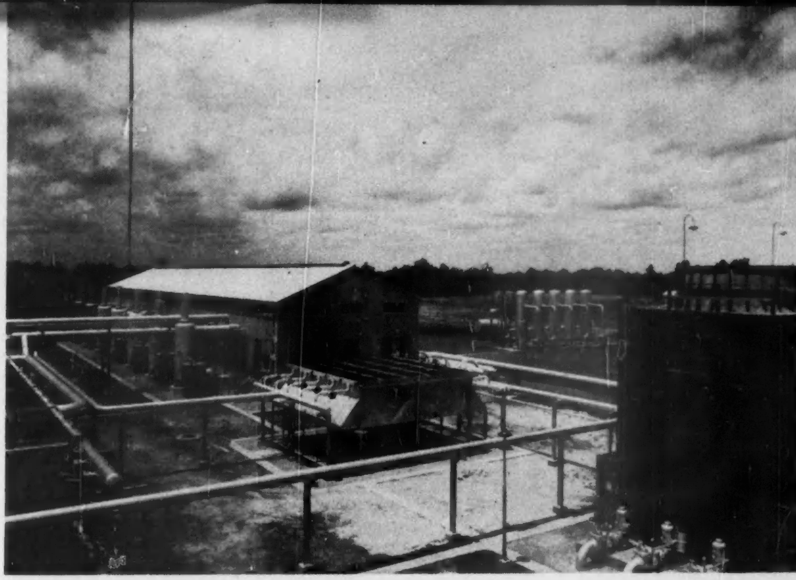
Why Microwave Radio?

You'll quickly recognize that successful operation of such a vast pipeline must depend on reliable communications over its entire length. And so it does. Of the four major media available for such an application today—privately owned open telephone lines, buried telephone cables, microwave radio, and leased telephone service—a microwave system was picked for the job because . . .

- It's highly reliable during emergencies caused by rain, ice, sleet, or windstorms.
- A 1000-mile six-channel microwave system costs only half as much as an equivalent system of open-wire telephone-pole lines.
- There would be no major right-of-way problems. Installation of additional channels along the system could easily be accomplished with minor expenditures.
- The system would provide a sufficient number of voice channels to meet all communication needs and would have infrequent service interruptions.

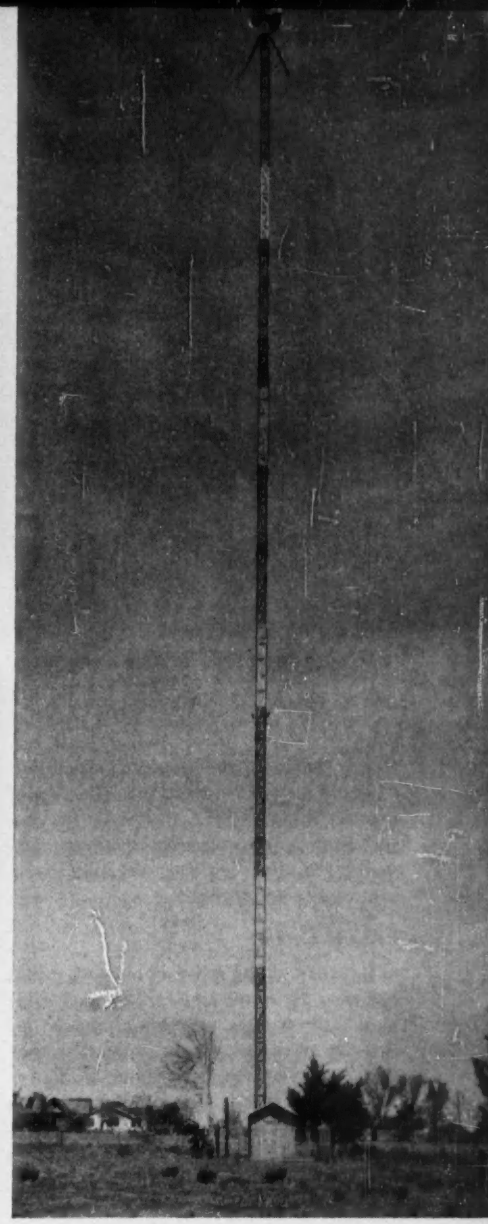
Microwaves, as their name implies, are extremely high-frequency radar-like radio beams. They travel in straight lines, and unlike a broadcast signal of much longer wave length, they don't follow the earth's curvature. And so each receiving and transmitting antenna must be within line-of-sight of one another.

The actual microwave antenna is only a few inches in length. It centers in front of a parabolic reflector (photo, page 54) that beams its energy to the



COMPRESSORS are located in stations spaced approximately 90 miles apart. The seven exhaust stacks at left connect to compressor-drive engines. Each station reports hourly to the chief dispatcher in the Houston office.

OPERATOR calls in gas temperatures and pressures from compressor station. By flipping switches on control unit, he can communicate independently with mobile radio trucks in field or tie them into microwave system's party line.



REPEATER stations amplify and pass on microwave signals between the compressor sites.

next station's antenna. When you employ different transmitting and receiving frequencies—as does Transcontinental's system—a single-antenna and parabolic-reflector assembly simultaneously transmits and receives signals.

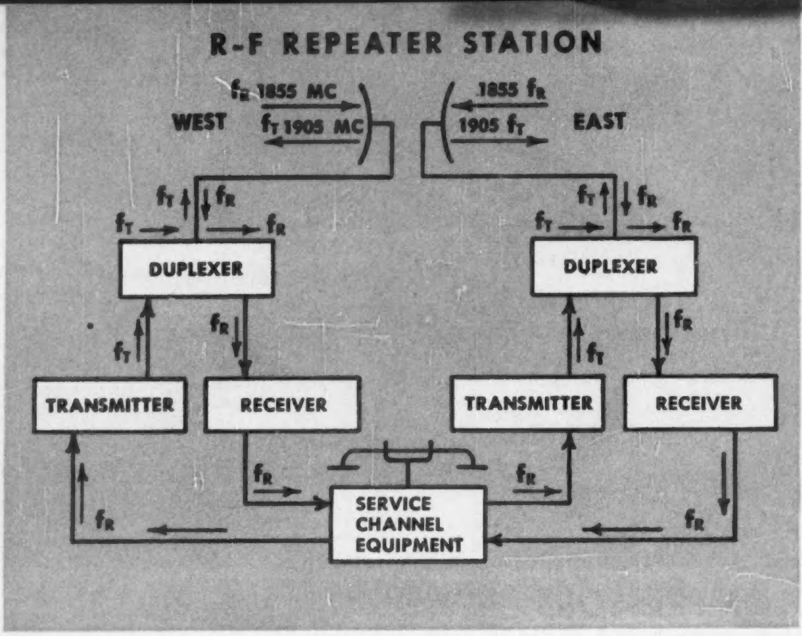
Party Lines

Let's look now at Transcontinental's communication system, built and installed by General Electric. The party-line circuits (illustration, page 55) feed all stations—compressor stations as well as district and business offices—along the 1840-mile route.

To contact compressor stations, the chief dispatcher uses the Dispatch Channel. This is the same one used by station superintendents to make their hourly reports. Because it's available at all communication points, the Dispatch Channel also provides communication between any two points along the system whether they are 10 or 1000 miles apart. Often it is used for conversations between successive compressor stations or for transacting business between a compressor station and its district office. Also available at all communication points is the Radio Channel, a second party line. This gives compressor stations at least two circuits to choose from.

Both party lines terminate in the Houston headquarters office. And when they are not being used for station-to-station conversations, they are used for traffic out of Houston to other points in the system. The "breaks" you see in the Dispatch and Radio Channels occur at terminal stations along the line. At each of these, the party lines terminate in a small control unit. There, the operator flips a switch to sectionalize a party line so that conversations can be carried on in his section without interference

TERMINUS of microwave relay atop building in Newark, NJ. Antenna is only a few inches long.



from others. By this means it's possible to hold six conversations simultaneously. When traffic demands it, the terminal operator breaks up these conversations by "cutting through" the sectionalizing switches.

Private Lines

Because of the great amount of traffic between Houston and the various division offices, six private channels go directly to these points. You'll note that the party-line circuits going to Baton Rouge, Atlanta, and Culpepper divisional offices are connected to the mainline circuit by "spur" microwave systems of lower frequency. These stations are located 12 to 18 miles from the nearest compressor station where the mainline circuit is available.

The spur microwave systems themselves have two channels. One connects with Houston via the private line, while the other connects to either of the party lines. Thus, an outlying division office can talk directly with headquarters over the private circuit, or to any compressor stations, or other division office on the party line.

At the two major terminals, Houston and Newark, the audio signal from each channel is connected to an office telephone switchboard. With this arrangement the switchboard operator can connect any of the local phone extensions to the microwave circuit. The switchboard connection also makes possible many other arrangements necessary for the pipeline's successful operation.

For example, the division superintendent at Baton Rouge may want to talk directly with the Atlanta office without monopolizing the party line throughout the system. In that case, the Houston operator will "patch" his private line to the Atlanta private line.

Radio on Wheels

A mobile VHF (very high frequency) radio system is essential to any pipeline if you are to keep interruptions in gas flow to a minimum. And in most applications mobile radio is standard equipment. It is one of the operator's most convenient tools, for by being in constant contact with repair groups and field supervisors he saves many hours of valuable time.

Transcontinental's 80 trucks and autos are equipped with 60-watt mobile radio units. To assist in dispatching them and directing their operations, all 22 of the compressor stations are furnished with 250-watt transmitters and companion receivers. Switching devices at each compressor station can tie in the mobile units with Party Line Number 2, the Radio Channel. In this way conversation can be held between mobile units and compressor or terminal stations hundreds of miles away.

Locating Stations

Since compressor stations are approximately 90 miles apart, you can readily understand why building towers tall enough to get line-of-sight communication over such great distances wouldn't be economical. A succession of one to three automatic repeater stations, unattended, are therefore used to accept, amplify, and relay the microwave signals between the compressor stations.

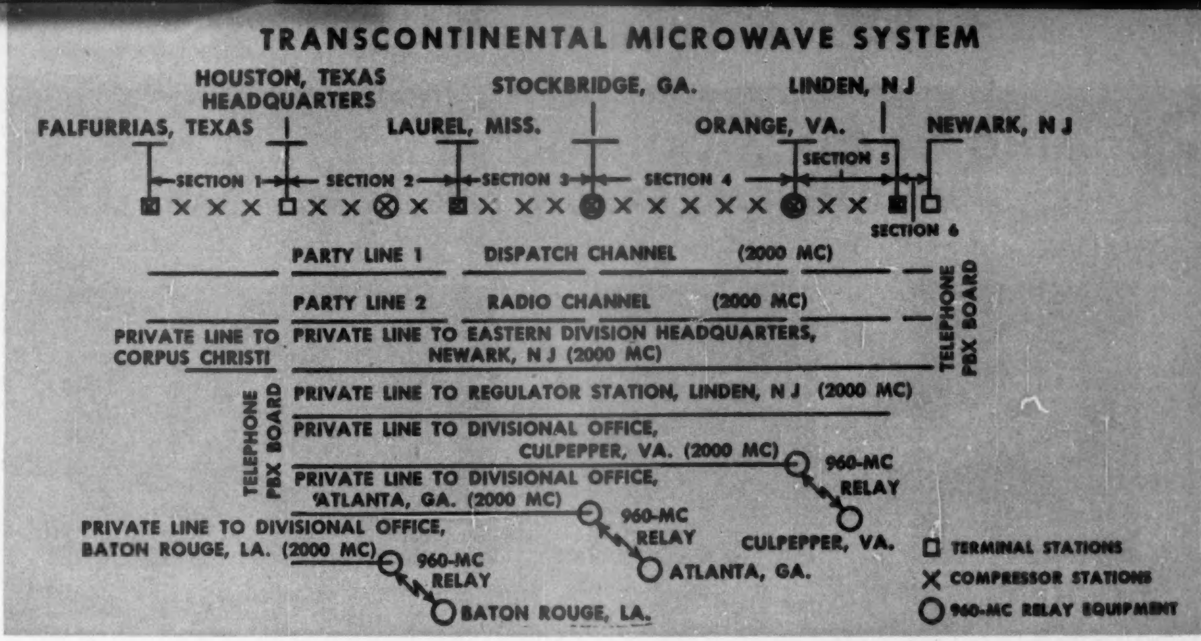
Thirty-six of these towers are in use, bringing the total number of stations to 59. Towers range in height from 50 to 350 feet; the average distance between them is 31 miles.

One of the major undertakings in installing the system was choosing sites. Compressor sites were, of course, fixed by the customer, but we had to select all repeater sites ourselves. The method used was a laborious one. It involved much traveling back and forth over possible paths, and much checking of intervening hills and obstructions.

In selecting sites, we had to consider many factors. An important one was cost: the site had to be available at a reasonable price. Then, too, inaccessibility for construction and maintenance often ruled out many that were otherwise highly attractive from the propagation standpoint. Availability of power was another important factor, for no matter how desirable a site might be, the cost of building several miles of power line into a hilltop or mountain location canceled its advantages.

The proposed paths were plotted on the most accurate large-scale maps available for the particular area, with several possible alternative routes. (Unfortunately, there were large areas for which no good maps were available. In some cases, we used aeronautical charts for preliminary layout and survey work.)

The next step was to plot ground elevations on suitable earth-curvature



paper—aeronautical altimeters were used to check elevations. From this profile plot, antenna elevations were determined to provide line-of-sight paths with the required clearance over trees and other obstructions.

After the station sites were selected and suitable areas of land obtained for purchase, necessary Federal Communications Commission (FCC) station construction permits and licenses were obtained. The Civil Aeronautics Administration (CAA) had to approve locations, actual tower heights, and the type of airway obstruction lighting for each station.

Tricky Relay

Let's now examine in nontechnical terms a typical repeater station (illustration, opposite page). A microwave signal f_R enters the six-foot parabolic antenna from the west and travels down the transmission line to a device called a *duplexer.*

The duplexer is a filter system that allows f_R to enter into the receiver without allowing the signal f_T, from the companion transmitter, to enter also. (Transmitter and receiver frequencies differ by 50 megacycles.) There the received signal f_R is detected, amplified, and passed to the Service Channel. This equipment provides a telephone circuit on Party Line Number 1, and furnishes push-to-talk communication for visiting servicemen. All of the other channels, dispatch and private, pass through undisturbed. The received signal is then passed on to the transmitter, through the duplexer, and to the antenna toward the east.

The signal from east to west passes through the repeater station in the same manner. Because both east and west transmitters operate on the same frequency f_T, and because both east and west receivers operate on the same frequency f_R, only one transmitter and one receiver are required for stand-by operation.

Repeater stations are so regulated that when trouble occurs in a receiver or transmitter, they drop out of the circuit and are automatically replaced by the stand-by units.

MICROWAVE-RADIO SYSTEMS are one of the author's primary concerns. Manager—Communication Engineering, Commercial Equipment Department, Electronics Park, Syracuse, Mr. Heiden is responsible for design and development of microwave, mobile, and carrier-current equipment.

In addition to this feature, each station is equipped with a fault-reporting unit so that failures may be reported to responsible maintenance personnel. It does this by sending out a coded signal that identifies the station, followed by another that identifies the particular fault. At each of the terminal stations, fault receivers pick up the signals. There the dispatcher notifies the maintenance man who proceeds to the repeater station to make necessary repairs.

Failure of the primary power is the most common type of trouble. To guard against interruptions of this kind, five-kilowatt engine-generator sets are installed at each repeater station. These are used only as stand-by power supplies, automatically supplying power when the main source is interrupted. Each time a stand-by unit takes over, fault signals are sent out—one when it starts, and one when it stops. Accordingly, total time elapsed between signals indicates the amount of gasoline used, determining when a maintenance man needs to be dispatched to refill the tanks.

Postwar Phenomenon

Today, Transcontinental's private system of microwave communication is the world's largest. It provides the equivalent of seven telephone lines or channels east and three channels west. And by adding more components—modulators and demodulators—the system can be expanded to 12 channels in each direction. (These

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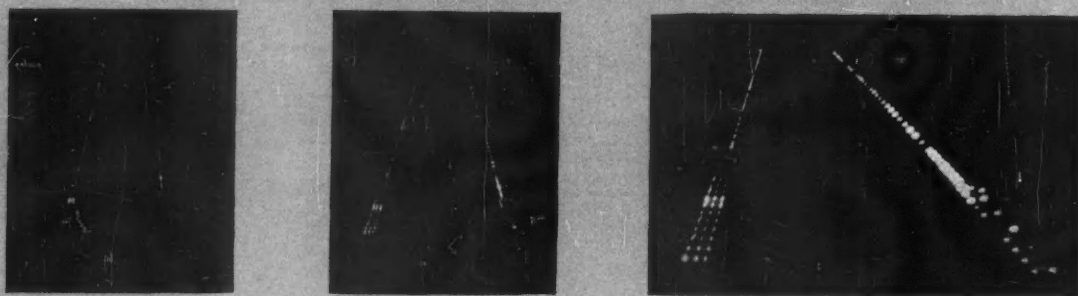
COMING IN FOR A LANDING AT WRIGHT-PATTERSON AIR FORCE BASE . . .



750 FEET 1½ MILES — 500 FEET 1 MILE — 250 FEET ½ MILE

. . . WHAT THE MILITARY PILOT SEES ON A CLEAR NIGHT

IN PEACE OR WAR, IN GOOD WEATHER OR BAD—THE MILITARY PILOT MUST SEE THE AIRSTRIP'S BOUNDARIES FOR A SAFE LANDING.

Lighting Military Airports

By G. M. KEVERN, P. H. GREENLEE, and H. N. MC INTYRE

The aviation movie of the early 1930's was a cinematic work of art. Remember how the hero, crouched at the controls of his plane, grimly sweated out a night landing in weather that was "ceiling zero." And how, while the heroine stood by, cracking her knuckles in despair, the control-tower operator coolly "talked him down." Those were the days! Of course, the pilot always made it—much to the relief of a gasping audience who slid back from the edges of their seats.

But fiction or not, landing a plane in bad weather was once an exceedingly dangerous business. Pilots flew strictly by the seat of their pants. And often as not, they scraped their bottoms on the control-tower lightning arrester or some other obstruction on the way in.

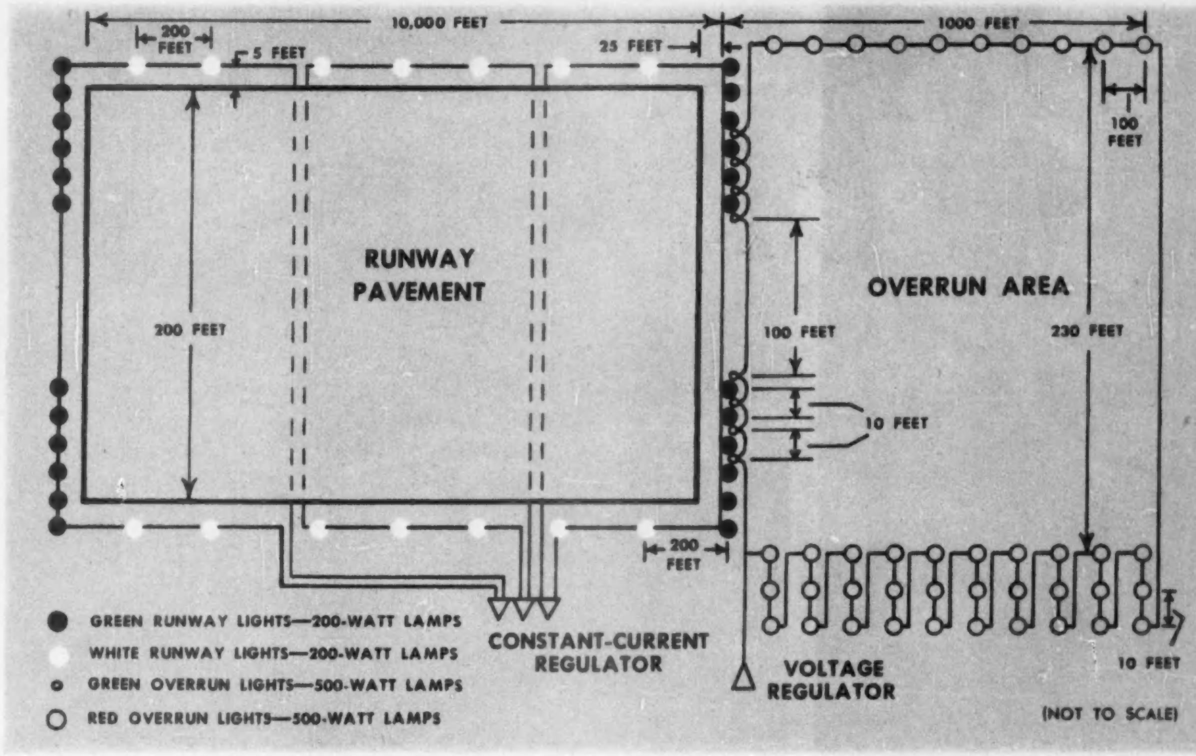
Changing Times

Nowadays you seldom hear of crashes resulting from a pilot's inability to locate the runway and make a safe "touchdown." Yet weather conditions can still be just as bad as those portrayed in the early films. True, we still have ground operators to talk the pilot down. But they no longer depend on the sound of the aircraft's engines overhead: instead, they actually see the aircraft on radar.

Ground Control Approach (GCA), as this method is called, indicates the approaching aircraft's position in space with great accuracy. It tells the radar operator whether the plane is on the right approach path, showing him also the position of other aircraft that might be dangerously close.

In addition, the pilot has instruments of his own. They are his electronic hook-up to the glide path indicator and runway localizer. Here radio signals emanating from the runway threshold are detected by receivers within the aircraft and translated to the motion of two needles on an instrument. One needle indicates right or left deviations from the runway center line, while the other indicates up or down deviations from the ideal glide path. (The latter is about three degrees from the horizontal.) Thus, if the pilot can keep these needles crossed at the zero position, he's on the exact center line of the runway and along the ideal glide path. Theoretically, if he followed these needles all

Mr. McIntyre—application engineer with GE's Lighting and Rectifier Department, River Works, Lynn, Mass.—joined the Company in 1947. Mr. Kevern is Lighting Consultant for the Equipment Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio. Formerly Chief of the Lighting Section, Wright Air Development Center, Mr. Greenlee is now an application engineer with the Grimes Electric Company, Urbana, Ohio.



LIGHTING CONFIGURATION OF A TYPICAL MILITARY RUNWAY. AIR FORCE SPENT YEARS DEVELOPING ELECTRICALLY FOOLPROOF SYSTEM.

the way down, he would make a perfect landing.

But vision is still all-important. And to be absolutely sure of landing safely, the pilot must see an actual indication of the airstrip's boundaries at a safe distance before touching his wheels down. High-intensity lighting beamed at him from outlining points on the airstrip accomplishes this. Because within limits, these pin points of bright light cut through fog and mist to provide him with a last-minute check on his instruments and on his own judgment.

Peace and War

For years engineers of the USAF Lighting Unit at Wright Field, Dayton, Ohio, have explored runway and approach lighting systems. They have looked into a multitude of ideas that would provide the military pilot with maximum safety. And at the same time, they've had to consider the peculiar needs of the Air Force at war—the absolute necessity for systems that are electrically foolproof. This means systems that can be quickly installed and serviced by even the most inexperienced airmen—systems that are lightweight and compact for emergency transportation to rear or forward areas, and that can be abandoned, if necessary, without too much cost to American taxpayers.

The nearest thing to these ideals thus far developed is the U.S. Air Force's packaged *runway* lighting set, used for all-weather operations. Even complicated *approach* lighting has been packaged. As a result, operational Air Force units can now order packaged runway or overrun lighting systems from USAF supply depots by catalog number as simply as you would order a set of workshop tools from a mail-order house. What's more, these sets are refinements of lighting and control equipment that have provided substantial savings of life and property. How? By allowing safe landings under weather conditions that would otherwise be considered unfit for flying.

(See the above diagram of a typical military landing strip for the relationship between runway and approach lighting. Approach lighting utilizes high-intensity red lights for outlining a cleared area 1000 feet long—called the *overrun area*—leading to the threshold of the runway. This area can be used by crippled planes for emergency landings or by heavily loaded bombers that overrun the runway during take-off.)

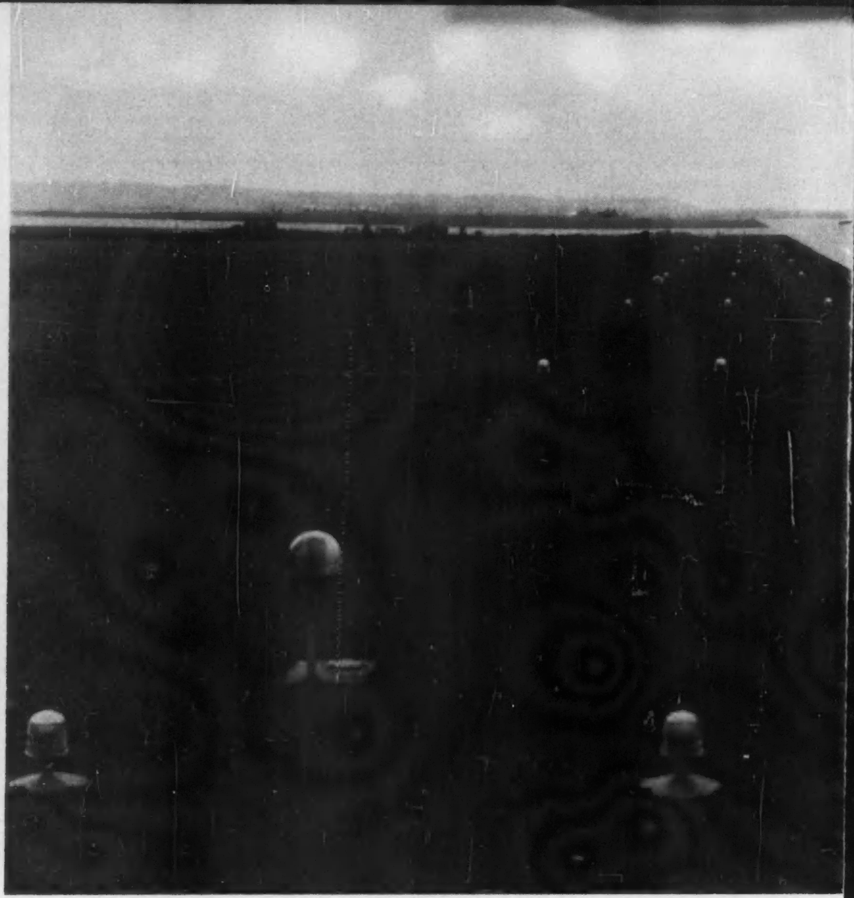
Both systems are designed for either permanent or combat-area installations and are made adaptable by varying only the method of installation. The outgrowth of this effort has paid an unexpected dividend: lighting fixtures and control for permanent installations that are cheaper and superior to devices formerly used. Several components of the two sets will have a sweeping effect on civil airport lighting practice.

Night Landing

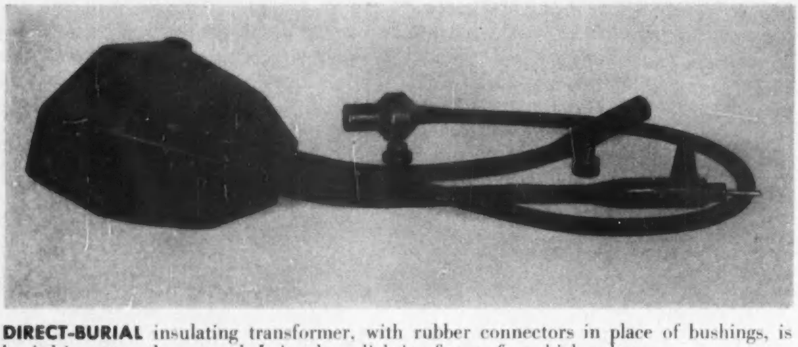
The sequence of photos on the opposite page were taken from a plane's cockpit as it approached a landing field at Wright-Patterson Air Force Base. They show just about what the pilot would see in clear weather. You'll note that the overrun area in the foreground and the runway behind it are not in themselves illuminated—only the outlines are seen. This perspective is sufficient to give the pilot indication of his position, which he can check on the electronically indicated glide path mentioned earlier.

While the overrun zone leading into the runway threshold is cleared of any obstruction, it isn't paved and normally wouldn't be used for landing. It simply serves as a margin of safety in the event

OVERRUN MARKER utilizes a 500-watt lamp and red filter for easy identification.



OVERRUN LIGHTING SYSTEM at Patterson Field, Dayton, Ohio. Left side of configuration shown here—visible in photo sequence of night landing—is indicated in runway layout on



DIRECT-BURIAL insulating transformer, with rubber connectors in place of bushings, is buried in wet or dry ground. It insulates lighting fixture from high voltage.

the aircraft touches down too quickly. Or its extra thousand feet can be used if the runway pavement isn't long enough for the airplane to make a safe stop.

The night photos were made as the aircraft approached the runway almost directly along the ideal glide path. As you can see, the lights are exceptionally visible along this line. Yet a pilot approaching not so ideally could still see them, even if he were considerably off course.

It took years of research and thousands of dollars to develop a high-intensity runway light to permit this. For the all-glass lens assemblies of each runway fixture incorporate all the lighting characteristics found desirable over a period of 12 years. Each unit controls the light from a 200-watt projection-type lamp, producing main beams directed toward the approaching aircraft. These beams are sufficiently wide to cover not only the ideal approach path but also the *region of guidance*—the limits to which the pilot can deviate from the ideal glide path during bad weather and still make a safe landing. Under normal weather conditions, however, each light can be seen all around the compass while the aircraft is circling for an approach. A similar amount of effort went into design of the 500-watt overrun marker (photo, top, left).

Weatherproof System

A lot of work was done to standardize and simplify components of the lighting sets and their installation. Normally procured, stocked, and issued separately for permanent installations, components are combined into packaged units when needed for combat areas. Either set would be used in the same manner.

For either combat-area or permanent-base runway lighting, three complete sets of high-intensity components are needed for each 10,000- by 200-foot runway. These are circuited on series loops (illustration, preceding page), while the overrun lights employ parallel cir-

page 57. Thousand-foot-long overrun guides pilot to runway.

cuiting. A full range of brightness control is essential to both.

You would be intrigued by the ease and simplicity with which these sets are assembled. For example, there are no permanent cable splices, even though potentials up to five kilovolts are experienced. Conductors are supplied in precut lengths with watertight molded-rubber connectors built in. Insulating transformers at each runway light—step-down transformers in the case of an overrun light—are also connected into the circuit by means of watertight rubber connectors.

A direct-burial insulating transformer (photo, left) is built for use on top of—or immersed directly in—wet or dry ground. A lighting fixture connected to its secondary is insulated from the high voltages of the series distribution loop, thus providing safety for maintenance personnel. Then, too, if in the series loop one lamp burns out, the rest will remain operative.

Along with watertight connectors, direct-burial transformers are probably the most important single development. They evolved after an intensive effort to obtain insulating transformers suitable for use with temporary installations in combat areas. When new molding techniques were developed and numerous difficulties overcome, these rubber-covered units were found to be superior in nearly every respect to conventional compound-filled metal-case transformers formerly used.

The molded-rubber cable connectors—originally developed for speedy installation in combat areas—were found adequate for 5000-volt service. Over-all system reliability is much improved: since spare cable assemblies and transformers are kept on hand, a faulty unit is easily disconnected and replaced with a spare one laid temporarily on the ground. If connectors are kept clean and dry until plugged together—and they will be if handled properly—the connection is as good as a conventional high-voltage splice.

Varying Brightness

A regulator, or constant-current transformer, was especially developed to supply the series circuits of the runway lights. Designed for immediate use on combat-area installations, only its input and output leads need be connected. The practical purpose of this device is to provide the same lamp current and, accordingly, the same lamp brightness regardless of the number of lamps in series. For if lamps were to burn out and there were nothing to limit current flow around the series loop, voltage across the remaining lamps would increase and they too would burn out.

Changes in lamp brightness are effected merely by moving a selector switch on a separate control transformer. This adjustment is made locally or from a remote point. The requirement for a particular lamp brightness depends on weather conditions. So as not to blind the pilot, lamps are run at minimum brightness in clear weather, and are visible for miles. On the other hand, they must be at or near 100 percent brightness to penetrate thick fog.

Because of improved design techniques, the regulator is probably the lightest, most compact device of its kind ever made for airport lighting. This feature is extremely important to the Air Force's logistics picture—all equipment must be transportable by air.

Brightness control of overrun lights must also be provided for the reasons mentioned. Here, a standard feeder voltage regulator was modified to control them down to five-hundredths percent of their full value. Speed of operation of this device is fantastic. A maximum of only seven seconds is needed to run from one brightness position to any other. This compares to two or three minutes needed by previous regulators!

Proof of the Pudding

The first installation of the new Air Force overrun lighting system was completed at Patterson Field, Dayton, Ohio, in January of 1952 (photo, left). This is considered an experimental installation; and while the components differ somewhat from those just described, their configuration and lighting performance are essentially the same.

Many test flights have been made. One, for example, was made under daytime weather conditions of zero ceiling with an eighth- to a quarter-mile object visibility. Several approaches were attempted in a B-25 using ground control approach. During the first two runs, the pilot followed GCA instructions until it became apparent that he could not make a successful landing because the plane wasn't properly aligned with the runway. However, he saw the overrun lights and in his opinion he could have corrected the course in time to touch down safely. Additional approaches were made and the pilot landed "contact"—that is, he had visual contact with the runway just before landing.

Although many more flight tests will be conducted under conditions of low visibility, it's equally important that the system be completely tested in good weather—when most flying is done.

A review of all Air Force accidents during a two-year period that resulted from over- or under-shooting the runway shows this: only a small percentage occurred when making an instrument landing under poor weather conditions. You can see, therefore, that the characteristics of lights intended primarily for good weather operations—such as off-runway light for circling guidance and the over-all appearance of the system from any point in the traffic pattern—must be given careful consideration.

Much Still Ahead

Despite the excellence of the new equipment, there is no slowdown in work to find even newer and safer methods of lighting. There is, for example, a need for satisfactory touch-down and warning-zone identification. (The latter is the final 1500 feet of run-

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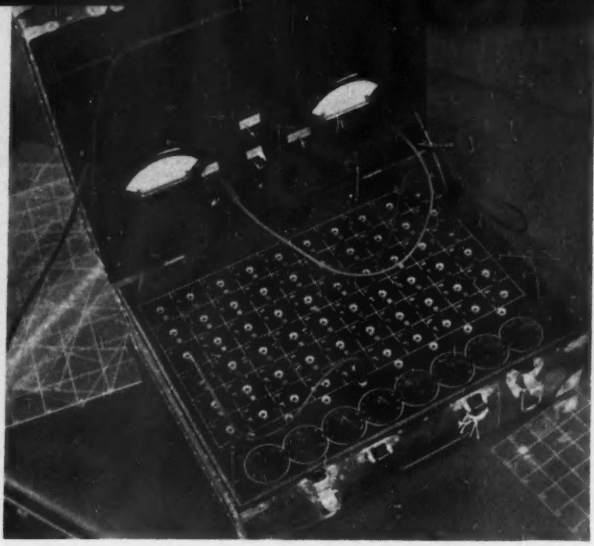

D-C NETWORK ANALYZER can solve many types of flow problems—from the flow of water through a pipe system to the flow of traffic through a congested thoroughfare. Per-unit analyzer (*above*) is designed specifically for studies of electric power distribution.

New Tricks for an Old Calculating Board

By J. F. FULLER

America's technological growing pains are giving rise to bigger, more intricate digital and analog computers for the solution of problems. But is it possible that sometimes these problems appear more complex than they really are? Perhaps we should look again to see if simpler tools and methods can't be used in solving some of them.

One such tool you can apply to problems in many fields is the old reliable d-c network analyzer (photo, left), a portable resistance-type analog computer. For wherever there's a flow of material through a system, it can almost always be used.

You can, for example, let d-c voltage from the power source be analogous to the pressure built up by a water pump, with current equivalent to water, and resistance representing the internal roughness—or impedance—of the system's pipes. When the switch is thrown, current will flow through the resistances. And this current, read on an ammeter, represents gallons per time-unit of water through the pipes. To find the water pressure at any point in the system, you have only to read the voltage at that point.

Process steam and building-heating requirements supplied from an interconnected grid system of steam pipes can be set up in the same way. Again, voltage represents steam pressure, current represents steam flow, and impedance of the pipes is analogous to resistance.

Traffic on congested streets is an example of material flow. There's no reason why you can't set up peak traffic on a calculating board so that bottlenecks can be located and eliminated. Peak traffic in cars per hour would be analogous to current, and the ease of travel through streets or tunnels—permissible number of cars per hour—would be expressed in terms of electric resistance. Then the number of cars at any point in the traffic stream would be equivalent to voltage.

The distribution of electric power to residential areas is a problem where a simplified approach pays you handsome dividends. It's quite easy to determine how much electricity is consumed by the average customer and then extend this planning to one square mile of customers. The system can be designed on the per-unit analyzer (photo, right) especially built for this purpose. (An example problem in more detail follows this article.)

These are but a few applications among possibly many thousands. For the d-c network analyzer is a simple tool whose use is limited only by the ingenuity of the engineer. Ω

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With GE since 1941, Mr. Fuller is an electric utility application engineer in the Engineering Division of the Rocky Mountain District, Denver. In 1953, Mr. Fuller received the Coffin Award for his work in the development of portable network analyzers for studying power systems.

Example Problem

If a residential area of one square mile is to be served by a distribution system, how do you calculate the most economical wire sizes and voltage drops using the per-unit analyzer?

Dividing the area into 100 squares, each area becomes one per-unit area with one per-unit load, and is one per-unit length on each side. One per-unit load flowing through one per-unit length equals one per-unit voltage drop. Therefore, it's only necessary to draw in the actual wires supplying this square mile and add up these per-units of drop to find the total drop.

Copper loss is equal to I^2R; accordingly, to find the total copper loss in a system you take the per-unit current flowing through each per-unit length and square these numbers. Dividing these by the wire-size resistance ratio gives the correct loss in each section. Adding them gives the total loss in the system.

Analog Computers —

(*Concluded from page 27*)

Analog computers are however no panacea for control problems. Still, by using them in a logical and intelligent manner you can reduce costs and speed development time, obtaining a better end product.

Much of the work of the analog computer can be done—at the expense of time and man power—by hand-operated calculating machines. But the analog computer is the only logical machine whereby transient performance of a complex system can be studied, and improvements made, without resorting to expensive cut-and-try methods on actual equipment. Ω

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Microwave Radio—

(*Concluded from page 55*)

remaining unused channels may later be utilized for additional voice communication, to carry signals to control motors, to read meters, to open and close valves, and for similar tasks.)

Tomorrow, you can expect that more long systems of microwave communication will be installed—for the use of microwave radio is growing by leaps and bounds. In 1950, for example, there were only about 2000 miles of private microwave systems authorized. Yet, estimated authorizations for 1952 exceeded 20,000 miles, and predicted authorizations for the year 1955 exceed 100,000 miles.

This striking growth has been called the "silent boom" by Martin Codel, a well-known commentator on industrial radio and television affairs. He says—

" . . . one piece of electronic's business is growing like mad without benefit of TV's glamour or anything else to catch public fancy—industrial microwave. FCC and those using or supplying equipment are continually surprised that this postwar phenomenon has attracted so little general notice. . . . " Ω

Lighting Airports —

(*Concluded from page 59*)

way pavement; there the pilot must begin braking his plane.) To this end, a joint CAA-USAF project has been established at the Civil Aeronautics Administration's Technical Development and Evaluation Center at Indianapolis.

New control devices and improved circuiting methods are also being looked into. Under development is a new and improved series constant-current transformer. It will, among other things, be used for brightness control while eliminating tap-changing contactors and the maintenance problems associated with them. Successful development of a larger version of this unit will probably mean that overrun lighting of the future may be supplied from series circuiting.

In short, everything humanly possible is being done to improve, simplify, and reduce the weight of present lighting components and their control. Meantime, the search for better lighting methods continues toward its goal of completely safe all-weather flying. And that day may be nearer than you think. Ω

G-E Weathertron Cools and Heats All-Electric Demonstration Home

New G-E product based on the heat pump principle provides final link in all-electric living

THIS ALL-ELECTRIC HOME in Dallas, Texas, is one of a series of architect-designed homes intended to meet the needs of today's family living by taking full advantage of modern electrical equipment available for the home. Built in cooperation with General Electric, this home contains an all-electric kitchen and laundry, hot water heater, scientific light conditioning, and all-electric heating and cooling by a G-E Weathertron.

THE G-E WEATHERTRON uses only electricity and air to *heat* this home without burning fuel and to *cool* it without using water. It furnishes three times as much heat as radiant or resistance heating does with the same amount of electricity. Since the Weathertron uses no water, it needs no cooling tower or special wells.

What the G-E Weathertron means to:

HOME OWNERS...Completely automatic indoor weather control is here. The G-E Weathertron adjusts itself to weather conditions, switching from heating to cooling and back within the same day—even within the same hour if necessary. It provides truly luxurious comfort all year round and once you set the thermostat, you need never touch it again. Your draperies, paint, rugs and wallpaper stay bright and new longer—even dusting is reduced.

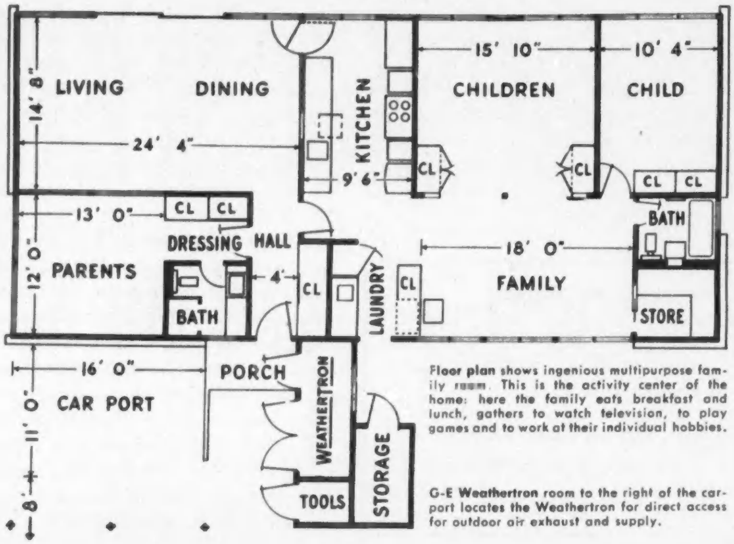
ARCHITECTS...All-electric G-E Weathertron year-round heating and cooling makes possible new simplicity in design and construction. G-E Weathertron makes chimneys and fireplaces unnecessary; the utility room can be placed almost anywhere since it needs no ventilation.

UTILITIES...The use of the G-E Weathertron in the average all-electric home can triple or quadruple normal residential power consumption. It means increased kilowatt-hour sales throughout the year.

Hugh Isley, General Sales Manager of the Carolina Power Company, calls this type of electric service "...the finest boost for all-electric living we've yet seen."

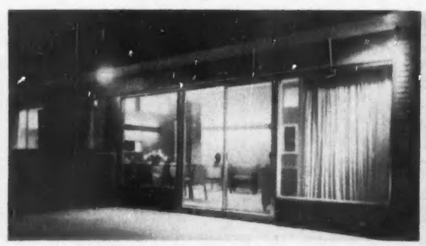
Progress is our most important product

GENERAL ELECTRIC



Floor plan shows ingenious multipurpose family room. This is the activity center of the home: here the family eats breakfast and lunch, gathers to watch television, to play games and to work at their individual hobbies.

G-E Weathertron room to the right of the car-port locates the Weathertron for direct access for outdoor air exhaust and supply.



Over 10,000 people turned out to see this beautiful home the day it opened. Builder and G. E. distributors reported unusually fine public reaction to home and its all-electric features.

G-E Weathertron Model YR-50, like the one pictured here, provides ideal year-round indoor weather for this Dallas home. Weathertron heats, cools, filters, circulates and dehumidifies.

AVAILABILITY...The G-E Weathertron is generally available in the south, southwest, and on the west coast—other locations to follow as soon as service and distribution facilities are established.

FOR MORE INFORMATION about the Weathertron, please write General Electric Company, Air Conditioning Division, Sec. GER-17, Bloomfield, N. J.

WEATHERTRON

ALL-ELECTRIC COOLING AND HEATING FOR HOMES, STORES AND OFFICES

G-E WEATHERTRON FORMERLY CALLED G-E HEAT PUMP

The name was changed because a heat pump *cools* as well as heats and this proved to be confusing to a lot of people. "G-E Weathertron" indicates more clearly the all-year-round benefits of this new heating and cooling system.

You expect the best value from G-E fluorescent lamps

Silicone coat on new G-E Rapid Start lamps helps them start quicker

Moisture in the air can make a fluorescent lamp slow to start. The wet film that condenses on the lamp is a good enough conductor to detour some of the electricity needed for proper starting.

General Electric has tailored a "raincoat" that stops this. It's made of silicone and breaks up the wet film into tiny droplets, leaving dry areas that interrupt the electrical contact. Less current is stolen. Starting is quicker, surer.

We call the coating Dri-Film*. The photo above shows the difference it makes. Moisture breaks up into droplets on the Dri-Film* lamp, forms a smooth coating on the ordinary lamp.

You get Dri-Film* on G-E Rapid Start lamps. It's invisible, won't rub off, helps assure you all the light you pay for. Many leading manufacturers have designed lighting fixtures to use Rapid Start lamps and their special Rapid Start ballasts. You *expect* the best value from G-E fluorescent lamps. Here's another reason you can.

For more information, write General Electric, Department 166-GE-11, Nela Park, Cleveland 12, Ohio.

*Reg. U. S. Pat. Off.

You can put your confidence in—

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