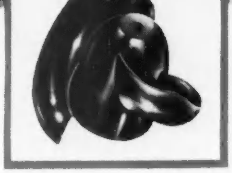
GENERAL ELECTRIC Review

SEPTEMBER 1952

Chemical Progress

News of developments from General Electric's Chemical Division that can be important to your business.



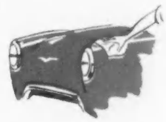
G-E CHEMICAL RESEARCH MAKES POSSIBLE
New Uses for Plastics

Development of G-E rubber-phenolic molding compounds widens use of plastics in applications requiring unusual strength and resilience.

Now General Electric chemical progress has greatly increased practical applications for plastics! G-E rubber-phenolics work successfully where other types of plastics often fail because rubber-phenolics have five to seven times the shock strength of conventional phenolic materials.

Typical of the new uses for G-E rubber-phenolics are the two dishwasher parts shown here. The silverware basket—formerly made of scarce brass—has the required strength and resilience to withstand dropped utensils and operating vibration. Like the impeller (see inset) it is resistant to hot water, strong detergents.

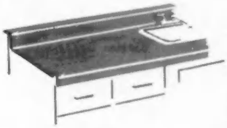
A few of the present uses for G-E rubber-phenolics include business machine parts, handles for heavy-duty machinery and bobbins for textile mills. Many more are sure to develop as industry takes advantage of this recent contribution of G-E chemical progress—other examples of which appear on this page.



Shining example! The new non-oily, easier-spreading furniture and auto polishes made with G-E silicones show how products may be improved by utilizing the remarkable properties of this new family of materials.

G-E varnished fabrics and tapes, part of the G-E line of insulating materials, have extraordinary resistance to moisture and heat-aging, are proving valuable for many dielectric and insulating uses.

For more information about any of the G-E chemical products or processes described on this page, write to General Electric Company, Chemical Division, Section 100-2A, Pittsfield, Massachusetts.



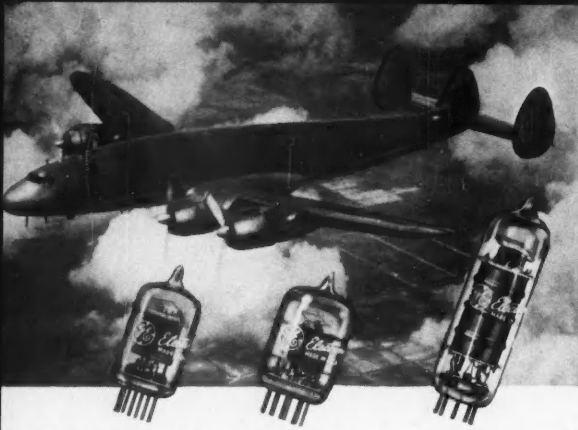
G.E.'s revolutionary new Monotop work surface (the *one-piece* G-E Textolite* backsplash-counter top for kitchens and vanities) is the result of G-E molding skill plus research in superior resins and varnishes for laminating purposes.

PLASTICS COMPOUNDS • SILICONES • INSULATING MATERIALS • GLYPTAL® ALKYD RESINS • PLASTICS LAMINATING, MOLDING, AND EXTRUDING

*Reg. U. S. Pat. Off.

You can put your confidence in—

GENERAL ELECTRIC

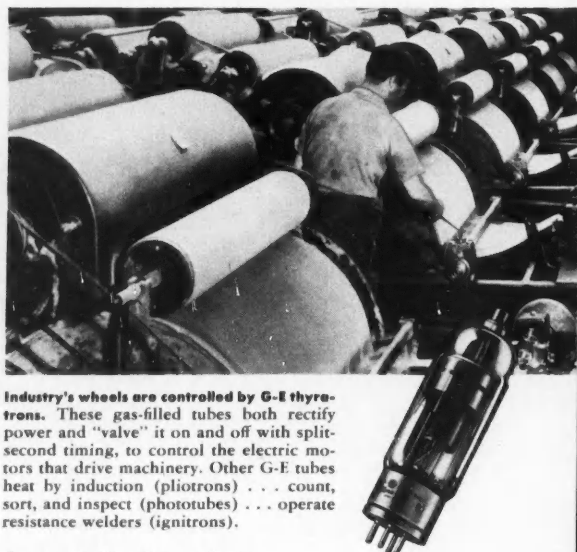


G-E 5-Star (high-reliability) tubes guide airplanes to safe landings. With the ever-growing use of radio-beacon and other electronic aviation equipment, need for tube reliability has become paramount. General Electric's specially designed, specially built 5-Star receiving types attain new standards of dependability—cut down tube replacements—greatly reduce equipment maintenance.

Your home TV is a series of tubes, with a G-E picture tube carrying on its face the image you view. The picture is vivid, lifelike, because G.E.'s famous Aluminized Tube—the picture tube that saves and uses light which other tubes waste—produces an exceptionally bright, clear image. A score of G-E modulator, amplifier, and other small tubes complete your TV chassis.

G-E TUBES—THE HEART OF ALL ELECTRONIC EQUIPMENT!

Radio-TV broadcast stations use G-E rectifier and power tubes at every stage between studio and sending tower. General Electric tubes pick up and amplify the electronic messages from microphone and studio camera, use these to modulate high-voltage d-c, and further translate the power into far-ranging transmitter wave impulses.



Industry's wheels are controlled by G-E thyratrons. These gas-filled tubes both rectify power and "valve" it on and off with split-second timing, to control the electric motors that drive machinery. Other G-E tubes heat by induction (pliotrons) . . . count, sort, and inspect (phototubes) . . . operate resistance welders (ignitrons).

For further information on tubes for any application, write to
Tube Dept., General Electric Company, Schenectady 5, N. Y.

GENERAL ELECTRIC

SEPTEMBER 1952 • VOLUME 55 • NUMBER 5

GENERAL ELECTRIC Review

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

COVER—This high-speed rolling mill is a typical example of the tools, equipment, and power conceived and developed by the engineer and made available to the American workman (Editorial on next page). From a painting by Peter Helck.

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.

ENGINEERS ARE NEEDED

The Centennial of Engineering is being celebrated this year. The American Society of Civil Engineers, the first engineering society in our country, was founded just one hundred years ago. Since that time societies representing all the other branches of engineering have been formed until today every engineer has a society he can call his own, if he but will. In recognition of their contributions the REVIEW will present a series of historical articles on these societies, the first of which appears on page 34 of this issue.

The growing importance of these societies however is only a reflection of the ever greater role that engineers are playing in American industry. The leadership our country has assumed in production may be directly attributed to our wise dependence on and use of engineering know-how. We are indebted to engineers not only for their development of new products and their improvement of old ones, but also for the building up of our tremendous capacity to produce (see cover). The power and the tools which engineers have given to American workmen have enabled them to outproduce workmen anywhere else in the world.

As the tools of industry have become more complex, however, the ratio of engineers to workers in industry has steadily gone up. The figures are:

YEAR	WORKERS IN INDUSTRY	ENGINEERS IN INDUSTRY	ENGINEERS PER 100,000 WORKERS
1890	7,800,000	26,800	344
1900	10,500,000	41,000	390
1910	14,500,000	84,000	580
1920	18,000,000	130,000	720
1930	20,000,000	215,000	1080
1940	20,400,000	261,000	1282
1948	24,300,000	350,000	1440

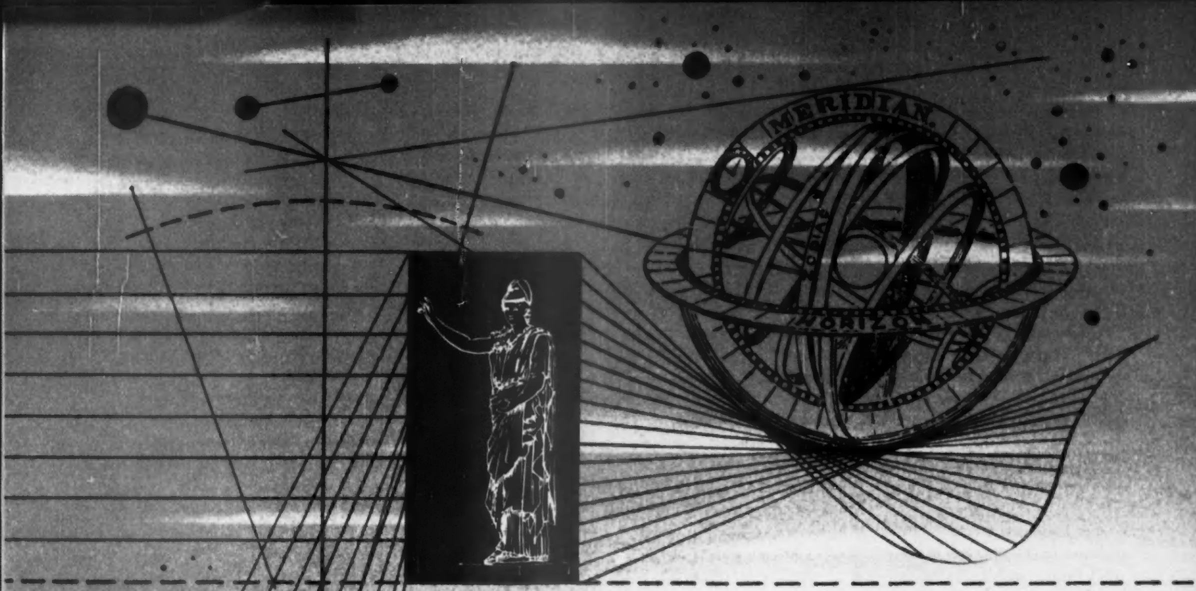
The indications are that for the year 1950 the number of engineers per 100,000 workers was about 1550.

The trend indicated in this table must continue, and the ratio of engineers to workers must grow even larger, for the world of power, electronics, and nucleonics is a world of increasing scientific and engineering content. The supply of engineering manpower however is becoming ever more difficult to maintain. In the past few years the number of young men graduating from engineering colleges has become smaller each year. If our engineer-dependent industry is going to continue its steady progress, engineers must use every possible means to encourage young men who have the proper interests and aptitudes to study engineering. While much has already been done to interest students in engineering as a career, much more must be done.

In this issue of the REVIEW (page 53) one plan with new opportunities for doing so is discussed: a plan for bringing high-school students to visit industry—not to see the plant, not to see the products, but to talk with engineers and to learn more about engineering. Engineers everywhere could very profitably work with their managements to promote this type of visit.

And in the over-all problem of keeping our ranks filled with competent engineers lies one of the greatest challenges ever given engineers and their engineering societies—a challenge they must meet.

EDITOR



TODAY'S EDUCATION AND TOMORROW'S ENGINEER

By DR. ROBERT L. SHURTER

No aspect of engineering education has been the subject of quite so much discussion in recent years as the role and amount of general studies in the engineering curriculum. Hundreds of papers and talks have centered on this problem—and the end is not yet in sight. Proponents of purely technical education have viewed with alarm what they call "the encroachment of the humanities and social studies" in the engineering course; advocates of general studies have been equally insistent that the engineer should be prepared for his responsibilities as a citizen through the study of history, literature, economics, and psychology.

This protracted debate in the arena of engineering education has unfortunately been characterized by meaningless clichés, some nonsense, and a great deal of misunderstanding. Advocates of the general studies have taken refuge in such pretty but arrogant phrases as "teaching the student to learn to live rather than to earn a living." At times they have been even more irritating in staking out exclusive claims to that vague quality termed "culture"—a word which quite properly is a red flag to most engineers, since truly cultured people are chiefly distinguishable by their reticence in talking about their culture.

On the other side, the spokesmen for strictly technical education have argued that the engineer will somehow acquire an interest in literature or music or art or history *after* he graduates, and that this vague form of educational osmosis after graduation makes undergraduate instruction in the general studies unnecessary. Their clichés find expression in such terms as "the dilution of technical content" or "impractical courses," or that unabashed summary of a materialistic viewpoint that "you can't eat Shakespeare"! Another segment insists that engineering students have had all the instruction they need in general studies during their high school years. "Why duplicate this in the college years?" they ask. Paradoxically, this same group is generally most critical of the poor preparation the student brings to college in mathematics, physics, and chemistry.

These attitudes are, of course, extreme; nevertheless they do exist and they do serve to illustrate the complexity of the problem of deciding what subjects and how much time should be devoted to general education in the framework of the engineering curriculum. It is my impression that most technological institutions have worked out a compromise rather than a thoughtful solution for these problems, and that they have done so largely on the basis of expediency instead of over-all educational principles.

Nor should anyone underestimate the difficulty of finding such a solution based on principle. By comparison, my good neighbors at General Electric's University of Light can quite easily decide whether a given situation demands an intense beam of light which illuminates one area or a smaller degree of illumination in all directions. But who is to decide whether the future needs of American industry and society require an engineer whose education has illuminated a few limited areas intensely or has shed its rays around the educational spectrum?

Under the present organizational pattern our institutions can make this decision in one of two ways: by administrative decree imposed from above by presidents or deans, or by group action on the part of the faculty.

The second method is, of course, most desirable since it is more democratic and gives those primarily charged with educational policy a sense of participation in and responsibility for the student's total education; it is also most difficult. For every engineering faculty is composed of specialists each of whom sincerely feels that no student's education is complete without some exposure to his particular specialty. Given only four years of the student's time and an already tightly packed curriculum, a decision involving a large number of the faculty is therefore difficult to reach.

That is why it is important that industry make its own needs known, for in all the discussions I have heard a point is always reached when some faculty member says, "Industry requires specialists" or "Industry wants broadly educated men." These generalized appeals to authority seldom descend to particulars; as a matter of fact, there seems to be no final decision as to just what industry does want. To see this in chapter and verse, you might take a look at the advertisement on page 61 of the May issue of this magazine giving excerpts from graduates 10 years out of college on "What Would You Suggest to Men Now Planning Their Careers?" Such varying opinions as "Spend at least 25 or 30 percent of your time in the study of the humanities," "Don't specialize too much," or "Take as many fundamental engineering courses as possible," and "Be thoroughly grounded in engineering fundamentals" probably illustrate the fact that neither industry, alumni, nor students have thus far arrived at a definitive answer.

". . . no graver danger to civilization . . . training scientists and engineers whose skills enable them to be leaders but whose minds are indifferent to their responsibilities as citizens in a democratic society."

As a matter of fact, similar opinions can be found in every type of American educational institution as is shown in a challenging new book titled *They Went to College* by Ernest Havemann and Patricia West. Based on a survey of graduates of 1037 American colleges, this informative study contains a lot of material on the opinions, activities, and attitudes of our college graduates, but it presents no conclusive answer to the dilemma of breadth or depth in education.

In the interest of greater understanding, however, I believe it is important that engineering graduates and members of industry be given at least tentative answers to the following questions—

Why should the humanities and social studies be included in engineering institutions?

What subjects shall be taught?

How shall these courses be taught and who shall teach them?

What do these studies accomplish?

Readers will have to judge my answers to these questions almost entirely in terms of their own experience in working with engineers. For in considering the role of the humanities and social studies in an engineering college, we are in an area where objective standards of measurement do not apply.

I am well aware that the reader who spends his professional career in research may consider my beliefs and convictions mere nonsense, while the sales engineer or administrator may react differently. I have tried in this article to label my opinions wherever I make personal judgments, though these judgments are in every instance based on more than 20 years of close contact with about 2000 students, whose later careers I have followed with considerable interest. My answers to the four questions I have raised should therefore be taken as one teacher's personal viewpoint—except that in answering the second question (What subjects shall be taught?) I have relied heavily on a program which has been in actual operation at Case for the past three years.

Why Humanities and Social Studies?

I believe that the answer to this question lies in two parts, which involve the engineer as both a member of society and as an individual. I can think of no graver danger to a technological civilization than the training of a generation of scientists and engineers whose knowledge of skills and techniques enables them to rise to positions of leadership but whose minds are indifferent to or naive about their responsibilities as citizens in a democratic society.

Such overspecialization in one area leads inevitably either to indifference about other areas of knowledge or, worse, to a kind of oversimplification from which stem such naive solutions to complex problems as "All we have to do to get along with the Russians is to send the right man over to see Uncle Joe." The most vexing problems of our era are not technical ones but human, and the engineer as a citizen will have to study all the history, economics, government, and human relations he can muster to grasp their complexity. The further he rises in executive responsibility, the more he will have to use his knowledge of human beings and of the way to get them to work together. And in this capacity his slide rule, his formulas, and his equations will not serve him well!

As an individual, the engineer—or for that matter any human being—ought to have interests and enjoyments outside his professional field; if he doesn't, he will outmatch Jack in dullness. One of the functions of his undergraduate studies in the other-than-technical area should be to awaken his interest in literature or music or art with the hope that he may carry on these interests after graduation. We hear much today of human relations or getting along with people—and no era ever needed this art more than ours.

But I believe that our education should also prepare us for getting along *without* people so that we have the inner resources of interests and ideas to meet the final test of human personality of being alone. If we find it difficult to be by ourselves, how can we expect others to find us interesting? The answer, then, to why include general studies in the engineering curriculum is: first, a knowledge of history, economics, political science, psychology, and human relations prepares the engineer for his responsibilities as a citizen; second, literature, philosophy, music, and art make him a more humane and interesting person.

What Subjects Shall Be Taught?

Before examining specific courses in the area of the general studies, I believe it is important to point out the way in which instruction in this area is generally organized in today's engineering colleges. As the result of a definitive report submitted to the American Society of Engineering Education about 10 years ago, most curricula today are divided into two "stems"—the scientific-technical and the humanistic-social—as the committee labeled them. The first of these includes, of course, all of the fundamental scientific courses and their engineering applications; the second comprises a collection of courses in English, history, economics, literature, psychology, philosophy, the fine arts, or foreign languages.

While the organization of such courses differs considerably in various institutions, the trend over the past five or ten years has been to put all these subjects together under one department or division with some such name as the "Humanistic-Social Department" or the "Division of General Studies" or the "Division of Humanities and Social Studies." In most engineering schools, this department or division is responsible for about 15 to 25 percent of the student's required courses; the committee of the ASEE recommended a minimum of 20 percent and an ideal of 25 percent. Suffice it to say, this report resulted in much healthy soul-searching among our engineering colleges, particularly as to the objectives of their general studies or humanistic-social programs.

"Most vexing problems of our era are not technical ones but human . . . the engineer as a citizen needs to study all the history, economics, government and human relations he can . . . to grasp their complexity."

In setting up the goals for such a program, I believe that the following aims are absolutely fundamental—

- To prepare the engineer to express his ideas clearly and concisely in both speaking and writing.
- To give him an understanding of and convictions about his responsibilities as a citizen in a democracy.
- To provide him with a knowledge of the background of the social organization within which he lives and of the great expressions of the human mind concerning man and society.
- To stimulate his interest in some aspect of the humanities or social studies as a basis for continued study or pleasure in these pursuits.

If we translate these goals into specific courses by which they can be attained we come up with some such program as this—

A one-year course of English which equips the student to write reports, letters, and memoranda and to express himself orally in committees, before professional and technical societies, and in his civic activities.

A one-year course in American Democracy which centers on the problems of today's citizen. Since these problems obviously deal with the individual in his relationship to government, the individual as part of a technological society, and the individual in his relation to others, such a course should combine areas usually labeled Government or Political Science, Economics, and Human Relations. Furthermore, because all contemporary problems have their roots in the past, this course should give sufficient historical background to enable the student to pass an enlightened judgment based on historical evidence. Above all else, it should incorporate the conviction that democracy by comparison with other forms of government is the most mature concept of human organization ever devised since it is based on the belief that free men can think independently without the need of a book like *Das Kapital* where it is all written down, fixed and immutable.

A two-year course which traces the social, political, economic, and cultural institutions of Western Civilization from Ancient Greece to the present. As an integral part of this, the contributions of science, technology, and invention in western man's long climb to the present should be a central theme. This course might well center on man's basic needs—

The need to make a living.
The need to organize into a society under law.
The need to express himself in religion, art, literature, and architecture.
The need to control his environment.

If, in the famous words of H. G. Wells, "Civilization is a race between education and catastrophe," the citizen of the 20th century must summon up every ounce of knowledge supplied by the best minds of the past to help him solve the problems of the present. A course of this type will succeed only to the degree that all its materials are selected on the basis of their relevancy to the present. And let no one naively conclude that just because a book or idea or problem is hundreds of years old it is out-of-date. Machiavelli's *The Prince* is as modern as the Kefauver committee; the rock which wrecked the ship of state of the Greek city states is the same as that which besets the future course of the United Nations; and the problems of Socrates or Antigone confront each of us in the 20th century. This timelessness of social and human problems and our need to bring all the best thought of the past to the problems of the present was undoubtedly what General George Catlett Marshall was thinking of when he wrote after World War II: "I doubt seriously whether a man can think with full wisdom and deep convictions re-

BROWSING ROOM in the Library at Case where the author is holding a class. The atmosphere created by such a location stimulates the give-and-take method of classroom discussion that helps to develop engineers into articulate and responsible citizens

garding certain of the basic international issues today who has not at least reviewed in his mind the period of the Peloponnesian War and the fall of Athens."

A group of one-year courses in which the student may select an area into which he wants to attain a greater depth of knowledge or pursue some interest. These elective courses belong properly in the senior year and should grow logically out of the subject matter of his previous studies. To give the student as broad an opportunity as possible for choice, this group should include courses in literature, music, comparative religion, philosophy, economics, international relations, psychology, ethics, and government.

These courses constitute what I would consider a minimum requirement to equip the engineer for life in today's world. Furthermore, they can be taught in the usual four-year engineering program without reducing the amount or content of the technical courses. I am convinced that future progress in engineering institutions will depend on our ability to provide a program in which both the technical and nontechnical aspects are fused, instead of separated. The program I have outlined offers this possibility.

But a program itself is not enough; for just as modern industry is fascinated by the fetish of the organization chart, the modern college has sometimes acted as if an educational program were an end rather than a means. Organizational charts and educational programs are no better than their personnel—and that is why educational progress can be measured realistically only in terms of the instructional methods used and the kind of teachers comprising the staff. As every undergraduate knows, the course that looked so beautiful in the publicity bulletin or catalog in September has sometimes lost its luster by November.

How Shall Courses Be Taught?

I believe that all the courses in the area of humanities and social studies should be taught by the discussion method rather than by formal lectures. The trite definition of the lecture system as a method "by which information passes from the notes of the instructor to the notebook of the student" contains a great deal of truth. Furthermore, if we hope to develop engineers who are articulate and responsible citizens, the give-and-take of classroom discussion seems to me to be an effective laboratory or workshop in the democratic method.

Above all else, the discussion method gives the student a sense of active participation. It forces him to think, to marshall his evidence before expressing his opinions; if he doesn't, the derisive hoots of his classmates are the most effective antidote to snap judgments and hasty generalizations. The sense of doing something, of not sitting passively by, seems to me to be one of the major benefits that group discussion under skillful leadership can confer. And this is particularly important during the formative years because it is so natural for young people to want to participate.

I well remember attending a Christmas dinner at which the two children of the family had been abundantly supplied with electric trains, automatic toys, and all the other mechanical marvels which indulgent parents and grandparents could provide. After a half-hour, the fascination of the trains and gadgets wore off, and the children were busily occupied for hours building forts, stores, and houses out of the cardboard boxes in which their presents had been packed!

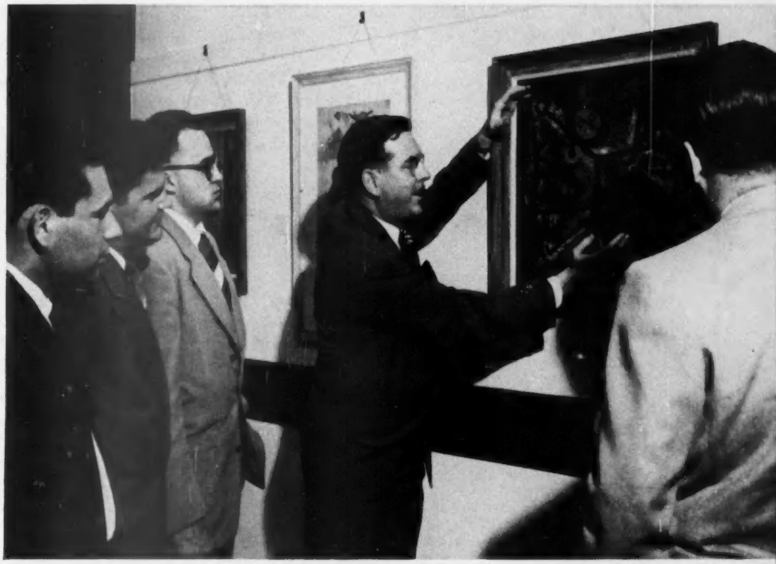
In an age when most of our leisure hours can be spent in passively watching other people on the television and movie screen, or sitting in the stands watching others play baseball or football, or in listening to music rather than playing it, our educational system has a special obligation to encourage participation—and in the classroom this means active discussion rather than passive listening. By the same standards, to transfer this judgment to another area, colleges would do well to insist on a broad program of intramural sports with the majority of students actively participating instead of the all too common practice of students by the thousands watching a squad of 60 to a 100 specialists march back and forth between the goalposts.

To teach in the kind of program I have suggested and to lead discussions successfully requires a special kind of teaching. In the first place, most college professors are fascinated by the sound of their own voices; that may be one reason they are teachers! But in discussion, they have to listen to vague and irrelevant comments; that this is sometimes inefficient cannot be denied, but I am convinced that discussion leaves a greater impact on the student's mind because he is learning by doing.

In the second place, the suggested program I have outlined requires a generalist—and most college professors are, or want to be, specialists. "Isolationism among scholars," as Dr. Killian of Massachusetts Institute of Technology aptly termed it, has little place in the humanistic-social area of a tightly packed engineering curriculum. The only way to get effective instruction within the severe time limits lies in integration within the courses—and if the instruction is to make any sense in the mind of the student, it must first of all be integrated in the mind of the instructor.

This seems to me a fundamental fact which educational institutions and the products of American graduate schools have too long ignored. In commenting on graduate education, *The Report of the President's Commission on Higher Education* made this significant statement: "Since less than a third of the holders of PhD degrees are primarily engaged in research—in educational institutions, industry, or government—it is unrealistic to confine graduate programs to the kinds of experience that contribute in the main to proficiency in research. . . ."

Certainly we want teachers who have a special competence in one area, but we want them also to see its relationships to other areas. The arbitrary compartmentalization of knowledge which marks much education is absurd if we take as our premise the obvious fact that the human mind is the focal point of all education. Fortunately, no technique has yet been found for splitting the mind into its Department of Economics, its Division of History, and its School of Literature. And while these may be useful organizational devices for the college administration, the staff concerned with general studies in a technical institution has a special responsibility to stress the interrelationship of science and technology, on the one hand, and their human and social impact, on the other. A similar responsibility, I believe, rests on the technical and scientific teaching staff; as Dr. Edmund W. Sinnott said at Sheffield Scientific School's Centennial: "The sciences must be taught not as a privileged and superior discipline but as parts of a great whole and against the background of all human knowledge."



REPRODUCTIONS from a 500-piece collection on display in the Main Building are an integral part of the course at Case. Pictures are changed frequently, and about 150 are loaned to dormitory students exposing them to art rather than Petty and Varga girls

What Will These Courses Accomplish?

I am convinced that study in the humanities and social studies has an intensely practical value for the engineer's career, quite apart from the aspects of personal enjoyment or personality development which I have already mentioned. If it is proper to assume that the engineer is likely to rise to executive positions in the future —and most existing surveys show that this assumption is well founded, then these future managers will undoubtedly have to deal chiefly with problems of human relations in the area of labor and management, and with government.

To cope with these problems adequately, these future managers will have to understand the general principles on which individuals and societies operate. For that reason, the habits of thought, the background information, and the standards of values, which today's engineering student has, are of the utmost importance to tomorrow's industrial society. In this context, it seems to me that study of the humanities and social studies can make four very important contributions to the total education of the engineering or science student.

In the first place, these studies can show the future engineer that there are social and human problems to which there is no one right answer. This is not to say that answers to these problems cannot be found, but rather to underscore the importance of understanding that there are human and social areas where formulas and equations do not apply. If there is one thing the average freshman or sophomore in engineering seeks, it is the right answer, whether it be to the third problem in yesterday's physics assignment or to today's calculus homework.

As a result of this exact discipline, he inclines to one of two beliefs when he comes to historical or contemporary social issues—that someone ought to tell him the right answer or that this is an area where anybody's opinion is as good as anybody else's. The techniques of discussion and the use of case studies in the humanities and social studies have a healthy effect in making him less inflexible, more tolerant. He comes to learn that, despite our phrase, there is no such thing as "the human equation."

In the second place, he learns that certain techniques and methods *do* apply in such studies as history and literature. If history has any significance at all, it is only because it is the study of human behavior. And the historian himself has developed patterns of behavior which form an important part of the young engineer's mental growth. He can learn to handle evidence, to choose and select significant data, to ask the right questions, and finally to make a wise decision. That is why it is disastrous to teach history to engineers as a collection of facts or a succession of dates, kings, or rulers; rather, it should be a study of human behavior throughout the ages in a wide variety of situations and contexts from which the students can learn about human experience by forming intelligent judgments based on evidence. The result, ideally, should be a greater maturity, the opposite of which is expressed in the sentence engraved over one American college library: "He who never escapes from the present remains always a child."

Third, the study of literature can be an illuminating experience in teaching the engineer that men are motivated not alone by logic but by their emotions. I would no more try to defend great literature that I would try to defend a symphony by Beethoven or the clean beauty of the Golden Gate bridge or the symbolic thrust of the UN building into the New York sky. This is an explanation, not a defense: I simply believe that literature, well taught, can enlarge a young man's horizons by giving him an insight into man's emotional make-up; by giving him unfamiliar points of view; by enlarging his experience with other times and other countries; and by helping him to distinguish between the cheap, the tawdry, the commonplace, and the great and timeless expressions of the human mind.

That much of our teaching of literature has not measured up to these standards, I am all too well aware. But the frequent comment of students that "I had Shakespeare crammed down my throat and I'll never read his work again" is no measure of Shakespeare but of inadequate teaching, and it imposes a special obligation on the engineering colleges to employ teachers of literature who by their knowledge, their enthusiasm, and their understanding can make the great writers come alive again.

Under such teaching we can perhaps restore among our graduates what is rapidly becoming the lost art of reading—an art whose significance is attested by a strange authority; for it was Adolph Hitler in *Mein Kampf* who said: "The fault with German education in the last century was that it produced men who liked books." The reading of books—and particularly great books—can produce men with standards of values, with convictions about freedom and human dignity who stand in the path of the Hitlers and tyrants of the world.

Finally, the humanities and social studies can give the engineering student a fund of ideas and experiences which make him more articulate. The plight of the man who was all dressed up with no place to go is too often matched by the technical man who can't talk about anything else but his own special subject. I have a high regard for instruction in public speaking, but unless speaking is motivated by ideas and convictions it becomes an empty gesture subject to the same comment that the Queen made to Polonius: "More matter, with less art." By emphasizing the matter of ideas along with the art of informal discussion, the general studies can help future engineers to avoid the famous admonition by Phillip Swain that they should attend technical meetings and then "go thou and do otherwise!"

To sum up, the humanities and social studies are important because they are centered on human beings rather than on things. In these studies man is the measure and if business, industry, and American society today have their technical problems, they seem to be outshadowed by the human problems. Our technical competence is superb; our humane techniques need development. This is what Secretary of War Stimson was saying in his significant words about the atomic bomb: "The focus of the problem does not lie in the atom; it resides in the hearts of men."

•

Teacher, author, speaker, and public relations consultant, Dr. Shurter at present is head of the division of humanities and social studies at Case Institute of Technology, Cleveland. He is also a business writing consultant; his most recent book titled EFFECTIVE LETTERS IN BUSINESS *was a choice of the Executive Book-of-the-Month Club.*

By way of conclusion, it strikes me as highly significant that the magazine of one of America's great industries includes in its pages an article dealing with one important phase of engineering education. More and more, our technical institutions and industry have come to realize that they are partners in developing the future leaders of a technological society. This relationship makes it increasingly essential that industry understand the problems and achievements of today's education; and it likewise imposes an obligation on our educational institutions to understand industry's needs.

The interest and support that industrial corporations have contributed to engineering institutions have been superb, and I believe that this co-operation can be even more helpful in the future. My own personal conviction is that this relationship can be effectively implemented in the future by having our industrial leaders encourage a greater degree of experimentation in our educational programs.

Specifically, I think that engineering education might attempt a greater diversity in its pattern, which strikes me as far too uniform at present. I should like to see attempts made to integrate the scientific and engineering courses within our curricula. I should like to see one or more institutions devise programs which give equal emphasis to the three major components of our education—the fundamental sciences, the applications of engineering, and the humanities and social studies. I would look hopefully to a program that would put far more emphasis on the economic and financial aspects of business and industry than any curriculum does at present. And I should like to see attempts made to break the academic lockstep of heavy required courses so that the superior student may develop his special talents and strike out on his own.

Perhaps these suggestions reflect only the temerity of one who is not an engineer. But if experimentation is the base of scientific and engineering progress, it would also seem to be relevant to engineering education. Only the future can decide whether such methods are pertinent, but that future is being shaped in today's education. That is why your attitudes and interest are so important, particularly as they pertain to the role of the humanities and social studies in engineering institutions. Ω

ALTHOUGH CONSIDERED IMPLAUSIBLE, TESTS SHOW THAT LOCOMOTIVE WHEELS SLIP AND LITERALLY "DANCE" ON THE RAILS AT HIGH SPEEDS

Slip

By R. M. SMITH

In the days when steam ruled the rails there was little mystery about locomotive wheel slip. Driving axles usually were coupled together, and when slip did occur, the engineer both heard it and felt it and took steps to correct it.

But with all-electric and diesel-electric locomotives it's a different story. Any one of 16 individually driven axles can slip, and the engineer may be 200 feet away with 6000 hp of laboring diesels in between. An automatic method of detecting and correcting wheel slip is necessary.

Is Slip Harmful?

Wheel slip isn't a minor annoyance—it's a factor that contributes to high motor maintenance bills. It's one of the chief causes of loosened and damaged armature windings, as well as harmful motor flashovers. Elimination of slip would also improve locomotive performance and prevent possible accidents because of locked axles.

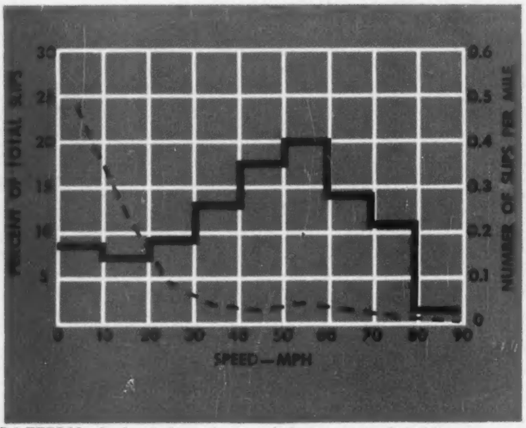
You are familiar with the slipping of wheels that sometimes takes place when a train is starting or pulling hard at low speeds. And for many years we thought that locomotives with electric drive would not slip at high speeds. Our reason for thinking this was based on the fact that the torque of a traction motor falls off as its speed increases. For instance, a typical diesel-electric freight locomotive develops about 60,000 pounds starting tractive effort before the wheels slip. At 50 mph the torque of the motors is one-sixth of the starting torque. At 50 mph, therefore, wheel slip could start only if the coefficient of friction were reduced from 25 to around 4 percent.

High-speed Slip

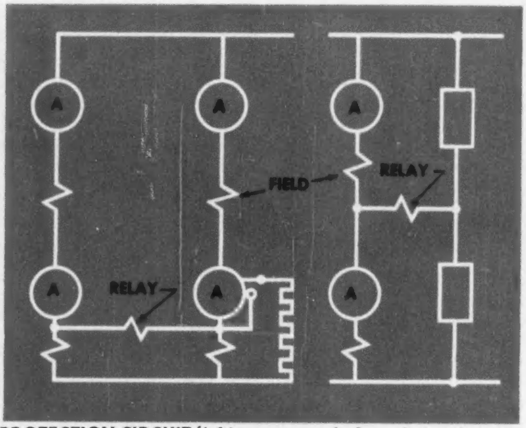
But as more and more diesel-electric locomotives went into service, the more and more we became convinced that high-speed wheel slip was taking place, even though the tractive effort did fall off.

To further investigate this problem, we equipped an Alco-GE passenger locomotive with speed recorders connected to all axles. A study of the recorder tapes showed that wheel slip *did* occur over the entire speed range, but that most slip occurred between 40 and 60 mph (curve, page 14). Analyzing these results, we find that wheel slips under 20 mph occur because the motor torque is high, and small changes in rail conditions cause slipping to start. As the speed increases, the riding qualities of the trucks become more important. In this medium-speed range, irregularities in the track and variable operation of the truck springs and equalizers will momentarily take weight off an axle and slipping will start. But as high speed is reached, the falling off of motor torque cuts down the frequency of wheel slip.

Most of the mileage during this test was at speeds of 50 mph and higher. Even though fewer slips per mile occur at high speed, it is logical to expect a



PATTERN of wheel slips observed during tests. Solid line is percent of total slips; dotted line number of slips per mile



PROTECTION CIRCUIT *(left)* measures unbalance in traction motor current. Other circuit measures differential armature voltage

greater percentage of slips in this region. This particular locomotive did most of its mountain climbing at 40 to 60 mph, a fact that helps to account for the high percentage of slips in this speed range.

How Slip Starts

One way of starting wheel slip is to reduce the coefficient of friction between the wheel and the rail. Water, oil, insects, or wet leaves will do the job.

Another way to start slip is to take weight off the motored axle. This doesn't happen much at low speeds, but it becomes more pronounced as speed increases. Rough track and switches accent the problem. Truck equalizers are supposed to distribute weight evenly on all axles. But if they're not free or if the truck springs are highly damped, the dynamic weight distribution, especially at high speeds, will be variable—the wheels literally "dance" on the rails—with an increase in the frequency of wheel slip.

At low speed we find that the leading axle in a truck is usually the most slippery, regardless of how we design the truck. A minor reason is that the leading axle has the job of clearing the rails of foreign matter. But the most important cause is weight shift that makes the leading axle the lightest axle. Weight shift is caused by the turning couple that exists when the locomotive is pulling. The drawbar, which exerts a backward force on the locomotive, is higher than the point of contact of wheel and rail where the equal and opposite reaction is exerted. The moment formed by this couple is balanced by a weight shift that takes weight off the leading axle and adds it to the rear one. A familiar example is the way the rear end of an automobile sinks down during rapid pick-up. (In this case, of course, the couple is formed by the mass of the car being higher than the wheels.)

The very nature of the design of locomotive wheels is another factor that causes wheel slip. They are constructed with a conical section on the wheel tread. This permits the wheels on an axle to center themselves between the rails and prevents "nosing" or back-and-forth movement between the rails. When the axle moves from the "center" position, there is a shift in the line of contact between the wheels and rails. This means that there is a difference in diameter between the two wheels where they meet the rails. Whenever this condition exists, one of the wheels must slip slightly because, obviously, they both must move the same distance forward. Hence, there is always a small amount of slipping whenever this centering action takes place. It is therefore logical to assume that the coefficient of friction of the locomotive in motion is lower than that at standstill.

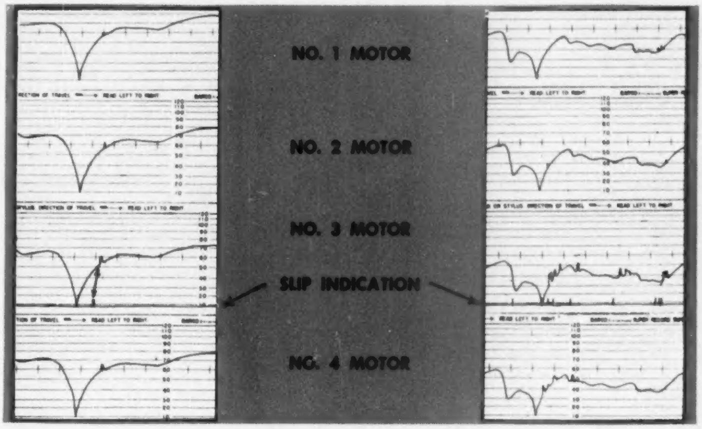
Method of Detecting Slip

The most common method of detecting wheel slip is to measure the voltage or current balance between traction motors. Unfortunately, the two much-used schemes of detecting unbalance for d-c series-type traction motors (diagram above) have several disadvantages.

The scheme that measures unbalance in traction motor current decreases in sensitivity at high speed. As the speed increases, the traction motor current drops. The relay, however, must operate on a fixed differential in motor current. This means that the speed differential between motors necessary to produce the required relay current is greater at high speed than at low speed, because motor amperes per revolution are lower. In addition, traction motor field shunting is used over part of the locomotive speed range, a factor that further reduces the current in the motor fields at high speeds. A further disadvantage of this system is that when a motor is cut out for any reason, wheel-slip protection on the remaining motors is lost, and then the system gives no indication of locked axles in the truck.

The arrangement that measures differential armature voltage has the opposite characteristics because the motor voltage is low at low speed. Since most locomotives change motor connections from series-parallel to parallel at some intermediate speed, it is not possible to use this scheme at high speeds where it has greatest sensitivity. The simplicity and low cost of these systems, however, have resulted in their wide use.

Various schemes of measuring acceleration are used on railroad passenger cars to prevent wheel sliding during braking, and it is often suggested that we use them to detect wheel slip on locomotives. But it's not quite so simple as that. The acceleration rates we encounter in locomotive wheel slip vary



SPEED-DISTANCE curves *(left)* show simultaneous wheel slip of all motored axles. Curves at right show sustained wheel slip on slippery rails

from about one or two miles per hour per second, up to 18 mph per second. Passenger car wheels, on the other hand, usually start sliding at a higher rate of deceleration. There is also the possibility that wheel slip may become stabilized at some value above locomotive speed, or that a locomotive may start with a locked axle. In either case there would be no acceleration to measure.

From the foregoing we can come to the conclusion that a comparison of axle velocities is necessary for adequate wheel-slip protection. Working on this premise, we recently developed a new system that has successfully passed initial tests. Its operation is based upon comparison of voltages that are proportional to the speed of the axles being protected. A time-delay relay provides protection against abnormal conditions, such as a locked axle. An additional feature is the provision of wheel-slip indication during dynamic braking.

Slip Correction

We can correct wheel slip in several ways. The one method almost universally used on diesel-electric locomotives in this country is to remove or reduce the traction generator excitation. A second method, proposed by a Swiss locomotive builder, is to make a light air-brake application.

During early experiments we did completely remove excitation from the generator, but we found that the sudden reapplication of the generator power was very likely to start a second wheel slip. It was apparent that it was necessary to control the rate at which power is reapplied. In our new system, excitation on the main generator is reduced to a point low enough to stop any normal wheel slip, but when the power is restored, it is restored gradually with a time lag of about half a second.

The scheme that involves a light automatic application of air brakes following a wheel-slip signal has not been tried in the United States. Our friends overseas claim that this method permits the locomotive to maintain higher average tractive effort under very slippery rail conditions, and sometimes even eliminates the need of sand. A light brake application, furthermore, does not completely kill the motor torque as does removal of generator excitation. The braking effect provides sufficient drag to slow the slipping wheel enough so that it will again lock in step with the rail. We feel however that this sytem is inherently slow as compared to the other.

WHEEL-SLIP protective equipment is one of the projects the author is working on in the Control Engineering Division of the Locomotive and Car Equipment Department, Erie. Mr. Smith is a graduate of GE's Creative Engineering Program and the Engineering Analysis Course

Simultaneous Slip

Another interesting fact we discovered during our locomotive tests was that simultaneous wheel slip of two or more motored axles is quite common. Actually, in 14 percent of all the cases we recorded, all four motored axles slipped. The charts (left) show sections of speed recorder tapes for each motored axle on the test locomotive.

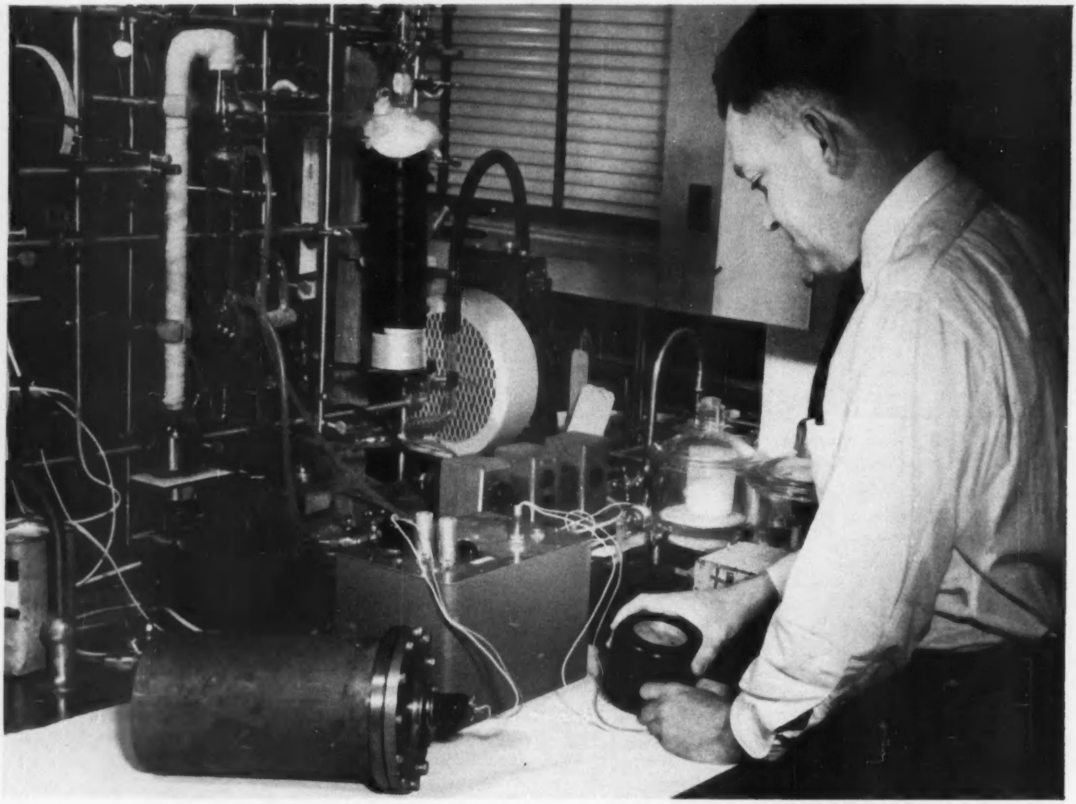
As a further test, we took oscillograms of the acceleration rate of several slips that occurred at high speed. With a measure of acceleration and motor torque it was possible for us to compute the coefficient of friction—it was found to be 1¾ percent for the worst case.

A close inspection of the original speed-recorder tapes (left, above) showed that the axles started slipping in a 1–2–3–4 sequence. The first axle reached the highest speed because it started slipping first. It was immediately detected and corrected by the new wheel-slip equipment on which we were conducting tests.

Speed Reference Necessary

These charts also point out the necessity of having some sort of a speed reference for any wheel-slip detection apparatus. Diesel-electric locomotives fitted with three-axle trucks usually have one idle axle per truck, which can be used for a speed reference. Locomotives with all axles motored present a different problem. A good wheel-slip detection system for use on such locomotives would probably have to be train-lined between the several units making up the complete locomotive so that we could get a satisfactory speed reference.

Both railroads and locomotive builders recognize the need for improved means of detecting and correcting wheel slip, particularly on passenger locomotives. It would help reduce motor maintenance costs and make for better operating locomotives. The system described shows promising results on field tests, and we expect widespread applications as soon as it is available commercially. Ω



AUTHOR WITH ION CHAMBER OF THE TYPE THAT PROMISES SUPERIOR RESULTS FOR RADIOCARBON MEASUREMENTS. IT'S A MEANS OF . . .

Measuring Low-level Radioactivity

By DR. DAVID L. DOUGLAS

The chattering of Geiger counters is being "heard" with increasing frequency in the literature of today, both technical and popular. Parading across your TV screens are white-clad figures cautiously measuring traces of lethal radioactivity in the dust of atomized areas. And more and more radioactive tracers are being used in agriculture and industry for various purposes. Recently there has been a flurry of excitement over radiocarbon dating—a technique that determines the age of archaeological and anthropological relics by measuring the amount of radioactive carbon that they contain.

All these developments depend on the measurement of radioactivity. Are there any new ideas in the field of low-level radioactivity? (Low-level radioactivity involves activities that are a thousand times below the lowest working level used in the average radiochemical laboratory.) What type of instruments are used and how sensitive are they? What is the lowest level of radioactivity they can detect?

But before we get into the instruments and techniques for measuring low-level radioactivity, let's take a look at the story behind radiocarbon dating, first in regard to the origin of . . .

Carbon-14

How is carbon-14 formed? The mechanics are straightforward: High-energy cosmic rays are always bombarding the earth's atmosphere, and for all practical purposes always have been. Reacting with the nuclei of air atoms they produce neutrons, among other things. The neutrons go careening off and finally slow down enough to react with nitrogen-14 nuclei. The result is a carbon-14 atom and a hydrogen atom. The oxygen in the air then attacks the carbon-14 atom and carbon-14 dioxide is formed; winds assure that the carbon-14 dioxide is well mixed with ordinary carbon dioxide in the air.

What happens to this carbon-14 dioxide that is being produced continuously in the atmosphere? For one thing it is absorbed by plants, trees, and all living vegetation. Animals and humans eat the plants, as well as the radiocarbon in the plants, thus building up a store of carbon-14 in their tissues. All this leads to the technique of . . .

Radiocarbon Dating

A dog dies and ceases to take in any more carbon. Five thousand years later an anthropologist discovers a bone fragment of the beast that somehow has been preserved. A carbon-14 measurement is made of the bone fragment (after proper preparation) and the scientist says that Fido was happily romping some 5000 years ago.

How did the scientist know? As soon as the dog died, its store of carbon-14 atoms began to disappear at a uniform rate—only one-half of the original store of radiocarbon remains after 5568 ±30 years (the half-life of carbon-14). It was an easy matter for the scientist to determine the age of the bone fragment by noting the amount of radioactivity that remained.

But don't you need a reference point from which you can hang this entire concept of radiocarbon dating? By all means, and the answer to that question illustrates the nicety of the theory.

We know that the rate of formation of carbon-14 has been constant since the beginning of time (it's based on the fact that cosmic-ray intensity has also been constant). And because the rate of formation of carbon-14 has been uniform for several times its half-life, a steady-state condition must have been reached. As a result of this steady-state condition, the total number of carbon-14 atoms formed in the atmosphere per unit time is equal to the total number decaying over the entire earth in the same period of time. Therefore, our reference point obviously must be the amount of carbon-14 that is contained in living carbon—carbon that exists right now.

Now that we have our reference point, it follows that a time-scale can be definitely established by taking the difference between carbon-14 activity in living carbon, and a sample X number of years old. Translating the difference into years is a simple matter.

Therefore, the two important aspects of natural radiocarbon distribution are: 1) the concentration of carbon-14 is the same in all living organisms—dog or dogwood tree; and 2) our dogs of today, for example, have exactly the same concentration of carbon-14 in their tissues as their canine counterparts of 5000 years ago.

Thus we have formed the structure upon which the theory of radiocarbon dating is built, a field that was pioneered by Prof. Willard F. Libby of the University of Chicago's Institute of Nuclear Studies.

Libby checked many of his results against samples of known age, such as Egyptian relics whose vintage was accurately known. The agreement between the radiocarbon dates and the known ages was excellent; the method was thus proved for ages up to 5000 years. In all, Libby and his associates have dated some hundreds of specimens with the results ranging up to about 17,000 years. Beyond this figure only a lower limit may be set.

The next and obvious question about radiocarbon dating is, "How far back in the past will the method take us?" But it's a question we'll have to defer until we find out something about the measuring of low-level radiation. (It should be mentioned however that carbon of geological origin, such as coal and oil, is so enormously antique that no trace whatever of radioactive carbon will be left.)

Carbon-14 in Living Carbon

There are two methods of estimating the carbon-14 content of contemporary carbon. One we needn't bother with, but the other involves measuring the radioactivity of a sample of carbon that has been carefully purified. Measuring the sample should be a simple task, but the low energy of the radiation emitted by the decaying carbon-14 atom complicates matters a great deal.

If a gram of pure carbon is spread uniformly over an area about the size of a playing card, there will be less than one particle per minute emitted from the surface. Because the counting rate decreases in direct proportion to the area, making the area smaller won't speed the process. Larger areas give larger counting rates but the rate is no longer independent of the thickness of the layer, a situation that makes things even more complex. (Later we shall see how the counting problem is solved.)

The result of such measurements gives 15 disintegrations per minute per gram as the specific activity of living carbon. This figure is in excellent agreement with results of the other method.

•

Dr. Douglas joined the staff of the Chemistry Section of the Knolls Atomic Power Laboratory at Schenectady, in October 1951, and is at this time engaged in nuclear chemical research. Prior to coming to General Electric he was a research fellow in chemistry at the California Institute of Technology where he worked on the application of ion chambers to low-level carbon-14 analysis.

Background Radioactivity

One thing that makes low-level measuring techniques so difficult is the ever-present nuisance of background radioactivity.

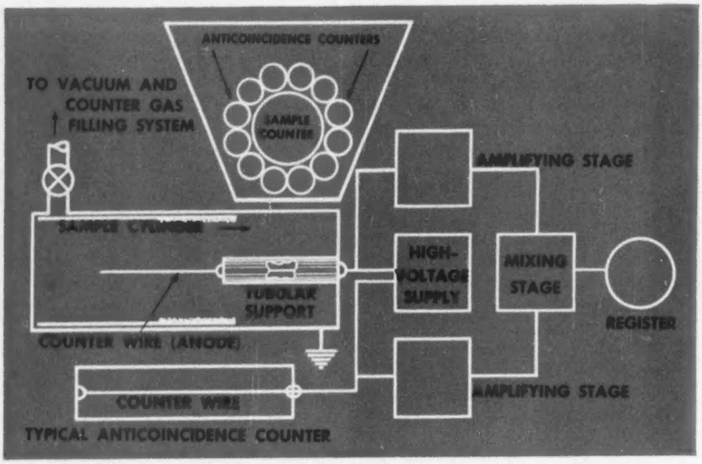
If you operate a typical Geiger counter in an area that contains no collection of radioactive materials, it still will register about 100 counts per minute. This results from background radiation and the counting rate is simply called the "background."

The particles (or rays) that make up this count are: 1) cosmic-ray mesons; 2) gamma rays emitted by the small amounts of naturally occurring radioactive elements (uranium and thorium and their decay products) that contaminate all materials such as wood, concrete, and metals; and 3) alpha particles, emitted from the same source as in 2, that are contained in the counter's materials of construction.

The alpha particles are unimportant, and four inches of lead around a Geiger counter will cut the gamma rays to about one-half of one percent of the unshielded value. By going deep into the earth you can escape the endless rain of cosmic rays. And exhaustive chemical purification will remove the last traces of radioactive materials that contaminate the materials from which your counter is built.

But regardless where you go or what you do you're going to get *some* background radiation.

Building a midget Geiger counter, it is true, will reduce the background count, but such a counter is of no use when you're working with samples of low activity. In fact, for low-level measurements a king-size counter is needed to get a significant counting rate. But the larger the counter the larger the



ANTICOINCIDENCE SHIELDING on Geiger counter helps reduce background level. To count background the sample cylinder is slid in the direction of the arrow so that the bare portion of the sample cylinder surrounds the counter wire

background; clearly the beginning of a vicious cycle.

How do we keep the counter a rational size and still reduce the background enough so that we can successfully do low-level work? One method used with Geiger counters is called . . .

Anticoincidence Shielding

The method is amazingly simple—the counter is merely surrounded by a ring of counters, and the circuits are so arranged that counts that occur simultaneously in one or more of the peripheral counters and the center counter are not registered (diagram above).

Libby and several other workers are using just such a counter for measuring the carbon-14 activity in samples ranging in age from zero to more than 15,000 years. The tube where the samples are placed is three inches in diameter and the shielding consists of eight inches of iron plus two inches of lead, in addition to the anticoincidence counters. The results are gratifying—the background changes from an unshielded 400 to 500 counts a minute to six to seven counts a minute!

For living carbon, the sample counting rate is about six per minute. To measure the counting rate of a sample with a statistical error (the standard deviation is commonly used) of 10 percent, a 48-hour count is required. The long counting time (divided about equally between sample counting and background counting) is necessary because of the low counting rate—the error in a given number of counts is proportional to its square root. A further reduction of the background would help a little by shortening the required counting time, but even with no background rate some 30 hours would be required for an error of one percent. Despite the handicap of the long counting times, Libby and his colleagues have dated hundreds of archaeological and anthropological relics.

Unfortunately, long counting times will always be necessary as long as one is restricted to Geiger counters because you can refine them just so far. In the field of low-level techniques, a Geiger counter is like a high-power microscope; by the very nature of its design you can make it just so powerful. After that you've got to shift to something of an entirely different design, perhaps an electron microscope.

One of the difficulties of the Geiger-counter technique is that the samples must be in a solid state. And it is interesting to note that only some five percent of the total number of beta particles emitted by carbon-14 penetrate the carbon layer and register as counts. If the solid carbon could be converted easily to some gaseous compound which could then be used as a sample, much greater counting efficiencies would result. But the only gases that can be prepared with any ease are carbon monoxide and carbon dioxide, and Geiger counters cannot tolerate appreciable pressures of either gas. Methane is an ideal gas, but it's difficult to prepare on a routine basis.

One device that shows great promise for low-level techniques is the . . .

Ionization Chamber

In an ion chamber an electric field separates the ions produced when the particles pass through the gas that fills the chamber. Ions of one sign (positive or negative) are collected on one of the electrodes. The amount of charge collected is then measured with an electroscope or electrometer and is a measure of the quantity of radioactivity present.

About three years ago the author, acting on a suggestion of Prof. H. V. Neher of the California Institute of Technology, Pasadena, began an investigation of the possible use of ionization chambers for the measurement of low-level carbon-14. The research that will be described was performed in the Gates and Crellin Laboratories of Chemistry at Cal Tech under the auspices of the U.S. Atomic Energy Commission.

It appeared to us that if we used carbon dioxide gas in a high-pressure chamber, we could introduce a large radioactive sample without an undue increase in background. Our rough calculations showed us that we could expect an ionization current of 7×10^{-16} amp from a 10-gram sample of carbon (converted to carbon dioxide). Clearly, the detection of such minute currents would require a special technique. In fact, it is virtually impossible to pass such a current through conductors that are in contact with insulators of any kind, because the current will be swamped by the strain currents caused by stresses in the insulators. Another hindrance is leakage currents that are about the same size, and sometimes larger, than the current we were trying to measure.

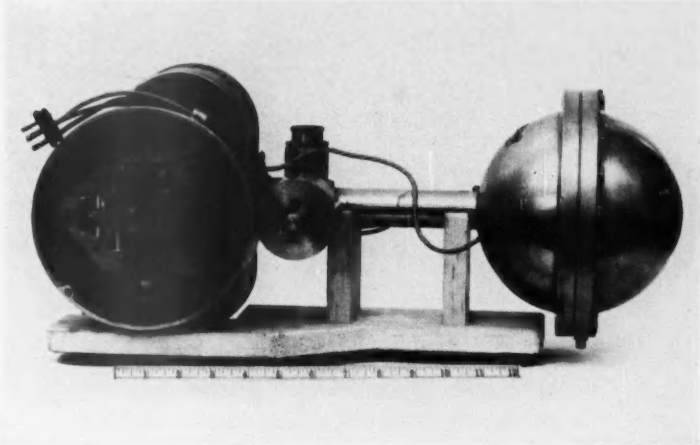
We decided that the only way to measure such small currents was to use a sensitive electroscope system. Fortunately, instruments containing such systems were available in the form of cosmic-ray ion chambers (photograph on opposite page). The spherical chamber has a capacity of 0.8 liters and contains a quartz torsion-fiber electroscope that has a capacitance of 0.6 ± 0.1 cm (0.66×10^{-12} farads). The recording is photographic and we were able to detect currents in the order of 1×10^{-17} amp which is just ample for low-level techniques.

But even these devices are by no means perfect; we still had to contend with background. Four inches of lead helped to reduce the gamma-ray contribution to insignificant proportions, and alpha emission from the walls of the device was reduced somewhat by the classical method of applying a thick layer of lampblack.

The cosmic-ray contribution to the background posed a problem because the only way we could eliminate it was to locate the instrument under a large mass of earth, water, or concrete. Fortunately, two suitable locations were available in the Pasadena area. The first was a large pit about 90 feet below the earth's surface on the Cal Tech campus that proved to be convenient for our work. Cosmic-ray intensity was reduced by 90 percent. The other site was one of the lower galleries in Morris Dam, a considerable concrete structure about 20 miles away. Here the cosmic-ray background was reduced to about one percent of normal value.

Over a two-year period we exhaustively tested the cosmic-ray instruments and various techniques of sample preparation. We did two experiments to verify Libby's estimate of 15.3 disintegrations per minute per gram as the specific activity of living carbon. Our results were 14.5 and 14.8, which we considered to be in good agreement with Libby's value.

But all during our tests the presence of background proved to be a headache. True, the effect due to the carbon-14 in living carbon was easily detected; but the sample effect to background ratios was disappointing—0.26 in the pit and 0.61 in Morris Dam. (A figure of 1.0 would be equivalent to that obtained with the anticoincidence-shielded Geiger counter.) We came to the conclusion that the alpha-particle background was still very high. Separate experiments indicated that well over 90 percent of the background observed in Morris Dam was caused by alpha particles emitted from the walls of the ion chamber. We measured the rate of emission and found that it was several times that of the best surfaces reported by other investigators. But preparing a surface that is substantially free of alpha emission is not a simple problem. Even clean steel, perhaps the best surface, emits at a rate of about one alpha particle per square



IONIZATION CHAMBER, of the type used for cosmic-ray study, was used by researchers for measuring low-level radiation. Spherical chamber is at right, recording camera is at left. This equipment was a forerunner of the type shown on page 20

centimeter per day. So in attacking this problem we took a direct approach—ion chambers were built in which the outer conductor (or wall) consisted of a grid of fine steel wires. Immediately we noticed a reduction of about 98 percent.

We also made another important design change in the new ion chambers. The torsion electroscopes are sensitive and difficult to build. Also, the photographic method of recording the phenomena is not the most convenient. A new type of electroscope, developed by Professor Neher, was used. This system measures the time required to neutralize a certain amount of charge on the collecting electrode, a factor that makes it easily adaptable to automatic recording. A schematic diagram and description of this latest model ion chamber and recording system is shown on page 20. At the present time final tests are being made on this instrument and the results so far indicate that the alpha-particle problem has been conquered. For instance, sample-to-background ratio of 0.45 was observed in the pit, a result that promises a ratio of five or more in Morris Dam. It is also possible that the circuits will be altered to shorten the discharge intervals so that such long counting times will not be required. (At the present time reliable dating can be done only in the dam, and a two-day count is required to reduce the statistical error to 10 percent.)

We are confident that this new device will soon prove to be quite superior to the Geiger counter for measuring low-level radiocarbon.

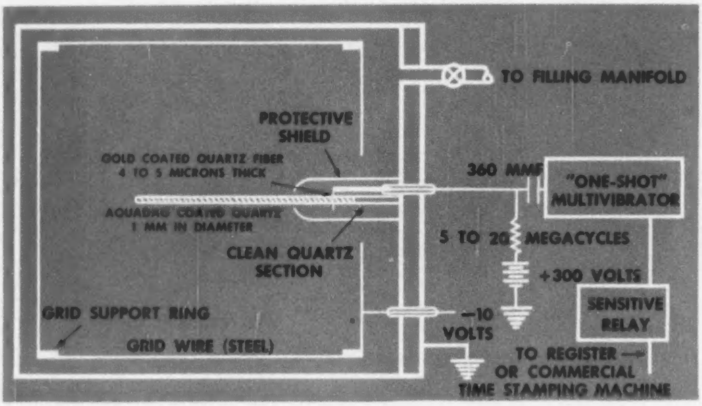
Two other instruments have possible applications in the field of low-level radioactivity measurements: One is the proportional counter which is a modified Geiger counter; the second is a pulse ion chamber with pulse height discrimination circuits. Both these devices possess the advantage in that they could be operated with anticoincidence shielding; but because the electronics involved is extremely complex, it is doubtful whether either one will find use outside the laboratory.

Dating with Ion Chambers

Although the greater majority of the work on the new ion chambers has been developmental, a few relics have been dated.

One sample was collected from one of the ruins in the Southwest by Harold Gladwin, noted anthropologist of Santa Barbara, Calif. By means of his tree-ring dating method, Gladwin established the average age of the sample as 1830 years. Two determinations on this sample yielded 2005 ± 370 years as the age by our ion-chamber technique. We considered this agreement satisfactory; the large error reflected the excessive statistical fluctuations because of the large alpha-particle contribution to the background.

CONTINUED ON NEXT PAGE



RECORDING ION CHAMBER, similar to one on page 16, uses high-pressure gas to stop alpha particles. In operation the quartz fiber conducts charge to the quartz collecting electrode. Immediately after the rod is charged, the fiber is repelled by electrostatic forces. As the negative ions are collected, and the charge on the collector thereby reduced, the fiber gradually approaches the rod. At some point in this process the "image-forces" predominate and the fiber is attracted to the rod, thus recharging it. This produces a pulse that actuates the register

The other relic dated was a sample of wood from the La Brea Tar Pit in Los Angeles. It was supplied by the late Prof. Chester Stock of the California Institute of Technology and was presumed to be contemporaneous with the sabre-toothed tigers and Dire wolves, remains of which abound in the tar. Two separate measurements gave us 16,250 ±2000 and 16,400 ±2000 as the age of the wood. We believe this result is noteworthy in that it marks the first estimate, with any claims to reliability, of the age of the late Pleistocene beasts.

In answering the question, "How far back in the past will radiocarbon dating take us?" our best estimate is about 20,000 years, using present instruments. If the instruments are refined further we may be able to reach back to 30,000 years, which would be the limit because of the small amount of activity.

Preparation of Samples

Although the instrumentation is critical, preparation of samples figures heavily into the end results. The chemical treatment necessary to assure radiochemical purity of the carbon or carbon dioxide samples is vitally important. You can appreciate that the chemistry *is* important when you consider that the radium content of wood (in terms of radioactivity) varies over the range of one to one hundred times the carbon-14 content. Another source of naturally occurring radioactivity in organic material is the ever-present potassium. This too will average many times the carbon-14 activity.

Basically, the sample is burned to carbon dioxide which is further purified by chemical scrubbers and repeated distillations in a vacuum system. After further chemical treatment the gas is either reduced to carbon or stored as a gas in small steel cylinders. One other precaution is always necessary in that the samples must be kept away from contact with air for any extended periods, because the air contains enough radon and thoron to contaminate the solid samples. It is necessary to maintain the same precautions with instrument surfaces that are exposed to the counting volume.

Other Applications

At the present time practically all emphasis on the use of low-level techniques has been in the field of radiocarbon dating. Other applications are possible.

For instance, the field of biology offers numerous applications. The usual tracer experiment involves administering small amounts of radioactivity to the plant or animal subject. But a problem arises because the plant or animal concerned is in reality quite a large reservoir of the actual element that has been labeled with radioactivity. (This is particularly true of carbon.) Large amounts of the radioactive material must therefore be used if *ordinary* counting techniques are employed. This may be fatal to the subject. Use of low-level counting apparatus would eliminate all such incidents.

Another application involves fertilizers. They can be loaded with very small amounts of radioactive ingredients, and the course of these tracers in plants can be followed with no danger to the scientists or innocent bystanders. Note that we can measure levels of activity well below those normally present, as radium and potassium, in living matter. The door is now open for biological tracer experiments on a grand scale without the use of potentially dangerous amounts of radioactivity.

In the various fields of engineering there are probably many applications of these low-level techniques. Chemical and metallurgical engineers will be able to include very small amounts of radioactive isotopes during the production of chemicals or alloys and will be able to check the final product by measuring the activity. The amount of activity used will be well below those that would be dangerous to users of the material.

A large-scale experiment now possible is the determination of the exact size of oil and natural gas pools in the earth by isotopic dilution. A small amount of the appropriate compound tagged to high specific activity with carbon-14 injected into the pool will be diluted by the oil or gas. A determination of the specific activity of the compound after mixing will give a good measure of the size of the oil or gas reservoir.

Libby has used this apparatus in the successful search for naturally occurring isotopes with such long half lives that they had been reported as stable by previous investigators. This is the only sure way to identify such activities, but we must mention that this is a field that is nearly exhausted. A closely associated field of research that may well benefit by the use of low-level techniques is the production of radioactive isotopes in low yield by high-energy machines such as synchrotrons and bevatrons. It is a lamentable fact that as one increases the particle energy, one is forced to accept a smaller "particle" output. Quite possibly low-level measurements will extend the useful results that can be obtained with high-energy particle accelerators.

The future is indeed bright for low-level radioactivity techniques. Ω

AMPLIFICATION PROPERTIES AND SMALL POWER REQUIREMENTS OF TRANSISTORS MAKE THEM A NATURAL FOR USE IN MANY ELECTRONIC DEVICES

Germanium Transistors

By DR. JOHN S. SABY

A new field of electronics is being created by the transistor, a three-element control device that utilizes a small current to control a larger one. Unlike vacuum tubes, with which you are more familiar, transistors require no heated filament for their operation. They're extremely small in size (above) and can operate effectively using power supply voltages as low as a few tenths of a volt.

The transistor was born several years ago. It was discovered then that current through a "cat whisker" (or wire—the term is borrowed from the crystal radio set of your boyhood) in contact with a piece of germanium could be changed by passing a smaller current through another nearby cat whisker. In fact, voltage, current, and power amplification could all be achieved with this simple device consisting only of a small germanium wafer and two pointed wires. Nevertheless the *point contact* transistor, as it is called, isn't so simple as you might expect. Actually, it's not yet as well understood as the P-N junction transistor—a much more recent development.

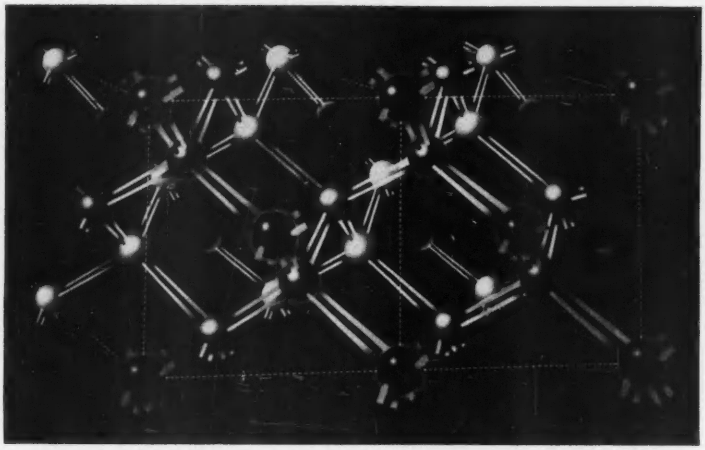
Semiconductor Fundamentals

Transistors are composed of semiconductors. Semiconductors are neither good conductors—like metals, which have a large number of free electrons: nor good insulators—like quartz, in which virtually all the electrons are tied up in interatomic bonds. If the atomic bonds of a substance are easily broken and a noticeable amount of conduction occurs at room temperature, we call that substance a semiconductor.

Germanium, one of the most important semiconductors, has four outer valence electrons on each atom. In the germanium diamond cubic crystal-lattice shown on the next page, each atom is joined to its four nearest neighbors by shared-pair atomic bonds requiring four electrons per atom. All four of the element's outer electrons are tied up by these bonds. Germanium would be an insulator except for one fact: these bonds are easily broken by thermal agitation—so that even at room temperature there is approximately one free electron for every ten billion germanium atoms. Small as this number may seem, there are sufficient atoms in a tiny bit of germanium to enable it to conduct heavy currents. Germanium therefore is not an insulator.

Of greater importance than temperature effects is conduction caused by impurities in germanium. Atoms with five valence electrons—such as phosphorus, arsenic, and antimony—can enter the crystal-lattice in place of germanium atoms. Here four of the five electrons will enter the interatomic bonds, the fifth electron being bound by only the slight electric charge on the nucleus. At room temperature, thermal agitation is sufficient to free these extra electrons so that they can wander through the lattice and conduct electricity. This is called N-type conduction (N for negative). Because they provide conduction electrons, the impurities are called *donors*.

On the other hand, atoms with only three valence electrons—such as boron, aluminum, gallium, and indium—can also enter the lattice. Around each of these the structure will be locally incomplete, forming a *trap* for one more electron. An electron from a nearby bond can then jump into this trap, leaving a vacancy, or *hole*, behind. Still another electron can migrate into the resulting vacancy, and so on with the process. By actual migration of electrons, the hole effectively wanders about the lattice and in so doing conducts electricity. This is called P-type conduction (P for positive) because the holes behave like positive charges (their apparent motion is in a direction opposite to that of the electrons). Impurities that can trap electrons are called *acceptors*.



IMPURITIES DETERMINE CONDUCTION THROUGH GERMANIUM'S DIAMOND CUBIC LATTICE

P-N Junction

When conduction is principally by electrons, a semiconductor is called N type; when it's principally by holes, it is called P type. However, N type and P type can and do occur in the same crystal. If they do, the junction between the N type and P type is called a P-N junction.

A P-N junction has the distinctive property that an electric current flows through it in one direction with ease—but only with great difficulty in the other direction. In other words, a P-N junction is a rectifier, and the mechanism of its action is what has made possible the transistor. Fig. 1 is a diagrammatic sketch of a P-N junction.

Referring to the figure, if the P region is made positive and the N region negative, holes and electrons are driven toward each other and recombine, each electron filling up one hole. The voltage need be only enough to keep this current going. This is the easy-flow, or forward, direction. If the P-type region is rich in acceptors while the N-type region has relatively few donors (so that there are few conduction electrons), most of the current crossing the junction is in the form of holes *injected* into the N-type region.

If we next connect the junction in the opposite, or inverse polarity, the electrons and holes move away from each other. The region close to the junction therefore has its conduction electrons and holes removed, thereby becoming an insulator. Such a region is called the *barrier layer*. The term barrier may mislead you a bit if it conjures up a mental image of a high wall or mountain in the path of the conduction charges. Actually the region is a temporary insulator only by virtue of the absence of holes and electrons.

An inversely biased P-N junction however will conduct electricity in the inverse direction if carriers are introduced. One way to do this is to heat the germanium so that bonds are thermally broken, supplying conduction electrons and holes. Another method is to shine light on the P-N junction—the light quanta releasing conduction electrons and holes. A whole family of photocells has come into being based on this phenomenon (refer to Dr. W. C. Dunlap's article in the March 1952 REVIEW).

Transistor Operation

Increasing the current through the barrier layer of a P-N junction can be accomplished by injecting carriers through another nearby P-N junction. This process, leading directly to the transistor, is shown in Fig. 2A. Here there are two P-type regions separated by an N-type region, resulting in two P-N junctions arranged back to back. If the right-hand junction, or collector, is biased with inverse polarity, then little current flows through the barrier region into the collector. At the same time, passing current through the left-hand junction, or emitter, in the forward direction causes holes to be injected into the N-type base region. Some of them will recombine with the available electrons, but many will diffuse across the base region and into the barrier layer. By virtue of these injected holes, the barrier layer ceases to be an insulator, and current flows as the positive holes are attracted toward the negatively biased collector. As you can see, a change in emitter current produces a change in the collector current.

A transistor of this type is called a P-N-P transistor because of the order of the ingredients in its germanium sandwich. The so-called N-P-N transistor works in an analogous manner as shown by Fig. 2B. Here you'll note that the bias polarities are reversed. The reason is that the N-P-N emitter injects electrons that travel through the P-type base and are collected by the positively biased collector. Presence of both types of transistors in the same circuit gives

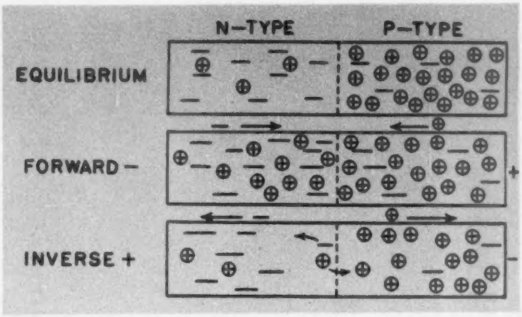


FIG. 1. P-N JUNCTION IN GERMANIUM CRYSTAL IS A RECTIFIER

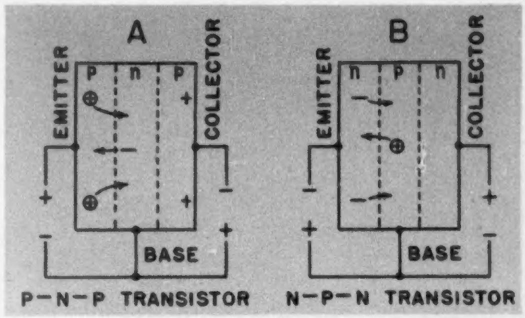


FIG. 2. TRANSISTOR COMPRISES TWO ADJACENT P-N JUNCTIONS

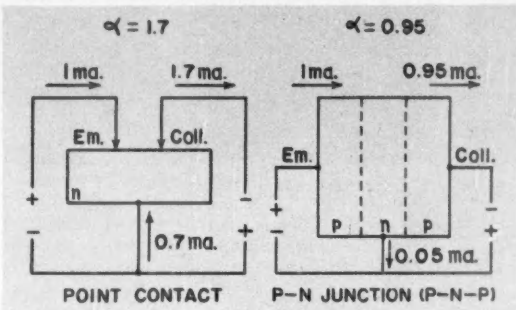


FIG. 3. COMPARISON OF TWO KINDS OF TRANSISTOR OPERATION

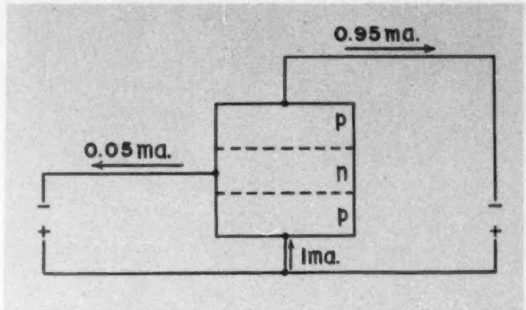


FIG. 4. JUNCTION TRANSISTOR UTILIZES SMALL BASE CURRENT

rise to a rich variety of possible applications. This situation is comparable to the imaginary state of affairs that would exist if vacuum tubes were also available to operate with negative plate-voltage—in addition to present operation with positive plate-voltage.

Junction vs Point Contact

Next, let's compare the junction transistor with the point-contact transistor mentioned earlier. In both cases, as shown in Fig. 3, the emitter injects holes into an N-type base; and in both cases, holes are collected by a negatively biased collector. The point-contact transistor usually collects more holes than were emitted, however. It has a physical multiplying mechanism (only partially understood) resulting in current amplification. That is, the current amplification factor—alpha—is greater than unity. Although this sort of amplification is an advantage in switching-circuits, such as used in computers, it often leads to instability in amplifier circuits of the hearing-aid variety. At present, point-contact devices are usable at higher frequencies than junction devices. They're noisier than the junction transistor however and are limited to uses requiring relatively small currents.

High current gain can be achieved in a junction transistor if alpha is close to unity, as shown in Fig. 4. The base current is small, and to apply the signal to the transistor it is connected as shown. Characteristics of this transistor (alpha is 0.95) are identical to those of Fig. 3. But by using the grounded-emitter connection shown, a current amplification of 19 is attained with the same voltage gain as before. If alpha is 0.99, the current amplification becomes 99. Obviously then, values of alpha close to unity are desirable.

Diffused Junction

Production of transistors always depends on the formation of P-N junctions. We've developed a process for producing P-N junctions at will, whereby donor and acceptor impurities are diffused into the germanium. This process has been further studied and utilized for the fabrication of transistors and rectifiers (for a description of production germanium rectifiers see Trindel J. Ferguson's article in the July 1952 REVIEW). Two P-N junctions are created back to back on opposite faces of a single crystal-slab of germanium, resulting in a P-N-P or N-P-N sandwich comprising a diffused junction transistor. Results used in this article, by the way, were obtained mainly with diffused junction P-N-P transistors.

Flea Power

For many electronic applications—such as the tiny pulses required to transfer information within a computer, or the preliminary amplifier circuits of a radio—only "flea power" is required for the signal itself. The useful signal power may be of the order of microwatts. (A microwatt, incidentally, is the power generated by a flea weighing one milligram and jumping 20 inches high every 5 seconds.) On the other hand, a

•

Dr. Saby joined General Electric in 1951 and is now engaged in research and development on transistors in the Electronics Division at Electronics Park, Syracuse. He is the author of several papers on transistors and is secretary of the IRE Professional Group on Electronic Devices.

TRANSISTOR MEGAPHONE AMPLIFIES NORMAL VOICE TO CHEERLEADER'S YELL

RADIO TRANSMITTER IS DEMONSTRATED BY AUTHOR

vacuum tube can't effectively amplify unless it is consuming a few milliwatts from its plate power supply. In addition, from 20 milliwatts to several watts are required to heat its filament. Yet, the junction transistor actually operates efficiently with a power supply that provides only a few microamperes of current at a few tenths of a volt—literally a flea-power requirement!

This difference may represent only a small power saving for each tube the transistor replaces; nevertheless it's vital to reduce the weight and expense of the power supply, as in hearing aids. Smaller power consumption also permits smaller size electronic gear because there's less heat to get rid of. For example, present components of the average radio could be packed into a much smaller space except that the concentrated heat from the tubes would cause damage. This same situation exists to an even greater degree in large complicated electronic gear, such as computers or airborne equipment, where reduction in size is an important goal.

Reliability

An electronic circuit originally in good operating condition will remain usable only until the first part fails. The greater the number of parts, the shorter the interval between failures. Reliability of the system as a whole is therefore poorer than that of its individual components: and becomes progressively poorer as the number of components increases. An ordinary home radio—an extremely reliable device—can be expected to operate many hundreds of hours between tube failures because the individual tubes have probable lives of a few thousand hours. But an electronic computer requiring thousands of these same tubes would probably operate only a few minutes between interruptions resulting from tube failures. Accordingly, components of extreme reliability are essential to complicated systems, and it's of utmost significance that transistors contain nothing that will wear out. Transistors properly protected from the effects of dirt and humidity have a potentially infinite life.

Power Transistor

Transistors are not limited, however, to operation at low power levels. Successful higher-powered operation at the audio frequencies is achieved with internal power dissipation of several watts. There's no theoretical upper limit to the power level that transistors can hope to reach, but there are practical considerations to contend with.

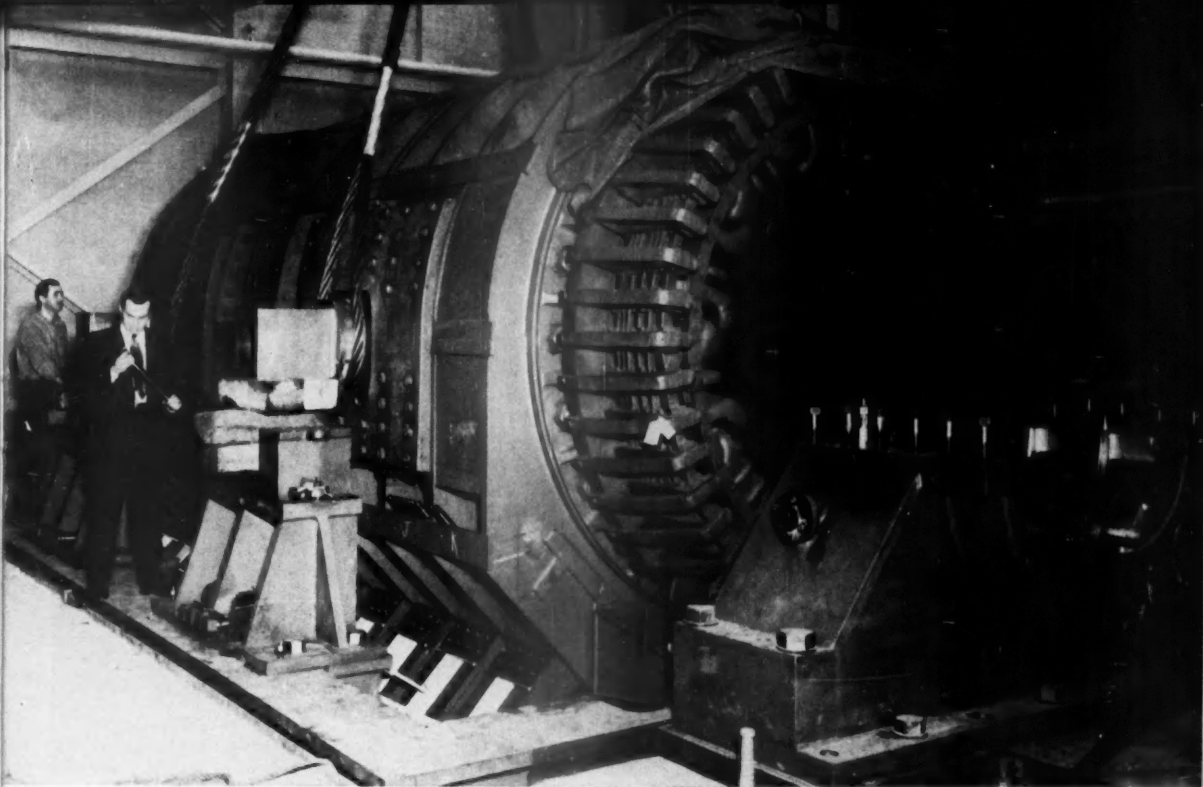
One of these concerns the behavior of junctions at high temperatures, where the holes and electrons liberated by thermal agitation cause large currents to flow that aren't subject to control by the emitter. This thermal leakage current in turn produces more heat that must be removed. Power transistors must therefore be cooled, and the effectiveness of the cooling system sets a practical limitation upon the upper limit of the power level. For example, a junction transistor that would safely dissipate one-half watt in the open air at room temperature could be operated at one watt if air-cooled—and perhaps five watts if cooled by running water. On the other hand, if it were embedded in a large block of plastic, it might only operate safely at approximately one-half of its open-air rating. It now becomes apparent that the power transistor must be packaged in a form large enough to dissipate its rated power—and the final package may be much larger than the transistor itself.

Transistors assembled in sealed envelopes the size of radio tubes were so constructed that, when used in audio amplifiers, they delivered outputs in excess of one watt with low distortion. This is merely a preliminary result but, like the transistor megaphone (above), serves to illustrate developmental results.

Frequency Response

The junction transistor has full gain at the audio frequencies but in its present state of development can operate with usable gain as high as a few megacycles. Point-contact transistors operate at frequencies approximately 10 times as high, and operation above

CONTINUED ON PAGE 60



REINFORCED END WINDINGS AND UNIQUE SUPPORTING STRUCTURE CHARACTERIZE THE WORLD'S LARGEST SHORT-CIRCUIT GENERATORS

Technical Highlights of the Switchgear Laboratory

Following our picture coverage of the new switchgear development laboratory in Philadelphia in the July issue of the REVIEW, we present several articles on technical features of the laboratory by engineers who were closely associated with designing the equipment—EDITORS

SHORT-CIRCUIT GENERATORS

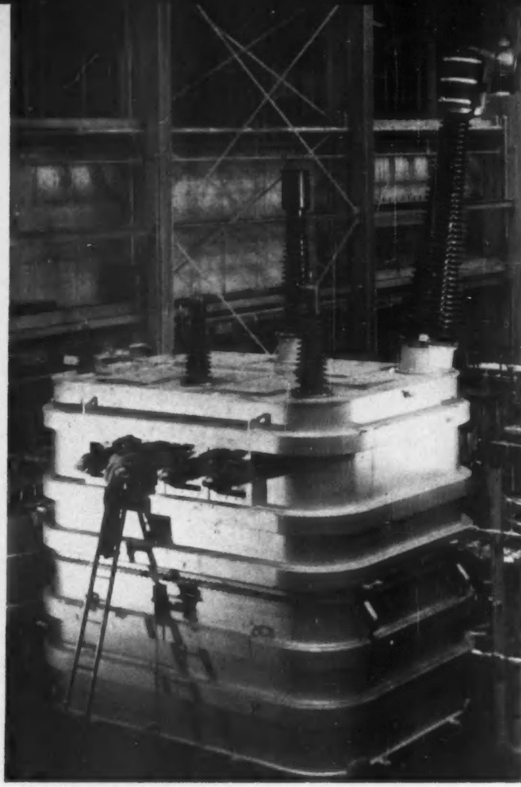
By C. E. KILBOURNE and DEAN HARRINGTON

Two generators installed at the new switchgear development laboratory are the largest short-circuit testing machines in the world. A stator for one of them is shown above.

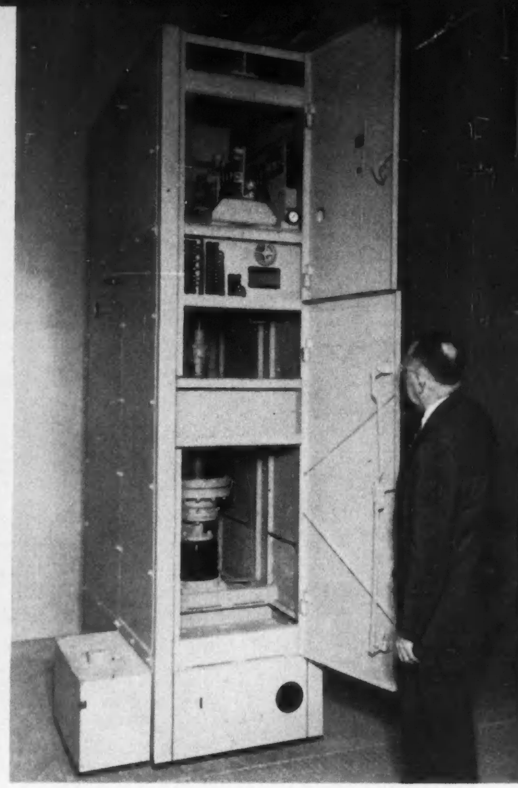
They are designed to furnish the short-circuit current necessary for testing circuit interrupters and developing large power-switching equipment. Alone, each will supply at least 1,625,000 symmetrical rms kva (2,665,000 asymmetrical) at the generator terminals during the first half-cycle of short circuit. Exclusive of power loss in the bus runs, together they will deliver 3,200,000 symmetrical rms kva (5,250,000 asymmetrical) to the test cells—this in the first quarter-cycle of operation, and at a three-phase voltage of 15,500 volts. They have a frame size equivalent to a 4-pole 1800-rpm 60-cycle machine nominally rated 12,500 kva.

New and interesting features were incorporated in the stators, rotors, and mechanical supporting members. For instance, special methods used for blocking the end windings were necessary to prevent the distortion that would otherwise result from tremendous magnetic forces created by the short-circuit currents. Note in the illustration that after the armature bars leave the stator core they are completely encased in helically cut blocking rings—giving them firm support right up to the loop connections. Circuit connections, too, are heavily supported by insulated steel brackets bolted to the end flanges.

Shocks associated with short-circuit testing had to be minimized. They are comparable to those resulting from the firing of a large naval gun. Ordinary spring mounting wouldn't do because the problem was complicated by the wide frequency range (25 to 60 cycles—each range of frequencies producing its own special problems) necessary for the testing schedule. And so an entirely new kind of supporting structure was designed. In the lower left part of the illustration a number of spring-plate assemblies are visible. They are legs (projecting at a 45-degree angle) upon which the stator rests. They point toward the center of the rotor shaft and hold the stator in perfect alignment with the rotor. When the torsional shock of a



SPECIAL TRANSFORMER WITHSTANDS 2800 TONS RADIAL FORCE



SYNCHRONOUS CLOSING OCCURS WITHIN 25 MICROSECONDS

short circuit occurs, the legs bend as huge leaf-springs and allow the stator to move through a small angle.

Two trunnions on each side of the stator carry no weight but move freely with the angular movement of the stator. During a 60-cycle short-circuit test their total movement, or vibration, is almost 3/8 inch, and during a 25-cycle test it is 1 1/4 inches. This is the largest known movement of such a mass under short-circuit conditions. Its very amplitude expends the forces and materially decreases the shock on the foundation, as well as on the stator parts themselves.

For operation at 8 to 12 cycles however, the movement of the stator is blocked by inserting snubbing plates between the trunnions and their supports. At these low frequencies the torque reversals are much slower; consequently, the impact effect is reduced.

Armature windings of each machine have two circuits brought out to separate terminals. With this arrangement, a choice of four three-phase voltages is available: for the wye connection, either 15,500 or 7750 volts; for the delta connection, 8950 or 4475 volts. Grounding one terminal of the wye connection raises the voltage of the other two to 15,500 volts above ground. The windings are therefore insulated for the latter voltage. This requirement places them in the 26,500-volt insulation class—the highest of such machines built in America.

Three factors greatly influenced the physical size of the generators. First of course was the rugged-duty cycle they must endure. Second, the slow decrement, or dropping off, of the short-circuit current—at the end of five electrical cycles the current has approximately 75 percent of its initial value. Third, maintenance of voltage on tested equipment over a four-hour period—the generator fields must be kept partially excited for this. As for their duty cycles, they are required to undergo 15 full-power shorts of 5 electrical cycles duration in one hour. To conduct tests at this rate full field excitation must be applied for approximately 15 minutes of every hour.

Dissipating the heat at full and reduced speeds dictated totally enclosed blower-ventilated units. A self-cooled machine isn't feasible because at lower speeds the rotor fan does not move an adequate amount of air. Economy in the construction of the enclosing features favored the use of air as the cooling medium.

Perhaps more indicative of their physical size is that at the date of shipment they established a new record as the heaviest single part shipped from the Turbine Division in Schenectady. When loaded onto flat cars, each stator weighed in excess of 200 tons.

HIGH-VOLTAGE TRANSFORMERS

By B. A. COGBILL

A normal power transformer in its entire lifetime may receive but a few accidental short circuits. Yet each of the high-voltage transformers (above left) will be deliberately short-circuited thousands of times a year—and at a point on the voltage wave calculated to give the maximum offset or asymmetrical current.

Twenty-eight hundred tons of radial force is constrained within each of the two custom-built units. This force is caused by the interaction of the magnetic fields of the high- and low-voltage windings produced during short circuits. Its effect is to collapse the inner low-voltage coils and burst the outer high-voltage coils. To resist it, the customary inside insulating cylinder around which the low-voltage winding is wrapped is replaced by an insulated steel cylinder.

Another of the problems involved in the design was the reaction of the core to the mechanical forces it incurs during repeated short circuits. For this purpose a number of core and coils structures of reduced size were built. These were tested to destruction by application of increasingly higher short-circuit currents. Two of the structures were physically as large as a 5000-kva power transformer.

Weighing in at 246 tons apiece, the high-voltage transformers are operated singly, in series, or in parallel—to obtain the wide range of voltages used in the high-voltage test yard. Low-voltage primary connections are made to four bushings mounted on the sidewall of each unit. Leads for the high-voltage secondary connections pass through six high-voltage bushings mounted on the cover. Although most tests performed in the yard are single phase, three-phase tests can be run with the two units connected in open delta. At some future date a third unit can be installed to make a complete three-phase bank. (For an installation view see p. 11, July 1952 REVIEW.)

Heat resulting from power losses in the windings is not significant: duty cycles of the transformers are of short duration with comparatively long intervals in between. It's because of this that radiators are not required, which accounts for the singular external appearance of the transformers. Absence of the radiators makes their physical size a bit deceptive. Even so, they measure 24 by 17 feet wide and 36 feet high.

Each transformer was disassembled for shipment to the laboratory. The transformer tank was shipped in two parts on separate flat cars.

SYNCHRONOUS CLOSING SWITCHES and BACK-UP PROTECTION

By E. J. CASEY

Predicting the magnitude of the short-circuit kilovolt-amperes developed in a test requires knowing at what point on the generated voltage wave the circuit will be closed. For by manipulating this point, or angle of closing, the displacement of the current wave is determined and this, together with accurately synchronized tripping of the test breaker, controls the preparation and waiting times of the test breaker.

To accomplish these things synchronous closing switches of the kind shown on page 26 are used at the laboratory. Its principal feature is the extreme accuracy with which its contacts can be closed. Operating in conjunction with the synchronized drum timer and electronic cycle-splitting timers in the control building, it can close the circuit at any point on the test voltage wave to within three electrical degrees. It's capable of withstanding the rated voltage of the station while in the open position, and has a minimum of prestrike, or arcing, before the contacts make. The switch is capable of closing a 15,500-volt circuit in which a momentary current as high as 270,000 amp may flow.

The design chosen for this switch is primarily a tubular contact rod engaging a cylindrical cluster of fingers. This entire arrangement is mounted in a cylindrical chamber and maintained under a 250-psi pressure while in the open position (pressure increases the dielectric strength of air). The operating mechanism is pneumatically opened and spring closed. A magnetic-flux shifting latch holds the switch in the open position against the force of the closing springs.

Protecting the generators and providing back-up protection for the circuit breakers under test are protective circuit breakers. If the apparatus on test should fail, damage to the generators and other station equipment is prevented, and damage to the apparatus on test is minimized.

Owing to the large capacity of the laboratory, circuit breakers with an interrupting capacity greater than any existing at 15,500 volts were needed. At this voltage they should be capable of safely interrupting 3,500,000 kva. They should have a maximum interrupting rating of 170,000 amp, and a momentary rating to withstand a current inrush of 270,000 amp.

With these features in mind, station-type air-blast circuit breakers of an *extended* rating were selected for the job. Their insulation level is commensurate with that of the generator winding—15,500 volts. They've been tested satisfactorily to the limit of the capacity they will protect, and are designed with an ample margin of safety. Contact replacement won't be necessary until after many months of service.

They're mounted in a plug-in arrangement of single-pole units that are completely interchangeable.

HIGH-CURRENT BUS

By E. M. TROISCHT

The high-current bus is the connecting link between three low-voltage single-phase transformers and test cell Number 5. Going and return connections for each leg of the three-phase circuit are carried throughout the length of the bus: final connections being made at the test cell. Each pair of bars carries the maximum output of a transformer, 124,000 amp, both ways under certain conditions. An arrangement of this sort provides flexibility and helps minimize single-phase reactance (the magnetic fields about the conductors tend to cancel each other).

Forces approaching three tons per foot of copper are set up because of the close spacing of the bars. Resisting them are four-inch aluminum H-beams that run the entire length of the bus, clamped in place at frequent intervals with heavy nonmagnetic clamps.

The bus is interleaved and insulated with 1/8-inch strips of flameproof insulation that provide mechanical as well as electrical protection. Interleaving throughout the length of the bus necessitated carrying the bus at different levels in the transformer room and at the test cell. Elevation changes were made by means of splices at right angles to the bus. The forces set up in these corners—more than double those in the unspliced portion—are restrained by heavy channel supports. Ω

Mr. Kilbourne is Electrical Engineer of the Engineering Department of the Turbine Division, Schenectady. Mr. Harrington is in the Generator Engineering Section of the Turbine Division. Mr. Cogbill, responsible for the development of large power transformers, is with Transformer and Allied Products Division, Pittsfield. Mr. Casey is assistant unit engineer, Power Circuit Breaker Section of the Switchgear Department at Philadelphia. Mr. Troischt, also at Philadelphia, is section engineer in charge of design and development in the Panel and Equipment Section of the Switchgear Department.

Diffusion of Gases Through Solids

By DR. FRANCIS J. NORTON

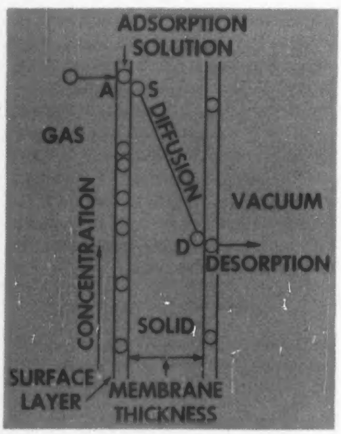
If you're a designer of experimental equipment there are certain combinations of materials and gases that you would avoid—helium with fused silica, and hydrogen with iron, are two. If they are used, there'll be diffusion of the gas through the solid even though your equipment is operating at room temperature and doesn't leak. And for work involving high-vacuum techniques it's essential that you know exactly the rates of permeation of many combinations of gases and solids.

Permeation and Diffusion

There's a difference between permeation and diffusion—

- Permeation is the over-all process for the transfer of gas from the high-pressure side, through a membrane, and out the low-pressure side.
- Diffusion is the process *inside* the solid membrane by which the gas atoms are moved along through the solid.

Diffusion is only one stage in the over-all permeation process as shown by this diagram—



The gas hits the surface and is absorbed at A as a surface layer. With high gas pressures this may be more than monomolecular. Then the gas dissolves in the body of the solid at S. Because there is a vacuum on the other side, the dissolved material diffuses down the concentration gradient to D on the low-pressure side. It then emerges, is desorbed, and enters the vacuum space.

Permeation Equation

At constant temperature, the total amount of material q permeating a membrane is given by

$$q = KAt(P_1 - P_2)/d$$

where K = permeation velocity constant
A = area of membrane exposed
t = time
P_1 = gas pressure on high side
P_2 = gas pressure on low side
d = thickness of membrane

This equation holds for glasses and polymers. For metals there is generally dissociation of the gas molecule on adsorption and passage of the gas as atoms (or ions) through the solid. This leads to a different pressure dependence for diatomic gases and the equation becomes

$$q = KAt(\sqrt{P_1} - \sqrt{P_2})/d$$

The equation relating the permeation constant K to the temperature is

$$K = A\epsilon^{-\frac{Q}{RT}}$$

where A is a constant, R is the gas constant, T is the absolute temperature (degrees C + 273), and Q is the heat of activation or energy of the permeation process. From this equation it is evident that a plot of log K against $1/T$ will give a straight line whose slope is proportional to Q.

Some Considerations

One general statement concerning the permeation rates through solids is that increase in temperature increases the rate exponentially. A few specific statements of interest are—

- Helium diffuses readily through polymers and glass, especially fused silica, but not at all through crystalline silica or quartz.
- Helium and the rare gases do not diffuse through *any* metal. Hydrogen goes readily through palladium, iron, and other metals, and will also permeate glass and polymers.
- Nitrogen will permeate steel but not copper. Its rate through glass is exceedingly low.
- All of the rare gases will permeate polymers. There are some specific cases, as natural rubber and carbon dioxide, where the permeation rate is large.
- Helium and neon will permeate glass, but heavier rare gases will not.
- Oxygen permeates silver relatively rapidly.

In all of these statements the words "do not permeate" mean that we are not able to measure permeation by our now-known methods.

It is also evident that, except for palladium, metals and glass are less permeable than are polymers, keeping the specific exceptions for helium and hydrogen in mind.

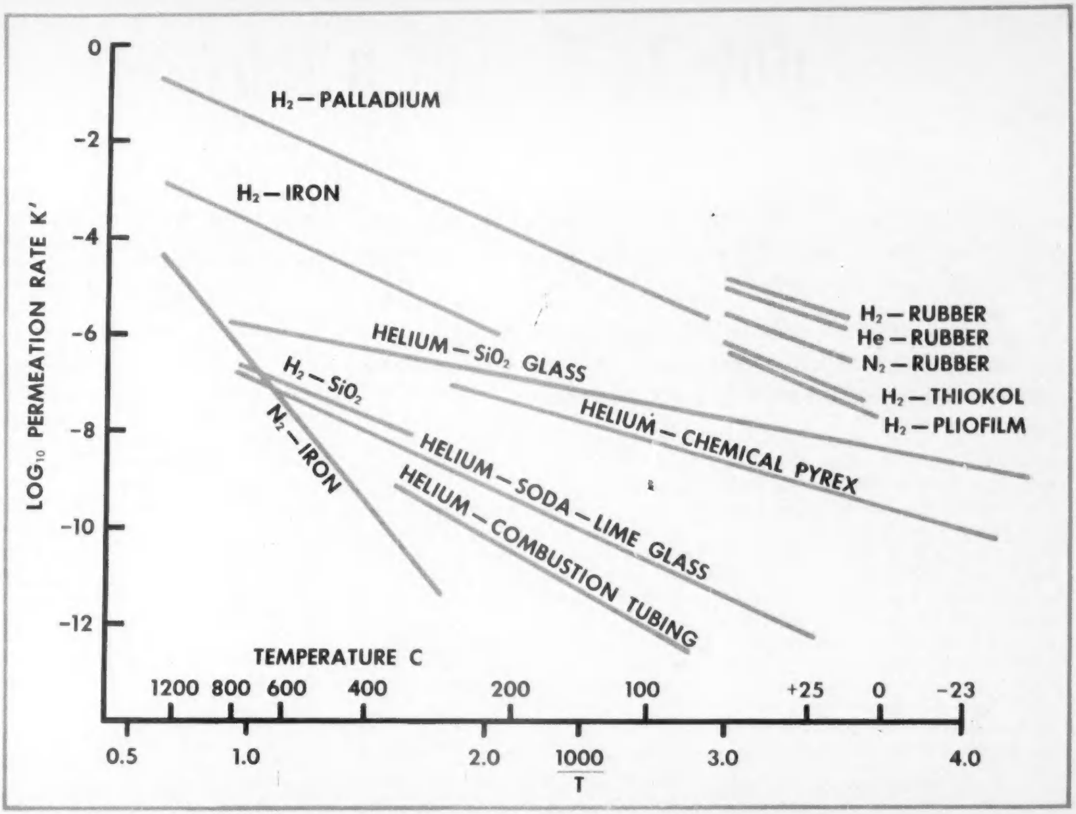
The assembled data on permeation are shown at the right. The lower limits to our ability to measure permeation, using the mass spectrometer as detection equipment and measuring means, are values of K' of about 10^{-13}.

A simple and direct observation of the effects of helium diffusion through glass at room temperature (25 C or 77 F) can be made. It's done by measuring the rate of loss of liquid nitrogen from a small silvered vacuum Dewar vessel after various periods of standing in helium gas. The particular Dewar on which we ran the experiment was made of chemical pyrex glass (Corning 7740). The initial rate of loss of liquid nitrogen from this Dewar, standing in air at 25 C, was 26 grams per hour. The flask then was placed in one atmosphere of helium at 25 C and the rate of liquid nitrogen loss was measured at intervals. After two days, loss started to go up, and after 12 days in helium, the loss rate was 182 grams of liquid nitrogen per hour. Before any helium exposure this Dewar had maintained its loss rate of 26 grams per hour over several weeks.

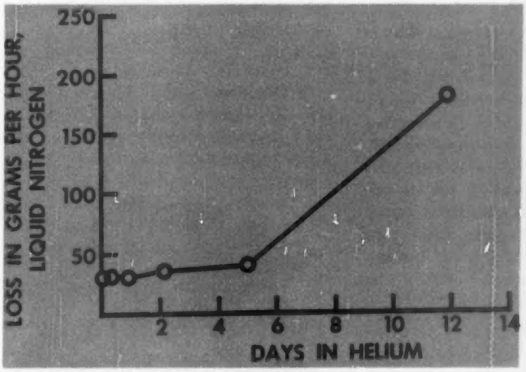
The plot of loss rate against days in helium (right) shows it takes a few

•

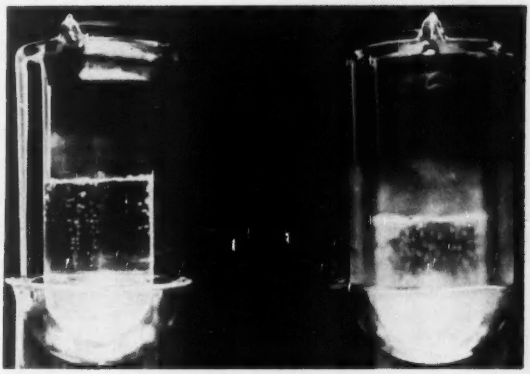
Dr. Norton is a Research Associate, Chemistry Research Department in General Electric's Research Laboratory at the Knolls, Schenectady. He is working in the field of physical chemistry and applications of mass spectrometry to many chemical problems: analysis, chemical reactions, and diffusion.



RATE OF PERMEATION of gas through solids. Units for permeation constant K' are cubic centimeter of gas (at normal temperature and pressure)per second per square centimeter of area per millimeter thickness per one atmosphere partial pressure difference



RATE OF LOSS OF LIQUID NITROGEN FROM DEWAR VACUUM FLASK



RIGHT FLASK SHOWS INCREASED RATE OF LIQUID NITROGEN LOSS

days to saturate the glass, after which the permeation of helium into the vacuum space occurs. This spoils the Dewar as a vacuum container. The value of the permeation velocity K' for Corning 7740 at 25 C is 8.3×10^{-10}.

Each of the two unsilvered Dewars shown above contain liquid nitrogen. The one on the left is normal, while the right-hand one has been in helium for several days. The latter shows the increased rate of liquid nitrogen lost, accompanied by cooling and frosting of the outer wall of this now nonvacuum Dewar flask. Ω

How to Select a Job

By MAYNARD M. BORING

● By applying the engineering principles of analysis and solution to this problem, the engineering graduate can wisely arrive at a final decision

● Considerations include advantages offered by training programs, job location and working conditions, recreational opportunities, the community, and associates

One of the most important decisions in a college man's life is often made in his senior year. For that's the time when most college men decide what their future is going to be. That's when they make up their mind where to go to work after graduation.

Unfortunately, a large number of college men are confused about this, even after graduation. They don't know what type of engineering activity they should follow. And their confusion may continue for some time after they've made their choice of jobs. As evidence of this, most of the engineers who become established in industry have later changed their activities; few of them actually follow with any exactness the plans they had when they graduated.

Some of the fault for this may lie in the college course itself. Basically, an engineering education is usually designed to train the graduate to be a design engineer, a development engineer, or a research engineer. Yet many graduates don't want to be limited to these fields; perhaps, they want to try a job which uses their engineering education only indirectly, rather than on a full-time basis.

There's some merit in that viewpoint. Furthermore, engineering is a living growing thing. It's constantly developing, and new opportunities are continually being created that may turn out to be very attractive. And those opportunities just didn't exist at the time of graduation.

There's still another reason why it may not always be the best plan to go into business with the fixed idea of becoming a specific type of engineer. Many fields of engineering are so interrelated that it's vital to have contact with many or all of them.

Fortunately, this situation does not necessarily mean that the engineering graduate must be baffled by a dilemma. It's one of those rare occasions where one can, indeed, have things both ways. The graduate who has training for a specific type of engineering doesn't necessarily have to restrict his activities to one phase. He can defer his decision.

The solution lies in the training programs, especially designed for college graduates, which are offered by many prospective employers these days. (See "Development of Engineering Leadership," REVIEW, May 1952.) Most engineering seniors hear about these training programs from the representatives of business who offer them jobs. But there appears to be some confusion about the real meaning of these programs.

The typical training program is designed to lay a foundation for business that will enable the trainee to become acquainted with all the facets of his employer's operations and to take his time about deciding just what fields of operations he wants to settle on. Thus it operates to the advantage of both the trainee and the employer: the trainee will ultimately be of much more value to his company if he has a good all-round foundation training and knows the ropes.

Here are some of the things that such a training program should do for the engineering graduate—

• Teach him where to find others who can help him move onward and upward in the organization.

• Teach him something of the basic operating procedures of his company. Such information is of considerable value in business today, although many young men entering business do not realize it.

• Teach him to be co-operative: that there is no place in modern business for the lone worker. In his association with other engineers of his own age, he will

Mr. Boring came to General Electric and joined the Test Program in 1916. Throughout his career his foremost concern has been the education, training, and development of the young engineer. As Manager, Technical Personnel Development Services Department, Schenectady, he directs these activities. He is Vice President in charge of Sections, The American Society for Engineering Education.

discover that there are no fences erected, but rather that there is a constant interchange of information among professional people.

• Help him to form early friendships with people who are going to follow different activities than his own, and such early friendships can be of vital importance to a young engineer who is getting started in business.

• Short-cut and formalize some of his basic problems, both from a practical standpoint and that of the classroom.

• Shorten his path to a responsible position.

• Broaden him much more than a specific assignment in one field of activity would do.

• Enable him to look over the field on a much more intimate and educated basis than he could have done as a senior.

• Permit him to try by actual experience different types of activity to determine where he fits best.

• Provide guidance and an opportunity for learning that he just couldn't get in college.

These are just some of the advantages which a training program can offer an engineering graduate about to enter a business career. Thus it is obvious that the company with such a program has more to offer the college senior than a company without one.

But the presence or absence of a training program is not the only thing which the graduating engineer should take into consideration in making his decision about what job to take. There are a number of other things he should think about, some of them more or less obvious and others not so readily apparent. For example—

The engineering graduate should take into consideration even such things as the recreational opportunities available in his prospective working location. After all, he's going to be in industry a long time, and he's going to live a 24-hour day, not just an 8-hour one.

Granting the validity of the preceding paragraph, we must also grant that the location can affect the graduate's ultimate happiness in other ways. If he expects to find his recreation largely in the theater, night clubs, or similar activities, he probably should select a job that would lead to a large city. On the other hand, if he feels that outdoor sports are important in his life, a job in a smaller community would probably fit his needs best.

He should consider whether his future home community will have adequate educational advantages, both for himself and for the children he expects to have.

Will the community of his choice permit his association with people of his own basic interests, or will he be isolated there as an engineer?

Will it allow him to develop his professional interests?

Will it provide him with a common ground for the type of social life he prefers?

His satisfaction with his job may be considerably influenced by the type of business his employer is engaged in. It may be important whether he goes

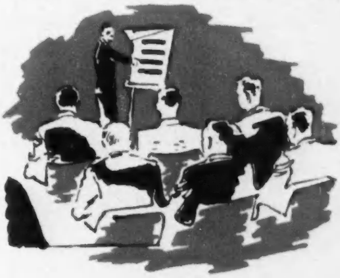
with a manufacturer of highly technical devices or with one which makes standard devices.

Will the company he works for provide ample opportunity for a long-time career? He should investigate to make sure it is not one that will go to pieces rapidly under normal peacetime conditions.

He may be attracted by an offer from a company with an abnormally high starting rate of pay. Under such conditions, he should ask himself: Why does this company pay more than others?

Will the community of his choice be a healthful one? He should consider, for example, whether he is seriously affected by sinus trouble or other respiratory afflictions and determine whether the community in question is good or bad for such sufferers.

If he is not already married, as many college seniors are these days, he'll



probably be getting married not too long after graduation. Will the environment, location, and climatic conditions be congenial or healthful for his wife? It probably goes without saying that it is vitally important for the wife also to live a happy and normal life. She needs to satisfy her need for a full, well-rounded life with ample opportunity for growth.

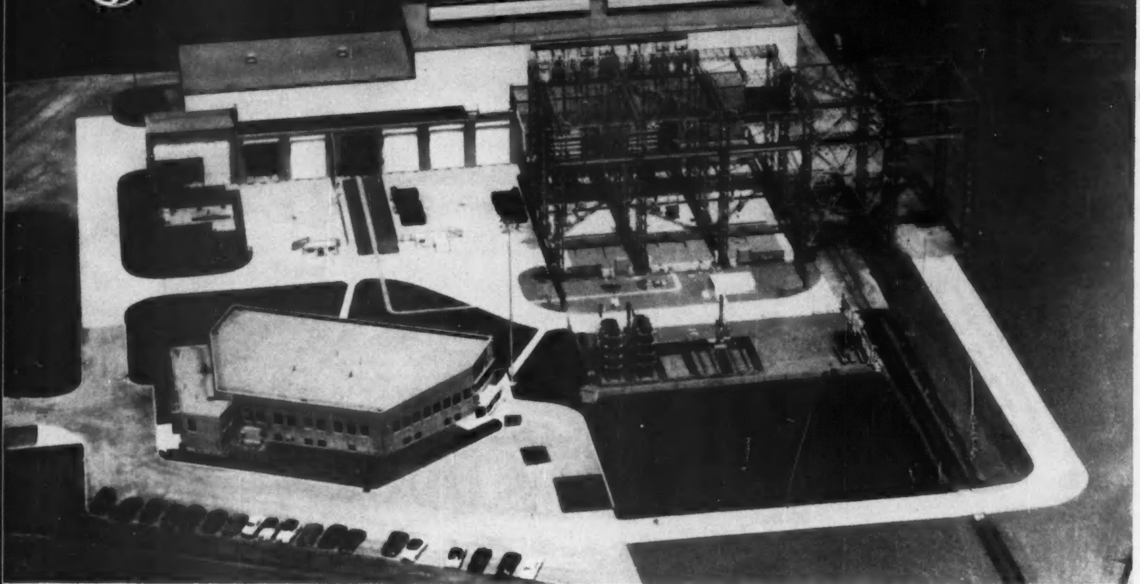
The expense of living is particularly important for young men who are starting a household of their own. So it would be well to inquire into living costs.

A very important consideration is the type of people with whom you'll associate. It is just as true in industry as it is in college that each of us has a peculiar make-up that is largely controlled by the type of people with whom we work. So perhaps it would be well to get acquainted with some of the representatives of the organization you are considering working for, to see if they're the kind of people you feel would be attractive to you.

There are, of course, many other factors that should be given serious consideration in the selection of a job. The engineering graduate should think carefully and well. He should try to match his own personal qualities with the organization he has in mind. He should think of the future and long-time opportunities rather than just flip a coin to make up his mind. It's surprising how many do just that.

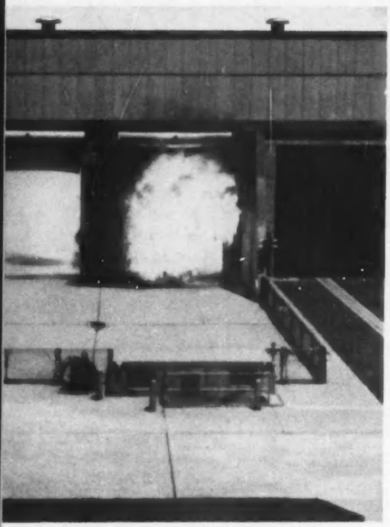
In other words, the engineering graduate should solve the problem in true engineering fashion. He should apply the principles of analysis and solution which he has been taught. If he does that, he should have no later regrets, and his future growth will be assured. Ω

ENGINEERING REPORTS:

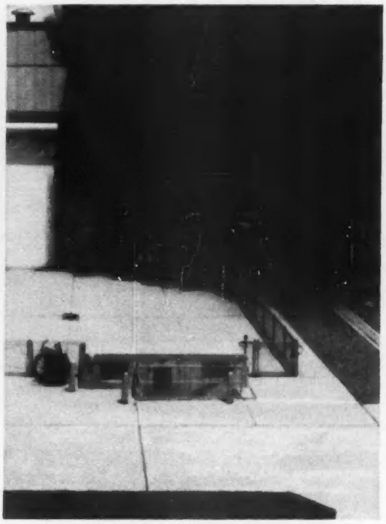


NEW ENGINEERING LABORATORY—making possible comprehensive tests on a scale never before possible—enables G-E engineers to make faster, more searching studies, clip months off major switchgear developments. Designed to keep pace with industry's increasing use of electric power, it has ten times the capacity of America's first such installation, built by G.E. in 1921.

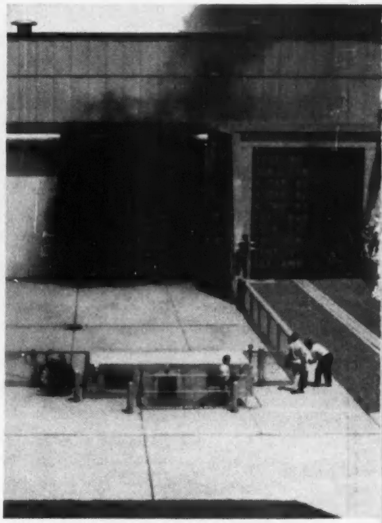
Billion-watt explosions improve



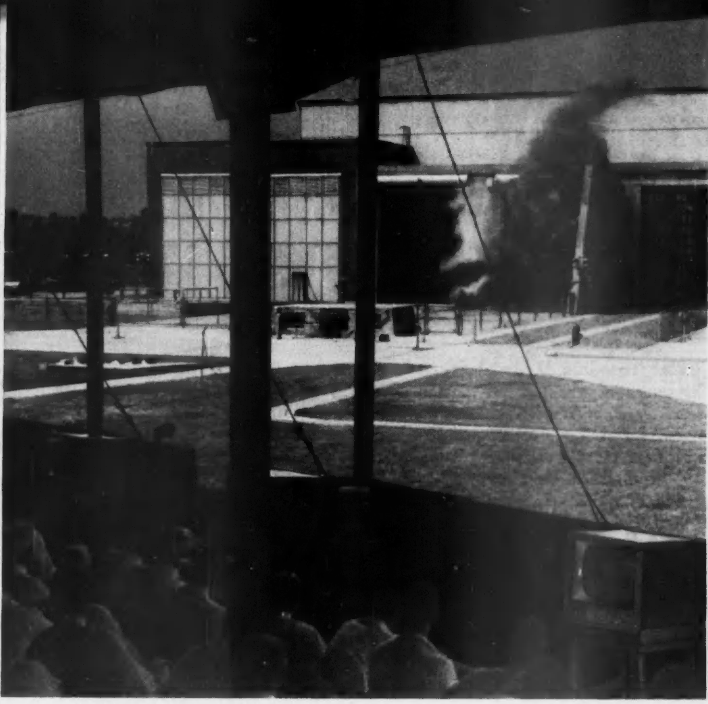
1 **FLASH** in one of five test cells results from deliberately testing a circuit breaker to destruction. Board at right indicates conditions of the test.

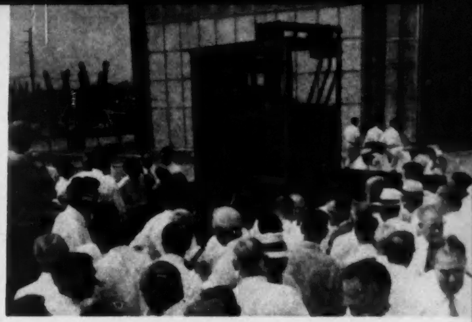


2 **SMOKE** emerges, while results of the test are automatically measured, recorded on film, and quickly made available for examination by our General Electric development engineers.



3 **OBSERVERS** emerge from observation booth facing test cells to inspect damage. Photos are from shatterproof windows in the control building.





AFTER DEMONSTRATION, visitors get a close-up view of damage done in test they have just observed. This 15-kv oil circuit breaker was tested at far above its 90,000-kva interrupting rating.

DEDICATION CEREMONIES included a dramatic demonstration of what happens when the interrupting capacity of switchgear is inadequate. Closed-circuit television equipment was effectively used to take opening-day visitors behind the scenes and to brief them on the nature and significance of tests they witnessed.

NERVE CENTER of new lab is this benchboard in the control building. Here, operators set generator output, then start automatic sequence sending up to 5,250,000 kva through equipment under test.

tomorrow's power equipment

New Switchgear Development Laboratory helps G-E engineers design higher-capacity apparatus for industry's growth

Increased mechanization and growing industrial capacity have caused America's use of electric power to skyrocket. Acting now—to help design the power-handling equipment you'll need tomorrow—General Electric has built the new Switchgear Development Laboratory in Philadelphia. Facilities at this new lab—largest of its kind in the world—make it possible to test switchgear under tomorrow's operating conditions. Here, new designs are subjected to extreme power surges, even tested to destruction, to prove their reliability.

You'll get these specific benefits from switchgear developed at the new lab: (1) greater continuity of power service in your plant, (2) better protection for your equipment and greater safety for your personnel, (3) lower original cost per unit of power handled, and (4) reduced maintenance expense.

This new laboratory and other G-E engineering facilities work for you when you specify "G.E." for electric apparatus. And where high-quality *system engineering* is required, G-E application engineers will draw on this engineering leadership in working with you and your consultants. Contact your local G-E Apparatus Sales Office—early in the planning. General Electric Company, Schenectady 5, New York. 672-5C

G-E ENGINEERS V. L. Cox, Manager–Engineering, Switchgear Dept. (right), and R. L. Williams, in charge of new lab, examine still-wet oscillograph films of test only two minutes after it was begun.

Engineering Leadership gives you better electrical systems from—

GENERAL ELECTRIC

AMERICAN SOCIETY OF CIVIL ENGINEERS

By WILLIAM N. CAREY and WALTER E. JESSUP

Since early in the life of the North American colonies there has been great interest in this country in new developments in engineering. Even the Continental Army of General George Washington included topographic engineers. And courses in military engineering were taught at the U. S. Military Academy at West Point from the time of its establishment in 1802; in fact, the Academy was established for the teaching of engineering.

In 1812 the first steamboat in America, Robert Fulton's *The Orleans*, took 14 days to make its maiden trip from Pittsburgh to New Orleans. Fulton was a civil engineer, and there were others. All were engaged in trying to find new ways, through engineering, of raising the living standard of the colonists; in fact, the term civil engineering was used originally to mean work in the civilian field in contrast to engineering for military purposes.

Continental carts and stagecoaches required bridges, and engineers were called upon to build them. The Erie Canal, built in the period 1817 to 1825, was followed by other canals. Canal boat portages, using steam power and ropes, were devised and used extensively. In 1829 Horatio Allen (later to become President of the American Society of Civil Engineers) imported from England the first locomotive to operate on a railroad in the United States. Extension of roads and railroads westward from the Atlantic seaboard began. Timber bridges of the types designed and built by civil engineers Burr, Pratt, and Howe gave way to iron bridges. An outstanding early (1846) iron-plate-girder railroad bridge with three 55-foot spans was built by James Mulholland, civil engineer for the Baltimore and Susquehanna Railroad. Completion of the first transcontinental railroad, with the joining of the Central Pacific and the Union Pacific at Promontory Point, Utah, was accomplished in 1869 under Theodore D. Judah, then chief engineer of the Central Pacific and a charter member of ASCE.

The need for civil engineering education was first met in 1820 with the teaching of civil engineering courses at Norwich University in Vermont. In 1824 a civil engineering curriculum was established at Rensselaer Polytechnic Institute in New York State. Today 132 accredited civil engineering courses are available to young Americans.

ASCE Organized in 1852

As a natural outgrowth of this early interest in civil engineering, a convention of 40 civil engineers met at Barnum's Hotel in Baltimore in 1839 to exchange ideas looking toward the formation of a society of civilian engineers in the United States. A committee was instructed to prepare a constitution and to decide on a name for the organization. The name selected was "American Society of Civil Engineers."

The idea of the new society took hold slowly, and it was not until 13 years later that a group of civil engineers met again to revive the 1839 idea. The historic meeting was held in the office of Alfred Craven, chief engineer of the Croton Aqueduct for the City of New York, on November 5, 1852. The name "American Society of Civil Engineers and Architects" was chosen for the new organization, and James Laurie of New York was elected the first president. A constitution and by-laws were read, discussed, amended, and adopted on December 1, 1852, and this time the birth of the Society was official. Then, as now, membership was open to "civil, geological, mining, and mechanical engineers, architects, and other persons who by profession are interested in the advancement of science." The first rolls included 48 charter members and six honorary members. From this beginning grew the first great national society of civil engineers, forerunner of the many engineering societies that cover the field today.

The American Society of Civil Engineers marks its 100th anniversary this year with a Centennial of Engineering celebration, which will emphasize the contribution of the engineering profession to the unparalleled development of this country. More than 50 societies are participating in the convocation, to be held in Chicago this month from the 3rd to 13th. The Engineers Joint Council group of societies closely associated with ASCE—the AIME, ASME, AIEE and AIChE—are working as a team to make the Centennial of Engineering a success.

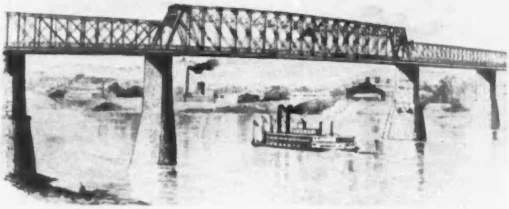
The Society Grows

From 48 charter members in 1852, the Society has grown to a membership of 34,500 in 1952. Members of ASCE Student Chapters are not included in this total. The Society has established 72 Local Sections, located in every state in the Union, and in Puerto Rico, Panama, Alaska, Hawaii, Mexico, Venezuela, and Brazil. Civil engineering students—11,000 of them in 132 engineering colleges—are now organized into ASCE Student Chapters.

Engineering is so taken for granted in every phase of our living today that it is hard to realize the relative youth of the profession in the United States and its phenomenal growth. Only 79 years ago in 1873 the ASCE Convention held in Louisville brought together what was described as "the largest group of civil engineers ever assembled on this continent—70 Members and Fellows." The membership of ASCE that year totaled 414. The membership

•

Mr. Carey is the Executive Secretary of the American Society of Civil Engineers. Mr. Jessup is Editor, Civil Engineering, *an illustrated monthly magazine published by the ASCE.*



AMONG THE FIRST modern truss bridge designs was that of Jacob H. Linville's Cincinnati Railroad truss which spans the Ohio. It was built in 1876 and followed the specifications of Louis G. F. Bouscaren, Member of ASCE

STARRUCCA VIADUCT built at Lanesboro, Pa., in 1848 for the Erie Railroad is a notable stone masonry structure of that age. Designed and built by James P. Kirkwood charter Member of ASCE and its President in 1868, it cost $320,000

of the five Engineers Joint Council societies now totals about 140,000, and the U.S. Bureau of Labor Statistics estimates the total number of engineers in the nation to be 400,000.

Membership in ASCE is on an individual basis. A Member must be a professional engineer of character, experience, responsibility, and attainment. He must be at least 35 years old, with at least 12 years of experience—five of them in responsible charge of engineering work of considerable magnitude. An Associate Member must be at least 27 years old and have had eight years of experience, with one of them in responsible charge of engineering work. A Junior Member is required to be 20 years old and to have had at least four years of experience. Graduation from an accredited engineering curriculum is considered the equivalent.

Technical Papers Published

The Society carries on its principal technical work through 14 Technical Divisions, each devoted to a branch of civil engineering. Specific fields of activity represented by the Technical Divisions of the Society are Air Transport, City Planning, Construction, Engineering Mechanics, Highways, Hydraulics, Irrigation and Drainage, Power, Sanitary Engineering, Soil Mechanics and Foundations, Surveying and Mapping, and Waterways. Three ASCE national conventions are held each year, one in New York and the others in selected centers of engineering interest. The operating budget of the Society for 1952 is about $860,000.

The obligation for professional men to contribute of their technical knowledge and experience for the benefit of the profession has been observed by members of ASCE since its start. The Society serves as a medium for the publication and dissemination of technical papers and for keeping civil engineers abreast of developments in construction. Its publications include separate papers published monthly as *Proceedings;* an annual volume of *Transactions* of the *Proceedings Separates; Manuals of Practice;* and since 1930, *Civil Engineering*, an illustrated monthly that gives special attention to construction and includes current Society news. ASCE publications may be purchased by nonmembers.

In its early days the Society did not anticipate the rapid growth of the profession nor the possibility of later division into separate branch societies. Hence the papers presented at early meetings covered the entire contemporary field of engineering and architecture. The first formal paper delivered at an ASCE meeting was presented by James Laurie, first president, and was entitled "The Relief of Broadway." It discussed the traffic problem on lower Broadway and proposed an elevated railway as a solution. Discussion of the traffic problem continued at subsequent meetings. The elevated railway has come and gone but the traffic problem remains. Other early papers included "Recent Inventions for Economizing Fuel in Generating Steam," "The Use and Abuse of Iron as Applied to Building Purposes," and "Results of Some Experiments on Strength of Cast Iron."

The value of engineering tests was emphasized in 1875 when President U. S. Grant appointed a board of army, navy, and civilian engineers to build a testing machine at Watertown Arsenal to test and establish the strength of iron, steel, and other metals. ASCE took an active part in the selection of the Board and its subsequent work. In 1878 Society committees were appointed to study cements, iron and steel, wood preservation, uniform testing methods, railway signals, bridge failure, and use of the metric system. The Society was largely responsible for the establishment of the country's standard time zones. It was also active for a dozen years in efforts to have the 24-hour system of indicating time, which is used abroad, adopted in the United States. The Board minutes for those years were actually kept on a 24-hour basis. An ASCE standard rail section, adopted in 1893, came into general use on the railroads of the United States. In 1908 the Society participated actively in President Theodore Roosevelt's conference on conservation of the nation's natural resources. During the depression of early 1930 ASCE promoted public works' construction to relieve unemployment.

Specialization and Unification

As the economy of the nation developed and technical knowledge advanced, some civil engineers began to specialize —in architecture, and in mining, mechanical, electrical and, later, chemical engineering. Each of these groups successively formed separate national bodies to further their special objectives: The American Institute of Architects in 1857; the American Institute of Mining and Metallurgical Engineers in 1871; the American Society of Mechanical Engineers in 1880; the American Institute of Electrical Engineers in 1884; and the American Institute of Chemical Engineers in 1908. In 1868 the word "architects" was removed from the name of the Society, marking a trend toward limiting the designation "civil engineer" to those who design and construct such works as bridges, roads, water and sewerage works, tunnels, harbors, irrigation projects, dams, airports, buildings, and foundations. The existence of these and other specialized national engineering organizations—nearly 100 of them—with an aggregate membership of more than 300,000, attests to the importance of specialization. To outsiders and even to engineers organization of the profession seems confusing. Steps are being taken to consolidate the interest of all engineers in their profession and to intensify their obligation to society.

Efforts to bring about closer co-operation among the national engineering societies go back to shortly after the turn of the century. Early evidence of such co-operation is the Engineering Societies Building. The Founder Societies—AIME, ASME, AIEE and ASCE—built and own the Engineering Societies Building at 33 West 39th Street, New York. Funds for the project came through a generous gift from Andrew Carnegie, supplemented by contributions from the co-operating societies. ASCE invested about $200,000 in the venture. Here the four Societies have their headquarters and a joint engineering library of 180,000 books and technical periodicals from all over the world.

Indicating its interest in other than technical matters, ASCE participated in the Centennial Exposition in Philadelphia in 1876; in the Paris Exposition of 1878; in the International Engineering Congress at the Columbian Exposition in Chicago in 1893; and in the Paris Exposition in 1900. It conducted the International Engineering Congress at the Louisiana Purchase Exposition in 1904. In 1900 the Society held its 32d annual meeting in London, during which the members attending were received by Queen Victoria at Windsor Castle. Conventions were held in Mexico City in 1907, and again in 1949. The 1881 convention at Montreal was the first held in Canada; there have been five Canadian conventions since then.

ASCE committees are constantly at work on matters affecting the professional welfare of members. Subjects that have been under committee study include: employment conditions, salaries, fees, engineering education, membership qualification, registration, ethics, public relations, and national affairs. For the welfare of its members the Society assumed leadership in the problem of collective bargaining for engineers. It has approved a group accident-insurance plan which is available to members. As another service to its members the Society maintains an office and a field representative in Washington, DC.

Registration of Engineers

A pioneer in the registration movement, the Society showed active interest in the legal registration of engineers as early as 1899. In 1911 it prepared a model registration law, which was made available to state legislatures. The ASCE Committee on Registration, in co-operation with other interested groups, has revised the model law from time to time and is still the central point for its distribution. All 48 states and the District of Columbia now have engineer registration laws, and at least 130,000 engineers of the present total of 400,000 are registered.

ECPD

In 1932 the four Founder Societies, together with the American Institute of Chemical Engineers, the National Council for State Boards of Engineering Examiners, and the American Society for Engineering Education, organized the Engineers Council for Professional Development (ECPD). In 1940 the Engineering Institute of Canada became a participant. ECPD is a conference body that functions as a co-operating agency, especially in the fields of education and training of engineers.

Best known of its achievements is the work of its Education Committee, which since 1935 has examined and accredited 656 engineering curricula in the 142 engineering schools in the United States. It is recognized as the accrediting body for all the engineering schools in the country.

Engineers Joint Council

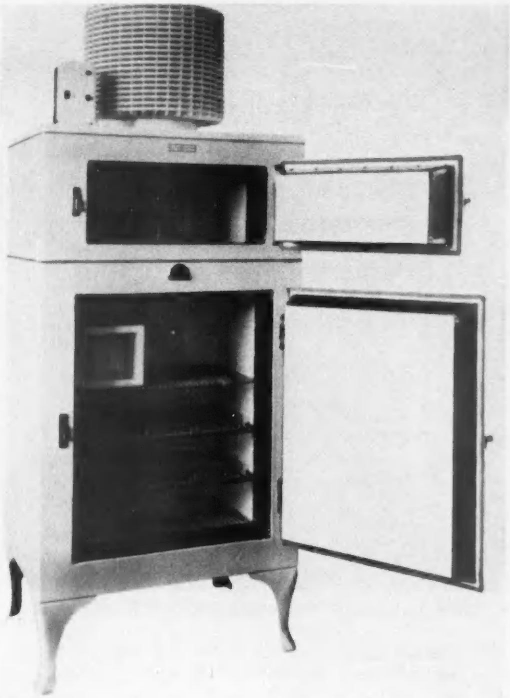
To promote co-operation among the five basic branches of the engineering profession, the four Founder Societies and the American Institute of Chemical Engineers, representing a combined membership of about 130,000 engineers, have established the Engineers Joint Council. The general objectives of EJC are to advance the welfare of mankind through the available resources and creative ability of the engineering profession, and to aid in developing sound policies on national and international affairs, in respect to ways in which the engineering profession can be helpful.

International Co-operation Developed

Marked progress has been made in developing co-operation among the engineering societies of the world. Together with the other EJC societies, ASCE participated in the formation of the Pan-American Union of Engineering Societies (UPADI), at a meeting in Havana, Cuba, in 1951. Last month there was a meeting of UPADI in New Orleans. ASCE has also been represented at meetings of engineering societies of the United States and Western Europe. At the third biennial meeting, held at the Hague in 1951, the name Europe-United States Engineering Congress (EUSEC) was adopted for the group. EUSEC includes 14 national engineering societies of Belgium, Denmark, Finland, France, Holland, Norway, Sweden, Switzerland, United Kingdom, and United States.

Contributors to Progress

The rolls of the ASCE have included such distinguished civil engineers as John R. Roebling, builder of the Brooklyn Bridge; Theodore Judah, builder of the first transcontinental railroad; Clemens Herschel, hydraulic engineer and inventor of the Venturi meter; Theodore Cooper, designer and builder of great bridges; John R. Freeman, famous for water-supply projects; Octave Chanute, who inspired development of the airplane; James B. Eads, pioneer in deep cofferdams for bridge foundations; William Barclay Parsons, father of the New York subways; Harrison P. Eddy, expert in the design of sanitary engineering works; Frank T. Crowe, builder of great dams; and Arthur N. Talbot, F. E. Turneaure, and Daniel W. Mead, pioneer teachers of civil engineering. Their records of accomplishment inspire pride in our profession. These engineers, prominent in their day, together with their contemporaries and 400,000 present-day peers in the profession, have contributed immeasurably to the building of a better America. Ω



THEN This combination refrigerator, first developed in the early 1930's, was never marketed

NOW Frozen-food section is held at 0 F, fresh-food compartment at 40 F in today's combination unit

"Making It Safe To Be Hungry"

By RALPH F. ROIDER

"Two tin cans and a piece of pipe" devised by a French monk in 1894 was the forerunner of today's hermetically sealed home refrigerator.

When Marcel Audiffren, a physics teacher in the college at Grasse, turned the handcrank of his dumbbell-like contraption, one end became hot and the other cold. Although his machine was necessarily crude, it is still recognized as a good design. After further development by a small French manufacturer, machines were placed on the market.

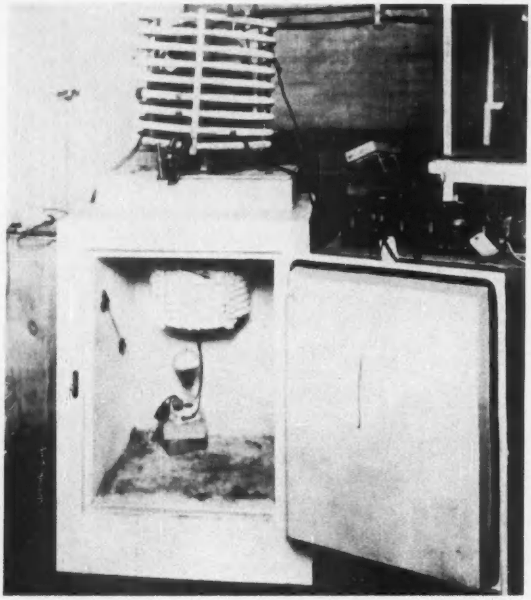
In 1910 an American tourist bought the American patent rights from Audiffren. And from 1911 to 1928 the Fort Wayne Electric Works, one of our subsidiaries and later the Fort Wayne Works of the Company, manufactured improved versions of the machine (page 40). About 150 to 200 were produced each year. They were relatively large (one-fifth to two tons capacity) and were used in hotels, hospitals, and restaurants. Many operated successfully for 10 to 15 years; at least two are still known to be in commercial operation.

Around 1915 a number of manufacturers began to think seriously about a refrigerator for home use. At first we gave consideration only to refrigerators of 12 to 15 cubic feet capacity, because it was felt that only people with large homes and incomes could afford them.

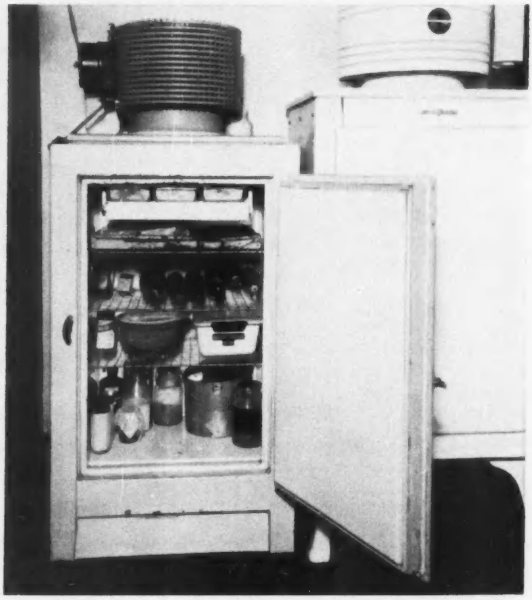
In 1917 the first developmental models, modifications of the Audiffren, were built. Seven units of this type were put together—all failed in two weeks to 15 months.

A year later one of our engineers conceived the radical idea of putting the motor inside the compressor shell, thus making possible a unit that was completely hermetically sealed. Power for the motor would be taken through the case by insulated leads. The idea was heartily derided until our research laboratory, at that time working on the problem of sealing glass to metal in the manufacture of light bulbs, came up with metal-to-glass leads that made complete sealing possible. The technique has remained basically unchanged to this day.

In September 1919 a model of the sealed-in design was built. About 30 of these water-cooled units were placed in



ONE OF THE VERY FIRST MONITOR TOPS ON TEST IN 1925



TOOLMADE MONITOR TOP IN DR. STEVENSON'S HOME IN 1926

homes where they operated for several years. The development of this machine continued for six years and encountered the usual number of headaches: speed-reducing gears failed, composition pinions would not stand up in oil and the sulphur dioxide, steel gears were noisy, varnish insulation came off and gummed up the parts, the copper brine tank proved smelly, and so on. Fortunately, all this grief took place in the laboratories or in the homes of engineering personnel. During this particular period, domestic refrigeration made little progress.

About this time our engineers, unhappy with the 60 pounds of brine required in these refrigerators and unhappy with other things as well, were toying with an air-cooled design. But the developmental costs so far had been terrific, and a decision had to be reached as to whether the Company should enter the domestic refrigeration business or drop further investigation.

In March 1923, top management delegated the late Dr. Alexander R. Stevenson, Jr. to make recommendations. In August 1923 he submitted a report that called for an air-cooled hermetically sealed unit. In September the report was approved and 20 air-cooled machines were authorized.

New demons arose to plague the engineers. The new design operated at higher temperatures and pressures and launched a host of new problems. More work was required.

Now that we were thoroughly in the business, leading designers throughout the Company were asked to submit their ideas and suggestions for improved units. On the appointed day, October 26, 1925, three were presented.

Chris Steenstrup's design was chosen. Steenstrup was a Danish immigrant who had rowed five miles every day to work to obtain training as an apprentice, and whose first job in America was digging ditches at $1 a day in Bridgeport. Later he became associated with General Electric, and as Supervisor of Mechanical Research in Schenectady became acquainted with refrigeration activity when he was asked to design a drawn-steel case to replace the heavy cast case of an earlier design.

Steenstrup's unit (page 40) could be mass-produced, provided the production men could adhere to the close tolerances he insisted on. They considered them fantastic, but with Steenstrup on the whip end, they were met.

On May 12, 1926, the first handmade solid-mounted machine with a flat-plate evaporator was exhibited at the NELA convention in Atlantic City. A few months later a toolmade unit went into operation in Dr. Stevenson's home (above) and ran for 13 years before it was removed for inspection.

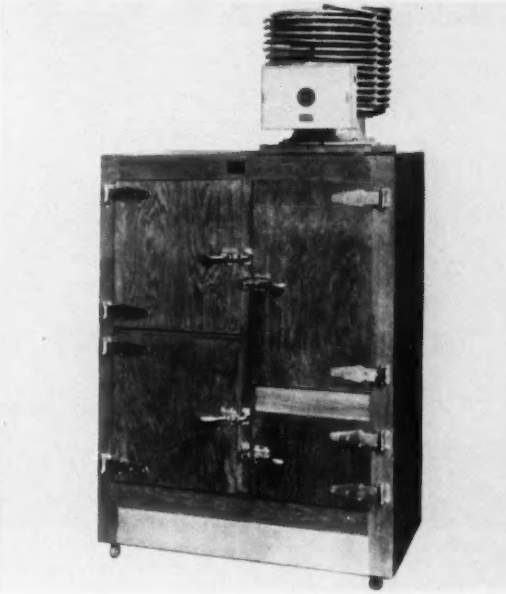
Twenty-five years ago last January 1, the Company authorized several million dollars for plants and equipment, and one million dollars for promotion (the title of this article was a slogan used in early promotion, as was the photograph on the opposite page). Production of home refrigerators was finally under way.

Monitor Top models of different sizes and forms were manufactured from 1927 through 1935.

One of the recommendations of the Stevenson report was that cabinets should be designed to go with the refrigerating machines. At first the refrigerating machines were merely installed in existing ice boxes (opposite page), but the wood construction proved troublesome. All-steel cabinets which we pioneered went into production in 1928.

In 1935 Steenstrup's new Scotch-yoke compressor that featured oil cooling and low pressure in the case was introduced (page 40). It went into production first on the Monitor Top, later in the Flatop version that had

EARLY PROMOTION EMPHASIZED ROOMINESS AND SIMPLICITY



EXISTING ICE BOXES WERE USED BEFORE ALL-STEEL CABINETS

the unit in the base compartment of the cabinet. This type compressor was used in all refrigerators until the war closed down production in April 1942.

Under Steenstrup's leadership a small but highly trained group of factory contact engineers and a quality-conscious factory organization steadily raised the quality level of the product. In the four years prior to 1942, hundreds of thousands of units were built so well that more than 99 percent were still operating satisfactorily after the five-year warranty had expired. In fact, one whole year's production of the Flatop model attained a record rate of less than 0.5 percent failure in five years.

Before the war, development work had been done on a connecting-rod type of compressor especially designed to use the higher-pressure Freon-12 refrigerant (page 40). By making the shaft horizontal instead of vertical, and by going to external spring mounting, a considerable gain in internal volume was achieved without increasing the external dimensions of the cabinet. This was important, because over the years the trend was to larger and larger refrigerator storage space; in time the external dimensions became critical. If they got too big, the homeowner would not be able to get the refrigerator into his kitchen.

The connecting-rod design is in current production at the Erie Works.

Before 1930 Steenstrup designed and built a combination refrigerator (page 37 shows an early model) that had a frozen-food storage space with its own evaporator and door, and a fresh-food storage space with its own cooling system and separate door. A single unit refrigerated both compartments. The project was dropped but shortly before the war several models were built, and in 1947 production was started on a single-unit combination refrigerator.

Designing a refrigerator is unconsciously assumed by most persons to be a routine matter, primarily because of the machine's trouble-free performance. But let's look at the complex job of a refrigerator:

The best fresh-food storage temperature is around 40 F, with a safe range between 34 and 45 F. If the temperature should drop below 32 F, freezing of fresh food may occur; if it goes much above 50 F (although 50 F was at one time the accepted temperature) for any extended time, the food may start to spoil. Therefore, the primary function of the refrigerator is to maintain a satisfactory food-storage temperature at all times with room temperatures above 100 F during midsummer (perhaps with 100 door openings each day) and below 60 F during winter.

No other home appliance—or the family car—is called upon for such unbroken operation; the refrigerator may operate only 20 percent of the time during normal periods, but it may be called upon to operate continuously for many hours during heavy summer usage. And every part—even the individual screws that hold the valve plate on the end of the cylinder—is designed for at least 25 years of life.

Here's how the performance (with 1927 as 100 percent) has improved in the past 25 years—

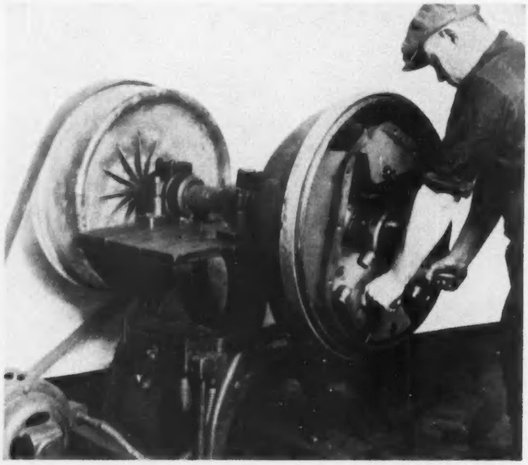
Year	Weight (pounds)	Capacity (Btu per hr)	Efficiency (Btu per watthour)
1927	100%	100%	100%
1931	85	130	117
1938	58	156	143
1947–1952	34	200	209

●

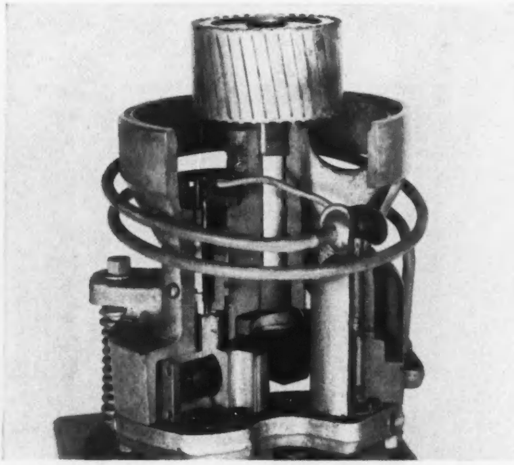
Upon leaving Advanced Engineering Program in 1926, Mr. Roider went into refrigerator engineering. He worked with Dr. A. R. Stevenson, Jr., later with Mr. Steenstrup until 1945. He is now with Field Service for Refrigerator Engineering, Major Appliance Division, Erie, Pa.

CONTINUED ON NEXT PAGE

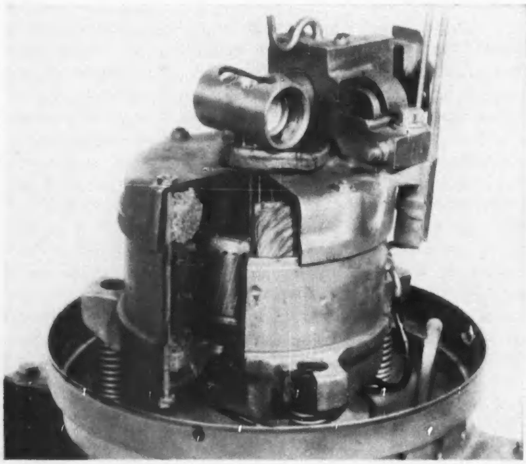
"Making It Safe To Be Hungry" (Concluded)



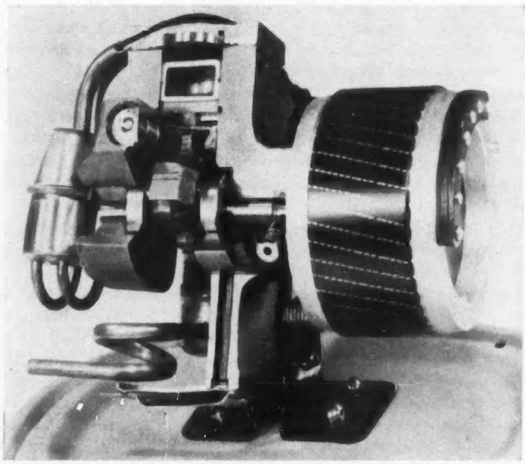
AUDIFFREN Two hollow sphere-like housings rigidly mounted on a short hollow shaft made up the American version (1911 to 1928) of the Audiffren machine. An external motor drove the shaft by a belt and the spheres rotated with the shaft. One sphere held the liquid refrigerant (sulphur dioxide) and acted as the evaporator. The other sphere (right) contained the compressor in which the cylinder was mounted on trunnions. A counterweight kept it in a vertical position. An eccentric on the shaft moved the piston up and down in the cylinder.



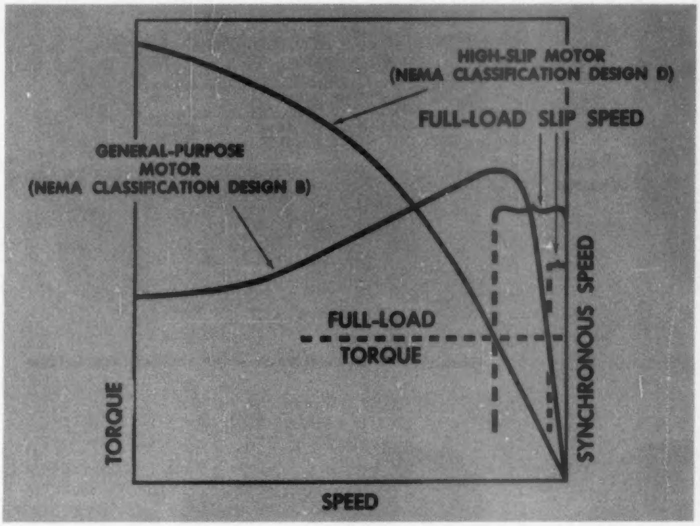
STEENSTRUP His original compressor (1925) consisted of a single cylinder that oscillated about two vertical trunnions on a steel bearing plate to allow intake porting for the refrigerant vapor as the piston moved back and forth from the crank on the lower end of the vertical shaft. A small piston adjacent to the refrigerant piston supplied lubricating oil under pressure to all bearings and to the oil-operated "unloader" that allowed the compressor to start and stop without a pumping load. The motor was above the compressor and the rotor was pressed on the compressor shaft. This unit was mass-produced.



SCOTCH YOKE In this compressor (1935) the rotary motion of the crank was translated into reciprocating motion of the piston in the stationary cylinder by a slide arrangement long known to design engineers as the Scotch-yoke principle. Oil under pressure from the small two-blade rotary pump on the lower end of the shaft lubricated the bearings. After this was done, half the oil was directed down the walls of the case where it was cooled, while the remaining oil passed over the end of the cylinder to cool the valves and then continued down around the stator windings to cool them.



CONNECTING ROD In this design (current production) the float valve used in all previous models was replaced with a long capillary tube that allows the high and low side pressure to equalize during the off period. This feature made an unloader unnecessary. The crank is located between the two shaft bearings instead of being overhung as in the Scotch-yoke type. A design feature involves an arrangement that prevents movement between the wrist pin and the connecting rod, thus eliminating noise and wear. Making the shaft horizontal resulted in a considerable gain in internal volume.



Slipping the Induction Motor

By R. Y. NEWTON

The punch press that formed the smooth, flowing, and vulnerable lines of your automobile imposed a distinctive type of loading on its drive-motor.

A large flywheel, used to give the tremendous punching power economically, stores rotational energy between strokes. To deliver the energy the flywheel *must slow down* during the punching operation. Otherwise, the instantaneous energy required would stall the motor. The drive-motor speed must therefore normally decrease with the sudden increase in torque caused by the punching operation.

But here's the hitch—an ordinary general-purpose induction motor won't slow down appreciably under an increased load. That is, its rotor doesn't slip (lose speed) but maintains a fairly constant speed until the breakdown value of torque is reached.

A special type of motor, the high-slip motor, is therefore necessary for punch-press drives. In the auto industry high-slip motors of enclosed construction are required—and such a design using conventional motor construction is very difficult. Recently a new motor, the extended-bar motor, was introduced which meets the high-slip requirement and at the same time makes possible a smaller, more efficient motor for a given horsepower rating. A sectional view of this motor is shown on the next page, upper right. It's totally enclosed and fan-cooled (TEFC), with an extended-bar rotor designed for better heat-transfer characteristics.

A comparison of the speed-torque curves of the high-slip motor and a general-purpose squirrel-cage motor is shown above. As a further comparison, consider the full-load torque and the slip speed (synchronous speed minus running speed) of the two.

The high-slip motor is usually designed for a starting torque of 275 percent of full-load torque and a slip speed of 5 to 13 percent, depending on the application. Slip at full load is an indication of how much the motor will slow down with increased load.

On the other hand, the general-purpose motor (in sizes 5 to 100 hp) is usually designed for a starting torque of 110 to 150 percent of full-load torque, depending on the speed, and a breakdown torque of 200 percent. The slip speed is made as low as possible for maximum efficiency, generally running from one to two percent.

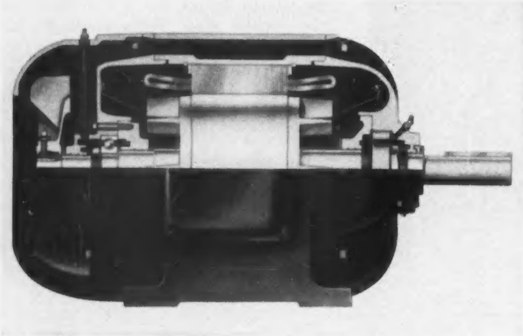
In the auto industry, where many large punch presses are used, TEFC high-slip motors are standard. Enclosed rather than open motors are used since the atmosphere frequently contains considerable dirt and metal dust that increases maintenance and shortens the life of an open motor (sometimes a forced-ventilated and filtered open-type motor is used).

Providing adequate heat dissipation in the TEFC high-slip motor presented a problem. To help you visualize its nature, refer to the sectional view of a TEFC general-purpose motor on the next page, upper left.

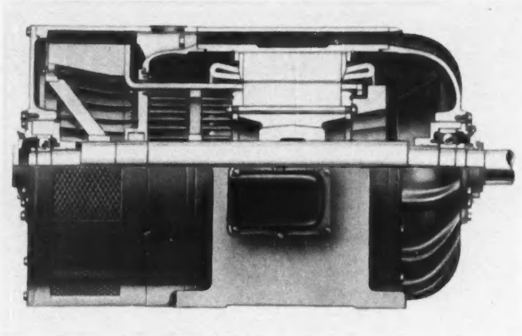
Here, heat from the stator windings and laminations is directly transferred to the motor shell by conduction, where it is carried away by the external circulating air. Conversely, conveying heat from the rotor is not so direct since it is: 1) transferred to the air inside the rotor; 2) drawn off by fans at each end; 3) carried to the bearing bracket over which external air circulates. In addition, there's some transfer of heat across the air gap. You'll note from this that the cooling of the stator is simple and effective, whereas the cooling of the rotor is less efficient because convection and more heat-transfer surfaces are involved.

Now the rotor resistance of a general-purpose motor is quite low, and therefore the heat generated in the rotor is correspondingly low. Not so with the high-slip motor. To get the high starting-torque and high-slip characteristic required of the latter, it's necessary to increase the rotor resistance. Since slip speed is proportional to power losses in the rotor, heat losses are inherently greater. In fact, they are several times larger than losses in a low-slip motor of the same horsepower rating when running at rated load. The stator loss is also somewhat higher for the high-slip motor because its reduced efficiency and power factor increase the stator current for the same motor output.

As you've seen, heating considerations penalize the allowable horsepower rating of a high-slip motor in two ways: First, it's a lower-efficiency motor and additional heat is produced; second, the bulk of this additional heat is generated in the rotor, where heat transfer to the

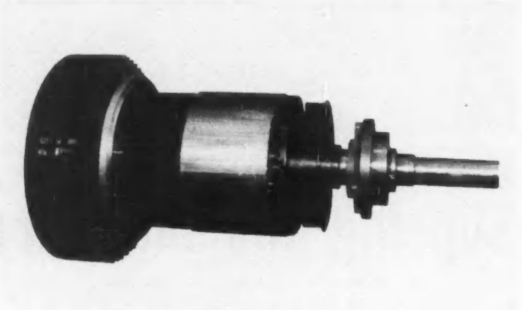


GENERAL-PURPOSE MOTOR IS SUFFICIENTLY COOLED, BUT . . .



HIGH-SLIP MOTOR CALLED FOR MORE EFFICIENT VENTILATION

ROTOR FOR ACCELERATING HIGH-INERTIA LOADS LED TO . . .



MODIFIED DESIGN SUITABLE FOR USE IN HIGH-SLIP MOTOR

motor casing is comparatively poor. Therefore, if you use a conventional design, size and weight are greatly increased over a general-purpose motor of the same horsepower rating, because of the higher rotor losses.

If, however, rotor heat can be generated outside the motor enclosure, you gain considerable advantage since the enclosure has less heat to dissipate. This is exactly what we've done through the use of a new extended-bar rotor design. In this way little or no increase in frame size is necessary to get the desired high-slip characteristics.

The rotor construction used in the high-slip motor is adapted from a special open-type motor in use for some time. There the problem was one of accelerating high-inertia loads where the heating was severe—particularly in driving centrifugal sugar extractors.

Such a rotor is shown on this page, lower left. The copper rotor bars extend several inches out from the rotor body on the upper end, and brazed to the end of these bars are U-shaped strips of high-resistance bronze. The loops constitute one end-ring of the squirrel-cage rotor and a high percentage of the rotor resistance; consequently, rotor heat-loss is concentrated in the loops. The other end-ring is of conventional design. A radial blade fan is also formed by the loops. It draws cooling air through the loops to dissipate heat generated there.

This type of rotor construction was changed slightly for use in the TEFC high-slip motor. In the new design the loops were replaced by thin blades of high-resistance material. They are brazed to the copper rotor bars, and a copper end-ring is brazed to the outer end of the blades, as shown in the illustration, lower right.

Mechanically simpler than the looped rotor, the new design is less costly to build. The blades provide excellent fan action. And heat-storage capacity—while less than that of the looped rotor—is comparable to the conventional bar-rotor and adequate for most applications.

A cross section of the enclosed extended-bar motor is shown in the upper right-hand illustration. To extend the rotor bars to the outside of the motor enclosure, the bar extensions on the front end pass through a rotating baffle plate. A close-running air seal is provided between the rotating baffle plate and the stationary end shield. In this way the inside of the motor is sealed off to prevent the entrance of dirt, moisture, and other foreign material. The seal embodies principles that are used successfully in the design of bearing housings where special precautions are necessary to exclude dirt from the bearings. Permafil compound, which sets extremely hard with no voids, is used to seal the holes where bars pass through the plate.

Reduction of weight is about 40 percent, and the space required for

•

With General Electric in Schenectady since 1946, Mr. Newton is a design engineer in the Design Engineering Section of the Small and Medium Motor Department. His present assignment includes design work on vertical motors, explosion-proof motors, sugar centrifugal motors, and extended-bar motors.

CONTINUED ON PAGE 60

"It's a Locomotive, It Ain't a Watch"

Review STAFF REPORT

Last June 9 the following internal telegram was issued by the Freight Transportation Department of the New Haven Railroad:

CONFIRMING PREVIOUS MESSAGE OUTLINING TEST RUNS FOR GENERAL ELECTRIC 5000 HORSEPOWER A-C ELECTRIC DEMONSTRATOR LOCOMOTIVES 5025-5026: EFFECTIVE TUESDAY, JUNE 10, AND UNTIL FURTHER NOTICE, PLEASE ARRANGE TO OPERATE THESE LOCOMOTIVES ON FOLLOWING TRAINS:

TRAIN	FROM	DUE LEAVE	TO	DUE ARRIVE
NG-3	CEDAR HILL	7:00 AM	BAY RIDGE	10:55 AM
GB-8	BAY RIDGE	1:30 PM	CEDAR HILL	5:10 PM

THE FOLLOWING TONNAGE RATINGS UNDER ALL RAIL CONDITIONS FOR THESE LOCOMOTIVES MAY BE USED:

EASTBOUND: BAY RIDGE TO CEDAR HILL—6200 TONS
WESTBOUND: CEDAR HILL TO OAK POINT—6200 TONS
OAK POINT TO BAY RIDGE—3750 TONS

IN ADDITION TO ABOVE TEST RUNS, THESE LOCOMOTIVES SHOULD BE USED BETWEEN CEDAR HILL AND BAY RIDGE OR BETWEEN CEDAR HILL AND OAK POINT ON EXTRAS AS REQUIRED PROVIDING THEY CAN BE RETURNED IN TIME TO COVER ABOVE ASSIGNMENT.

A FEW DAYS later I drove through the sun-seasoned hills of New York State and Connecticut to New Haven where I met J. F. "Johnnie" Walker of General Electric's local office who is responsible for customer relations with the New Haven Railroad. Walker is relaxed, neat, and has handled railroad and locomotive customers for the past 15 years. He told me about GE's demonstrator locomotive as we sat in his office overlooking the famed "Green" of Yale University.

Operating a demonstrator on a railroad is worked out on a consignment arrangement, usually for a period of a few months. The railroad furnishes crews and all normal maintenance, and the manufacturer supplies service engineers and takes care of any other expense. The railroad gets a new piece of motive power and the manufacturer gets firsthand operating data. "The only thing we ask," Walker said, "is that the railroad use the locomotive as often—and as hard—as possible. That's the only way we'll find out how good it is."

One of GE's primary purposes in bringing out this new design was to see if a low-cost all-electric locomotive could be built. "In the past," Walker said, "all-electrics were cheaper per horsepower than diesels, but with diesels being mass-produced that no longer holds. The demonstrator is our attempt to bring the cost of all-electrics down so that they're competitive with diesels."

Electric locomotives on the New Haven and Pennsylvania operate under 11,000-volt 25-cycle power and use a-c traction motors, which would seem to be logical. But as he explained it, the d-c traction motor (when used on locomotives operating under a-c power) is a strenuous contender because of lower weight and first cost. This is true even though expensive and space-consuming conversion equipment such as rectifiers and motor-generator sets is required. This fact evidently didn't dismay engineers of the Locomotive and Car Equipment Division at GE's Erie Works because they designed a new axle-hung a-c commutator motor that they felt would not require any more maintenance than a d-c motor, and also would mean less equipment aboard the locomotive.

Another advantage, Walker explained, is that the a-c commutator motor is inherently a powerful machine that can operate at the extremely high short-time ratings that are necessary for accelerating heavy trains and ascending grades. He opened a handbook and pointed to some figures. They showed that the demonstrator has a normal rating of 5000 hp, but with overvoltage taps on the transformer can go to 10,000 hp for short periods. Tractive effort is high because all four axles of each unit are motored and all weight is on the drivers.

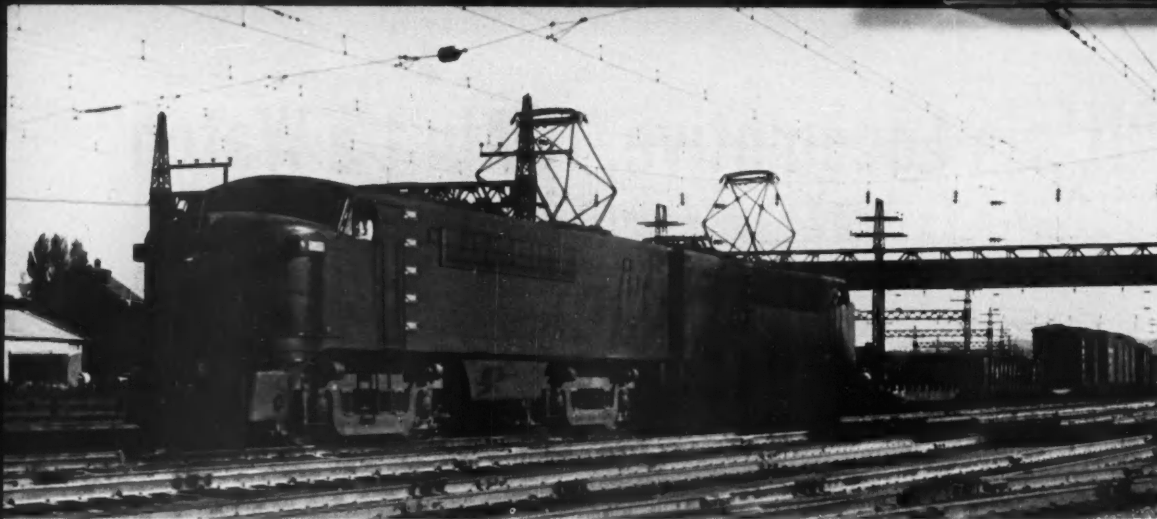
After talking awhile longer about details of the new locomotive, Walker suggested we go over and see some of the men at the New Haven. We left his office and drove the few blocks to the railroad's new building near the downtown passenger station. There we met B. J. "Benny" Lawlor, Chief of the Freight Service Bureau of the Freight Transportation Department. Lawlor is in his late forties and enthusiastic about freight trains. In a large office he spread out a map of the nearby Cedar Hill Freight Terminal and told me about operations on the New Haven.

"Your locomotive will be pulling westbound NG-3 tomorrow for the 88 miles to Bay Ridge. You'll leave from about here," he said, standing and pointing to the New York departure tracks on the map. "Coming back you'll be hauling GB-8."

I asked him what the train symbols meant. The "N," he told me, is the code for "New Haven," while the "G" stands for "Greenville, NJ." "NG-3 carries general freight—scrap, paper, empties, and so on—that has come in from Boston and Maybrook, for example. It's all stuff for the Pennsy at Greenville except for something that may be dropped at Bridgeport." Although the freight was carded for Greenville, it would be handled by the New Haven only to the Bay Ridge terminal on the western edge of Long Island. There, New Haven car floats would ferry the cars across the Upper Bay to the Pennsy's Greenville Yards.

Eastbound GB-8, Lawlor said, was a "hotshot" freight for Boston. "Actually it's a continuation of the Pennsy's CG-8 that comes into Greenville from Chicago. This is a fast train. We also call it a 'market train.'" Loaded with perishables it is due in Boston at 11:55 each night. "We have an advertised arrival in Boston and by five in the morning we had better have the cars placed at platforms for market. If they're not, we're subject to claims and liabilities."

THE NEXT morning at 6 o'clock I left the Hotel Taft and drove to the Cedar Hill Yards in the northeast section of the City of New Haven. After parking at the Railroad YMCA I walked across a foot bridge. The day was



WESTBOUND FREIGHT NG-3 LEAVES THE NEW HAVEN'S CEDAR HILL YARDS BEHIND GE'S NEW 5000-HP ALL-ELECTRIC DEMONSTRATOR LOCOMOTIVE

cool and the sky was high. Diesel switchers and power for through freights, like prehistoric monsters, lazed and rumbled in the yards below. To my left were the departure tracks for New York and Maybrook freight. Straight ahead were the engine houses and a mile or so in the distance I could vaguely make out the humping areas where eastbound and westbound cars are classified. Cedar Hill is the largest freight classification yard east of the Mississippi. On an embankment to the right the twin tracks of the Shore Line to Boston made a graceful arc to the East.

Descending from the foot bridge, I walked across the yards toward the motor storage tracks where the electrics are stored and inspected. Against the dark green of the New Haven locomotives the dusty black finish of Nos. 5025–5026 was easy to distinguish. Although they have the general profile of a diesel, they have a light high-stepping air that is in contrast to the squatiness of a diesel.

It was 6:20 when I arrived at the locomotives. There I met Ralph D. Nicholson, general road foreman of engines, who told me that the crew had arrived a few minutes before and was checking details in the cab. The pantographs were already up. During the night, Nicholson said, the sand boxes had been filled, the running gear inspected, and other routine maintenance taken care of.

While we were talking, the crew climbed down and Nicholson introduced me to Wade R. Bowden, the road foreman, who would be going on the run. Bowden is a hearty individual with a vigorous laugh who has been with the New Haven for 36 years. He talks with a Southern drawl and is sometimes known as "Rebel." "But I'm really an adopted Yankee," he enthusiastically assured me. Bowden introduced Engineer Daniel S. Driscoll, a veteran with the New Haven since 1912, and Fireman Johnny E. O'Connor. I also met Johnny Todd, one of two GE service engineers from the New York Office who is assigned to the demonstrator. Todd has been handling diesels and electrics and multiple-units with the New Haven for a number of years, and speaks a good deal like Marlon Brando.

Driscoll, Bowden, and Todd climbed up to the cab and I followed. O'Connor went to the rear unit. The cab of an all-electric, I found, is about the same as that of a diesel. It measures seven by ten feet, head room is ample, and everything is painted a medium gray. The view is fine because eye-level is 13 feet off the ground.

Todd checked the instrument panel as Bowden adjusted the engineer's seat. He said, "All set?" and at 6:35 started for the departure tracks where the cars of NG-3 were waiting.

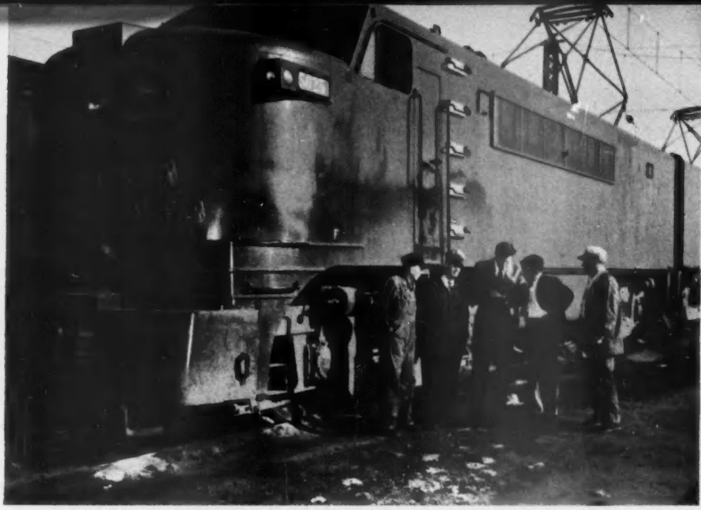
After coupling onto the train Bowden did paper work on the previous day's run. Driscoll sat in the fireman's seat, and Todd left to get some cigarettes. The cab was decently quiet because the traction-motor blowers were on low speed.

Todd came aboard after a while and at 6:56 Bowden checked the brakes on the entire train. This is a simple procedure that follows simple rules: After the train is pumped up, the engineer sets the brakes and then notes the pressure drop in one minute. On a train of 100 cars or less, the Interstate Commerce Commission allows seven pounds leakage; if more than 100 cars, the allowable leakage is five pounds. Bowden said the reading was four. "I checked the locomotive brakes on the pit. We're allowed five pounds . . ." Driscoll spoke up from across the cab. "That isn't right . . ." Bowden raised his hand in a mock gesture of restraint. "Wait. I was going to say that the New Haven is such a good railroad that the ICC regulations aren't good enough for *us.* We're allowed only *four* pounds."

Seven o'clock passed without notice by the crew. Every so often during the next half-hour Bowden would casually ask no one in particular what was holding things up. I got the impression that a lot of time on freight runs is spent in waiting.

I asked Bowden about train orders. "That's old-style railroadin'," he said. "No train orders on the New Haven. We run under signal indications all the way." He explained that above each track were two signals, one above the other. The top one—green, yellow, or red—gives an indication of conditions in the next block. The bottom signal tells whether the dispatcher is planning to cross the train over to another one of the four mainline tracks.

A few minutes before 8 o'clock Conductor Tom Lynch climbed up with the package of waybills and shoved them between the control pedestal and the windshield. Bowden said, "What have



DRISCOLL, BOWDEN, *REVIEW* REPORTER, TODD, AND O'CONNOR AT ENGINE PIT

we got?" "Four for Bridgeport, 84 for the Pennsy," Lynch replied. "Tonnage is 2626." "No weight but a lot of cars," Todd remarked. "Set?" Bowden said. He pushed his hips back into the seat and sat upright. His right hand was on the air brake and his left hand notched the throttle back to 6. The time was 8:05. NG-3 got under way. Out of the yards the speed indicator read 18. "You own the railroad, Wade," Todd said, as the first signal showed green.

Shortly after we passed the New Haven station, Bowden called me over from where I was standing near the fireman's seat. "See that '75' up there," he said, pointing to a small sign hung on one of the catenary bridges over the tracks. "That means 75 cars have passed the station. I'll give it a few more lengths before we pick up speed." He waited, then pulled the throttle from 16 all the way open to 21. The motor-current meter read 3150 amp and the speed was 36 mph.

Slightly west of New Haven, Bowden said, "I'll make the hill at 30." He paused and added, "I think." He and Todd laughed. "These babies are peppy. A diesel couldn't do better than 25." NG-3 made the hill an edge over 30 mph.

The demonstrator has 21 "steps," or "notches," on the throttle quadrant, compared to eight on a diesel. Each of the 21 steps represents a tap change on the transformer. Occasionally Todd would yell something like, "Way back to the control panel, Wade!" when Bowden would notch it wide open. They would both laugh. The control panel is in the bulkhead behind the engineer.

I noted that there are fewer instruments on all-electric than on a diesel-electric. There are seven: speed indicator graduated to 80 mph, motor amperes, braking amperes, two meters for air pressure, trolley amperes, and trolley volts. The motor amperes gives the indication for motors 1 and 2; turning a selector switch gives it for motors 3 and 4. If the meter reads 3150, it means motors 1 and 2 are drawing a total of 3150 amp. Multiplying that figure by four gives the total current for both locomotive units.

AT 8:40 Bowden stopped on the mainline in East Bridgeport and the crew broke the train four cars behind the locomotive. With the four cars in tow the demonstrator proceeded down the track about a half mile, then backed off the mainline into a westbound siding. The remaining 84 cars of NG-3 sat like ducks on the mainline. After further shuffling, the four cars were dropped and 40 were picked up from another yard track.

At 9 o'clock Lynch came aboard with another bundle of waybills. He tied them into the ones he had from New Haven. "Here's the total: 124 for the Pennsy; tonnage is 3699. One under the limit." During the previous afternoon Lawlor had said that the westbound limit from New Haven to Bay Ridge was either 125 cars or 3750 tons. Traffic on the mainline and distance between automatic block signals holds the length to 125 cars, and the west-bound approach to the Hell Gate Bridge—the ruling grade—limits the gross weight.

It was 9:24 when a longer and heavier NG-3 left Bridgeport.

EVER SINCE I had met the crew three hours before, the talk had always centered on railroads, railroad equipment, or railroad men. Autos, baseball, or other subjects just weren't discussed except once when Todd found a white running flag on the cab floor, wedged between the control pedestal and the forward bulkhead. It was a piece of metal painted white. Bowden said it didn't belong to the New Haven because they used cloth flags to indicate if a train was a "special." Todd said it was probably left over from the demonstrator's run on the Great Northern. "You know what you ought to do, Wade?" Todd said. "Why don't you paint it up, put your house number on it, and stick it in your front lawn?" Bowden let out a roar. 'Look. None of that stuff. I have enough trouble with my house. You know what happened to me a few years ago with that bunch of road foremen I work with? I went on a vacation and when I came home I found that they had put my house up for sale. That's the way I found it when I came back. I had an awful time." He roared again.

All-electrics are quieter and cleaner than diesels. There isn't any throbbing from engines or whistling from turbo-superchargers; only the noise of the running-gear and the high-pitched whine of the blowers. But there's not much difference in riding qualities. In both there's an easy side-to-side motion, not much up-and-down movement, and little bouncing. The New Haven has a good road-bed. "These babies are the cleanest thing on the road." Bowden remarked. "People think diesels are clean but they're not. Lots of oil and soot. Sometimes my wife tells me that I get dirtier on the diesels than I did on the steamers." He laughed.

East of Rye the signals were yellow-red. West of Rye, in the next block, they went red-red. Bowden brought the train to a stop and shook his head. "One of the hardest places on the road to get stuck." He pushed his cap back irritably and made some statements about all dispatchers in general and particularly about one who would stop a heavy drag on a grade. "You can't argue with City Hall," Todd said. Bowden laughed and said he guessed all any engineer could ever see was the length of his own train.

CONTINUED ON NEXT PAGE

While waiting, three passenger trains went by; two were locals.

After five minutes the signal showed green. Todd moved over and stood behind Bowden, I watched from the center of the cab near the windshield. With his right foot Bowden operated the sander switch to feed sand to the rails. He had the throttle back to 6 when the slip indicator flashed red on the instrument panel and a buzzer sounded. He shut off power, shook his head, shoved the reverse lever, and ran the locomotive back a length or so to put in train slack.

He threw the reverse lever forward and notched out again. The locomotive slipped. No one said anything and Bowden said to no one in particular, "Worst place in the road to stop. Not only a grade but also a reverse curve."

Again he went into reverse and this time put in more slack. He fussed with his cap and pushed himself upright in the seat. More sand as he pulled the throttle open. The needle on the motor-ampere indicator topped 4000 and quivered against the pin. Slowly the train eased ahead. Everyone relaxed. Bowden looked around. "You can start 'em, but you don't like to stand too long on one spot on them armatures. This is a good locomotive. I work them hard. It's a locomotive, it ain't a watch. Locomotives are on railroads to do a job. If they don't do the job, I say take 'em off. This is a sweet baby."

A little later NG-3 rolled past the Grand Central branch-off at New Rochelle Junction and hit the Oak Point Yards at 11 o'clock.

Bowden started the long westward climb to Hell Gate Bridge at 29 mph. Straight ahead, hidden by a faint haze, were the towers of Manhattan. Off to the left was the arch of the bridge. The locomotive swung into the curve and went over the bridge at 30 mph and 3400 amp. Below was a bright view of parkways and some of the greenery of city developments.

ABOUT NOON NG-3 was brought to a stop at Bay Ridge and the last 84 cars were cut off. Todd left the cab to get coffee and sandwiches.

After waiting 10 minutes for a dumpy Long Island switcher that was working a string of box cars, Bowden took the remaining 40 cars toward one of the four car-float piers that were a half-mile away. The string was cut off, but there wasn't room to cross over to an empty track unless the locomotive went onto the float bridge. As the locomotive got closer, Bowden yelled down to a yard conductor and asked if it was okay. He got the nod and proceeded. A car-float bridge with 244 tons of locomotive on it does not feel substantial. Straight ahead was 50 feet of track with white-caps at the end. Bowden stopped. Switches were thrown, the locomotive backed off the pier and proceeded to the eastern part of the yard where a section of GB-8 was waiting.

Todd returned shortly afterwards with food and I asked him about his responsibilities as a service engineer. I had noted that all during the trip he was taking readings on the various meters and indicators and recording them on his clip board. He told me about his duties while we ate, and afterwards I went back into the locomotive with him where he showed me a recording watt-meter and an indicating watthour meter. "Schenectady wants this stuff," he told me. "From this they can get power costs and compare it to diesel fuel costs."

ONE ADVANTAGE of all-electrics and diesels when operated as multiple units is that the locomotive doesn't have to be turned around for the trip back, as is the case with steam locomotives. The engineer merely detaches the two airbrake handles, the reversing lever, and the blower control handle, and walks through the locomotive to the other end where he puts the handles in place.

After the changeover Bowden lowered the forward pantographs and put up the other ones. I asked him why. "On this railroad we always use our trailing trolleys. That way, if one should get knocked off, it won't drag the other one along with it. If an accident should happen, we'd still have the forward trolleys to get by on." He went on to explain that only one pantograph was used for each locomotive unit. "You can't get any more power with two."

Shortly before 2 o'clock, about one-half hour after scheduled departure time, the locomotive coupled onto GB-8. It stood on the southernmost departure track, adjacent to a high concrete retaining wall.

A little later Lynch threw a package of waybills into the cab. Todd picked them up and read the slip of paper on top. "A good weight. Tonnage is 5206 and we've got 111 cars." Bowden was happy. At 2:19 he turned around in the engineer's seat, yelled, "All set?" pushed his cap back a little, fed sand, and notched the throttle. The ampere indicator moved up to 4000 and hit the pin. The slip indicator remained dark and GB-8 rolled out of Bay Ridge. Leaving that spot, Todd told me later, was one of the toughest jobs on the New Haven.

The eastbound approach to Hell Gate was made at a mild pace; it's a lighter grade than westbound and the load limit is 6200 tons. A long drag on Hell Gate is a handsome sight. Coming off the approach toward Oak Point the signals went red. Todd called me over to the cab door behind the engineer's seat. He pointed back. Far away on the other approach of the bridge was the end of GB-8. "It's a long train," he said.

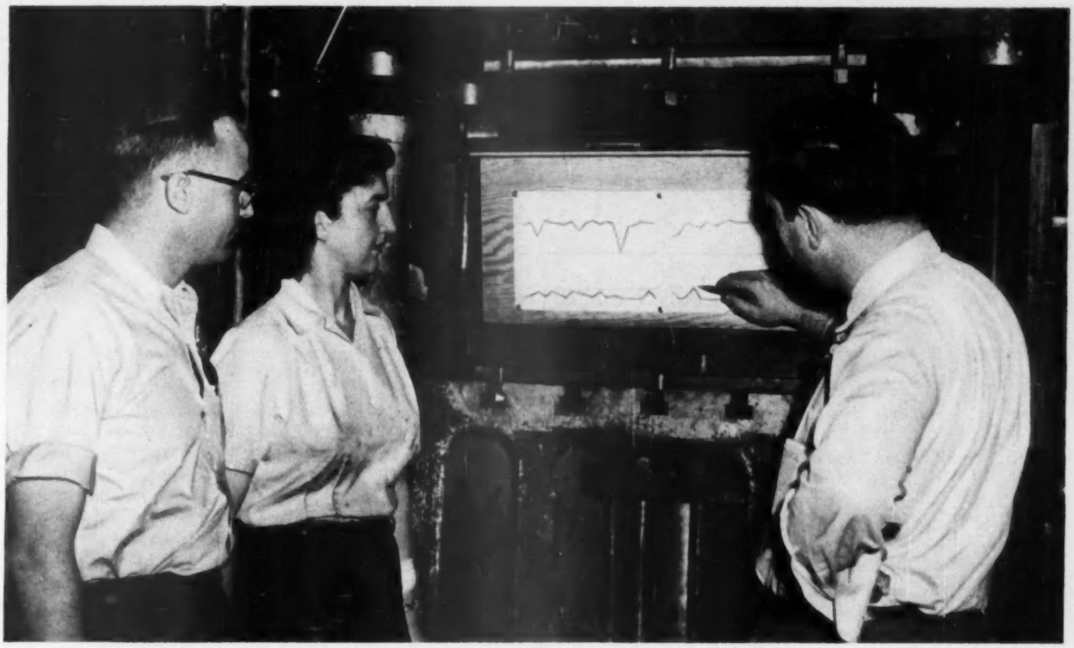
While waiting, one of the Pennsylvania's new *Senators* went by. Bowden said perhaps he would follow her in and spoke favorably of any dispatcher who had that much understanding. He never saw the *Senator* again.

From New Rochelle to west of Stamford GB-8 rolled at 50 mph, the freight speed limit on the New Haven-New York stretch. Bowden was happy to get the signals because of the heavy commuter traffic west of Stamford. The countryside of Westchester County is green and gently rolling with golf courses, woods, housing developments, convertibles, and station wagons all around.

At 5:54 GB-8 stopped in Cedar Hill's eastbound receiving yards. Fifty-one cars were cut off and the locomotive pulled the remaining cars to the eastbound hump. Yard switching, I soon found, isn't always done by switchers. For 40 minutes Nos. 5025–5026 worked back and forth and waited around.

At 6:48 Bowden stopped at the engine pit where he had started nearly 12 hours before. The crew and I climbed down from the cab. O'Connor and Driscoll left; Bowden, Todd, and I went into a nearby shack to wash. Shortly after, the three of us walked toward the Railroad YMCA. A four-unit Alco-GE diesel eased by headed for the Shore Line departure tracks. "She'll probably take her the rest of the way," Bowden said.

In a half hour GB-8 would start its final lap to the produce markets of Boston. —PRH



QUALITY CONTROL CHART FOR PLASTICS MOLDINGS IS A CHECK ON PRODUCT'S PLANNED DISTRIBUTION AND A RUNNING RECORD OF TRENDS

Statistical Methods in Industry

By DR. JAMES H. DAVIDSON

When I was younger, statistics was the science of large numbers. Now, it seems to me rapidly to be becoming the science of no numbers at all!
Oswald George,
A British Statistician

Statistics is one of those words in the English language that is used to convey a wide variety of meanings. It's for this reason that the term *statistical methods* will be used here.

It's said that the application of statistical methods in industry is the greatest advance in manufacturing in the last quarter century. Be that as it may, many progressive corporations—as well as the military procurement services—are firm in their belief that the proper use of statistical methods obtains better quality engineering and a better quality product with greatly reduced costs and considerably better employee relations.

Discounting its use in studying games of chance, probably the earliest recorded application of statistical methods to practical scientific investigation occurred in 1876. Charles Darwin was then studying the effects of pollination on the growth of plants. To help him analyze the maze of accumulated data, he called in the mathematician, James Galton.

From this application statistical methods spread rapidly to experimental agriculture and biology. Their use, therefore, became an accepted and proved supplement to scientific investigation long before they were introduced to industry.

How do statistical methods help industry achieve more economic production through more uniform quality, more meaningful standards and specifications, and more reliable test data? Let's consider some specific cases and see how statistical methods help you.

In general, statistical methods are discussed in relation to five separate fields of endeavor. They are: 1) process control; 2) sampling and inspection; 3) commercial and accounting application; 4) design of experiments and analysis of data; 5) research on new statistical methods.

Process Control

A simple example of process control is a one-man business of the sort prevalent 75 years ago. For instance, the owner entered his office in the morning and sorted the mail. If there were any orders, he'd go to a pile of raw materials in one corner of the shop, select the proper ones, and then proceed to assemble the units by hand. If they were completed at the end of the day, he'd pack them up and mail them on his way home.

Such a manufacturer had little trouble with raw materials or parts that wouldn't

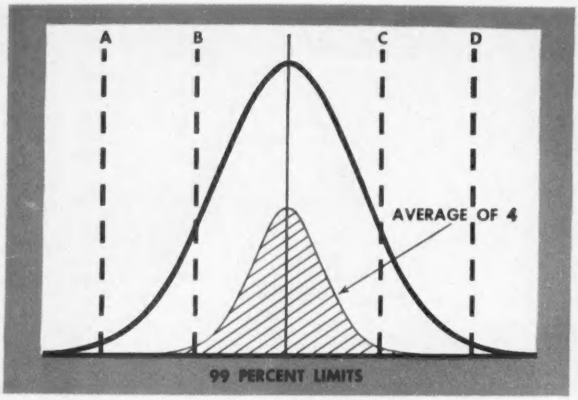


FIG. 1. BELL-SHAPED DISTRIBUTION OF 100 MEASUREMENTS

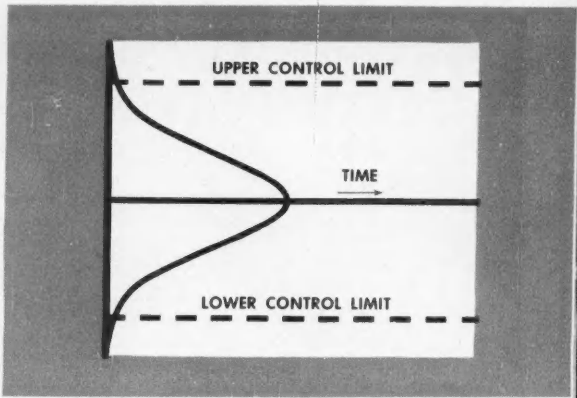


FIG. 2. QUALITY CONTROL CHART IS OBTAINED FROM FIG. 1

fit. His specifications and tolerances (the few he did have) were naturally liberal. Even so, if parts didn't fit, he could easily take time to adjust or rework them.

Things, of course, are a lot different today. In a great many cases, performance and tolerances acceptable in early industrial years are now inadequate. Rework is a costly item and it's necessary to have things right the first time. Elaborate systems of process checks and inspections have grown to be a heavy financial burden.

Statisticians, on the other hand, recognize that each manufactured part can't be made *exactly* like every other—or even like a standard.

For example, suppose 100 people were asked to measure the length of a single object, say an ordinary kitchen table. You might expect almost perfect agreement if the measurement were made with a rough yardstick, reading only to the nearest foot—providing, of course, that the table were an even number of feet long and that the answers were given only to the nearest foot. However, if you gave these people a fine steel rule and requested them to give the result to the hundredth of an inch, you would get a wide variety of answers. Now, if these were plotted against their frequency of occurrence, you would have approximately the large bell-shaped distribution curve shown in Fig. 1. That is, assuming an accurate scale and unbiased effort, more results would fall on and about the true length than at any other reading. If now the individuals had pooled their answers in groups of four, the 25 averages would be distributed as shown by the curve with the shaded area.

Having this much of a start, and knowing the mathematics of the distributions, it's an easy matter to predict the *limits* within which you can expect random variation. These are shown by the dotted lines *A*, *B*, *C*, and *D* in the same figure. The lines *A* and *D* include 99 percent of the individual answers. Lines *B* and *C* include 99 percent of the averaged answers. These limits allow for *prediction* and *control* of future values. For instance, say you measured the table in question and came up with a measurement farther from the average than the limit line. Then it could be said with an assurance of 99 percent that you had committed an error in reading—or at least some cause was in effect to make your measurement significantly different from those of the first 100 people. If four people were to average their results and discover that the average was outside of the limit lines *C* and *D*, the same statement could be made. It must be noticed that these criteria for the average of four pooled answers are much more sensitive than those for an individual reading. The average method has this additional advantage: even though the individual measurements do not come from the normal distribution shown by the center line in Fig. 1, the average values—for all practical purposes—will be distributed in the manner shown by the shaded curve.

If now Fig. 1 is turned on its side and the limit lines extended as shown in Fig. 2, you have the framework for a *quality control chart*. You can see how this becomes a chart to record the progression of individual values or averages with time. It gives a quantitative measurement for determining when measurements are significantly different from the established planned distribution. Further, it gives a running record of trends.

For example, if you were to make continuous measurements on the table and plot them on Fig. 2, you could immediately detect the time when a reading error was made. In a like fashion, when the parent distribution represents chemical batches, screw-machine-piece measurements, motor performances, casting weights, or any other measurement made during processing, then the control chart is a tool for keeping the process on the beam. The control limits become fair machine or operator capabilities. In-process specifications that fall within these limits certainly should be examined most closely—because it will be predicted that more than one percent of the units *must* fall outside the specifications by chance variation alone.

Of course the application of quality control involves a great deal more than statistical methods. There is the human

For 10 years Dr. Davidson, holder of a U.S. Naval Bureau of Ordnance award for development work, has been associated with statistics in research and manufacturing. He came to General Electric in 1950 to organize and direct the Statistical Methods Section of the General Engineering Laboratory, Schenectady, where his group now serves as a consultation center.

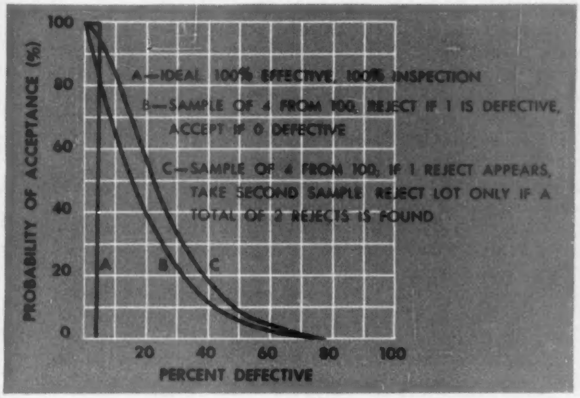


FIG. 3. OPERATING CHARACTERISTICS OF SAMPLING PLANS

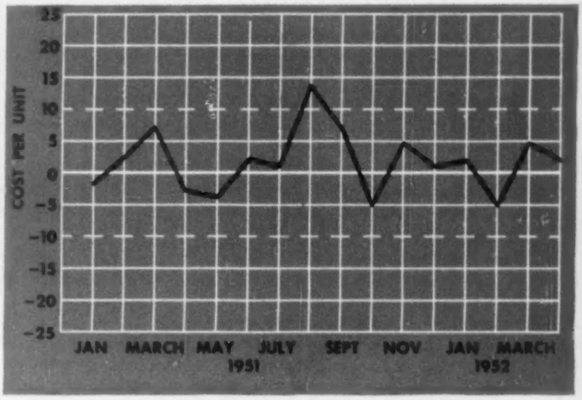


FIG. 4. COST CONTROL CHART FOR MANUFACTURED PRODUCT

side. In general, the closer you can approach the feeling of pride and craftsmanship already present in every operator, the quicker he'll generate a feeling of quality mindedness and be disposed to produce a consistently high quality product.

Sampling and Inspection

Inherent to any quality control program is the sampling inspection of incoming raw material and outgoing product. When you are faced with an incoming shipment of 500 drums of oil, 600 packs of sheet steel, 200 drums of wire, or the like that must be sample tested, there is no question about the need for statistical methods.

Sampling plans are divided into two general classifications. They are *attribute* and *variables*. An attribute plan is one in which the piece to be inspected is classified either as good or bad; a variables plan is one in which the unit is actually measured and the measurement recorded. For certain attributes such as odor, taste, or general appearance a variables plan may be unpractical. Great strides are being made, however, in applying statistical methods to help measure quantitatively even these quantities: particularly in the foods and beverages industries. A variables plan, as you would expect, gives a good deal more information about a lot of material. Also, from the viewpoint of the number of samples necessary to clarify the lot, it's more efficient.

Within each of these classifications there are three types of plans; namely, *single*, *double*, and *multiple* plans. The single sampling plan has the advantage that a decision about the lot is made after the first sample (one or more units). Its disadvantage is that usually it requires the inspection of more units in the long run than do the other types of plans. In a double sampling plan either one or two samples may be taken. On the basis of the first sample (which generally consists of fewer units than for a single sampling plan giving the same protection) a decision is made to reject, accept, or to take the second sample. If a second sample must be taken, the decision for acceptance or rejection is made with the combined sample (which generally consists of more units than for a single sampling plan giving the same protection). Multiple sampling plans carry the same process described for double sampling to further steps and may require several samples before a final decision is reached. A multiple sampling plan in the long run, however, requires the fewest number of samples for a given quality assurance.

In any sampling plan there are two types of risks or uncertainties: the chance of accepting a defective lot (usually known as the consumer's risk); and the chance of rejecting a good lot (often known as the producer's risk).

A sampling plan can be completely characterized by its operating characteristic curve, Fig. 3. This is a plot of the percent defective material vs its probability of acceptance. The operating characteristic curve of an ideal sampling plan is shown by curve *A*. This curve shows a vertical drop at the maximum fraction defective to be tolerated. Such a plan, however, would require a 100 percent inspection which was 100 percent efficient. To indicate the improbability of such a condition, it is interesting to note that on the average a 100 percent inspection is found to be only 85 to 88 percent efficient at best.

Consider now the simple case of the acceptance of sheet rubber on the basis of appearance alone. Suppose you find it necessary to accept the rubber in batches of 100 sheets and decide to sample four sheets from each batch. Further, you decide that the lot will be rejected if as many as one sheet is found defective in the sample. If 10 sheets are defective the chance of accepting the lot under such a plan would be—

$$\frac{90}{100} \times \frac{89}{99} \times \frac{88}{98} \times \frac{87}{97} = 0.65$$

As other fractional defective lots are considered and their chance of acceptance plotted, the operating characteristic curve as shown by line *B* in Fig. 3 can be developed. Note from the curve that a lot of 1.25 percent defective would be accepted 95 percent of the time. This point has been termed the *acceptable quality level* (AQL) of the plan. Note also that a lot as bad as 43 percent defective will be accepted 10 percent of the time. This point has been designated as the *lot tolerance percent defective* (LTPD).

Suppose you now decided to give the lots a second chance so that when a single defective was found on the first sample, a second sample would be taken into account—and the lot rejected only when a total of two defects were found. The operating characteristic curve would then be changed to curve *C* in Fig. 3. You can see that the AQL of the plan has been increased and the slope of the curve has been decreased. The latter indicates a less-sharp screening action by the plan.

Recent trends in sampling theory have a sliding value for the definition of AQL rather than the stationary 95 percent. Other types of plans—such as continuous sampling—have been designed for continuous production, thereby making provision for increasing or decreasing the amount of sampling continously, depending upon the process average. Therefore, the poorer the quality, the more sampling would be done. In general, the trend is to make the sampling plan as sensitive as possible to changes in process average—yet guarantee an acceptable quality product.

Commercial and Accounting

You can't expect the cost of a particular operation to remain constant from week to week or month to month any more than you can expect the measurements on our table, or the units from a production line, or the chemical analyses of successive batches, to have exactly the same values. By the mere nature of things some variation must be expected. The question is: How much variation can be tolerated before an investigation into causes is justified?

As an example of how a control chart can serve you, let's consider the case of a department manufacturing a product that through the years seems to have about leveled off in unit cost. Standard cost has been established and variations are noted by the accounting department each month. The control chart made for this product is shown in Fig. 4 and the center line of zero indicates standard cost. When the cost is more than standard, it is shown on the plus side; less than standard, on the negative side. At one time it was routine to investigate every point that was reported above the zero line. This practice caused difficulties and consumed a great deal of everyone's time. Not only was the cost department wasting efforts by yelling wolf with justification, but also the foremen involved resented being called to task for relatively minor variations beyond their control. As long as the points remain within the control limits, the chances are even that when a month's cost is more than standard, the next month will be less. When a point is outside the limits, however, there is a 99 percent assurance that a drastic change occurred. A chart of this nature therefore gives you a running history of costs, and also a criterion that everyone must recognize as indicating a significant deviation from the standard plan.

The foregoing example shows one of the uses for indicating random variations in cost. At the same time, the variation in cost is predicted by the chart limits into the future with known precision.

Other analyses of cost variation might include in the evaluation the cost of handling sales—as compared to the amount of sales billed—or the prediction of service costs based on the amount of production. In this field we have found that cumulative costs can be predicted with amazing accuracy and precision. The error of prediction for a particular monthly cost, however, must contain a large allowance for spotty variations in work load and consequent variations in billing times.

Design and Data Analysis

In the fields of engineering evelopment and research, as distinct from manufacturing, the applications of statistical methods are of a more mathematical nature. Once you are convinced that your measurements are subject to a random variation, the way is open for a substantial increase in efficiency of experimentation and analysis.

Most problems involving the design and analysis of an experiment require the combined efforts of the experimenter and the statistician. The techniques for design and for squeezing out of data all its information have become so complex that the engineer or the researcher could not spare the time necessary to study many of them. It is therefore desirable to add another member to his team—the statistician.

Scientific methods commonly used in research consist of three essential steps: hypothesis, experiment, and analysis of results. The fundamental difference between engineering with and without statistical methods boils down to the difference between a concept that does not allow for chance or uncertainty (except in a very unscientific manner), and one that accepts the laws of probability as an attribute of nature. Under the highly refined discipline of scientific work today variations can't merely be dismissed as an experimental error by the researcher. On the contrary, the variations between repeated observations give as much information about the process as do the observations themselves and so must be measured and interpreted in terms of physical happenings.

The general object of designing an experiment is to devise a scheme whereby the most information is obtained from the fewest number of observations. Up to a point you can usually say that the more observations made the greater will be the information gathered. However, an economic balance must be made between manpower and money on the one side and useful information on the other. The size of an experimental design can range anywhere from the *factorial design* (Table I) on the one end to the so-called *Latin square* (Table II) design at the other.

In a factorial design, all combinations of variable are tried. As an example of this, take the following actual experiment.

One characteristic used to measure the acceptability of silicone gum-rubber batches is viscosity. It was desired to know whether there was a significant variation between drums of the material (that make up a batch), between operators making the tests, or between various types of viscosity measuring jars. If there had been three drums, three operators, and three types of jars, then 27 runs would be required for a complete factorial design. The results of such an experiment can be shown in the manner of Table I, where each figure represents the sum across the three jars.

Table I represents the sum of the three readings made by operator 1 on drum 1; the sum of the three readings made by operator 2 on drum 1; and so on. Sub totals 1391 and 1384 are the totals of the readings made by operators 1 and 2—the difference between totals results entirely from the difference between operators. The reason is that each of the other variables is represented in an equal manner in the total. In the same way the difference between 1303 and 1369 results entirely from the differences between drums 1 and 2.

From this pattern, you are able to compare the effects of drums—one to the other—and the effects of operators, without fear of any biasing or weighting. Any interacting effect between drums

TABLE I

FACTORIAL DESIGN—(27 EXPERIMENTS)

VISCOSITY OF SILICONE GUM-RUBBER BATCHES

Each Figure in Square is the Sum of Three Determinations (One for each jar)

	OPERATORS			
Drums	1	2	3	Total
1	447	432	424	1303
2	465	454	450	1369
3	479	498	511	1488
Total	1391	1384	1385	4160

TABLE II

LATIN SQUARE DESIGN—(9 EXPERIMENTS)

VISCOSITY OF SILICONE GUM-RUBBER BATCHES

Each Figure in Square Represents an Individual Determination

	OPERATOR			
Drums	1	2	3	Total
1	151_A	150_B	139_C	440
2	159_B	140_C	149_A	448
3	140_C	183_A	140_B	463
Total	450	473	428	1351

Totals: A (jar 1) = 483, B (jar 2) = 449, C (jar 3) = 419

and operators can be measured by noting the total variation among all nine values in Table I—subtracting from the total the variation resulting from differences between drums and differences between operators. The result is a measure of the variation among the nine values that cannot be traced alone to drums or operators (nor could it be traced to jars). It is considered to be caused by any relative effect that might occur between operators and drums (that is, a tendency for operator 1 to read high values for drum 2, while operator 2 reads high values for drum 1, etc.). In addition, the random error is caused by inherent variation in the test method and any other unknown or unconsidered variables. It is considered to act alike upon all values. In the example it would be identical to the interacting effect of all three variables together.

If you next wanted to compare the effects of drums and operators without necessarily considering *interacting* effects, you would use the Latin square design shown in Table II. Here only nine determinations are run. Referring to the Table, subscript A stands for the first type of jar, subscript B for the second, and subscript C for the third. By comparing the total of the three A's with the total of the three B's, you can see the difference is attributable to the differences between jars. This is because the other two variables considered would be operated in a like manner in both cases. The other two variables—drums and operators—would of course be compared in the same way as before. Again, the error term in this case would be the difference between the total variation of all nine values, and the total variation considered for operators, drums, and jars. This error term, however, would include all interactions and they could not be separated.

The two experiments outlined represent extremes in the manner of investigation for this particular problem. Table II represents a minimum of effort to obtain a given amount of information about the variables. Conversely, Table I represents a maximum effort to obtain somewhat more information: which may or may not be essential in a specific problem. Between these two extreme approaches lies a whole series of possible experimental designs known as *fractional replications.* While at present relatively little has been published in the journals or the textbooks about these designs, they are being used more and more in our work because the average problem does not need the extreme treatment. It is the very flexibility of the statistical designs for experiments that makes it difficult to decide on the appropriate one for a particular problem. You must be the one to decide how far you want to go in choosing between the shotgun approach of Table II, where relatively little is already known about the variables and a quick inexpensive answer is required, and the rifle approach of Table I, where you have more information about known variables. The solution for each must be hand-tailored to the particular problem and the proper way chosen among the several that are possible.

Research on New Methods

In the field of statistical methods, as in many others, you must constantly be in touch with the frontiers of new mathematical developments—indicated by current publications and the thinking of leaders in the field. All too often the applied statistician is called upon to solve problems for which the mathematician or the mathematical statistician has not well prepared the way. One of the most widely recognized and important problems of this nature can be categorized under the heading of "life testing."

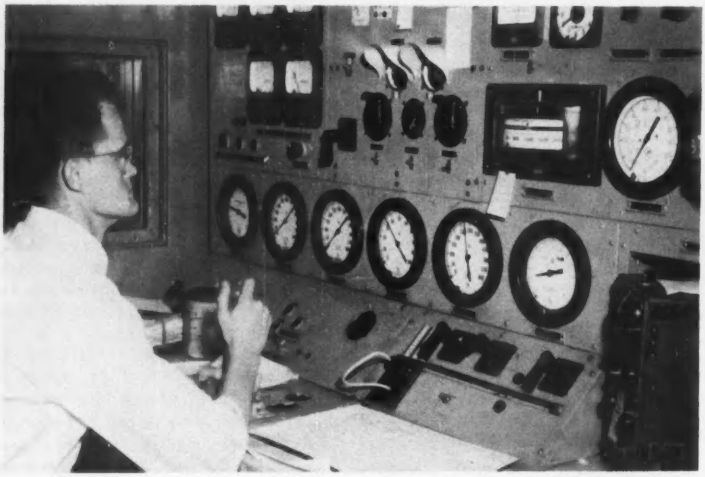
The problem of life testing appears in almost every phase of engineering development. The question, How long will the product last under normal usage? is indeed a highly important and common one. A great deal of time and effort is spent in devising and executing tests that will, in a short time, simulate the stresses and strains of the normal life of the manufactured product. It's indeed a serious engineering problem to devise a test so that a refrigerator will receive in a thousand hours the same amount of wear and tear it may be expected to receive in 20 years. Therefore, it's appropriate that some care be given the analysis of resulting data.

CONTINUED ON NEXT PAGE

TABLE III

k Percent \ P in Percent	99.9	99	95	75	50
0.1	6977	4652	3026	1401	701
1	689	459	299	139	70
2	343	229	149	69	35
3	227	152	99	46	23
4	170	113	74	34	17
5	135	90	59	28	14
10	66	44	29	14	7
15	43	29	19	9	5
20	31	21	14	7	4
25	25	17	11	5	3
30	20	13	9	4	2
35	16	11	7	4	2
40	14	10	6	3	2
45	12	8	6	3	2
50	10	7	5	2	1

The number of units required in a sample for a Life Test so as to be sure (with an assurance of *P* percent) that fewer than *k* percent of future units represented by the sample will fail in a time shorter than the shortest life observed in the sample.



STATISTICAL METHODS are essential to a comprehensive analysis of the data taken from this maze of instruments during the testing of an aircraft jet engine

In many instances, as typified by the case of the refrigerator, only a relatively small number of units can be placed upon test at any one time. After the first failure it's desirable to discontinue the test because months might be spent in waiting for the second failure. How best to interpret the data resulting from such a test was the first problem undertaken by our statistical methods section. The problem was considered to be one of making the best prediction about the life of the production units represented by the sample tested. Since samples are often costly (as in the testing of resistance to radioactivity), the first question asked by the experimenter is, How many units should be put on test?

In Table III are listed the sample sizes necessary to make various predictions about the material represented by the sample, with various corresponding assurances. You can see, from the Table that if 14 units are placed on test and the first failure occurs in 1000 hours, then you could—

Predict with an assurance of 50 percent that fewer than five percent of the production represented will have a life less than 1000 hours

Predict with an assurance of 75 percent that fewer than 10 percent of production represented will have a life less than 1000 hours

Predict with an assurance of 95 percent that fewer than 20 percent of production represented will have a life less than 1000 hours.

A similar tabulation can be easily prepared based on the second or third or fourth failure, but in each case the prediction made would be based on the information provided by only one failure. The next problem is how you can use all the information when you have a set of samples in which there has occurred a number of failures The answer to this involves some knowledge of the type of frequency distribution of the failure times.

The establishment of a likely distribution might be done empirically and its validity limited to the type of product investigated. Or, it might happen that an established distribution, like the *normal* or the *log normal*, will have wide enough practical applicability that it can be used to approximate a variety of cases. These are questions which are presently being studied by our statistical section.

Progress is also being made in the vast new field of application known as *operational research*. This branch of statistical methods was concerned with the best tactical use of material and manpower during World War II, and has become an important study in its own right. Although industry has had relatively little chance to avail itself of operational research, it's the author's belief that it will gain importance during the next few years, as its benefits can be demonstrated.

It's hoped these few glimpses into the general philosophy and operation of statistical methods have shown not only present statistical thinking but also the direction of the next immediate advance. The application of statistical methods in industry can be considered as a logical consequence of the general trend toward more scientific, highly complex manufacturing. As tolerances on precision parts and components narrow, and as government costs complicate the economics of production, the demand for uniformly high quality, efficient engineering, and cost control increases at an astounding rate.

No longer is it feasible to await decisions made by human judgment alone. Modern industry requires modern methods. Ω

ASSEMBLY OF SENIOR HIGH-SCHOOL STUDENTS AND PANEL OF ENGINEERS WITH AUTHOR (STANDING, LEFT) GIVES YOU AN IDEA OF . . .

How to Hold an Engineering Day Rally

By GEORGE A. RIETZ

It is difficult to determine just what incident in the life of a teen-age student will start him on the pathway to a career in engineering or science. Perhaps an interest will be created by a particularly perceptive teacher in one of the lower grades; perhaps it will be the showing of a technical movie, a science demonstration, a talk at a rally, or the viewing of some outstanding engineering project. Perhaps the turning point will be one of these factors, perhaps a combination of all.

Although we can't pinpoint any single factor, we can utilize a series of techniques to help steer qualified students to the field of engineering. Many of these techniques, such as counseling sessions and participation in Career Days, have been used by engineers throughout the years to assist school authorities in offering guidance and encouragement to students.

But there is still another technique that we have tried with success; it's a technique that can supplement those already in use, and it's a technique that we feel can be duplicated in thousands of other communities with the same promising results.

With America's future engineers and scientists now in the classrooms, with a fresh school year ahead, and with the present—and probably sustained—shortage of engineers as an overshadowing specter, the opportunity to stimulate interest and enthusiasm in engineering careers is unparalleled.

This idea I'll outline contains new opportunities. It bears the uncomplicated label of "Engineering Day Rally" —and the objective is simple enough: Hold a meeting and answer questions about engineering as a career. But the results we obtained—four students almost immediately enrolled in engineering colleges, plus a demand from school authorities that we present a series of similar meetings this school year—are tremendously encouraging.

To aid you in setting up meetings in your area the points presented on page 55 will prove helpful. They are based on experience gained from our exploratory meetings.

The mechanics of setting up the meeting are important and so is the

PUBLICITY PHOTOGRAPHS such as this one placed in the students' local newspapers help to create further interest in the Engineering Day Rally

program. Following is an outline describing a program that has been used with success.

Open the meeting with a few words by a guidance counselor or teacher from one of the participating schools. He acknowledges the co-operation of the engineers from industries and then introduces one of the host engineers to act as a discussion leader.

The leader states the objective of the meeting—that it is being held to answer questions the students have regarding engineering, science, and college, and that it is to tell them of the broad fields of professional engineering. He emphasizes that no student should leave the meeting with an unanswered question, because adequate time will be allowed for answering questions from the floor after the prepared questions have been handled.

He clarifies the meaning of the word engineering as applied to this particular meeting—that we are not thinking of the engineer who runs a railroad locomotive or who looks after a large building, such as their own school. He emphasizes that this meeting will discuss the type of engineer who has made possible our transportation and communication systems, radio, television, armaments, modern production facilities, and so on.

He also points out that it is impossible to show them engineers at work because there is no set pattern, and they might not recognize real engineering effort as such. However, some of the results of engineering effort can be related and shown by a short movie. For instance, the 18-minute color-sound movie "Shining Rails" is ideal. Not only does it cover accomplishments in several fields of engineering but is also geared to the high-school age level.

After the movie the leader summarizes his remarks. Keep them brief, because it is essential that the meeting move rapidly and that no one person hold the floor for too long a period of time. At this particular point in the meeting, a "break" is valuable. To maintain the college atmosphere one idea is to have a quartet from a local college sing a few selections. Encourage group singing for a few of the songs.

Mr. Rietz is Manager of the Educational Relations Department, Public Relations Services Division, Schenectady. He is responsible for contacts with schools and colleges for services and relations, and for the interchange of ideas between the Company and educational institutions. He has been with General Electric since 1926.

After the change of pace, the next item on the agenda is the answering of questions that have been submitted in advance. The physical layout on the stage (see photograph on page 53) is not complicated, but arrange it so that all members of the audience have a chance to see, hear, and understand. At one table on the stage place four or five selected seniors from various participating high schools. Provide each student with a sheet containing his share of the questions that were submitted. Be sure that these students are introduced and their school acknowledged. At another table on the stage place four to eight graduate engineers that represent a variety of jobs. Introduce each by name, give the college from which he graduated, plus his present affiliation and responsibility. Emphasize that they represent a variety of job assignments. This provides an opportunity to point out that college engineering training equips the individual for a broad variety of jobs. It is also advantageous to mention that 40 percent of American management is engineer-trained.

The discussion leader then asks the high-school boys on the stage to read in turn the questions they have on their list. It is advantageous if the leader repeats the question so that all can hear. He then asks for volunteers from the engineering panel to answer the question. (The discussion leader can bring the audience into the discussion occasionally by asking if the panel has fully answered any particular question.)

It is important that the panel of engineers is not rehearsed. But do give them a copy of representative questions in advance. This is primarily so that they can have an idea of the types of questions that are involved. Caution the panel members about overselling the engineering profession.

The discussion leader emphasizes in advance that the answers are to be short, practical, to the point, and must be given on a volunteer basis. Because 25 to 50 questions will be handled, long-winded answers are not in order. Also emphasize that any panel member can take exception to the answer given by another member of the panel. I assure you that with such an understanding, a carefully selected panel of engineers of varying ages and experience will furnish all the inspiration and enthusiasm needed to make your meeting a success.

After the written questions are answered, the discussion leader calls for questions from the floor. The panel answers them in the same manner.

In closing the meeting, the discussion leader acknowledges the close co-operation and help of the high-school authorities and expresses the gratitude of the engineers in being able to help the students. If the meeting is closing ahead of schedule, he suggests that the panel is available for personal questions after the meeting is over.

Here are the questions of the type you will receive in advance . . .

"What high-school courses are necessary for me to take if I desire to go on to an engineering college? What are the mathematics requirements for engineering? Why foreign languages, if they are required?"

"What opportunities will I have for advancement in engineering fields? What kind of jobs does engineering lead to?"

"What salaries do engineers get? We have heard that they are low."

Although the preceding outline of a meeting has placed emphasis on an Engineering Day Rally for senior high-school students, we must also reach students in the 8th and 9th grades. It is there that a large number of potential engineers and scientists are lost when they decide *not* to take algebra. For that reason we are suggesting that you also plan meetings of the above general character to which only 8th and 9th graders are invited. Emphasis should be on the importance of taking mathematics and science courses through high school so that they will be prepared to choose from a broad group of jobs—whether going on to college or not. The questions for such a meeting would be considerably different because the students would not be too interested in college. Also, the college glee club could be omitted and the time used for several spectacular science demonstrations. It is still essential that you keep the meeting under two hours in length.

In a rally of this type the importance of such courses as mathematics, science, and others should be covered in a practical and impressive way. Prove that they bear directly not only on engineer-

PLANNING AN ENGINEERING DAY RALLY

Hold an Engineering Day Rally for high-school seniors who expect to go to college, and who feel that they have some interest in engineering or science. Include guidance counselors and teachers, and promote the meeting as a rally.

Hold the meeting at some place other than the school, and in an auditorium that is suited for such presentations. Be sure a public-address system is available, plus facilities for the projection of movies or slide films. Our experience proved afternoon meetings to be the best.

Keep the length of the meeting between one and one-half to two hours in length.

Have the guidance counselors and teachers collect the students' questions and submit them in writing a week or 10 days in advance of the meeting. (Questions from the floor are answered after the prepared questions have been handled.)

Invite as many students, counselors, and teachers as can be comfortably accommodated in the auditorium. Do not make it necessary for guests to stand.

Be sure that all planning and operational details represent close co-operation between the school authorities and the individual engineers sponsoring the meeting.

Have each school select its students and faculty, and clear the number with a central chairman who is responsible for limiting the guests to the capacity of the auditorium.

Enlist the aid of individual engineers, civic clubs, or local industries to handle the transportation of pupils from each individual school to the meeting place.

Do not attempt to combine either a factory trip or extensive exhibits with such an informational meeting. Bulletins and brochures, however, can be distributed as the students leave the auditorium.

Where a large auditorium in some industrial or civic center is available, there will be additional benefits to the students by mixing high schools of two or more nearby communities. (At one of our meetings, representatives of 24 senior high schools attended. Total attendance was about 400.)

Keep the meeting objective. Do not allow commercialism or a sales talk for any one company, or field of engineering, to creep into the program.

Take pictures of students from various schools for release to their local newspapers.

CONTINUED ON PAGE 60

Economics of Cable Sizes in Power Feeders

By CHARLES T. PAUGH

Standard practice in catalogs of electric cable is to list sizes up to 2000 MCM (million circular mils) for secondary power feeders. Some recent catalogs, however, have not listed beyond the 1000 MCM size. A small demand for the larger sizes of cable, resulting from an unfavorable rating in the current capacity tables, is apparently the cause of this. There is a tendency to shy away from large cable sizes in favor of multiple parallel conductors. Indeed, large distribution panels are commonly offered with 500 MCM maximum size cable connectors and multiple connectors if required.

Unfortunately, a large portion of power feeders are selected on the basis of their ratings in the code table of current capacities. This table is based on the allowable temperature rise of the insulation used and does not take into consideration voltage drop and corresponding power loss in the feeder through all the years of its service. Some overenthusiastic proponents of heat-resistant insulation encourage this practice.

A thorough study of the business of voltage drop shows that for average conditions feeders with a two percent voltage drop—compared to the next smaller size—will usually liquidate the added cost in about five years or less. In addition, they frequently have desirable reserve capacity for future overloads. Another advantage is that they make practical the regular use of moisture-resisting thermoplastic insulation with a 60 C rating, which costs less than others with a higher rating.

The primary object of this article is to supply the means for specifying the most economical power feeders for circuits rated 600 volts and lower. It takes into consideration relative purchase prices of the various cables, the installed cost per unit length of each (including conduit if used), and performance capability for transmitting power.

A suitable unit for comparison of performance capability of various feeders is the unit P, which is defined as

(1) $$P = L \times I / dV \times 1000$$

where,

L = feeder length in feet
I = load current in amperes
dV = feeder voltage drop
(1000 is included for brevity.)

Several sources of data are available from which the numerical value of P can be established for various sizes of cable and combinations of cable used in feeders. Though taken from 440-volt 3-phase 60-cycle feeders, the data are applicable to any common secondary voltage.

There are several ways to determine P, depending on what you are looking for. To make P a function of cable construction only and independent of load power factor, it is assumed that the voltage drop and impedance drop in the cable are approximately equal. Based on the average value of power factor—0.8 to 0.95—this assumption introduces only a slight error and makes P much simpler to calculate. For low power-factor loads, such as welders, the true voltage drop should be calculated and equation (1) used to evaluate P.

In most instances, however, the assumption is sufficiently accurate, thus

dV = impedance drop (volts phase to phase)

$$= IZ_1\sqrt{3}$$

(2) $$= LIZ\sqrt{3}/(1000)$$

where,

L = feeder length in feet
I = load current in amperes
Z_1 = ohms to neutral impedance
Z = ohms to neutral per 1000 feet

Substituting the value of dV from (2) into (1) gives

(3) $$P = 1/(Z\sqrt{3})$$

Equation (3) was used to calculate values of P.

Figs. 1 through 5 give visual relative value to the developed data. To produce more uniform curves the Awg size cables are plotted along the abscissa scale on the basis of their circular mil size. Cable insulated with polyvinyl chloride and rated at 60 C was used for sizes 4/0 and smaller. Heat-resistant neoprene-insulated cable rated at 75 C was used for the larger sizes. Therefore, the values of P for 4/0 and 250 MCM cable will differ slightly from calculated values, but for the sake of simplicity only single curves are drawn.

Until recently Mr. Paugh of Glen Burnie, Md. was chief engineer with a large industrial company in Baltimore. He is a registered professional engineer in several states and also a Fellow of the ASME. At the present time he is a plant engineering consultant.

Fig. 1 graphically illustrates the values of P for all cable sizes up to 2000 MCM, and for the two common conditions of three single-conductor cables in a steel conduit, or mounted on insulators in open air. It points out the inadvisability of using cable 1000 MCM or larger, since there is, relative to cost, only a small increase in P. Thus, all all other graphs are limited to 750 MCM. In addition, curve B points out the substantial reduction in performance with separate phase conductors, spaced 12 inches, and discourages the user from this type of construction. Note that the P value of a 2/0 conductor (5.5) is 37 percent that of a 2000 MCM conductor (14.8), but—and this is important—uses only one-fifteenth the copper.

Fig. 2 is similar to Fig. 1 and is plotted to double scale for better accuracy in the useful range. The curve for single conductors in a steel conduit is the same as shown in Fig. 1; the others were selected for appropriate comparison with the latter. As the graph shows, open conductors at any spacing are uneconomical. The performance of self-supporting aerial cable is particularly noteworthy, indicating that it should be given full consideration whenever practicable. Where conduit is required, any of the nonmagnetic materials has a definite advantage over steel provided the conditions permit its use. Direct burial cable with nonmagnetic shielding has the same performance values. This graph is intended for regular use in feeder selection and specification.

The curve for single conductors in steel conduits is again plotted in Fig. 3, curve A. Curves of two and three conductors are added to show the advantages of multiple conductors in this range of sizes. A good example of the use of Fig. 3 is the following: One can

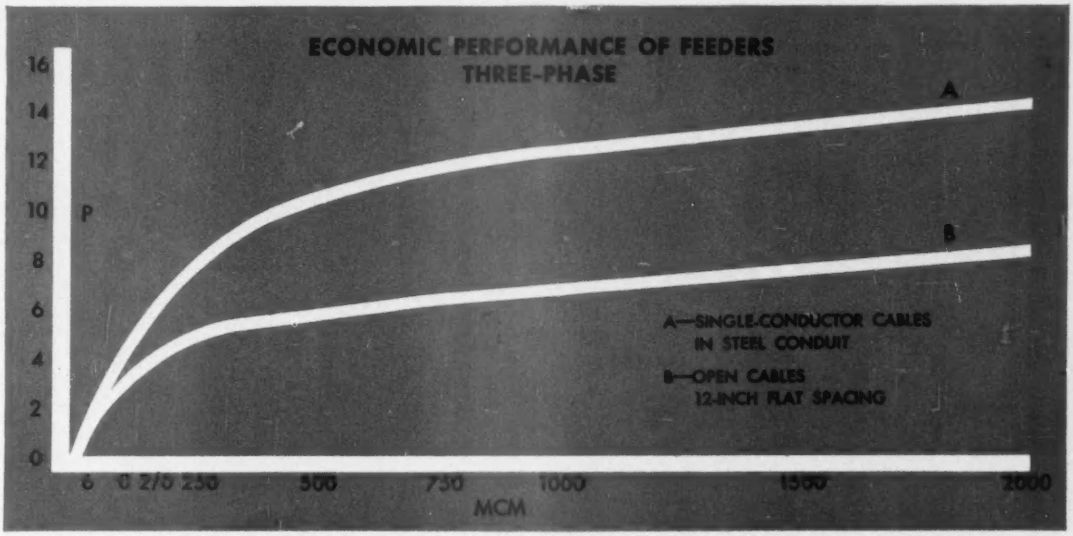


FIG. 1. SMALL INCREASE IN PERFORMANCE CAPABILITY *P* OF CABLE SIZES 1000 MCM AND UP DOES NOT JUSTIFY ADDITIONAL COST

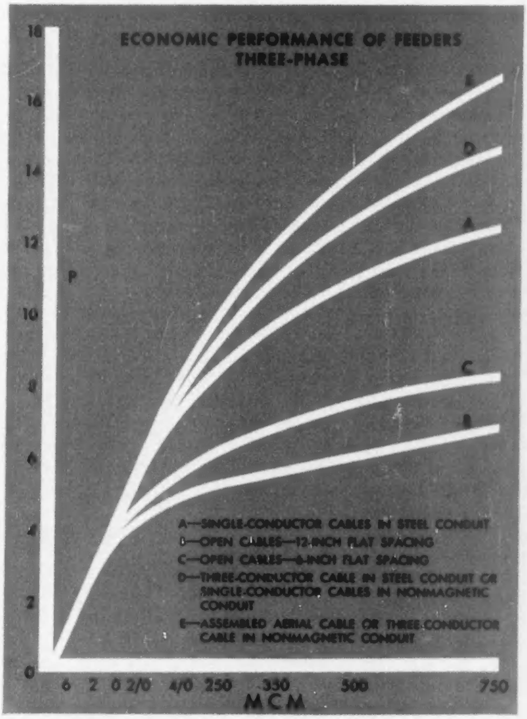


FIG. 2. PERFORMANCE of self-supporting aerial cable is particularly noteworthy. Curve *A* is same as shown in Fig. 1 above

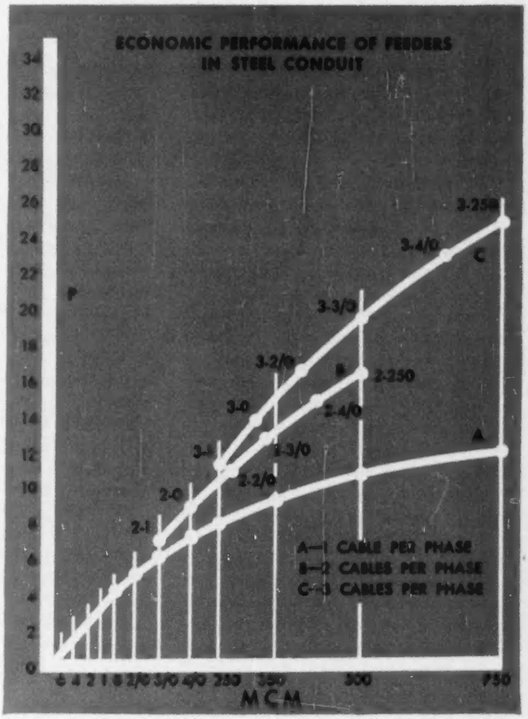


FIG. 3. COMPARISON of curve *A* with curves of two- and three-conductor feeders point up the advantages of multiple conductors

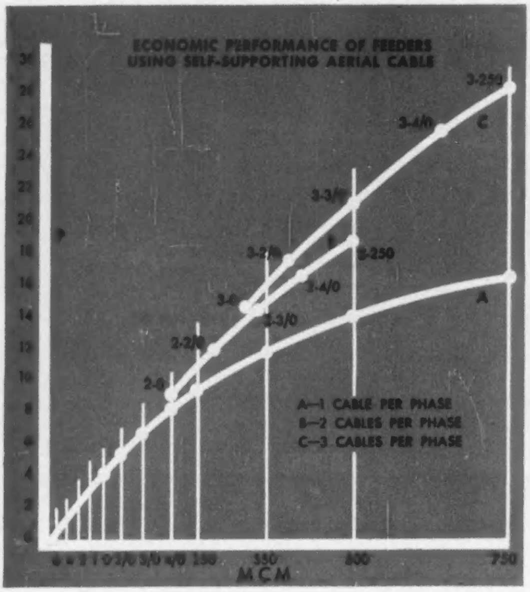


FIG. 4. WIDER USE of self-supporting aerial cable in feeders is encouraged because its performance is superior to other types

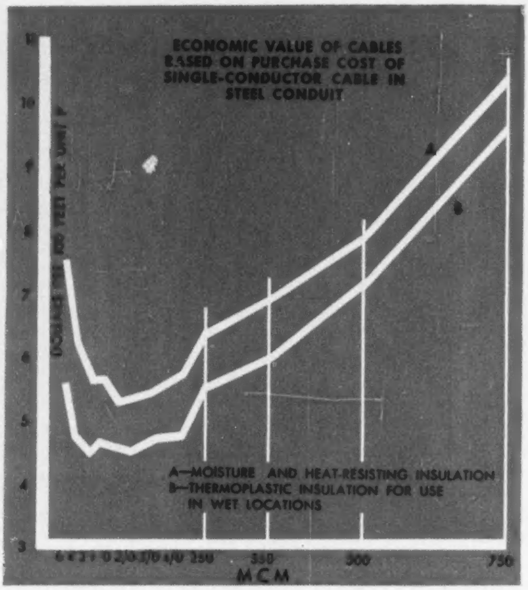


FIG. 5. LOWEST UNIT COST per unit of performance capability is obtained with sizes 4 to 4/0 cable—all other sizes cost more

tell at a glance that three No. 0 size cables in parallel have a higher equivalent *P* than a single 750 MCM cable yet they use only 42 percent of the copper.

The curves of Fig. 4, are drawn for self-supporting aerial cable or "preassembled aerial cable" as described in some catalogs. Its performance exceeds the other types and is therefore recommended for more extensive use.

What cable specification will produce the required performance for the lowest investment? Fig. 5 attempts to answer this question—it includes the purchase price of the various sizes of single-conductor cable and uses performance values as installed in steel conduit. It is at once apparent from the graph that the lowest unit cost per unit of performance is obtained with sizes 4 to 4/0 cable—all other sizes involve higher cost.

The question of insulation, a substantial cost factor, now arises. Synthetic rubbers have made possible excellent heat-and-moisture-resisting compounds—the compound used on Versatol* geoprene cables being typical. However, along with its high quality is a comparatively high cost. Thermoplastic insulation for use in wet locations, such as that used on Flamenol* cables presents a substantially favorable price list. The insulation on Flamenol wire SI-58175 is considered to be the minimum insulation thickness advisable for industrial power wiring. Its characteristics fully qualify it for use in all normal power-wiring applications where operating temperatures do not exceed its specified rating. Normally, it is specified by the author for such general use as permitted by the code—except where a 75 C rating is required.

The Table on page 59 is based on the installed cost of steel conduit, carrying Flamenol cable up to 250 MCM. For sizes 250 MCM and larger Versatol geoprene cable is used in place of Flamenol. The costs are based on regular estimating figures in use during 1950; they include direct labor but not overhead. Similar tabulations can be constructed based on other conditions, but differences shall be mainly a relative shift of costs. The Table is in general agreement with Fig. 5. It exhibits substantial economy in the use of multiple cables and indicates that the need for cable larger than 250 MCM should be viewed with suspicion. Notice the advantage in using multiple conductors when the *P* factor is seven or higher.

But what about ampere capacity ratings of the various combinations? Isn't it true that these values must be checked to assure their being equal to the load requirement? The answer is yes. For feeders longer than 200 feet the current rating will usually be found greater than required, but for shorter feeders a larger cable size may be in order. However, the larger cable size has a higher *P* factor, with a lower power loss, and hence should liquidate the added cost in a reasonable time. Multiple conduits are sometimes used with multiple conductors to avoid the 80 or 70 percent derating factor for six or nine wires in a single conduit. This is an unwise practice since there's no increase in the *P* factor to offset the added cost.

The use of the Table will be illustrated by a few examples:

(1) Amp 300
Volts 440
Length 270 feet
Ambient 30 C

Two percent voltage drop allowed

$P = L \times I / dV \times 1000 = 270 \times 300 / 8.8 \times 1000 = 9.2$

From the Table, on the basis of the voltage drop alone, two 1/0 Flamenol

POWER FEEDER SPECIFICATION DATA

P	Cable Size	Cables Per Phase	Conduit Size	Cost in Dollars Per 100 Feet	Ampere Rating NE Code	Dollars Per 100 Feet Per Unit P	Economic Choice *
2.0	4	1	1¼	$136.00	70	$68.00	
3.0	2	1	1¼	151.00	95	50.30	
3.7	1	1	1½	189.00	110	51.10	
4.6	0	1	2	237.00	125	51.50	
5.5	2/0	1	2	260.00	145	47.20	
6.6	3/0	1	2	286.00	165	43.40	
7.4	1	2	2½	342.00	176	46.30	B
7.7	4/0	1	2½	356.00	195	46.30	A
8.2	250	1	2½	421.00	255	51.40	B
9.2	0	2	2½	378.00	200	41.10	A
9.5	350	1	3	532.00	310	56.00	C
11.0	2/0	2	3	468.00	232	42.50	A
11.0	500	1	3	622.00	380	56.60	C
11.2	1	3	3	472.00	231	42.20	B
13.2	3/0	2	3	521.00	264	39.50	A
13.8	0	3	3	526.00	262	38.10	A
15.4	4/0	2	3	586.00	312	38.00	A
16.4	250	2	3½	755.00	408	46.00	B
16.5	2/0	3	3½	634.00	304	38.40	A
19.8	3/0	3	3½	713.00	346	36.00	A
23.1	4/0	3	4	848.00	410	36.70	A
24.5	250	3	4½	1085.00	535	44.30	A

Wiring in steel conduit for up to 600-volt three-phase 30 C ambient NE Code ratings.
Size 250 MCM and above—Versatol Geoprene Cable insulation with 75 C rating.
Below 250 MCM—Flamenol Cable SI-58175 thermoplastic insulation with 60 C rating.

*A—Preferred
B—Second Choice
C—Uneconomical

cables per phase in a 2½-inch conduit would suffice. This combination, however, would carry only 200 amp.

To carry 300 amp the Table gives three possibilities—

(*a*) One 350 MCM per phase at cost per unit *P* of $56.

(*b*) Two 4/0 Awg per phase at cost per unit *P* of $38.

(*c*) Three 2/0 Awg per phase at cost per unit *P* of $38.40.

On the basis of cost per unit *P*, the most economical selection is (*b*).

(2) Amp 150
Volts 440
Length 645 feet
Ambient 30 C
Voltage drop two percent
$P = L \times I/dV \times 1000 = 645 \times 150/8.8 \times 1000 = 11$

From the Table, three choices are available for $P = 11$

(*a*) One 500 MCM per phase at cost per unit *P* of $56.60

(*b*) Two 2/0 Awg per phase at cost per unit *P* of $42.50

(*c*) Three No. 1 Awg per phase at cost per unit *P* of $42.20

All three alternatives have current ratings in excess of the 150 amp required. Alternate (*b*) is chosen over (*c*) because, although slightly higher in cost per unit *P*, the termination problem is simpler.

The use of moisture-resisting thermoplastic insulation on single and multiple conductors in very short feeders is justified. For, if its use in long feeders to obtain a high *P* factor with a maximum voltage drop of two percent is justified, then—since voltage drop, power loss, and cost are proportional to length—the use of the same size cable in short feeders is equally justified, though the voltage drop may be much less than two percent.

For general use the presently available moisture-resisting thermoplastic insulation has a code rating of 60 C copper temperature. In some applications 80 C is permitted, but where the ambient temperature is above normal, a substantial derating factor is applied. Therefore, it is apparent that at particularly high ambient temperatures, some other type of insulation must be used. It is here suggested that at about 50 C (ambient temperature) consideration be given this transition.

It maybe argued that the use of sufficient copper to limit voltage and power loss calls for a greater amount of copper. But on the other hand, the use of multiple conductors definitely reduces the amount of copper which would normally be required. Use of these recommendations should result in a reduction of copper used in electric cable. The author sincerely believes that the present industrial wiring losses might be halved.

Procedures for Economy

Limit normal specifications to 4/0 maximum cable size and double check all cases that appear to require larger than 250 MCM.

Discourage the use of all regular-type cable larger than 500 MCM (this could be reduced to 250 MCM).

For short feeders requiring very high current capacity, consider other constructions such as bus-duct, annular, or segmental cable. Catalogs *should* include more data on these types of cable.

Make wider use of preassembled aerial cable.

Wherever practicable, eliminate the use of all separated and spaced single conductors.

Where conduit is required, give more consideration to the nonmagnetic materials. For aerial cable consider use of moisture-resisting thermoplastic insulation. Ω

**Registered trade-mark of General Electric Co.*

Transistors—

(Continued from page 24)

50 megacycles is occasionally accomplished. Everett S. Read of the Electronics Laboratory has developed a radio transmitter (page 24) using junction transistors.

High-frequency response is a complicated function of collector capacitance, transit times, and the diffusion process whereby minority carriers wander from emitter to collector. Transistors are now operating in a frequency range where each new increase in the top frequency opens new applications. It's therefore understandable that high-frequency effects occupy an important position in the agenda for further research.

A transistor has unique characteristics of its own and shouldn't be considered merely a substitute for a vacuum tube. To do its job properly, the circuit must be engineered to take advantage of the transistor's characteristics. First applications of importance will be low-frequency circuits, where it's essential that size, weight, and power consumption be minimized. Systems of great complexity may soon turn to transistors as a means of improving reliability.

Temperature limitation upon germanium transistor operation depends on the ease with which conduction electrons are freed by thermal agitation. This is a fundamental property of germanium itself. Other semiconductors are known to be less affected by heat. Higher-temperature and higher-power transistors may result from studies now being carried on with other semiconducting materials.

With this picture of transistors in mind, you are in a position to compare the reasonableness of various proposed transistor applications with the limits of their present capabilities. Although the ultrahigh-frequency kilowatt transistor seems remote on the basis of our present knowledge, remember that 25 years ago 10 megacycles was considered "high" frequency—at that time theoretical limitations of vacuum tubes were believed understood.

The transistor undoubtedly has basic limitations, but the practical limits of its application will be determined principally by the ingenuity and resourcefulness with which its development is carried out. Ω

High Slip Motor—

(Continued from page 42)

mounting is about 30 percent less than the conventional construction. Smaller, lighter, and less expensive supporting structures or foundations are required.

Motors of the new construction are inherently better able to handle severe accelerating duty. Increased horsepower per unit of rotor weight (because of the smaller iron core) makes it possible to perform repeated accelerations—accelerations at a rate that would have been prohibitive before because of high rotor inertia when the motor was made large enough to dissipate the heat.

Improved power factor and efficiency result from maintaining the air gap at normal values. With the old conventional construction, the rotor was considerably hotter than the stator. To prevent mechanical interference when the rotor expanded, the air gap was made abnormally large. The electrical design of such motors was severely handicapped, but this limitation doesn't apply to the new design. Here, most of the rotor heat is generated outside the motor enclosure and the rotor body remains comparatively cool.

A decided increase in efficiency of around five percent is realized with the new motor. This results from less windage loss, normal air gap, and reduced iron and copper losses that normally result from the smaller-size motor core.

Compared with the open forced-ventilated and filtered-air motor that is sometimes used in place of enclosed construction for punch-press drives, and extended-bar motor offers weight the space reduction of about 12 percent.

Considerable field experience was gained with the extended-bar motor during the past two years. It's given excellent service in every instance. Besides applications utilizing the wide speed regulation of high-slip motors, such as for punch presses, they are also used on applications requiring repeated accelerations of high-inertia loads—hoists and centrifuges, for example. Here, their high starting torque and rotor heat-storage capacity are desired. They have also been applied to conveyor drives, and to several large presses.

With its design tailored to meet the requirements of enclosed high-slip motors, the new motor fills a basic need. It should find wide application. Ω

Engineering Day Rally—

(Continued from page 55)

ing and scientific careers but also on other vocations and professions.

If conditions are favorable, it would be wise to set up similar rallies for 10th- and 11th-grade students that would bear on their particular interests.

"Follow-through" on the Engineering Day Rally is important. The long-range benefit from this program might be heightened if the discussion leader challenges the students to form, or join, an Engineering Club in their school. But before such an announcement is made, be sure that the school authorities have agreed in advance.

Such a club, sparkplugged by an alert engineer, will corral and identify potential engineering students, will remind them to take the necessary preparatory courses throughout high school, and will bring them interesting and valuable engineering information throughout the school year. Reports of accomplishments by engineering clubs include "Larger number taking mathematics," "Students scrambling to make up overlooked courses," "Good scholarship being promoted," and "Better understanding of engineering."

Such engineering clubs open to students of all high-school grades are an effective means of identifying prospective engineers and scientists and preparing the largest number of properly qualified youngsters for engineering colleges. It is essential that the engineering advisor and the sponsoring faculty member work together to give the club members responsible parts in regular programs, and to provide outside talent and features, as well as projects that will keep the students continually challenged and alert.

Other follow-up techniques include scheduled factory-inspection trips, plus the furnishing of engineering speakers for Career Days at individual schools.

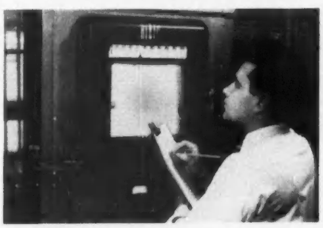
It is said that high-school students today have some 30,000 possible jobs to consider so there is little wonder they are confused. But with well-planned Engineering Day Rallies, engineering clubs, and skillful guidance and counseling on the part of individual engineers, we feel sure that an increasing number of qualified students will have an opportunity to learn more about their future careers in engineering and science. Ω

FASTER ANALYSIS WITH X-RAYS

Chemical analysis by x-ray absorption is now successful on a commercial scale with the G-E X-Ray Photometer, saving hours of valuable laboratory time, and freeing the analytical chemist from tedious routine work. Petroleum refiners slash time and cost determining tetraethyl lead in gasoline, and sulphur in oils.
See bulletin GEC-412A*.

NEW MERCURY VAPOR DETECTORS

Users of mercury compounds can now determine harmful concentrations of mercury vapor with the new, completely redesigned G-E Mercury Vapor Detectors. Electronic and chemical detectors provide either instantaneous or continuous indication. Electronic detector pictured being used to check curing oven in laboratory of silicone rubber plant.
See bulletin GEC-312*.



MEASURES MOISTURE IN GASES

G-E Dewpoint Recorder gives continuous indication and record of dewpoint temperature in gas streams from ambient to minus 90 deg. F. Manufacturers and distributors of gases measure moisture content at different stages of manufacture and various transmission points. See bulletin GEC-588*.

***To obtain these publications, contact your nearest G-E Apparatus Sales Office, or write General Electric Co., Section 687-101, Schenectady, N. Y.**

Operator observes cracking pattern of natural gas sample with G-E Mass Spectrometer.

NEW ELECTRONIC INSTRUMENTS SPEED CHEMICAL ANALYSIS

Research and production chemists benefit by better results—faster

Rapid chemical analysis, by electronic means, makes the G-E Mass Spectrometer an important tool for the modern chemist. Because it measures a basic fundamental unit—mass—it does not suffer from many of the limitations of physical methods. For basic research and routine process control of most gaseous and liquid mixtures the G-E Mass Spectrometer is ideally suited.

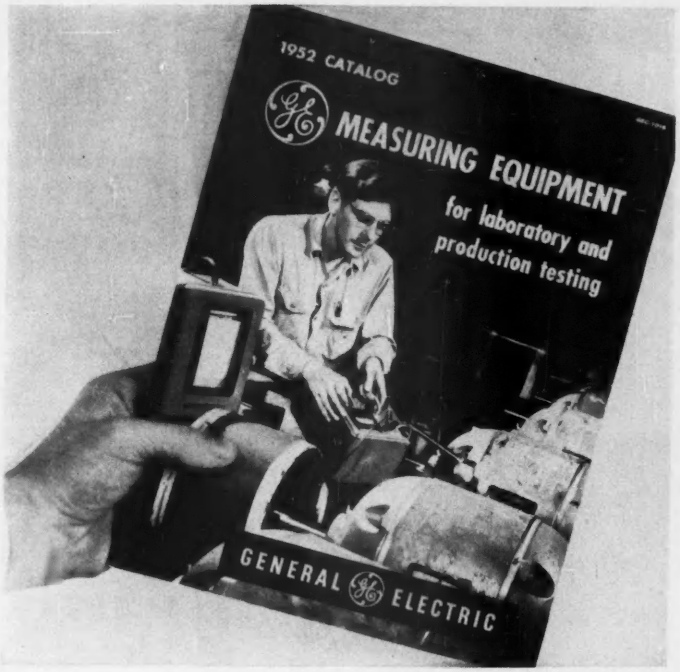
It automatically records peaks at mass numbers ranging from 1 to 600, and separation of a dozen or more compounds is common practice. Immediate results save time in the identification of common impurities and traces of rare isotopes. High resolution permits complete separation of high-mass elements.

Here is another example of G-E research and development—linked to produce more and better instruments for modern industry. See bulletin GEC-587*.

Convenient sample system facilitates introduction of unknown gas mixture.

GENERAL ELECTRIC

39,540 Copies Already Requested



General Electric Offers Complete Catalog of Measuring Equipment

TABLE OF CONTENTS

125 DIFFERENT DEVICES for production and laboratory testing are described and shown in this new catalog.

GENERAL ELECTRIC

Send today for your free copy of NEW 80-page catalog containing condensed information about all G-E Testing and Measuring Equipment.

Section 602-222C
General Electric Co.
Schenectady 5, N. Y.

Please send me GEC-1016, 1952 Catalog of General Electric Measuring Equipment for laboratory and production testing.

NAME____________________

POSITION____________________

COMPANY____________________

ADDRESS____________________

CITY__________ZONE_____STATE______