GENERAL ELECTRIC Review

TOMORROW'S ENGINEERS READ THE COMICS

PAGE 20

SEPTEMBER 1953

New cable withstands 1400 F flame for 24 hours in grueling laboratory test.

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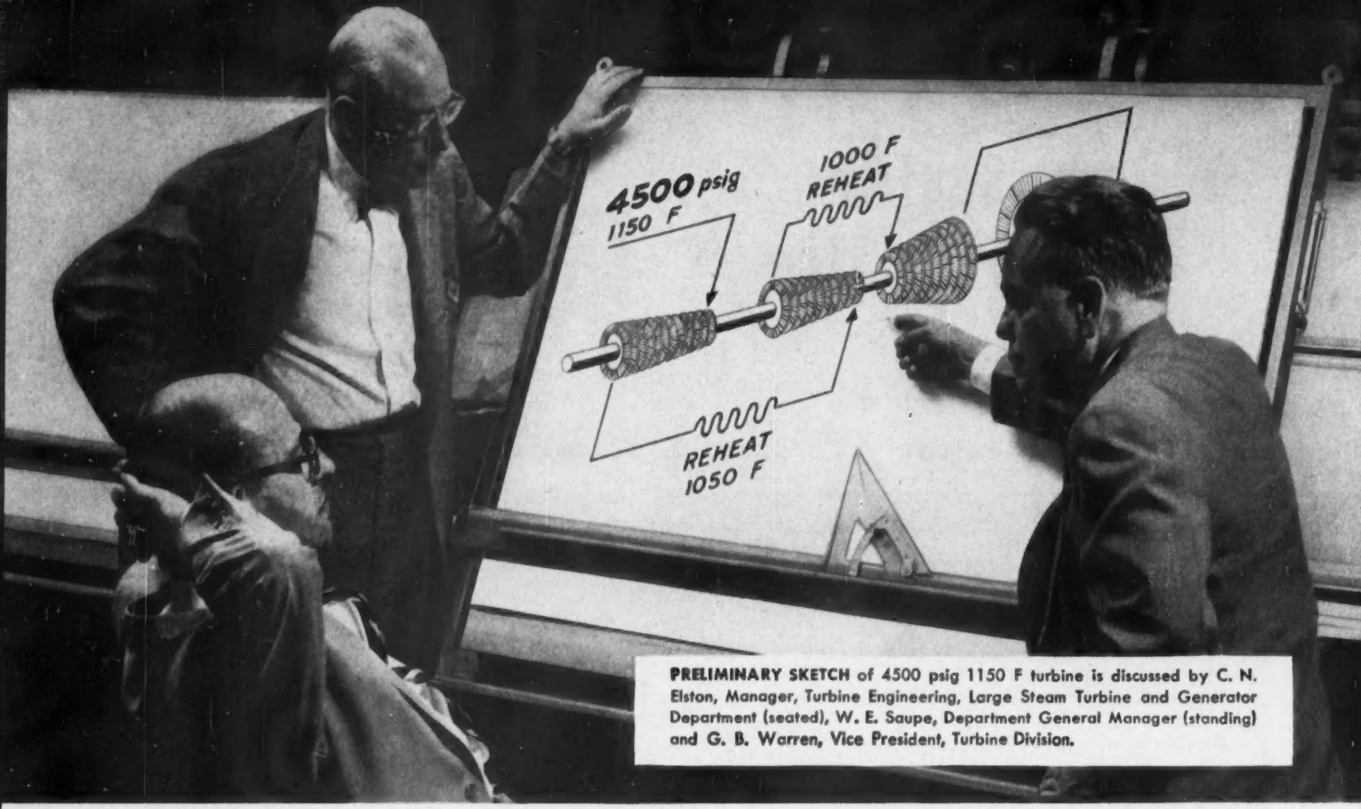
GENERAL ELECTRIC Review

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

COVER—Small boys plus comic books equal entertainment and education today for tomorrow's engineers. For the story of GE's comic book series, see page 20. Photo by George Burns.

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.

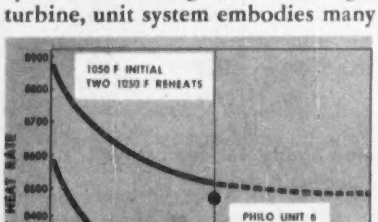
. . . THE CONTENTS OF THE GENERAL ELECTRIC REVIEW ARE ANALYZED AND INDEXED BY THE INDUSTRIAL ARTS INDEX, THE ENGINEERING INDEX, AND SCIENCE ABSTRACTS. . . . SIX WEEKS' ADVANCE NOTICE, AND OLD ADDRESS AS WELL AS NEW, ARE NECESSARY FOR CHANGE OF ADDRESS. . . . ADDRESS ALL COMMUNICATIONS TO: EDITOR, GENERAL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



PRELIMINARY SKETCH of 4500 psig 1150 F turbine is discussed by C. N. Elston, Manager, Turbine Engineering, Large Steam Turbine and Generator Department (seated), W. E. Saupe, Department General Manager (standing) and G. B. Warren, Vice President, Turbine Division.

G.E. doubles steam turbine pressure to gain new efficiency in power generation

A continuous program of co-operation and research between American Gas & Electric Service Corp., Babcock & Wilcox Co. and the General Electric Co. has led to the development of a new unit for the AG&E system. This single boiler—single turbine, unit system embodies many



IMPROVED STATION EFFICIENCY is obtained through increasing temperature and pressure, as boldly done for Philo Unit No. 6. Studies indicate that for any further significant increases, considerably higher initial and reheat temperatures will be required to take advantage of pressures higher than 4500 psig.

new and forward-reaching technological ideas that will contribute to an expected over-all plant thermal efficiency of more than 40%.

The new G-E 4500-psig turbine will operate at almost double the present highest steam pressure utilized for power generation. Initial steam temperature of 1150 F (present highest 1100 F used in another G-E machine) will be followed by two stages of reheat, the first at 1050 F, the second at 1000 F. A newly developed high pressure turbine is used in tandem with a turbine of the reverse flow type developed by G-E engineers several years ago.

NEW MATERIALS NEEDED

Because of these high temperatures some of the working parts such as inner shells, stop valves, control valves, steam leads, etc., must be constructed of special alloys. A feature of the control system of this unit will be an initial temperature regulator which will protect both the steam boiler and the turbine in a manner similar to an initial pressure regulator on a conventional boiler.

POSSIBLE REDUCTIONS

The embodiment of these higher pressures, higher temperatures and new ideas of reheat in a moderately sized commercial unit and its installation and operation in the Philo Plant of the Ohio Power Company will provide experience in the design, manufacture, construction and operation of the newly developed equipment. This daring forward step should make possible new world standards of efficiency in the generation of electric power and it may open a new era for America's Electric Utility Industry. It may ultimately make possible capital investment reductions by compressing unit sizes and bringing about more effective utilization of materials.

General Electric Co., Schenectady 5, New York.

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MORE POWER TO AMERICA

GENERAL ELECTRIC

Putting Electricity to Work . . . Around the World

BRAZIL takes a swift step to market!

Across Brazil . . . through farms and cities, serving agriculture and industry . . . speeds this G-E locomotive. It's a powerful, custom-designed worker for the Paulista Railway . . . served by General Electric locomotives and power equipment for the past 30 years.

By supplying electrical equipment and technical knowledge . . . G. E. helps railroads all over the world function smoothly, economically, dependably.

General Electric's unmatched facilities are at your service when you contact a G-E office. Skilled engineers—drawing upon years of G-E experience—make electricity serve you better.

INTERNATIONAL GENERAL ELECTRIC COMPANY

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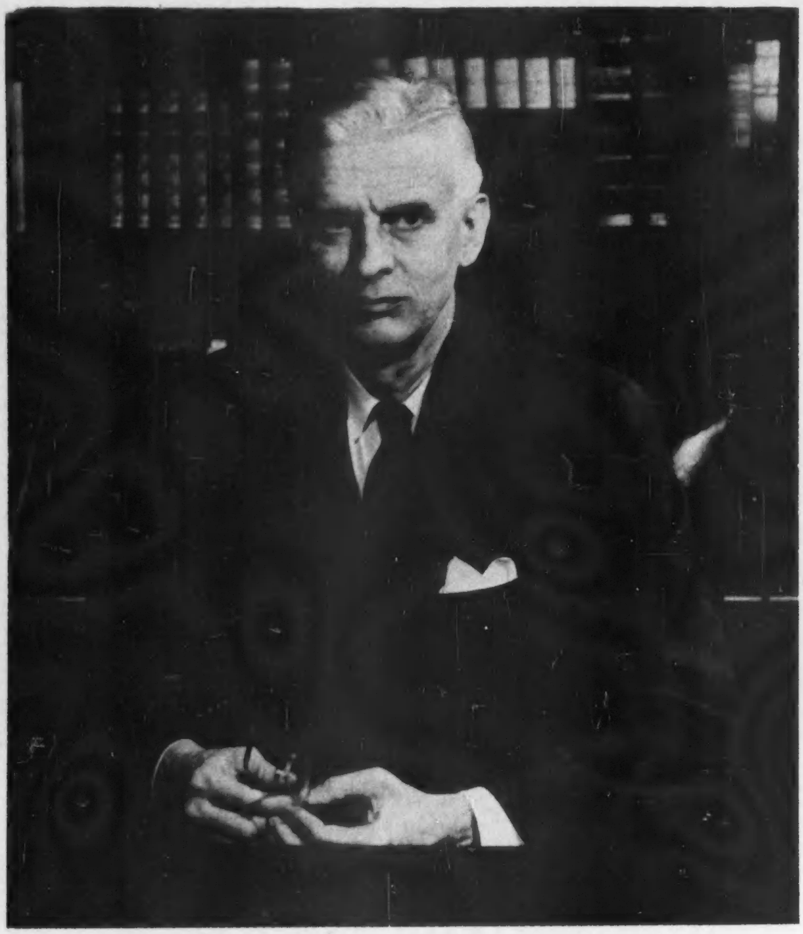


"I believe that the future holds incomparable advantages for those who are willing and able to face up to individual and collective challenges."

CLARENCE H. LINDER APPOINTED VICE PRESIDENT OF ENGINEERING

Clarence H. Linder, vice president and former general manager of General Electric's Major Appliance Division, was recently appointed vice president of engineering and head of the Company's Engineering Services Division by G-E President Ralph J. Cordiner.

Mr. Linder was graduated from the University of Texas in 1924 with a BS in electrical engineering. He later received his MS from the same school.

Joining General Electric in 1924 as a student engineer on the Test Course at Schenectady, he later completed the Company's three-year Advanced Engineering Program.

In the following years Mr. Linder rapidly advanced in diversified fields, culminating with his appointment as assistant to the general manager of the Apparatus Department in 1949.

In 1950, Mr. Linder was named manager of engineering and manufacturing for the Company's former Affiliated Manufacturing Companies Department. A year later he became general manager of the Major Appliance Division. He was named vice president late last year.

As manager of the Major Appliance Division, Mr. Linder was instrumental in developing the plans for Appliance Park in Louisville, the largest single project that the General Electric Company has ever undertaken, a project that will cost in excess of $200-million.

With this varied background and experience, Mr. Linder is confident of the future, and believes it holds unlimited possibilities: ". . . the growth of the electrical industry in the next decade will be very great indeed . . . product leadership is the key to a virile participation by General Electric in this unprecedented industry growth forecast."

"In my almost 30 years . . . with General Electric, I do not recall a single instance where, in any extensive, well-considered expansion, the future was overanticipated.".

"We are . . . heirs to a very bright future!"

THE ENGINEER AND HIS PROFESSION

The contributions of the engineer are everywhere about us. They are in every product made for the use of man. And the advancement of these products through the years has brought to American industry a vast strength and power for service to mankind.

Just as an example, in the short span of years from 1935 to 1950, industry brought us, among other things: radar and television, nylon and other synthetic fibers, the continuous-flow chemical plant, the diesel-electric and gas-turbine-electric locomotives, silicones and synthetic rubber, penicillin and antibiotics, cortisone, the jet engine, magnesium and titanium for structural use, the electronically controlled automatic machine tool, the fork truck, the electronic computer, the germanium diode and the transistor, and nuclear power. Some of these had been discovered or were in some stage of existence before 1935; nevertheless, they were brought into widespread application in the short period of those 15 years.

In parallel with all of these contributions were the continual improvements in those products which we had *before* 1935: the automobile, the railroad, the airplane, the telephone and radio, home appliances, lamps and lighting, the highways and bridges and buildings and houses, the vast electric power systems, electronics, plastics and chemicals, metallurgy, instruments for measurement and control, health systems, the distribution of foods, and improvements in materials of every kind.

All of these new and improved products were the result of untiring research by scientists and of bold development, design, application, operation, construction, and management by engineers. And through increased productivity in the manufacture of goods by the tool and machinery equipment engineers and the factory production engineers, immense heights of production output were attained.

The vastness and multiplicity and complexity of these operations in industry are made possible by the engineer and his associates. With his zeal to go forward, the engineer opens new doors. His opportunity for service is his open sesame to achievement. And in American industry today this is as great as the power of industry itself.

This opportunity has given to the engineering profession the highest mark of service. For the products the engineer has made available have given humanity the opportunity for a fuller life and made it eager for more.

Even though people do not spontaneously recognize him in his products, the engineer still has the urge to provide more new products and to improve present ones. Of science and engineering there is no end. Neither is there any end to the opportunities for the engineer or the need for his contributions.

But the engineer has to work without ceasing to bring about all these things. He must continually study to have knowledge even beyond the special. He has to train himself to have skill even beyond the skillful—to have judgement as to action, and wisdom as to compromise. And he must carry responsibility for human safety.

Above all, the engineer must have an appreciation of his responsibilities—responsibilities for contributions in service to his fellow men. These responsibilities are both specific in engineering and broad in leadership, guidance, and the direction of others as he makes the materials and the forces of nature available for man's continuing use.

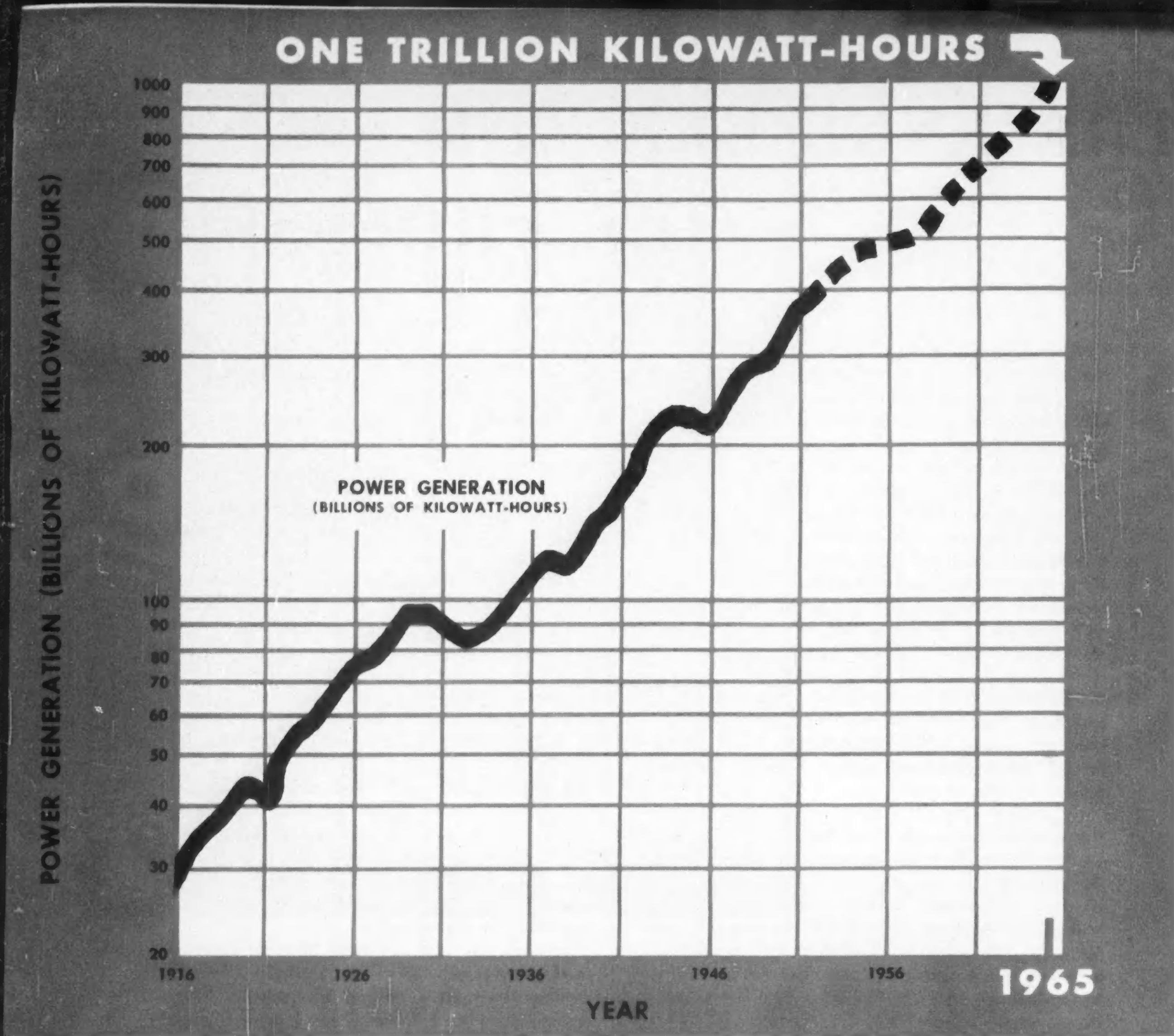
These are the attributes of the engineer. These are the attributes of the engineering profession.

The engineer is a builder. I like to think of this great quotation from Ruskin as the basis of his building:

"Therefore, as we build, let us think that we build forever. Let it not be for present delight, or for present use alone; let it be such work as our descendents will thank us for; and let us think as we lay stone on stone, that a time is to come when these stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor and wrought substance of them: 'See! This our fathers did for us!'"

Everett S. Lee

EDITOR



AMERICA'S HUGE ELECTRIC POWER INDUSTRY IS GROWING AT A REMARKABLE RATE—MORE THAN SEVEN PERCENT COMPOUNDED YEARLY

Power for Tomorrow

Review STAFF REPORT

With our annual consumption of electric energy doubling every 10 years, a trillion-kilowatt-hour year in 1965 is a certainty if the trend continues. This is pointed out by B. L. England, past President of Edison Electric Institute, in his article on the opposite page. He tells how the use of electricity has forged ahead in the past 10 years, how it will grow in the next 10, and how electric utilities are preparing to meet that growth.

But what about equipments and systems to generate, transmit, and distribute a trillion-kilowatt-hour load? Must there be significant increases in capabilities of steam and gas turbines or hydroelectric plants as we know them today? And how much will atomic power, now in the development stage, contribute to the over-all picture? Are transmission and distribution systems adequate to carry this huge load, or will they undergo radical changes? Finally, what about engineering manpower—where will it come from?

To get answers to these and other questions, REVIEW editors queried various members of GE's engineering management team—specialists in their respective fields of electric power. Their replies, given in this REVIEW Staff Report, make it very clear that America's electric power industry is an aggressive one, ever ready to open up new frontiers of growth and development.
—EDITORS

GENERATION

Today approximately 80 percent of America's generating plants are steam-electric, and the remainder, hydro-

THE LOAD AND WHERE IT IS COMING FROM

By B. L. ENGLAND

Electric power is basic to the complex pattern of our modern civilization. And the development of ways in which it is able to serve us has become practically synonymous with the forward steps of American living.

This fact puts an increasingly heavy responsibility on our electric utilities and electrical manufacturers—those who supply the nation's power and who supply both the electric equipment and electric appliances to utilize it.

In pacing American progress our electrical industry has developed with amazing magnitude and rapidity. The United States Department of Commerce said recently: "Electric power has been growing three times as fast as the average [growth] for all industries, or close to 10 percent annually since 1900." On this basis we more than double our electric output about every 10 years.

Ten years ago, when the industry's annual electric generation was about half its present 400-billion kilowatt-hour output, many of the means by which electricity serves us today were finding little use. In the residential field, for example, refrigerators, radios, washing machines, and lighting headed the list of applications then achieving the greatest customer response.

But today television leads them all, and the list includes a host of other appliances gaining widespread customer acceptance—dishwashers, dryers, freezers, room air-conditioners, and electric blankets. For all practical purposes, these appliances were practically unheard of 10 years ago.

The whole range of industrial power applications shows dazzling potentialities. Also on the horizon is an ever-growing commercial market, with cooking appliances, better store and office lighting, and air-conditioning to contribute important new electric load.

Electrical applications in the farm field number 200 or more. Here, the electrical industry is faced with a big job and a great opportunity to put these—and applications yet to come—where they will contribute most to the farmer's prosperity and the agricultural benefit of the nation.

We can, through logical projections of services already being rendered and immediately in prospect, gain some idea of the tremendous future ahead. For example, we can foretell that farms using 50,000 kw-hr annually will become commonplace; this is nearly 18 times their present yearly average. In the American home—with its all-electric kitchen, fully automatic laundry, color television receivers, intercommunication system, and year-round climatic control—there may be a connected load of 50 kw, a demand of 10 kw, and an annual consumption of 25,000 kw-hr, about 12 times today's average. The modernization tempo will increase in factories and offices, which might be considered 100 percent electrified now, with new electric equipment performing miracles of production and efficiency hard to imagine today.

What will we view as ordinary only 10 years or so from today? When we remember that the electrical industry is the concrete multimillion-dollar embodiment of what was once considered the wild figment of an individual imagination, nothing seems impossible.

During the last 30 years, the trend of the electrical industry's growth has compounded yearly at more than seven percent. If we consider this its normal rate, then by 1965 the industry's annual generation of electric energy will be over one trillion kilowatt-hours—more than 2½ times last year's generation.

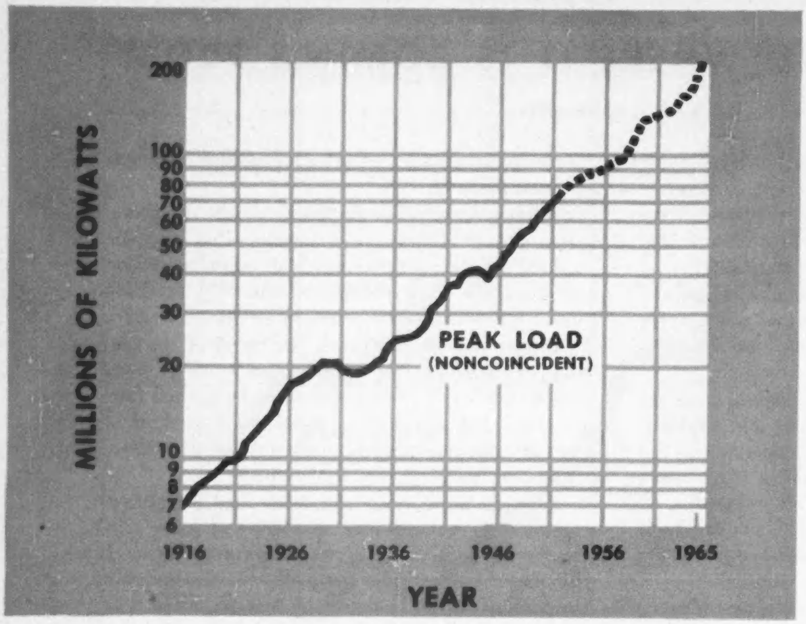
Looking at it from the peak load standpoint, the nation's electric utilities in 1955 will have a peak of about 100-million kilowatts, according to the Edison Electric Institute's semiannual electric power survey of April. This is 2½ times the utilities' 1945 peak. And in 1965, the peak may be on the order of 200-million kilowatts.

In just 10 years then, from 1945 to 1955, the electrical industry will have more than doubled its generating capacity—from 50-million kilowatts to about 115 million. And during that 10-year span, the electric utilities—installing by far the greater part of the new capacity—will have spent about 20-billion dollars on new construction, or 7½-billion dollars more than our entire investment in electric plant and equipment at the end of 1945. We are putting what amounts to, in essence, two electrical industries where one stood.

At the rate we are advancing today, we can positively expect that only 10 years hence we will have achieved in new power facilities the equivalent of all that provides electrical service now after some 70 years of development.

The electrical industry's expansion of facilities has been carefully planned to meet any foreseeable requirements of peace or war. Electricity being the basic flexible energy needed for manufacturing either defense materials or civilian goods, it is not affected by conversions from one kind of production to the other. And where special defense loads appear, special arrangements are made to meet them. Outstanding examples of this foresighted co-operation are the five-company Electric Energy, Inc., and the 15-company Ohio Valley Electric Corp., formed to supply large quantities of electric power to the Atomic Energy Commission's installations.

Unparalleled in history, the electrical industry's huge construction program is a measure of our confidence in the future. And as we build new load to utilize the nation's growing electric plant to best advantage, we see endless opportunities for developments in electrical living. We see no limit to what electricity can do for mankind.



PEAK LOADS grow at a fairly consistent rate. Power systems of the future will need greater reserve capacity and standby equipment than they now have to handle them.

electric. Because new hydro sites are limited to undeveloped natural resources, the major portion of *Power for Tomorrow* falls to steam-electric generating stations. A primary objective in their development must be to keep down the cost of generating this power.

According to Alan Howard, Manager of Engineering, Turbine Division, and J. B. McClure, Manager of Power Generation Engineering, such an objective can be achieved only by continuing two outstanding trends in the utility industry: larger size units and improved efficiency.

For example, the average size of turbine-generators shipped in the past 10 years has increased from 50,000 to about 90,000 kw. In terms of individual sizes, the largest 3600-rpm machine in service increased from 70,000 to 156,250 kw, with a 208,000-kw unit now on order. Similar increases in the size of cross-compound turbines have taken place: the largest unit presently on order is 260,000 kw.

Experience indicates that savings on installed cost-per-kilowatt are appreciable with these larger-size units. But while gains from using still larger ones are tapering off, further substantial savings can probably be achieved. Far more important perhaps is their reduction in operating-labor cost per kilowatt-hour. Few more operators, if any, are needed for the large generating unit than for a small one.

Offsetting these advantages to some extent however is the greater reserve capacity required on the system when the larger units are used. Still, increases in system size and in the use of high-capacity interconnections between systems will tend to minimize this factor. And it will probably be economical to use much larger units in the future than those now under consideration—provided they will give the same degree of reliability.

The second way to keep down generated-power costs is to continue the steady improvement in station efficiency. Looking back 25 years this time, the best stations then consumed one pound of coal per kilowatt-hour. Today they consume three-quarters of a pound. Likewise, average coal consumption in the same period was reduced from 1.9 to 1.1 pounds per kilowatt-hour. Accordingly, even if the average station of the future is no better than the best one today, its coal consumption will decrease to about 0.93 pounds per kilowatt-hour by the trillion-kilowatt-hour year of 1965.

The broad requirements for the future, then, will be single-generating units of larger capacity that are built to operate at more advanced steam conditions.

Boilers

Paralleling the trend in generating units, high-capacity reheat boilers are being built to supply turbines up to about 220,000 kw. But increasing capacity beyond this extent becomes more difficult because enlarging the boiler's dimensions doesn't enlarge its heat-absorbing surface as rapidly as its furnace volume.

Major boiler manufacturers are accordingly using multiple furnace construction for the larger capacities. Employing a single boiler drum, the gases merge in the superheater and reheater areas. These designs make capabilities of at least 300,000 kw immediately practical, with the ultimate development to be considerably in excess of this amount.

Development work is under way on boilers that will operate at higher temperatures and much higher pressures. And although raising steam pressures above the critical value—3206 psia—will require radical changes in boiler design, work has progressed to the point where a station to operate at 4500 psig is now undergoing design.

Pressurized furnaces will become more common in the future. In these boilers, the furnace is operated slightly above atmospheric pressure and sealed to prevent leakage. With the induced-draft fan eliminated, all power can then be concentrated in the forced-draft fans—whose power will then be increased by approximately two-thirds of that previously required by the induced-draft fan. This reduction in total fan power, plus elimination of air leakage into the boiler, can raise boiler efficiency about one percent.

Turbine-Generator Sets

The historic trend in the size of turbine-generator sets should continue as long as savings in installed cost are realized and the reliability of large units is maintained.

While the ratings of tandem-compound 3600-rpm machines should move considerably upward, it's likely that many of the largest machines will be cross-compound units. For this type of machine—with its larger exhaust area and consequent better efficiency with good vacuum—will probably prove more economical in many applications. An additional advantage, at least in some installations, is its shorter length.

The maximum steam temperature in use for many years has increased at the fairly consistent rate of 12 F per year; machines are now in operation with steam conditions of 1100 F and 2350 psig. And along with these higher temperatures has come general adaption of the reheat cycle, particularly for the larger generating units. For example, one station now undergoing design will operate at steam conditions of 4500 psig, 1150 F, with a double reheat. The first reheat is to 1050 F, and the second to 1000 F. This major development will be a stepping stone to even higher temperatures and pressures—and further improvements in generating-station efficiency. The search for still higher efficiencies may result in the use of combination gas-turbine and steam-turbine cycles with supercharged boilers.

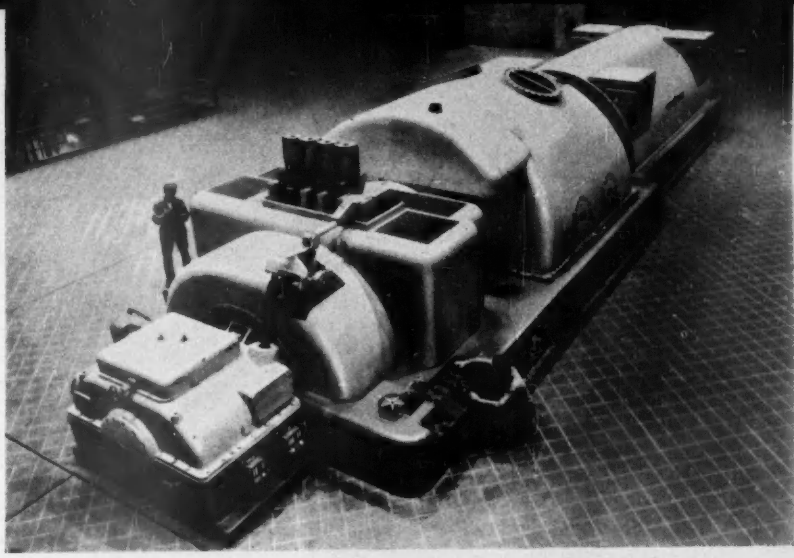
As for generators, progress in their design has been as remarkable as that in turbines. General use of hydrogen cooling at higher pressures, development of oriented strip steel, improvements in the mechanical-magnetic properties of forgings, and the development of new conductor materials—all have been factors making possible generators that match the ratings of 3600-rpm turbines. And on top of these comes the latest development—liquid cooling of armatures and direct cooling of rotors. This remarkable achievement will permit much larger ratings of generators—in the same frame size—and opens the way to increased size of the 3600-rpm tandem-compound turbine-generator set.

Water Power

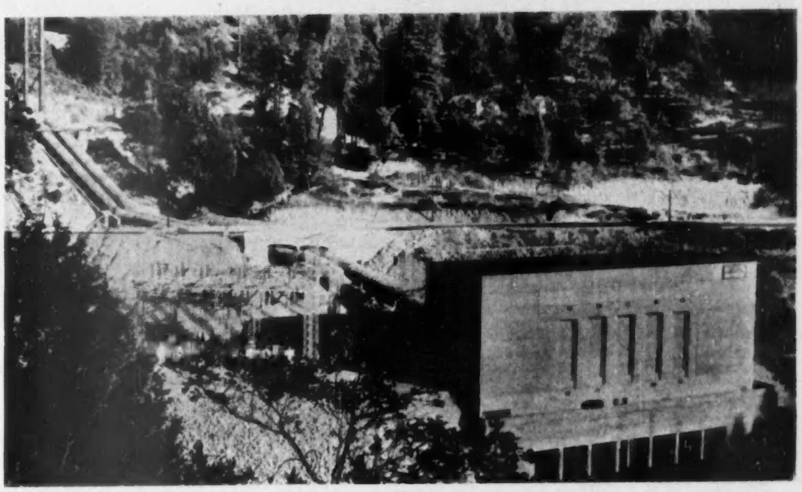
Unlike steam turbine-driven generators, the rated output and speed of a hydraulic turbine-driven generator are not chosen by the designer. Instead they are dependent on nature—the quantity of water and head available at a given water site. Also, output and speed are dependent on the type of turbine proposed as prime mover.

In the words of A. H. Lauder, Manager of Engineering, Large Motor and Generator Department, this wide range of conditions has produced a great diversity of generator ratings—the largest to date is 108,000 kva. This has stimulated engineers to make new advances in analytical methods of predicting losses and heat transfer, and to seek to improve air flow.

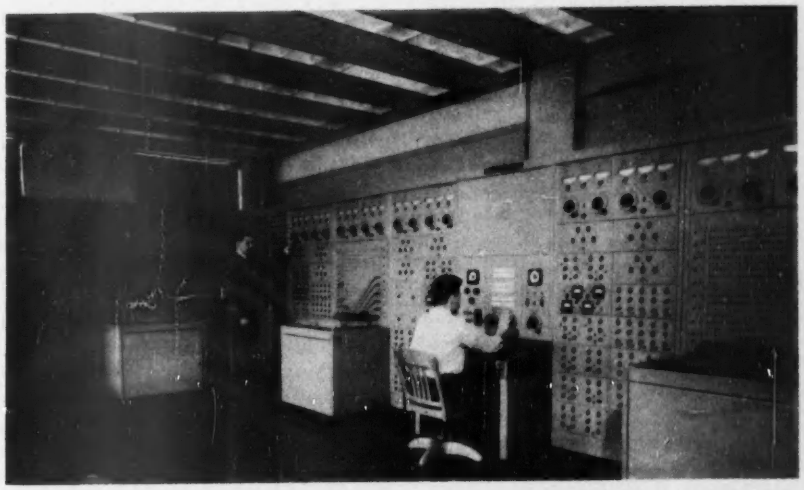
Recent trends in hydraulic turbines have added to the diverse requirements of a hydraulic turbine-driven generator. In the low-head range—20 to 100 feet—the use of Kaplan turbines of greater output at lower speeds calls for generators of larger diameter. Such machines require 1) a rotor to withstand high overspeed while maintaining the small



MODERN steam turbine-generator set rated 80,000 kw. Similar machines of much greater capacity and efficiency will shoulder the major portion of future power expansion.



HYDROELECTRIC power station with two vertical hydraulic-turbine-driven generators rated 37,500 kva at 180 rpm. Here, engineers will concentrate on improvements in generator design.



NETWORK ANALYZER will grow in importance to the electrical industry. Its value lies in shortening the time between the study stage and production of technical products.

LARGEST circuit-breaker is rated 25-million kva. But will it be large by tomorrow's standards? Present concepts of circuit-breaker design are almost sure to be inadequate.

air-gap clearance inherent in low-speed design, 2) a bearing to carry millions of pounds, and 3) a bracket to maintain level support of the bearing at all loads.

At the same time, construction of large Francis turbines for higher heads has brought about a demand for larger generators running at higher speeds; the same is true of multijet vertical impulse turbines. With regard to electrical design, these generators are in the class of synchronous condensers, but they're designed to mechanically withstand runaway speeds of 1.6 to 1.85 times normal speed.

To meet these requirements, new methods of attaching poles must be evaluated and new types of rotor construction must be considered. Materials having superior machinability and magnetic properties combined with good machinability must be searched out. Another problem peculiar to machines of this class is the fast and accurate machining of slots in rotor spiders weighing 200 tons or more.

What about the future? In the low-speed range, there doesn't seem to be a need for machines appreciably larger in capacity. And for the high-speed range, larger machines will be developed as the need arises.

Atomic Power

Atomic power appears certain to become an energy resource of even greater reserve capacity than conventional fuels. It is expected to begin augmenting electric power from conventional fuels as soon as it can compete with them economically. Its growth will therefore depend primarily on economic incentives, and it cannot suddenly replace any substantial segment of conventional power plants.

On the other hand, its great potential, coupled with the mass of work needed to bring it to fruition, warrants considerable interest and effort by industry in certain directions now. This has led to continuing exploratory studies by a number of electric-utility teams, starting about two years ago. Such interest and effort is increasing and expanding in scope.

At present a large industry is engaged in manufacturing atomic fuels—to be used in military weapons, however, not as commercial fuels. Because of unique properties of atomic fuel, atomic propulsion gives submarines, naval ships, and aircraft important tactical advantages unobtainable with conventional fuels. However, electricity generated with atomic energy as the fuel is the same as that generated with conventional fuels, and economically it must be competitive.

The development of conventionally fueled electric-generating plants has been so successful, says R. G. Lorraine, Engineering Department, Apparatus Sales Division, that atomic-fueled plants must improve greatly to be competitive. Nevertheless, there are many competent people who, through reason or foresight, believe that commercial atomic-energy generating plants can be brought to successful fruition.

Atomic fission and the radiation that accompanies it lead to many problems. Unusual materials of high purity are needed for structures within the reactor and associated systems. Radiation shielding, remote-control materials-handling devices, special coolants, and heat-transfer systems—all must be used extensively. In addition, machinery and process equipment must have the utmost reliability. These factors, which complicate the design and location of the plant, plus the need for meticulous supervision of operating conditions and control of classified information, increase materially the relative cost of building and operating atomic power plants.

Still, substantial progress in solving these unusual problems is being made. Many solutions are being found in programs planned to reach national-defense objectives—such as the operation of nuclear reactors to produce plutonium and the development of atomic power plants for the propulsion of submarines and aircraft. Each specific solution in these programs is not necessarily transferable without change to atomic-electric plants. But the aggregate experience is of utmost importance to land-based power. As the accumulation of this experience continues, its rate of utilization in furthering the development of land-based plants is expected to increase.

TRANSMISSION

Today there are more than 250,000 circuit-miles of a-c transmission in the United States. And these circuit-miles have increased at a greater rate than the increase in generating capacity.

Similarly, the increase of higher-voltage transmission—on a percentage basis—is greater than that of lower-voltage transmission. The trend is to transmit larger loads greater distances.

According to S. B. Crary, Manager of Analytical Engineering, this trend should continue, particularly with the building of larger generating stations at a distance from their loads.

In the natural evolution of our power systems, higher circuit voltages are superimposed on existing lower-voltage systems as the load density and the size of power blocks increase. Also, higher voltages are usually necessary to interconnect systems and to bring in a block of power from a distant source. Although small in percentage of total circuit-miles, the higher power-carrying capability of higher voltages makes them important elements of the transmission system. Again, because they represent new advances in engineering and economy, they are of more general interest than the lower-voltage transmission systems.

It is now widely accepted that the most effective way to decrease the cost of transmission is to increase the circuit loading. This philosophy is being applied not only to the higher-voltage systems but to the lower-voltage levels as well.

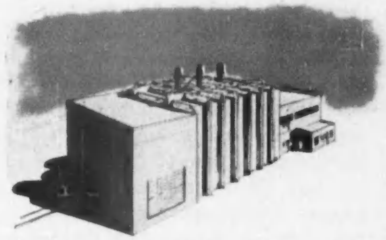
The new 330-kv transmission system of the American Gas and Electric Corporation will have a conductor capable of carrying approximately one-million kilowatts per circuit. And the Aluminum Company of Canada is now building a 288-kv transmission line through rugged terrain using a 2.2-inch diameter conductor. The latter will carry 850,000 kw per circuit, and in an emergency, may even be required to carry greater loads.

Many operating companies have studies under way to determine what voltage to use in transmitting increased loads of the future. For this task they have a considerable background of knowledge in design and performance of transmission systems. Such knowledge in their hands is assurance that new systems will have high reliability and low cost.

One of the more important problems that required analysis and laboratory and field tests, as well as operating experience, is determination of the conductor size and arrangement, and tower design, at voltages above 330 kv—including radio and television interference factors. Considerable progress has been made in transmission tower design and methods to reduce cost of their construction.

Will transmission lines of the near future in the United States utilize voltages higher than our present 330 kv? Almost one-million kilowatts of emergency loading per circuit has been achieved with a 1600-amp current loading at 330-kv nominal, 350-kv maximum. This appears sufficient to meet most requirements.

Specific areas in the future may encounter a load growth requiring even higher voltage and current. For there's economic pressure to superimpose a more efficient system on older existing systems. In such systems, American equipment manufacturers place no limit on higher voltages and currents when justified economically—even those exceeding Europe's 380-kv voltage level and America's 1600-amp current level.



SOUND-TESTING laboratory for GE's power transformers. More fundamental data on transformer noise are needed.

Power Transformers

Growth of annual power consumption to a trillion kilowatt-hours in 1965 will mean doubling the total kilovolt-ampere capacity of power transformers in service. Besides this, the kilovolt-ampere and voltage ratings of individual transformers will have to be increased to new highs. In terms of manufacturing, more facilities will be needed. Also, more productivity must be achieved through better design and manufacture—and more industry-wide standardization—of power transformers.

The size of a generator transformer may increase to 500,000 kva with a voltage rating approaching 500 kv, states Lynn Wetherill, Manager of Engineering, Power Transformer Department. For ease of handling and installation the unit will be shipped upright in its tank. And based on present methods of design and construction, its core, coils, and stripped-down tank probably won't weigh more than 500,000 pounds. It will however require larger railroad cars than currently used to transport power transformers.

Since much new load will be added in communities already developed and where space is limited, there will often be an urgent need for reduction in a transformer's size, noise, and vibration. But accomplishing such objectives will require more efficient use of engineering manpower and developmental facilities in these areas . . .

- Transient voltage distribution—electromagnetic models should be used to evaluate alternative winding designs.
- Losses—intensive study will be needed to reduce copper and iron losses caused by eddy and circulating currents.
- Noise—more fundamental data are required on transformer noise and in magnetostriction measurements—made both on steel sheets and on the completed transformer.
- Vibration—tests on completed transformers must be evaluated so that resonance can be avoided in the finished product.
- Insulation—new materials and the nature of oil breakdown under steady-state and transient conditions will bear continued investigation, as will corona measurement techniques.

Switchgear

Switchgear is the police force of electric power systems. It directs traffic, maintains order, detects crimes, and apprehends violators. The job ahead of switchgear as power systems grow toward the trillion-kilowatt-hour mark is a big one. For the speed and alertness of its relays, and the capacity and alacrity of its circuit breakers will certainly have to grow far beyond present-day standards.

If the maximum of circuit-breaker interrupting capacity continues to increase at recent rates, states V. L. Cox, Manager of Engineering, Switchgear and Control Division, the trillion-kilowatt-hour year of 1965 would see breakers rated many times higher than their present maximum. Other factors in system design are apt to limit this trend, however, so that astronomical ratings aren't likely.

Present day concepts of relay and circuit-breaker design are almost sure to be inadequate, so new ideas must be brought forth and developed into practical designs over the next 10 years. For example, in the field of high-power arc phenomena, circuit-breaker design has thus far revolved about controlling and restricting the arc, while comparatively little is known of laws governing its inner workings. A more complete knowledge of these laws would prove a powerful tool. Similarly, research must be made into the chemistry and physics of the arc's surrounding medium and into materials used for arc-producing contacts. This should include a search for media more appropriate than air or oil—now used almost exclusively in breaker design—and for contact materials chemically compatible with these media.

For reliable, accurate control of contacts and of interrupting medium movement in the higher-speed circuit breakers, mechanical problems require solving. Already, developments under way give promise of thoroughly reliable electronic protective relays, with speed and sensitivity far beyond inherent limits of electromagnetic devices. Means of transmitting to protective relays the quantities they must measure should also be improved, because instrument transformers now used are costly, especially where high voltages are employed.

These are a few of the many areas open to the switchgear industry in the search for new ideas. Success will depend in large measure upon specially trained engineers and scientists set apart for the task and equipped with the best possible tools. And as the tempo of expansion increases, the importance of close co-ordination of apparatus development with system development will become ever more apparent. In the latter field, electric utility and consulting engineers will naturally play the leading role. For from their experience and knowledge must come the foundation the manufacturer builds his designs on.

DISTRIBUTION

Load growth is a normal thing in the power and light industry. And on an industry-wide basis it continues to be fairly uniform. But from the viewpoint of an individual system, this isn't always true. For to an individual company's distribution system, load growth appears highly erratic.

Load growth for the past 30 to 40 years reveals that future loads will present no sudden changes to the industry, states D. K. Blake, Manager of Power Transmission and Distribution. Statistics show that domestic load has been growing much faster than the large light and power load. Should their relative rates continue, the domestic load in kilowatt-hours will equal the large light and power load within 20 years. This is important because the distribution system of a domestic load needs more poles, wires, and transformers than does a power load. Hence, growth in the domestic area is the real challenge to the adequacy of present distribution systems.

Total geometric rate of growth, nine percent compounded yearly, is composed of six percent growth in the individual consumption, and three percent in new customers. This means greater load density and therefore, lower investment per kilowatt of peak load as far as lines, poles, transformers, and substations are concerned. On the other hand, the trend of people to move into the suburbs causes lighter loads and higher costs per kilowatt.

How far, then, can industry continue its present distribution practices? Basically, load growth is conveniently handled by 1) reducing the spacing between distribution transformers, 2) increasing the size of distribution transformers, 3) reducing the length of primary mains emanating from a feedpoint, and 4) increasing the size of distribution substations. All this may be done without a major change to the system while still not exceeding the accepted thermal and voltage limitations.

Thus modern overhead systems for domestic load areas are adequate, from voltage and thermal viewpoints, for greater residential loads than are now foreseen.

ENGINEERING MANPOWER

It might be argued that building a power system to handle a trillion kilowatt-hours annually—2½ times our present annual consumption—wouldn't take much technical effort. Why not get out drawings of existing equipment and have the order reproduced?

To ask this question is to answer it, says W. Scott Hill, Manager, Technical Recruiting. For the engineer seldom builds anything without injecting into it new knowledge and discovery. And to do this, he must devise new designs.

By now everyone is aware of the statistics of engineering manpower for the years ahead. This critical situation gives the engineering graduate a wide choice of positions. Naturally, he will look for the greatest challenge, the greatest growth, and the greatest opportunity for a full engineering life: In the field of electric power, he will find this life. For in placing what is essentially two electrical industries where one stood—and thereby increasing America's productivity and world leadership—tough problems will have to be solved by him. And though these problems may not be readily seen at this time, they will cover every branch of engineering.

In research and development there are problems of providing new materials and of learning more of present materials and phenomena. In design, the engineer must provide larger units for better efficiency, while the application engineer must seek ways to increase their performance and output. Construction and operation of these units will also present problems. And finally, there are problems in management. They will give every young engineer an opportunity to exercise his executive ability in the fields of electrical, mechanical, chemical, metallurgical, and civil engineering—and in extensions of these fields. In this way, each engineer has a chance of increasing America's productivity through electric power.

Much is being done throughout the electrical industry to make up for the shortage of engineers. Standardization of components is a must and can be further extended as a means of utilizing engineers more effectively. Flexibility to change these standards is essential because the aim here is not to freeze progress, but to free engineers from job-shop details, letting them concentrate on sound and widely accepted developments.

Digital and analogue computers also offer possibilities of relieving engineers of laborious tasks. Their value lies in shortening the time between the study stage and the final trouble-free production of involved technical products—and in expanding the area of study.

Technicians and those with less than full engineering training should be used in greater numbers than at present. As a part of the engineering team, they will assist the engineer to make maximum use of his professional training. At the same time, turnover of engineers in the industry can be further reduced by studying losses and devising sound remedial policies.

These are some of the things that can help the young engineer in the years ahead. In addition, industry must provide him with courses that will extend his basic education. Government—and particularly the military—should recognize that this is primarily a technological world, and that its survival may depend on how effectively those with technical training and ability are utilized. For the young engineer has the challenge of providing the power for tomorrow and of carrying developments into a new electrical era—an era of vastly greater national productivity. Ω

BITS, LANGUAGE EFFICIENCY, AND INFORMATION THEORY

By DR. R. L. SHUEY

TABLE I DISCRETE INFORMATION

(1) Information in message i (expressed in bits)

$$= -\text{Log}_2 \text{ (probability of message } i) = -\text{Log}_2\, p(i)$$

(2) Average information per message

$$\underset{\text{number trials} \to \infty}{\text{Limit}} \frac{\overset{i}{\Sigma} \text{ (Number times message } i \text{ occurs) } (-\text{Log}_2 \text{ probability message } i)}{\text{Total number of trials}}$$

$$= \frac{\Sigma ni\,[-\text{Log}_2\, p(i)]}{N} = -\Sigma\, p(i) \,\text{Log}_2\, p(i)$$

(3) Information (i sent j received)

$$= -\text{Log}_2 \frac{\text{(apriori probability } i \text{ sent)}}{\text{(probability } i \text{ sent if } j \text{ received)}} = -\text{Log}_2 \frac{p(i)}{p_j(i)}$$

(4) Average information when j received $= -\overset{i}{\Sigma}\, p_j(i) \,\text{Log}_2 \dfrac{p(i)}{p_j(i)}$

(5) Average information per message $= -\overset{j}{\Sigma}\, p(j) \overset{i}{\Sigma}\, p_j(i) \,\text{Log}_2 \dfrac{p(i)}{p_j(i)}$

Man's dominant role in the world today is largely due to the ability of the human brain to evaluate and constructively utilize information. The rapid advance of civilization during the last three centuries is, to a great extent, a result of man's discovery of methods of recording information and communicating it to other men and, in particular, to later generations.

What will be discussed here is the meaning of information, the theory that has recently been developed for handling this commodity from an engineering standpoint, and some examples illustrating the application of the theory.

We are interested in two things: the processing of information and its transmission. The human brain and the mechanical computer are examples of devices that process information; the attempt of this article to provide you with information is a good example of the transmission of information.

Our primary concern will be the subject of the transmission of information. We will not discuss the *meaning* of the information transmitted; that comes under the heading of semantics.

Definition of Information

On Election Day in 1948, you knew the papers the next morning would announce that either Harry Truman or Thomas Dewey had been elected President of the United States. Probably you were quite sure that the announcement would favor Dewey; and if it had, you would have been inclined to say that it had provided very little information. You would have reasoned that it had only told something you knew already. In fact, if you were absolutely certain of the outcome, the paper would not have provided you with any additional information, and there would have been no object in buying a paper. Of course, you were *not* absolutely certain, and so you purchased a paper and were undoubtedly surprised to find the banner headline announcing that Truman had been elected. I think you will agree that this headline conveyed much more information than the expected headline would have. In a sense, a less likely, or less probable, message conveys more information than a likely message. In other words, messages having a high probability of occurrence contain little information. An extension of this argument leads to a definition of the information contained in a particular message in terms of the unexpectedness or uncertainty of that message. This in turn is equivalent to a definition in terms of probability.

So far we have decided that information should be measured by some function of probability. The exact definition used is that the information contained in a specific message is equal to minus the logarithm of the probability of that specific message. This is indicated in equation (1), Table I. The unit of information is a "bit," when the logarithm is taken to the base 2.

The logarithm has been selected so that information will be additive; this additive feature is shown in Table II. Assume that you first receive one of four equally likely messages, or two bits of information. You then receive one of eight equally likely messages, or three bits of information. The total information received is five bits. Suppose that instead of receiving two separate messages, as indicated before, you receive both messages together as one message. There are now 32 possible messages, all equally likely, and you will receive five bits of information. It should be noted that information will be additive regardless of the base of the logarithm. The base 2 has been selected so that the unit of information—the bit—represents one yes or no choice, the simplest message possible.

To illustrate the meaning of a bit, let us assume that you know all the 2×10^9 other inhabitants of the earth equally well. One name is selected at random from this group and written on a piece of paper. You are to ask YES and NO questions until you can determine who's name is on the paper. How many questions are necessary? (This is equivalent to the radio and television quiz program "Twenty Questions," but where the number of questions permitted has not been specified.) It is clear that the message on the paper has probability of $1/(2 \times 10^9)$. Thus, the information contained is $\text{Log}_2\,(2 \times 10^9) = 30.9$ bits, and only 31 questions are necessary. If each person in the world

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TABLE II

ADDITIVE FEATURE OF INFORMATION

Example	Number of Equally Likely Messages	Probability of Message	Information per Message (Bits)	Remarks
1	4	1/4	2	
2	8	1/8	3	
3	32	1/32	5	The 32 possible messages can be made up from examples 1 and 2.

Information in message $i = -\text{Log}_2\, p(i) = -\text{Log}_2$ [probability of message i]

TABLE III

PHYSIOLOGICAL INFORMATION LIMITATIONS

Receiving Organ	Amount
EYE	
Eye proper	4.3×10^6 Bits per second
Optic nerve fiber	5 Bits per second per fiber
Optic nerve (9×10^5 fibers)	4.5×10^6 Bits per second
EAR	
Ear proper	8×10^3 Bits per second
Auditory nerve fiber	3.3×10^{-1} Bits per second per fiber
Auditory nerve	10^4 Bits per second
BRAIN	
Estimated capacity of brain to accept information	100 Bits per second

is assigned a binary number, every number will contain 31 digits—for example, 100110001...(to 31 digits) ...The number of possible assignments is $2^{31} \approx 6 \times 10^9$. Clearly, 31 YES or NO questions will determine the number and thus the name. The strategy is to ask YES and NO questions that divide the remaining likely answers into equally probable groups.

In this example it appears impossible with precisely 20 questions to determine the name on the slip of paper. However, all persons are not equally well known and the number of reasonably likely names is small enough that 20 questions should suffice. Here is an illustration:

Suppose that the 20-question game just described is played for a very long time. The information contained on any one slip of paper is given by equation (1), Table I. We can, of course, compute the total information by adding together the information from each slip of paper. Then we can divide the total information by the number of slips of paper and thus compute the average information per slip of paper. This calculation is shown in equation (2), where the final result in bits per slip of paper (or message) is given in terms of probability. The implication is that if the proper questions are asked, this is the average number of questions that will be needed to determine a name. The proper question will always divide the remaining likely answers into two equally probable groups and select one of these groups.

Listen to the "Twenty Questions" program and see whether in your opinion the panel is following this optimum technique.

Language Efficiency

In an information-transmitting system we are concerned with a message transmitter, or message source. The source in general will transmit many messages in succession, and it is the particular messages that can be compared to the slips of paper in the question game previously described. The computation of the average information per message is identical with the computation of the average information per slip of paper that we have already made.

To see the importance of this average, let us consider an information source that is transmitting English text (for example, the typewriter on which this article was typed). For simplicity, assume that the source is limited to an alphabet of 27 symbols; namely, 26 letters and a space. Let us consider how efficient English text is as a means of transmitting information by the use of a 27-letter alphabet. How does it compare with the ideal?

The ideal language, in the sense of having a maximum of information transferred per symbol, would be one in which letters occurred with equal probability and in all combinations. This follows from equation (2), for such a language would make the right-hand side of the equation maximum. In such a language all combinations of letters would be words and all combinations of words would make sense. The information per symbol would be:

$$-\sum^{i} p(i)\,\text{Log}_2 p(i) = -27\left[\frac{1}{27}\text{Log}_2\frac{1}{27}\right] =$$

$$\text{Log}_2\, 27 = 4.75$$

The number of five-letter words in this fictitious language—excluding spaces, of course—is $26^5 \approx 1.2 \times 10^7$. It is interesting to compare this figure with the approximately 6×10^5 words of all lengths listed in Webster's *New International Dictionary* (Unabridged). Clearly, the number of words in the ideal language far exceeds that of English. Thus there is more uncertainty as to what a word will be, and the information conveyed per word and per letter greatly exceeds that of English. The reason is that all combinations of letters in English are not words. There are definite constraints in English.

Dr. Claude E. Shannon of the Bell Telephone Laboratories has estimated that the information content of English text lies between 0.6 and 1.3 bits per symbol. Assuming that the 1.3 figure is the correct estimate, English text conveys only about 30 percent of the information that an ideal 27-letter language could. In communication theory it is therefore said that the redundancy of English is 70 percent. Another interpretation of the redundancy is that 70 percent of the letters can be omitted and later restored from the known statistics of English. (It is interesting to note that Hebrew script—both ancient and modern—uses no vowels.) To put it yet another way, if you have a secretary who can type a given report in 10 days, she could type the report in three days, provided it was written in a nonredundant language. (This, of course, assumes that she could type random letters as rapidly as English text, which probably is not strictly true.) Now, of course, it is possible that your secretary would make one mistake during the three days of typing. Because in the ideal language all arrangements of letters make words and all arrangements of words make sense, this one error would change the meaning of the entire report. It is therefore apparent that it is not desirable to have a nonredundant language. Instead, we want a language with just sufficient redundancy so that when errors are made the reader can correct the errors from what he knows of the basic statistical structure of the language.

In radio and television, for instance, the main source of errors in the communication link is noise; for example, atmospheric noise from the transmission media and static from electric equipment. Energy from noise will occasionally, when added to the energy sent to represent a specific symbol, lead to the incorrect interpretation of that symbol. In the presence of noise the above criterion reduces to just sufficient redundancy to permit the correction of noise errors.

In the presence of noise a modified definition of information must be used. This is given in equation (3), Table I. Without discussing this modified definition in detail, several factors are worth noting:

If there is no noise, then $p_j(i) = 1$ if $i = j$, and $p_j(i) = 0$ if $j \neq i$. Under these conditions, equation (4) reduces to equation (1), and equation (5) to equation (2).

If i is sent and j is received, the recipient of the message is unable to definitely say what was sent or how much information he has received. All that can be said is that on the average if j is received, a certain amount of information is received; namely, that given by equation (3). In other words, only an estimate of the i that was sent can be made.

Coding

An ideal communications system would be one in which all the redundancy that is not needed to combat errors and noise is removed before the message is transmitted. Whether such a system is economically feasible depends on cost consideration, and at the present time it is neither technically possible nor economically justified. However, the radio spectrum is only so large, and as we add more and more communications channels, it will become increasingly important to change to systems that conserve bandwidth. As we shall see, information theory indicates that potentially tremendous savings can be made.

An ideal system, shown on the next page, depicts the definite engineering problem of transmitting a message between two points. This is usually referred to as the communication problem.

The device that removes the redundancy at the transmitter is called a coder; the device that restores the redundancy at the receiver is a decoder; the output of the coder is the coded message.

The system relating the symbols of the original message to the symbols of the coded message is the code. For example, three dots in Morse code represent the letter *S*. The entire Morse code is the code, the dot and dash are code symbols, and the three dots that make an *S* are a code group.

The necessity for restoring the redundancy at the receiver merits discussion. If the ultimate destination of the information is a computer or some other instrument designed to operate with optimum nonredundant notation or language, it is not necessary to restore the redundancy. The coding and decoding operations would then primarily correct errors. If the ultimate destination is a human being or some other device that has definite preconceived opinions as to the forms in which it will accept information, the redundancy must be restored. For example, the familiar birthday telegram is transmitted as a rather simple short code. The recipient, however, would be unwilling to accept the code in lieu of the telegram. An even better example is television. The only information that we get with a given frame is, to a first approximation, essentially the change in the picture since the last frame. I think you will agree that you would be unwilling to view a picture that showed only this change.

Remarkably, it is theoretically possible to perform the coding and decoding operations indicated in the ideal system diagram. Shannon has shown that such codes exist; we shall call them ideal codes. However, specific ideal codes, except in very simplified situations, are not known. Shannon's proof indicates that in an ideal code the code groups will be quite long and will represent long segments of the message. For example, in coding English text, whole pages or whole books might be assigned code groups. A code group would specify one of all such possible pages or books of typical English text. The improvement gained by utilizing optimum coding results from not assigning code groups to arrangements of letters that are not English text. In other words, the optimum communications system will not transmit messages that have zero probability of occurring. Errors can be corrected in a very long code group because the effects of noise can be accurately predicted.

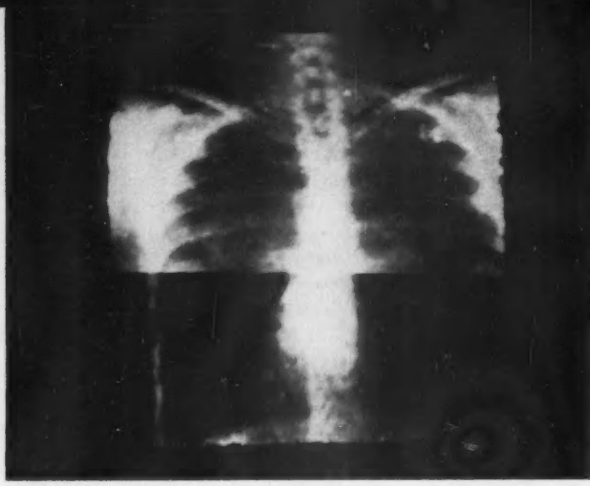
One other important feature is disclosed by information theory—namely, as the system approaches the ideal, the required delay time for coding becomes longer. This is serious from a practical standpoint because it is not always possible to wait a long period of time for a message. With present techniques there is an even more important limitation. Delay in the coder implies storage of information in the coder. No adequate information storage devices exist at the present time. For example, electronic storage tubes have an information capacity of roughly 10^4 to 10^5 bits. To store information pertaining to all possible pictures on a television set, about 10^6 bits of storage are required. For good operation coding should take place over many successive pictures; or, in other words, a storage capacity much larger than 10^6 bits is needed.

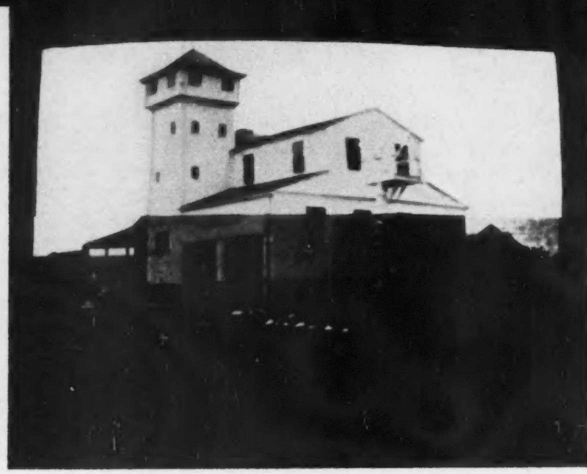
In a theoretical limit we know it is possible to code messages so that all of the redundancy not needed for combating noise is removed. Unfortunately, it has not been possible to determine coding schemes in other than the simplest practical cases. There is a further serious practical limitation: the components needed for such schemes are not available at the present time.

Continuous Systems

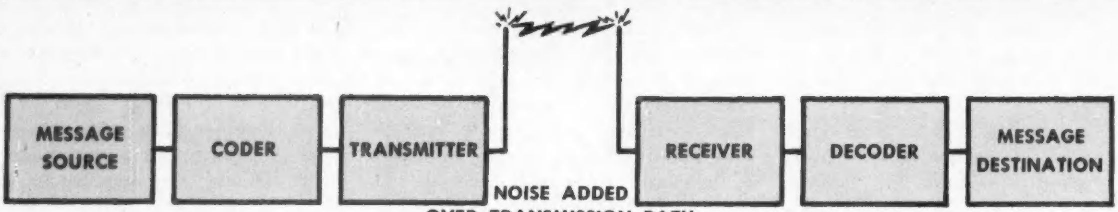
What has been said with reference to discrete systems such as symbols, alphabets, and language can be easily extended to continuous systems—for example, telephone and television. The distinction is that in a discrete system the possible messages are limited to a discrete or finite set; in a continuous system the possible messages are any of the infinite number of continuous functions of time. The summation signs occurring in Table I become integral signs. A few differences, of course, distinguish the two types of systems.

An example well known to you is television. In considering the English language we were concerned with its statistical structure; in television we are concerned with the statistical structure of a picture. For example, the brightness at one point of a picture definitely changes the probability of the brightness of the adjacent points.





THE PICTURES SHOWN HERE ARE EXAMPLES OF MATCHING THE PICTURE-BRIGHTNESS SCALE TO HUMAN EYE RESPONSE.



CODER—Removes all redundancy not needed to combat noise and errors.
TRANSMITTER—Transmits coded message.
DECODER—Decodes received signal correcting errors due to noise and restores message to original form by restoring redundancy.

THE COMMUNICATION PROBLEM—A DEFINITE ENGINEERING PROBLEM OF GETTING THE MESSAGE TO THE DESTINATION.

We noted that an ideal language would have a tremendous number of words in it compared with the actual number of English words. It is equally true in television that the number of possible pictures is far greater than the number of actual arrangements that make sensible pictures. For example, there are roughly 10^5 picture elements in a television picture; and if we assume 32 different levels of intensity, the possible arrangements of intensity are therefore $32^{10^5} \approx 10^{(1.5 \times 10^5)}$. Now, most of these arrangements will never occur, for they look like snow, or noise, and are not pictures. It is therefore theoretically foolish to design systems able to send so many arrangements that will never be sent. If pictures are 99 percent redundant—and the redundancy may well be higher—it is in principle possible by proper coding to replace the present six-megacycle channels with ones about one percent as wide, that is, 60 kilocycle. These new channels would operate with roughly one percent of the signal power. The degree to which such a change would simplify the channel assignment problem is obvious. Of course, until circuit components are available that will permit optimum coding and decoding, this theoretical system cannot be constructed. Furthermore, to attain the ideal requires infinite delay and storage. Our concern is therefore to approximate the ideal.

Human Limitations

So far we have considered the strict communications problem of getting a message between two points in the most efficient manner. We have seen that the exact message can be transmitted more efficiently if we use proper coding. Usually at the message destination something is known about the message before it is received. For example, we expect that a letter we receive will be in English; similarly, when we look at our television screen, that the pattern will be a picture. Our previous knowledge represents information that need not be sent, and when we remove redundancy we are removing that information. The savings made by such methods—and they are the savings we have discussed to this point—result from the known statistical structure of the expected message.

Now let us consider information savings of another type: specifically, the savings that can be made by knowing that a human being has certain fairly definite limitations on his acceptance of information. To a large degree these limitations should determine the design of a communication system to transmit information to a human subject.

The human body is a communication system in the sense that when we touch something with our fingers the nerves in the finger tips send information to the brain. The intelligence is transmitted by the number of pulses per second sent down a nerve fiber. (It is interesting to note that civilized man invented this type of modulation in the last 30 years, whereas it was developed and reduced to practice by evolution many ages ago.) The nervous system transmits information from different parts of the body and the brain proper processes it.

The human body can accept information only through the senses of taste, smell, touch, hearing, and sight. The receptors of these various senses themselves have information limitations. These limitations are both of quantity and form. For example, it is well known that the just-noticeable change of brightness in vision is approximately a fixed fraction (Fechner's fraction) of the brightness. This means that the levels of acceptance of the eye are on a logarithmic scale. It follows that information presented to the eye should be on such a scale. As an example, the pictures on the opposite page are photographs on laboratory television equipment. The upper region of the chest x-ray has been matched to the eye response; the lower region has not. In the picture of the building just the opposite is true. Notice the difference in the detail. To readers familiar with photographic terminology, the gamma in the two parts of the picture has been controlled independently.

The other human limitation is the amount of information the brain can accept. Approximate information limitations of the ear and eye are given in Table III, along with an estimate of the capacity of the thinking part of man's brain. The startling conclusion from the table is that the brain is incapable of utilizing all of the information that can be received by the senses.

Let me make one brief remark concerning this. Specifically, the information mismatch largely results from the fact that the brain selectively scans the information presented to it. In present-day high-quality music and television the information that can be presented to the eye and ear, except for statistical redundancy, is fairly well matched to the information capacity of the eye and ear. In light of the severe limitations of brain capacity, there are applications where this is a great waste.

In a system like commercial television where there are many simultaneous or parallel viewers whose brains may make different selective scans of the information presented to them by their eyes, sufficient information must be sent to allow all possible scans. Of course, if the viewer's scanning statistics were known, they could be exploited—a possibility long used by magicians. Regardless of the number of parallel viewers, information not physiologically acceptable to the sense receptors can be ignored. For example, if under given conditions the eye can detect only 10 levels of brightness, it is foolish to send 20.

In applications where the listener or viewer can be trained so that he no longer requires a choice of information scanning, such as some military applications, it should be possible to design equipment so that the brain capacity is the limitation.

TABLE IV INFORMATION EXAMPLES

Information Source	Normal Bandwidth (Cycles per Second)	Information Sent (Bits per Second)	Information That Could Be Sent (Bits per Second*)	Estimate of Maximum Bits per Second Acceptable to Brain
Printed text (200 words per minute)	Assumption is that all letters take equal space. Bandwidth is not applicable.	15 to 30	100	100
Speech	3000	100 Redundancy is not known	12,000	100
Music (High-fidelity)	15,000	Redundancy is not known	60,000	100 (Parallel viewers must be considered)
Television picture	4,000,000	40,000 Redundancy is not known	16,000,000	100 (Parallel viewers must be considered)
Communication system 25 Cycles per second	25		100	100

* In all but printed text a signal-to-noise ratio of 15 is assumed.

Table IV illustrates the potential capacity of communication channels in everyday use and indicates what a small fraction of their ultimate potential is being used. The music and television examples are complicated by many viewers or listeners who may wish to extract different information from the signal. For this, the 100-bits-per-second figure of brain capacity is not applicable.

As was indicated for speech and certain other applications, the 100-bits-per-second figure should ideally determine the system design. For example, a 3000-cycle-per-second speech channel can potentially transmit 12,000 bits per second. However, the brain can only extract 100 bits per second from speech—or from anything else, for that matter. It is therefore clear that the actual intelligence of speech cannot be greater than 100 bits per second; the remaining 11,900 potential bits per second must be redundant so far as the human receiver is concerned. Of course the implication is this: If we knew what features of a complicated spoken sound carry the intelligence, and if this unknown part could be separated out, speech could be transmitted over a bandwidth of about 25 cycles per second. Extensive work is now being done in many laboratories to determine just what does carry the intelligence of speech.

The remarks about speech and hearing can be extended to vision, and Table IV indicates some of the numbers involved. What carries intelligence in a picture? Very little work has been done on this problem. The potentialities are apparent.

Future Potentialities

Communication and information theory is essentially the logic of communicating, processing, and transmitting information. By its application, it is possible to determine the limits of ideal systems and to obtain some indication of how to design systems that are approximately ideal. Unfortunately, the components needed are not available, and thus the burden of application is immediately put on the shoulders of the component designers and inventors.

It has been pointed out that present communications systems are far from ideal. They occupy much more bandwidth and require much more power than is theoretically needed. As noted savings in the future can be expected from two different methods of approach: by exploiting the statistics of the messages; and by sending only the amount and form of information acceptable to man's brain and sense receptors.

Although the original development of information theory took place largely at MIT and the Bell Telephone Laboratories, more recent years have seen major contributions from all over the world and from all fields of science. At present, many laboratories are actively working in the field. In the future it is to be expected that the techniques of information theory will become working tools of the electrical engineer, the psychologist, the physiologist, and others. Ω

1 Story conference roughs out ideas for comic book (*author, right*). After final story board is approved . . .

2 Artists render oversize page layouts in full color prior to four-color printing process. After printing run . . .

Tomorrow's Engineers

By DWIGHT

Teachers, parents, and lawmakers were bitter about newsstand comics in 1945. But in the public relations field, although we were well aware of the adult fear that comic books were producing a crop of juvenile delinquents, we couldn't escape the conclusion that the medium had attractive possibilities for mass communication.

With these thoughts in mind we decided that a little cautious experimentation might lead to something interesting. And cautious it had to be, because even though we believed the comic might become an unusually attractive teaching aid, we had no intention of its backfiring on our public relations program.

After some preliminary discussions the first move was to consult professional comic-book writers and artists who, with the help of our staff, would bring the first story up to the finished-art stage. The plan then was to hold a conference before deciding to print or drop the entire project.

We found the professional artists and writers in the comic-book field to be a well-educated capable group, who were becoming more and more disgusted and bored by the industry's outpouring of brutes and miracle men. But they were convinced that color continuity could do the job that was proposed.

When the project got under way, this group found that their chief difficulty was convincing our staff that selection was the first principle of comic-book art; that even with 70 pictures it was impossible from an interest standpoint for them to combine narrative and everything known by G-E engineers about the "generation of electricity."

But after three months of work the first hand-colored hand-lettered art-board flats were completed. Although they looked good in this form, the decision to proceed with a printing was yet to be made. To get further reaction on the project, the art-board drawings were shown to several vice presidents and managers. Their opinions were to mold the final decision. And the results of these previews were indeed stimulating because the eight members of management who saw the colorful boards had so much fun looking, reading, and commenting that they not only gave their approval to the project, but also suggested many themes for future series.

Thus encouraged, 300,000 copies were printed in the first run and sent as examination copies to science teachers in high schools throughout the country. At the end of a month the stock was gone, and hundreds of requests were piling up. (Since that time the comic-book series has been to press 55 times.) Typical of requests was one that read: "So we have come to this! Please send me 120 copies!"

Why Do Comics Succeed?

Looking back, it's now easy to determine why this series of comic books is practically an integral part of instruction in many high schools throughout the country . . .

- Printed on mammoth presses on newsprint stock in quantities of 500,000 to 3,000,000, the unit cost is low enough to be consistent with amounts allocated for youth-advertising purposes.
- Many textbooks are in use six or more years, and in terms of such things as atoms, gas turbines, television, and fluorescent lamps, they are therefore obsolete; but today's teachers, wishing to keep up with progress, will accept industry's help—and furthermore urge industry to share their responsibility in the classroom.
- This series of comic books, approved by the Company's technical experts, has a reputation for accuracy and authority. Only *Adventures in Jet Power* has required extensive revision, and the fault oddly enough lies with engineers who refuse to design and manufacture a last-word turbojet engine and airplane, and have done with it.

3 Distribution is made. On one day this year, 3.6 tons of school publications—157,000 pieces—were mailed. Final . . .

4 Use in the classroom where 30 percent of General Electric's educational booklets are used as in-class texts.

Read the Comics

VAN AVERY

• Young people accept the comic technique as convincing, exciting realism and enjoy learning along with the main characters, Johnny and Jane. Through vicarious experience they learn; and because learning is fun, they remember.

What Teachers Tell Us

How do we know that comic books are effective teaching tools, and that they are helping create a favorable atmosphere for industry and the engineering profession?

First, you can't very well argue these points: knowledge precedes appreciation, and a growing appreciation of the scientist's discoveries and the engineer's applications, and public approval of the objectives and policies underlying a company's operation go hand in hand with industrial and professional progress.

This series of comic books is under constant scrutiny in graduate schools of education. For instance, we recently received a thesis that reported a study carried on with the help of pupils in elementary grades four, five and six (most readers are much older) with the most difficult comic book *Adventures Inside the Atom*, as the only text used for the "experimental" groups. Control groups used other noncomic materials. In this thesis the author attempted to ascertain whether "certain atomic energy concepts" could be understood by fourth-, fifth-, and sixth-grade pupils. Here are his conclusions:

"Because of the concrete presentation of atomic energy by this [comic] booklet the writer believes that it aided the teacher in making an adequate presentation of the constructive uses of atomic energy. . . . Children who cooperated in this study made significant gains as measured by a multiple-choice test. . . . Grade-group means showed little change between the pretest and final test results for the control groups. . . . The experimental groups showed statistically significant gains. . . . On the basis of this study, it seems reasonable to believe that many children can benefit from technical atomic energy instruction."

In 1951 we conducted a survey to determine how thousands of our teacher friends were using this series of comic books. After the returns were studied, the final report showed that 77 percent of the teachers used them with exceeding enthusiasm, and that the remaining 23 percent apparently had worked hard to fill in the spaces for unfavorable criticism. In this 11-page study the only adverse comment that appeared often enough to report was that "comic books are an inferior form of art, and passing them out endorses the use of *all* comic books."

This summary gave us, for the first time, a definite idea of what happened to comic books in the classroom: 45 percent were assigned as supplementary reading; 30 percent were used as source material and classroom texts; 28 percent were used for optional studies outside reading; and other uses totalled 3 percent.

It was equally important to know that in the opinion of teachers these booklets filled a definite need. Thirty percent reported that having been exposed to a subject through G-E comic books, pupils were more interested in (science) subject matter. Pupils learned more quickly and retained the information for a relatively long time, 28 percent of the teachers reported. And 16 percent of the teachers said that pupils learned by sharing the main characters' experiences.

A Pennsylvania teacher wrote: "It would take me months to put over the same idea. You may be interested in the enclosures."

The enclosures indeed were interesting. One was a Statement of Procedure that explained how, on 10 consecutive school days, 10 of our comic books were the sole text used in a general-science class. Another was an objective test of 50 questions that was given on the eleventh day, together with a Summary of Results.

The test questions covered a great variety of things: What happens when a wire cuts a magnetic field, Newton's Third Law of Motion, how fluorescent lamps work, fission, electronic tubes, the number of miles of electrified trackage on the Pennsylvania Railroad, the Edison effect, and others.

The class average on that test was about 80 percent, and the boys and girls who were exposed to this experiment had an average age of 14.

Further reports have come to our staff. They give some indication that studies already begun will prove that this type of "text" can convey knowledge in equal measure to children of high or relatively low intelligence—as measured by conventional tests. It appears that superior groups are not showing markedly higher learning and retention than slow groups, when the comic book is the text.

(It's also interesting to note that some 30 big-name colleges have made class use of this series of comic books for quick reviewing of subjects.)

They Reach the Millions

These comic books are "engineered" with exceeding care. If you've ever worked out a crossword puzzle, you know that putting down a wrong vertical word will make it impossible for you to find crossing horizontal words that fit. Similarly, if you choose for a comic book an extended development of a narrative element that requires too many frames, there simply aren't enough frames left for the important expository elements. Or, if the expository elements block out into too many frames, the story suffers; that is, the thing becomes just another series of textbook diagrams. The story *must* capture interest so that the young reader will *care* when his counterpart (main-character Johnny) learns some basic scientific principle. As a teacher, the comic book has few rivals.

Its most attractive competition is the motion picture—which, incidentally, is blocked out in very much the same way. Actually, the movie, when skillfully done, is probably the best of all teaching tools; it is progressive action rather than a series of stills, and it has the added benefit of sound. But, at a fraction of the cost per impression—and at a fraction of time—the comic book can reach millions of boys and girls. The term *millions* is used purposely, because surveys show a pass-on readership of three-plus. It's now difficult to determine, within millions, the total readership of the 35-million copies that have been distributed, because it's impossible to count the number of parents who also have read our booklet—or the youth and older people of Finland, Denmark, France, and Italy who have read them in "strip" form as a result of various translation rights.

As a Recruiting Aid

Thirteen comic books have been produced since 1945. Twelve of them deal with basic scientific principles, the application of these principles in G-E products, and the historical evolution of the electrical industry.

Number 12 of the series, *Adventure Into the Future*, is a long-range recruiting piece for the engineering profession.

Excluding narrative, what is this booklet driving at?

Main-character Johnny says: "I'm going to be an engineer! What can I do about it while I'm still in high school?"

Answer: Study the right subjects, math and science for example. . . . About half the high-school graduates who would like to follow an engineering program in college find they haven't taken enough math and science to qualify! Plan your future now! Have some sessions with your school's career specialist.

Question: What about job opportunities?

Answer: An engineering degree opens the door to a number of interesting and challenging jobs. Even if a young man hasn't a college degree, companies need lots of skilled machinists and other craftsmen, and a wide variety of technical experts. . . . There are more women engineers than ever before. There are many interesting jobs, too, for girls without college degrees—assisting with laboratory work, experimental testing, analyzing data . . . each job lightening the scientists' and engineers' burden.

Question: What if I am not sure what type of engineering I want?

Answer: Be sure you want to be an engineer, that your subject choice and interests point that way. Find out what colleges require for admission. Get the groundwork first. Worry about specializing later. . . . Engineers aren't born, they're made. Rather, they make themselves. There's no such thing as an engineer "type." There's a job in engineering to suit the tastes and talents of everyone.

Question: Suppose I start to become an engineer and change my mind?

Answer: You'll be that much more eligible for a greater variety of jobs. Engineering students learn to think, to stick with a problem until it's solved . . . and business and industry want and need people who have been trained to think.

As the story closes, Johnny says: "Count me in our 'adventure into the future.'"

Of the two- to three-million readers of this comic book that came off the presses in October 1952, many may have been persuaded by its message. Many will take the prerequisite math and science and perhaps go on to join the great body of engineers in America.

Has this particular approach been effective? One of the sincerest compliments to the effectiveness of this booklet is the fact that teachers have written: "Naturally, you or we don't expect or want every boy and girl to be an engineer, so we are using this booklet as a guide to the type of information that should be sought no matter what the choice of career."

What Adventures Next?

We don't know. But we do know that Johnny is anxious to explore the heat pump, the atomic submarine, and many other wonders of these exciting years.

The comic book has a more secure place as a teaching aid than was ever dreamed possible. And we are sure that, as the years go on and new "adventures" roll off the presses, it will prove even more valuable, and gain more acceptance with the engineers of tomorrow. Ω

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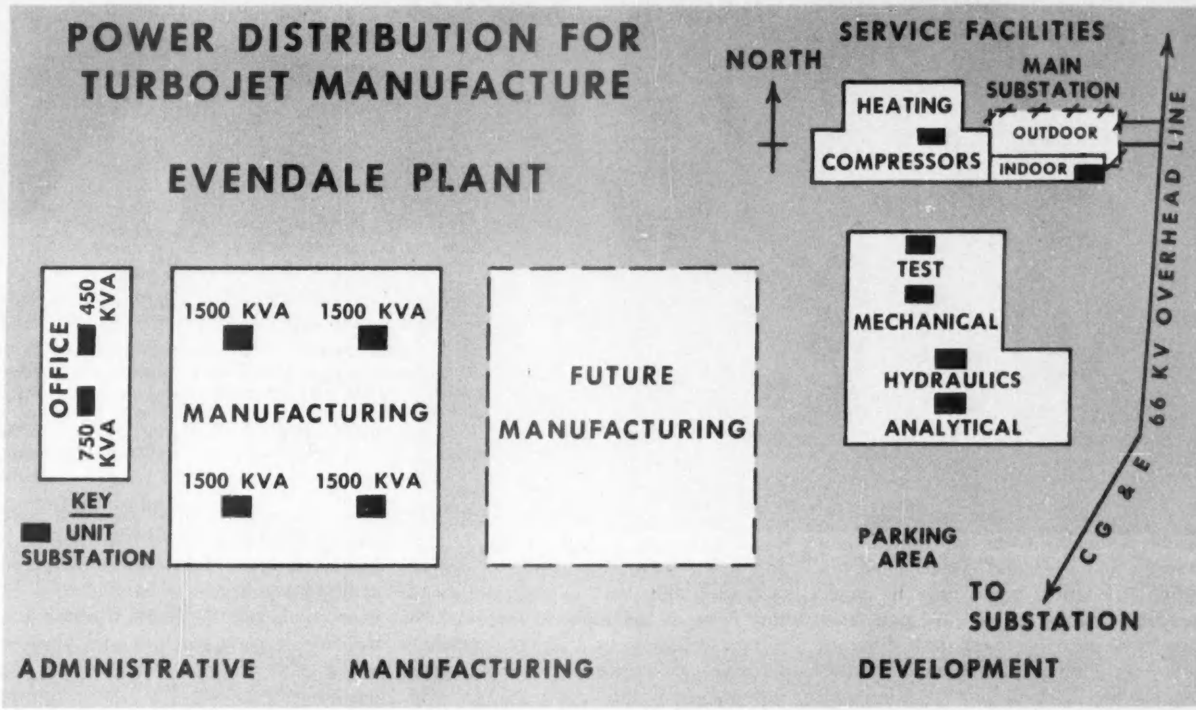
For 16 years Mr. Van Avery taught English in college and public schools. Joining GE's Public Relations staff in 1943, he has been Supervisor, Editorial Services Unit in Schenectady for the past five years. Booklets, posters, charts, and periodicals are prepared by his unit for use as supplementary texts and motivating tools in thousands of classrooms.



ARRANGEMENT OF FACILITIES FOR GENERAL ELECTRIC'S NEW JET ENGINE CENTER AT EVENDALE, OHIO, USED AS THE MODEL IN A . . .

Primer on Power System Design

By R. MORGAN WILSON

Designing the power system for a plant in a new industry isn't as difficult as it might sound. Fortunately there's a remarkable similarity among power systems of all industries. Study the basic patterns of power distribution in modern cement plants, paper mills, and chemical plants and you'll find them much the same.

In planning any system, it's desirable to fully utilize the engineering experience manufactured into power-system equipment. For that way you obtain the maximum benefit of its application. What's more, the confidence you have in such equipment is fundamental to the design of a good system.

Power for Turbojet Manufacture

As an example of a power distribution system applied to a modern industrial plant, take General Electric's new turbojet engine manufacturing and development facilities at Evendale, Ohio, about 12 miles north of Cincinnati. There the arrangement of facilities (plot diagram, above) was determined by production considerations. Our problem was to design an electric system that would deliver power to the buildings that housed the utilization equipment—such as motors, lights, and electric furnaces.

The new facilities consist of a one-story parts manufacturing building with 250,000 square feet of manufacturing area, and a 60,000-square-foot basement for a cafeteria, building services, and associated functions. To the west of the main building is a two-story administration and engineering building with 145,000 square feet of floor space. A number of buildings to the east comprise the jet engine component development center. All this was of course in addition to facilities that were already in operation at Evendale, which had to be integrated with the new power installation.

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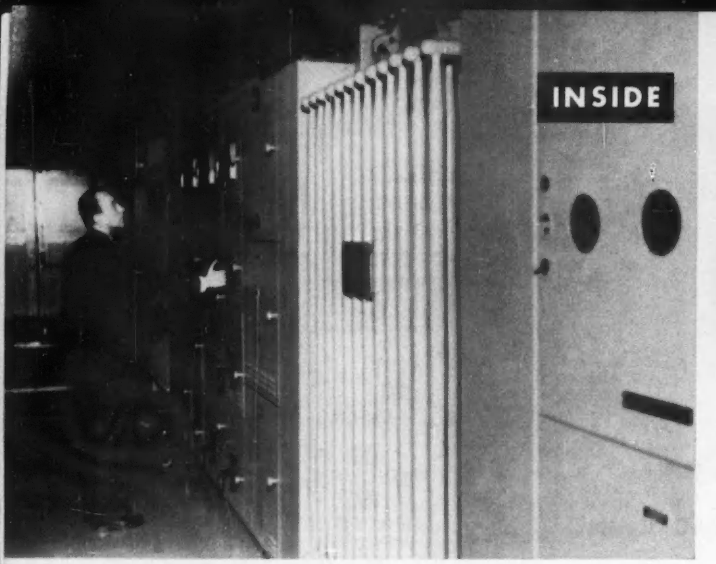
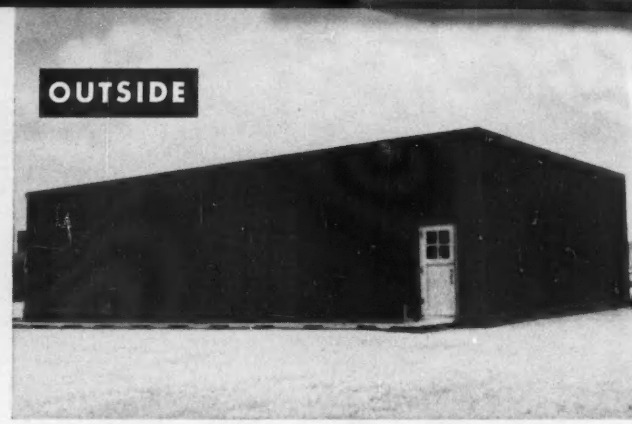
Mr. Wilson—industrial application engineer at the General Electric Company's Denver office—frequently writes and speaks on power problems. He is responsible for the application of General Electric apparatus in industrial plants for the Rocky Mountain District.

A major problem faced the local power company, Cincinnati Gas and Electric Co. Besides the 65,000-kva required by existing facilities, the new component-development testing facilities would have a 35,000-kva demand. And this additional demand would place a burden on the utility's system. The problem was finally settled by agreement that all major development tests be scheduled between midnight and six a.m. This meant that Evendale would have an off-peak load; that is, one that didn't occur at the same time as the utility's peak load.

An Ounce of Prevention

The question of a reliable source of power is an important one to the designer of industrial power systems—for no system can be more reliable than its source. It's always desirable to have more than one source of power.





ONE OF FOUR all-weather penthouses on the roof of the manufacturing building. Each penthouse encloses a 1500-kva two-transformer load-center substation rated 13,200/480 volts and a fan room housing the building's ventilating equipment. Resident engineer (*left*) checks operation of air circuit-breaker feeding overhead busway in manufacturing area below. Right to left are interrupter switch, transformer, and low-voltage switchgear.

At Evendale, a 66-kv circuit was readily available from one CG&E substation, and a second circuit from another substation could also be made available. So we decided to bring these two lines into the plant from different locations. They would be fully protected by relaying, normally operated in parallel, but arranged so that an operator could select either line for use. Then if either line were knocked out of commission—for example, by collision of an automobile or airplane into one pole line—circuit breakers would automatically isolate the faulted line, leaving the second one to serve the plant.

. . . For Manufacture

After we'd settled how power was to be brought in, there remained the problem of distributing it to the equipment that would utilize it. We considered first the power distribution at *utilization* voltages, as distinguished from the higher *distribution* voltages at which no utilization equipment would be applied.

For the manufacturing building, a 480-volt line-to-line wye connection with 277 volts available from line to neutral (480Y/277 volts) was selected as the best utilization voltage for machine tools rated 200 hp and lower, and for fluorescent lighting. Machine-tool drive motors would be connected 480 volts, three-phase, and the lights connected 277 volts, single-phase, the latter distributed over all three phases to give a balanced load. Transformed from the 480-volt system, 120-volt single-phase power would supply fractional-horsepower motors, hand tools, and plug-in receptacles.

Next, for maximum economy we decided to serve the utilization equipment from *load-center* unit substations—relatively small substations that transform the distribution voltage to the utilization level—located near the center of each load area. (In this way you avoid long runs of the more expensive low-voltage utilization cable, more expensive because of its larger cross-sectional area.)

Load-center unit substations rated between 500 and 1500 kva were selected, depending on the load density of kilowatt load per square-foot of floor area. Determined by the spread of load distribution over the area, the substations were placed to serve loads within 100 to 300 feet.

Four 1500-kva load-center substations proved to be most economical for the manufacturing building. Each substation in turn consisted of two 750-kva transformers and their associated switchgear. The two transformers would provide a high degree of reliability because the primary of each would be served from a different incoming distribution circuit. And so each group of feeders from one transformer secondary could be switched to the other transformer during maintenance or if a fault occurred.

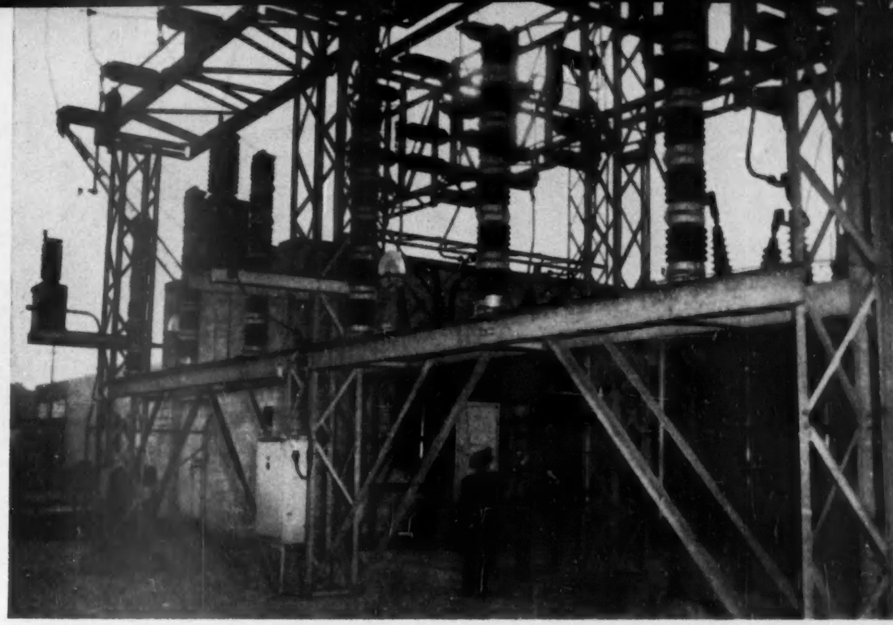
Although it is sometimes desirable to locate load centers right on the factory floor, circumstances dictated they be installed in penthouses (photo, above). The reason for doing so was simple—in this one-story building, roof space was inexpensive compared with space on the factory floor, or in the basement. Besides, it would be only a short distance from the substation feeder breakers on the roof to the overhead plug-in busway on the main floor. Such a combination makes for an economical roof installation.

Based on the load density in the manufacturing building, the overhead feeder circuits to serve the area were chosen as 400-amp three-phase four-wire busway sections. These would be spaced at 50-foot intervals in parallel rows on overhead beams. A plug is inserted into the bus at each machine-tool location and a cable dropped to connect to the machine's terminals. For 120-volt power the plug-in busway is supplemented by a trolley bus, connected at intervals to the main busway by plug-in circuits fed from 25-kva step-down transformers.

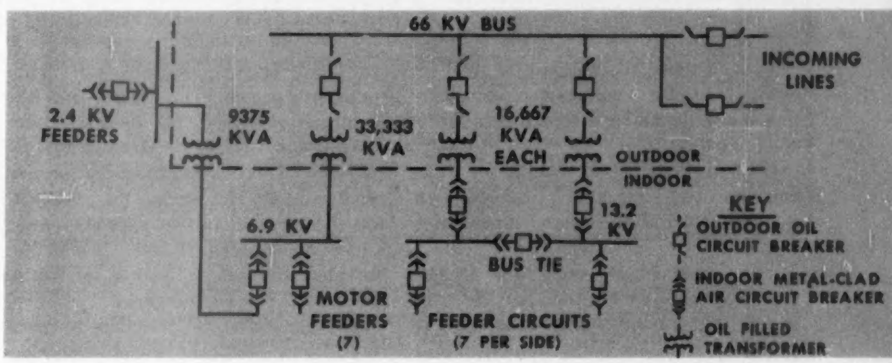
. . . For the Office

In any office building the main problem is lighting, although air conditioning is becoming an increasingly greater load. In engineering offices draftsmen want high-intensity lighting in the 50 to 75 footcandle range. General office workers are satisfied with somewhat less—about 25 to 50 footcandles will do. You must provide high reliability for lighting circuits since work will nearly always cease when lighting fails. On the other hand, air conditioning, although important, can be off for short periods without impairing work efficiency. And so it isn't as critical a service as lighting.

The lighting load in the office building at Evendale would take some 400 kw—this figure to include power for calculating machines, plug-in receptacles, and some ovens in the cafeteria. For this small load a two-transformer 450-kva substation was chosen. Secondaries connected 208Y/120 volts, the two transformers provide the necessary degree of reliability. To serve the air-conditioning motors directly, a single 750-kva substation was provided. Both substations were located in the basement, because the office building is two stories, with the major portion of the load concentrated on the first floor. (Incidentally, if



INCOMING LINE SIDE of 6.9-kv package substation that supplies power to large motors. Visible in upper foreground are incoming line terminations. Incoming line's circuit breakers and the substation building are in background. Note in one-line diagram (below) that the 66-kv circuit breakers feed stepdown transformers connected to the indoor switchgear.



you were to select a lighting system for a *large* office building today, you'd find that in most cases a 480Y/277-volt system with fluorescent ballasts connected line to neutral and the recently developed 24-volt control is highly desirable.)

. . . For Testing Facilities

As designer of a system, you must specify the utilization voltages at which the various motors will operate. The question is one of economics. For you've got to obtain the proper economic balance between insulation level and conductor size throughout the distribution system as well as in the motors. Insulation level is favored by low voltage; conductor size, by high voltage. Both are cost-determining factors.

The general range of horsepower ratings versus economical voltage levels in motors is . . .

Up to 200 hp, 480 volts;

200 to 2000 hp, 2400 volts;

1500 to 5000 hp, 4160 volts;

4000 to 12,000 hp, 6900 volts.

Total horsepower involved, the number of motors of each rating, and the area over which the load is distributed will influence your final decision on utilization voltages.

The Last Step

Connecting the source of power to the several utilization voltage systems is the final step in design of a distribution system. Sometimes you find it desirable to modify your selection of a utilization voltage when you start considering the economics of distribution. For example, 2400 volts is seldom economical without a large concentration of motors particularly applicable at that voltage. It is better to use 4160 volts. All motors are then applied at 4160 volts or 480 volts and an intermediate voltage eliminated.

In industry, 4160 volts or 13,800 volts is commonly used for power distribution; the former when loads are less than 10,000 kva and of averagecon centration; the latter for heavier loads or where large areas must be served. Both voltages were used at the Evendale plant; the main substation was arranged as shown in the one-line diagram above.

The 66-kv incoming lines were terminated as near as possible to the major load—large motors of the component-development division—and power for the motors was transformed directly from the source voltage, 66 kv, to the utilization voltage, 6900 volts. This plan eliminated a distribution voltage for the major load and resulted in a saving in equipment cost and copper losses. We considered the single 66- to 6.9-kv transformer adequately reliable for the test facilities. Located in the same building as the 6900-volt motors were the 2400-volt motors. They therefore could be served from a 6900- to 2400-volt transformer. Such a double transformation—66 to 6,9 kv and 6.9 kv to 2.4 kv—was economical because of the diversity of the motor loads. And also a 6.9- to 2.4-kv transformer is less expensive than one of the same kilovolt-ampere capacity but with a 66-kv primary.

For the low-voltage load centers—600 volts and below—the distribution voltage chosen to serve them was 13,800 volts. This was done because the total load was almost 20,000 kva and would cover a large area. To provide a high degree of reliability at the 13,800-volt distribution voltage, two transformers were used to reduce the 66-kv source to that level. A separate source-voltage feeder circuit and circuit breaker were provided for the primary of each of these 66- to 13.8-kv transformers; secondary breakers were also provided. In the event of a fault in one transformer, a relaying system was designed to trip the primary and secondary breakers, thereby isolating the one faulted transformer without interruption to the load on the other. Then, circuits on the faulty transformer's secondary could be switched over by closing a tie breaker; the unfaulted transformer would carry both loads.

The feeder circuits from each of the two 13,800-volt transformers were arranged to feed different transformers at each load-center substation; that is, no two of a given load center's transformers would be fed from the same 13,800-volt line. Thus a fault on one 13,800-volt distribution feeder couldn't affect the primaries of *both* load-center transformers. Once the fault on that circuit is isolated,

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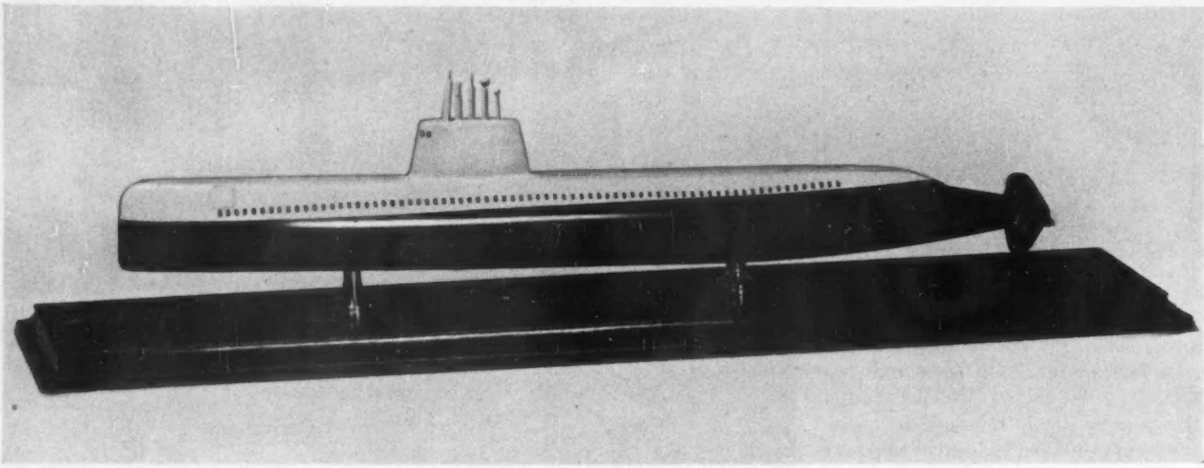


APPLICATION OF NUCLEAR POWER TO A HIGHLY REFINED END PRODUCT—THE SUBMARINE—POSES NEW AND COMPLEX PROBLEMS IN . . .

Designing a Submarine Power Plant

By W. W. KUYPER

There's more to designing a nuclear power plant for a submarine than putting a reactor and a steam turbine into a standard hull.

Conventional power plants for submarines pose enough problems: a nuclear power plant is many times more complex.

The power plant—regardless of the type—must be so located that the ship will be dynamically stable in an upright even-keel position, both submerged and on the surface, and it must be capable of control by adjustment of buoyancy tanks.

This is the conventional problem of undersea craft—a problem that forces limited patterns of arrangement on both the shipbuilder and the equipment supplier. For instance, weights and centers of gravity must be watched far more closely than in surface vessels that can usually sink a little deeper in the water. It's too easy to make a nose-heavy or tail-heavy submarine, or one that's heavier than its displaced volume of water, even when the design says it isn't.

Conventional Systems

On the nuclear submarine now being built, the engine room itself is filled with machinery that is well known and understood. The turbines and motor-generator sets are so mounted that ship structure dislocations, within certain limits, won't disturb the alignment of the assemblies. The condensers can withstand submergence pressures, and the piping is designed to operate under thermal and mechanical stresses in close quarters. The air-conditioning system condenses all the steam that escapes, and the electric system supplies power where it's needed. Proper means are provided for safety release of boiler pressure at full submergence.

All equipment is designed to meet Navy shock requirements. And because the life of the vessel may depend on it, the response speed of the entire propulsion system is more rapid than for surface vessels, and considerably more rapid than for central station power plants. The control of all the vital auxiliaries is centralized to assure quick handling in emergencies. All equipment is designed to tolerate unusually large degrees of pitch and roll because submarines are relatively unstable.

The foregoing are all problems in applying well-known types of equipment and systems to a highly refined end product. But when you take a radically new type of power plant and attempt to apply it, not only does practically all of the preceding apply, but many new problems also enter the picture.

Unconventional Systems

In designing a nuclear power plant for a submarine (illustration, opposite page) four factors dominate all design considerations within the secondary shield:

- Because the secondary shield is thick and heavy, it must be kept as small as possible, and the components within it must be compact and closely packed.
- The equipment within must be located for easy servicing.
- For all practical purposes, a reactor, once in operation, never stops producing heat. (Actually, its rated output falls off rapidly at first, then slowly over a long period of time.) Therefore, adequate cooling must be provided at all times, even in the event of a power failure.
- The systems can be designed as hermetically sealed units that won't require any additional coolant to be added during a voyage. Or they can be designed for very low leakage—small amounts of coolant would then be added during the voyage.

There are two choices of reactor compartment design. . .

- Allow entry to the compartment for replacement or repair.

Joining GE in 1933, Mr. Kuyper spent three years on the Advanced Engineering Program and has since held several engineering management positions in the turbine field. Formerly Manager, Engineering and Production at the Knolls Atomic Power Laboratory, Schenectady, he is now Project Engineer, Product Development Laboratory, Large Steam Turbine and Generator Engineering Section; Schenectady.

• Design it so that all the vital components can be removed without entry to the compartment.

The second idea is possible only with simple systems; and it has a further drawback in that some of the basic piping may be inaccessible.

Special equipment for dockside or tender servicing must be carefully planned and developed. If any special coolants are required, they must be supplied, and provision must be made for handling large quantities of radioactive material. In this regard the designer must always remember the necessity of adequate safeguards for the surrounding community.

Emergency cooling—cooling the reactor after a power failure—by natural convection of the primary coolant requires that adequate pressure heads be available under extreme conditions of pitch and roll, that the primary coolant remain in the system, and that it be allowed to transfer its heat somewhere. An auxiliary system is probably required for final heat transfer to the sea.

Unconventional Components

Systems are made up of components: they, too, present new problems to the designer.

Because the primary coolant becomes radioactive, and also to avoid pumping excessive leakages back into the system, it's important that the valves don't permit leakage from the system. If water is used as a coolant, it involves high-pressure valves with sealed-in electric actuators, or piston-operated valves with the necessary auxiliary systems. It's easy enough to write the specifications, but it's difficult to design and develop reliable valves and equipment for this type of service.

If liquid metal is the coolant, the valves must be sealed against lower pressures. Even so, the hazards associated with a small leak of sodium are probably greater than with water. In addition to the various paths of development open for water valves, a bellows-sealed stem appears practicable at the lower pressures. Again, the problem is to assure reliability.

To avoid leakage where water is used as a coolant, pumps have been developed in which the motor is submerged in the primary fluid.

When you consider the application of liquid metal pumps in submarines, it is immediately apparent that there must be no leakage. Because of this, you must use either electromagnetic pumping, or canned and submerged motors driving centrifugal pumps. Both types are practicable; both require extensive and concentrated development and design effort to bring them to an adequate stage of reliable performance. (Some of the early liquid electromagnetic pumps are described in the May 1952 REVIEW.) Another difficulty is that electric insulation in the pumps must be able to withstand the radiation of the fluid being pumped.

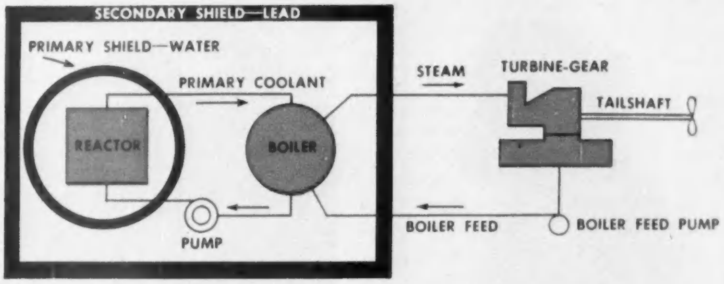
Regardless of what system is used, each must have additional and special equipment: purifiers for the fluid, heaters for pipes where sodium is used (melting point 208 F), and leak detection, pressure, temperature, and flow indicators.

The boilers for nuclear power plants using water as a coolant have an inherently low temperature drop for heat transfer. The average temperature of the water must be sufficiently below the boiling point at the pressure used to avoid local boiling in the reactor. This in turn leaves little temperature margin for the boiler when even moderate pressures are used in the steam system. The end result is boilers of large surface area that must be shielded by the secondary shield to protect the crew from the induced radioactivity in the coolant.

With sodium as a coolant, much larger temperature drops are available (boiling point of sodium at one atmosphere is 1621 F). But using such high drops and temperatures brings up the serious problems of thermal dislocations and shock. In addition, because of the violent chemical reaction between sodium and water, it's necessary to provide a double barrier between the two fluids. This further hampers the designer because it requires construction of devices that are unusual and that tend to be awkward to manufacture and maintain. Close design requires knowledge that can be made available only by extensive fundamental study and experimentation.

Reactor Problems

Reactors for the submarine power plant—or for any nuclear power plant—are combinations of 1) nuclear fuel, 2) a moderator to slow the neutrons



SUBMARINE NUCLEAR REACTORS

The two submarine nuclear power plants now being built have been designated: STR—Submarine Thermal Reactor, water coolant; and SIR—Submarine Intermediate Reactor, sodium coolant. The thermal reactor effects most of the fissions with neutrons at slow or thermal speeds; the intermediate at intermediate speeds.

In both types of reactors, the primary coolant—water or sodium—is pumped through the reactor and boiler in series to transfer the heat to the steam. The steam drives the main turbine and the auxiliaries necessary to run the plant.

The region outside the reactor is protected from the neutrons in the reactor. Neutrons tend to make radioactive anything they strike. Accordingly, the reactor itself is surrounded by a primary shield to stop the neutrons. Light elements, such as the hydrogen in water, are effective for this purpose when combined with nuclear poisons.

The coolant becomes gamma radioactive when it passes through the reactor. To protect personnel from the dangerous gamma rays, a shield, preferably of high density, surrounds all components that contain the primary coolant.

Although General Electric has been involved only in the design of the SIR, the problems associated with both power plants are similar, and for general unclassified discussion they can be treated together.

For both STR and SIR, the power plant designers have relied directly on the Electric Boat Division of the General Dynamics Corporation for the solution of the ship problem.

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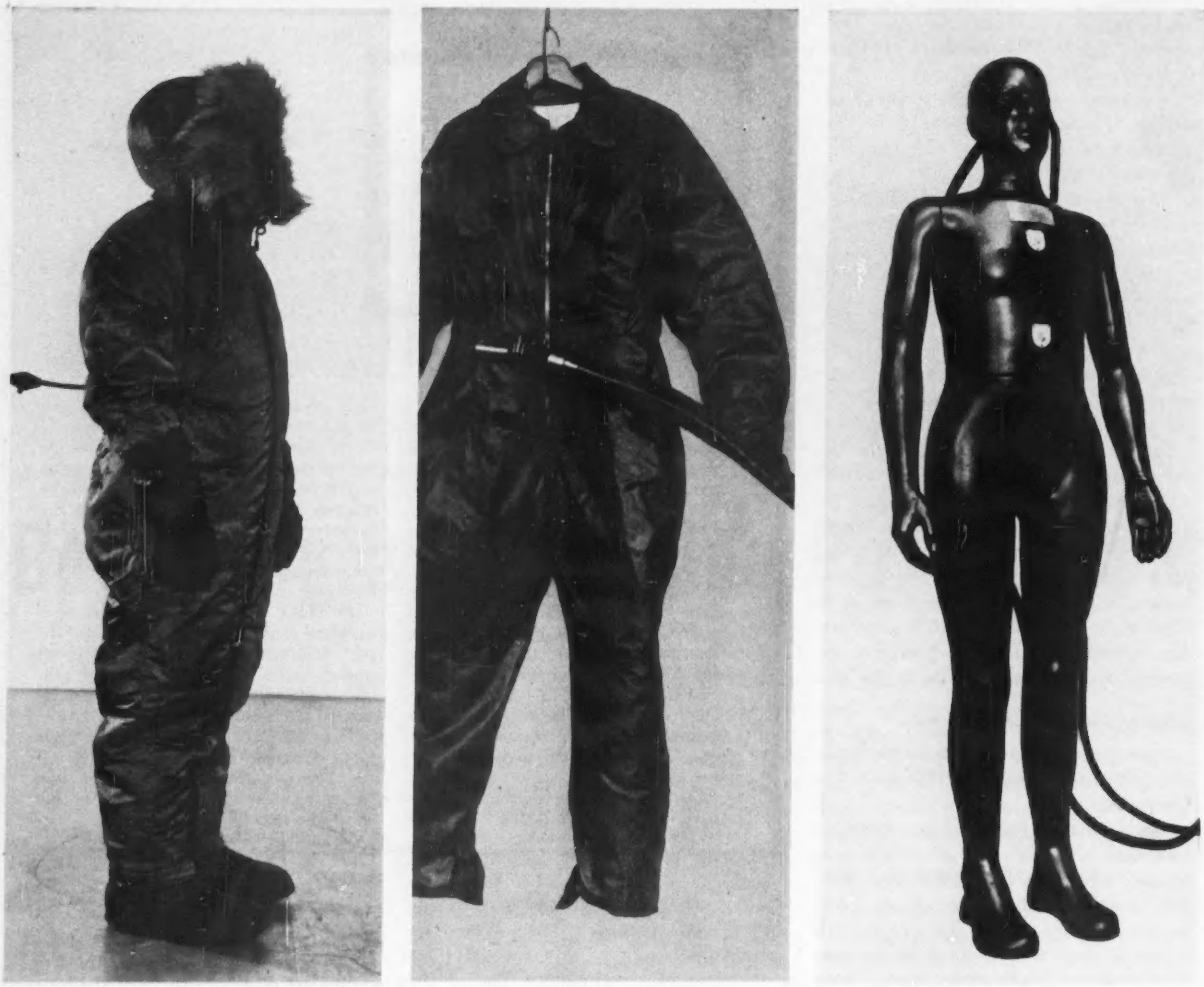

ELECTRICALLY HEATED FLYING SUIT IS USED IN THE AIR FORCE; ANOTHER (*CENTER*) HEATS AND COOLS. SLEEPY JOE EVALUATES BOTH.

New Applications for Electric Heat

By R. F. SAMBLESON

You can use the principle of the electric blanket in many ways besides keeping warm on cold nights during the rough winter months to come.

Modifications of the electric blanket are used to keep oxygen masks, goggles, and blood plasma from freezing at high altitudes and low temperatures; to prevent ice formation at critical points on TV antennas; to keep the rolls of rolling mills warm during shift changes and week-end shutdowns; and to maintain the proper temperature of rocket propellants.

Your automatic electric blanket is designed to maintain comfortable body temperatures despite changing room temperatures. The first variation from this fundamental use came during World War II when an urgent need arose to keep aircrew members warm during high-altitude flights. Although the physiological factors involved are about the same whether it's an electrically heated flying suit or a household automatic blanket, the flying suit is a bit more complicated; −65 F temperatures are involved.

Your body is basically a heat-generating mechanism, and it must steadily lose a certain proportion of this generated heat. If it doesn't, you die—it's as simple as that.

For comfort in any given environment the heat loss from your body must be at a constant rate. If the heat loss is too great, you feel chilly; if the heat loss is too slow, you feel overheated and stuffy. The fundamental consideration in designing electrically heated coverings for human use is, therefore, to maintain a relatively constant rate of body heat loss in varying temperatures. For the flying suit this involves a considerable study of the physiological factors, an evaluation of various types of clothing, and methods of applying additional heat.

The "Clo"

As a starting point, physiologists have established the value "clo," defined as one unit of insulation. In everyday terms one clo is about the equivalent of a man's business suit. Thus, the average person—undressed, and resting comfortably at 84 F—can achieve the same degree of comfort at 72 F with one clo of thermal insulation.

Roughly, one clo of insulation can be defined as that amount of insulation necessary to protect the human body for a 12 F lowering of room temperature. When you consider −65 F in terms of these values, you can readily see, without laboring through complex calculations, that an excessive amount of clothing is necessary for protection at such a low temperature. Actually, the wearer of an adequate amount of unheated clothing wouldn't be able to move. Thus, electric heat is necessary to replace the major part of the thermal insulation.

Flying suits, in general, are designed to protect; that is, to provide comfort for aircrewmen down to approximately +40 F *without* electric heat. From there on down to −65 F a proportionately larger amount of heat is delivered by the flying suit as the temperature decreases. In effect, electric wattage takes the place of the additional thermal insulation. It's this basic principle that is applied to both automatic electric blankets and electrically heated clothing.

Although nomographs have been established to show the relationship between ambient temperature and power in terms of clo value, they are used only as a starting point for the design of electrically heated clothing. Final values must be determined after a series of cold-room tests and under actual flying conditions.

Work for Armed Services

There have been many other applications of the general principle of utilizing electric heat to replace and supplement thermal insulation in both the military and commercial fields.

With respect to developments for the armed services, the work can be divided into two classes: heated equipment for personnel and heated blankets for equipment.

In the first category there's now active development work on electrically heated flying suits to meet the changing conditions brought about by the increased range and higher altitudes of today's aircraft. The latest version of the Air Force's electrically heated flying suit (photo, left, opposite page), is a coverall complete with parka and drop seat. It can maintain body comfort in temperatures down to −65 F, and the wearer has complete flexibility of motion. Electrically heated gloves and shoes are also used with this suit.

In this particular application the proper amount of wattage to compensate for body heat loss must be provided; but more important, the distribution of heat with respect to the areas of the body must be correct.

Several factors are involved: First, the rates of heat loss are not the same for all parts of the body. For instance, fingers and toes have a maximum amount of surface area for their size as contrasted to the chest area, where the reverse is true. Because of this fingers and toes are most likely to become frostbitten.

Second, the best skin temperatures for comfort in the various areas of the body differ greatly; that is, hands and feet may vary anywhere from 75 to 95 F without causing an uncomfortable feeling. However, an internal temperature drop of but a few degrees results in extreme discomfort accompanied by shivering.

As a third factor, pressure points such as the feet, back, and elbows have different heat-loss characteristics than other parts of the body.

In the fourth place, thermally self-protected areas, such as the back of the knee and the crotch, must be treated differently.

Electrically heated gloves and shoes impose another problem because flexibility requirements are at a maximum and hands and feet are most sensitive to temperature changes.

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When Mr. Sambleson came to GE in 1929 he had a variety of assignments that eventually took him into automatic blanket development. He is Manager—Engineering, Special Products Section, Automatic Blanket Department, Bridgeport. During World War II he visited Air Force bases in Europe regarding electrically heated equipment.

Cooling, Too

Because of the constantly changing concepts of aerial warfare, there is the problem of throwing off heat from supersonic aircraft. This presents a dual problem: The pilot must be kept warm in temperatures as low as −65 F; and under certain conditions of flight, he must be cooled off when the temperatures reach as high as 200 F because of air friction or solar heat. To meet these requirements, there has been some developmental work on a ventilated suit (photo, center, opposite page) that provides heating or cooling by means of a control that anticipates these changes. The cooling is done by refrigerating equipment; the heating by resistance heaters and a blower. A duct system in the flying suit distributes in correct quantity the warm or cool air where needed.

"Sleepy Joe"

In the past most of the development work on flying suits was done on human subjects in a refrigerated room. But people differ, and they have a strong aversion to sitting for eight hours in a room cooled to −65 F clothed in a rig that was perhaps known by the subject to be inadequate—even when they are well paid for it; it thus became necessary to devise another means of testing. To handle this assignment without any back-talk or deterioration of employee relations, an electrically heated robot was developed in the form of a copper man (photo, right, opposite page). He quickly acquired the moniker of "Sleepy Joe." He's essentially a copper shell of a man, built to average Air Force aircrew dimensions, and is heated by a multitude of electric circuits that can be controlled to duplicate human heat output under various conditions. Thus, Joe's heat output can be regulated—or standardized—so that reliable evaluation of heated clothing can be accomplished.

Several varieties of Sleepy Joe were developed and built—a standing man, a sitting man, and also a supply of hands and feet for testing gloves and shoes. The original Sleepy Joe didn't confine his activities to testing flying suits; he has been to Hollywood, appeared in a movie, and after returning from a trip to Canada, was incarcerated in the U.S. Customs Office until his nationality was definitely established. Joe's family is still increasing; he just acquired triplet brothers destined to evaluate clothing for ground personnel.

CONTINUED ON NEXT PAGE

HEAD THAT BREATHES IS WIRED TO SIMULATE HUMAN SKIN TEMPERATURES; COMPLETE WITH ITS FINAL LATEX COATING (*RIGHT*).

Unfreezing Oxygen Masks

Another important use of an electrically heated blanket for aircraft use is to keep temperatures in oxygen masks below the freezing point. At −65 F the normal moisture-laden exhalations quickly freeze on the interior of most masks and a short time later freeze the oxygen valve, thus preventing the wearer from getting any oxygen. At times this can be fatal. To combat this hazard, a variety of oxygen-mask heaters were developed to maintain nonicing conditions and thus permit the free flow of oxygen.

In the development of these heated oxygen masks another unusual test problem arose when attempts were made to evaluate various methods of heating. Again, testing the equipment on humans proved to be the main difficulty. It's not pleasant to sit in a test room for four to eight hours at −65 F; and it's doubly unpleasant when you have to wear an oxygen mask—a device that's uncomfortable to wear even when it's warm, and downright disagreeable when it freezes up.

A breathing head (photos, above) was therefore developed to take over the testing assignments. It's not only heated to simulate human heat capacity, but it's also capable of throwing off varying amounts of controlled moisture. By this means standardized test results and reliable data were obtained. Unlike Sleepy Joe, this breathing head remained anonymous.

Another contribution of the electric blanket to the Armed Services is the casualty blanket that's used for air evacuation of wounded from front lines to base hospitals, both by conventional air transport and helicopters. These blankets are similar to the ones in your home, except that they're of a more rugged construction and are designed to be adequate for comfort down to −65 F. Also, they cover the patient completely from top to bottom. They're regulated by automatic controls that not only compensate for temperature changes but also for changes in wind and altitude as well.

Air evacuation of the wounded poses another problem, again because of the cold temperatures encountered. Blood plasma won't flow any more readily than any other liquid at low temperatures, so an electrically heated blanket was developed to keep the plasma fluid at all times (photo, top, next page).

Defrosting Goggles

Another military development, while not strictly a blanket, is designed for defrosting of aircrew goggles and facepieces. At low temperatures the inner surfaces of the goggles tend to frost up because warm body moisture in the form of vapor lands on the cold goggle lens. An electrically heated sandwich with a resistance-wire pattern molded in the center of the thermoplastic goggle lens solves this problem. Because the resistance wires are quite close to the eyes, they are completely out of focus and aren't visible to the wearer (second photo, opposite page). The wires are of a dull oxidized material to eliminate reflections, and the wattage density necessary to do the defrosting job is low enough so that it doesn't cause discomfort to the wearer.

Another recent development for the Air Force is an electrically heated suit for the use of ground personnel who service aircraft.

Helping Equipment Operator

Equipment as well as personnel must perform efficiently at low temperatures, regardless of whether airborne, on land, or on the sea.

To aid the Armed Services, heaters have been developed for rockets to maintain battery—or propellant—temperatures for guided missiles. For accumulators, boost pumps, and hydraulic system components, heaters have been developed to maintain effective working temperatures of the fluids. There have also been heaters developed for bombsights, servo-gyro units, aerial cameras, jet-assist take-off rocket motors, optical instruments, and for deicing of external surfaces such as air scoops and vent pipes.

Industrial Uses

The electric blanket is also finding its way into the industrial field.

For instance, in two-temperature refrigerators the mullion, or dividing strip, between the "cold" section and the "cool" section is subject to frosting unless a few watts of heat are continuously applied.

In the cold-rolling of metal sheets, friction develops enough heat in the rolls to keep them warm. But if the rolls should become cold between shifts and after week-end shutdowns, breakage can occur on first use because of the rapid temperature rise. Electric blankets prevent this at a considerable dollar saving (photo, bottom).

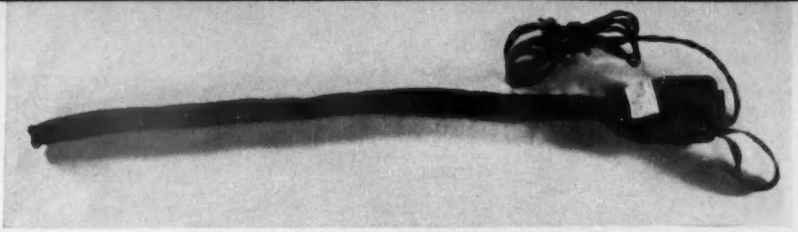
In large generator assemblies, prewarming of the stator bars is desirable as an aid to straightening operations and for correct, fast assembly to stators. Preheating by electric blankets accomplishes this.

On TV transmitting antennas, electric blankets prevent ice formation at critical points.

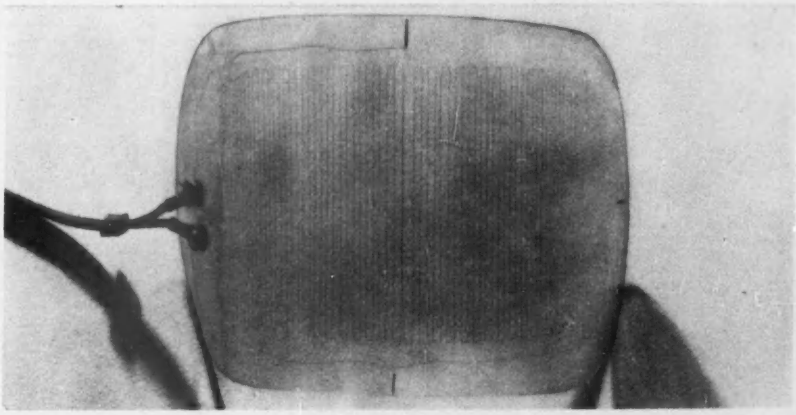
Experimentally, the electric blanket has been used as electrically heated drapes for household use, as ambulance blankets, and to replace the water-heated packs used in the treatment of polio, as well as in chicken brooders, and photographic developing tanks. Another experimental use involved an attempt to maintain the temperature of bananas at about 55 F on the retail store counter to prevent spoilage. Bananas are kept at this temperature from the time they are picked until they reach the retail outlet and then there is no temperature control whatsoever. The scheme looked promising but some of the merchandising problems involved were a little too difficult, and the project was dropped.

Future Promising

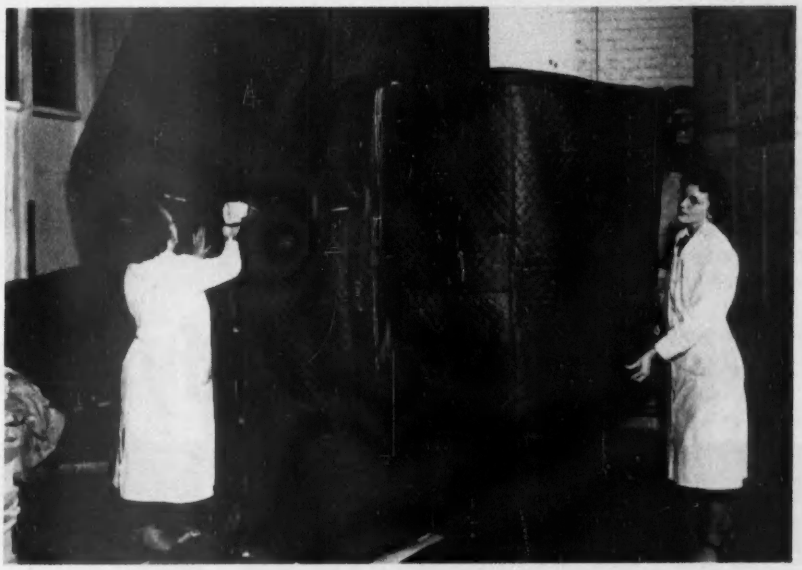
The automatic electric blanket has come a long way from the original conception of "merely a piece of wire and a piece of cloth." In modified form its uses in the military and industrial fields are many. The basic fundamentals of design are still the same, but the jobs it can now do are many and varied. After recent developments in this field, it's apparent that the real scope of potential usefulness of electric blankets has barely begun to be explored.Ω



ELECTRICALLY HEATED BLANKET KEEPS BLOOD PLASMA FLUID IN COLD TEMPERATURES.

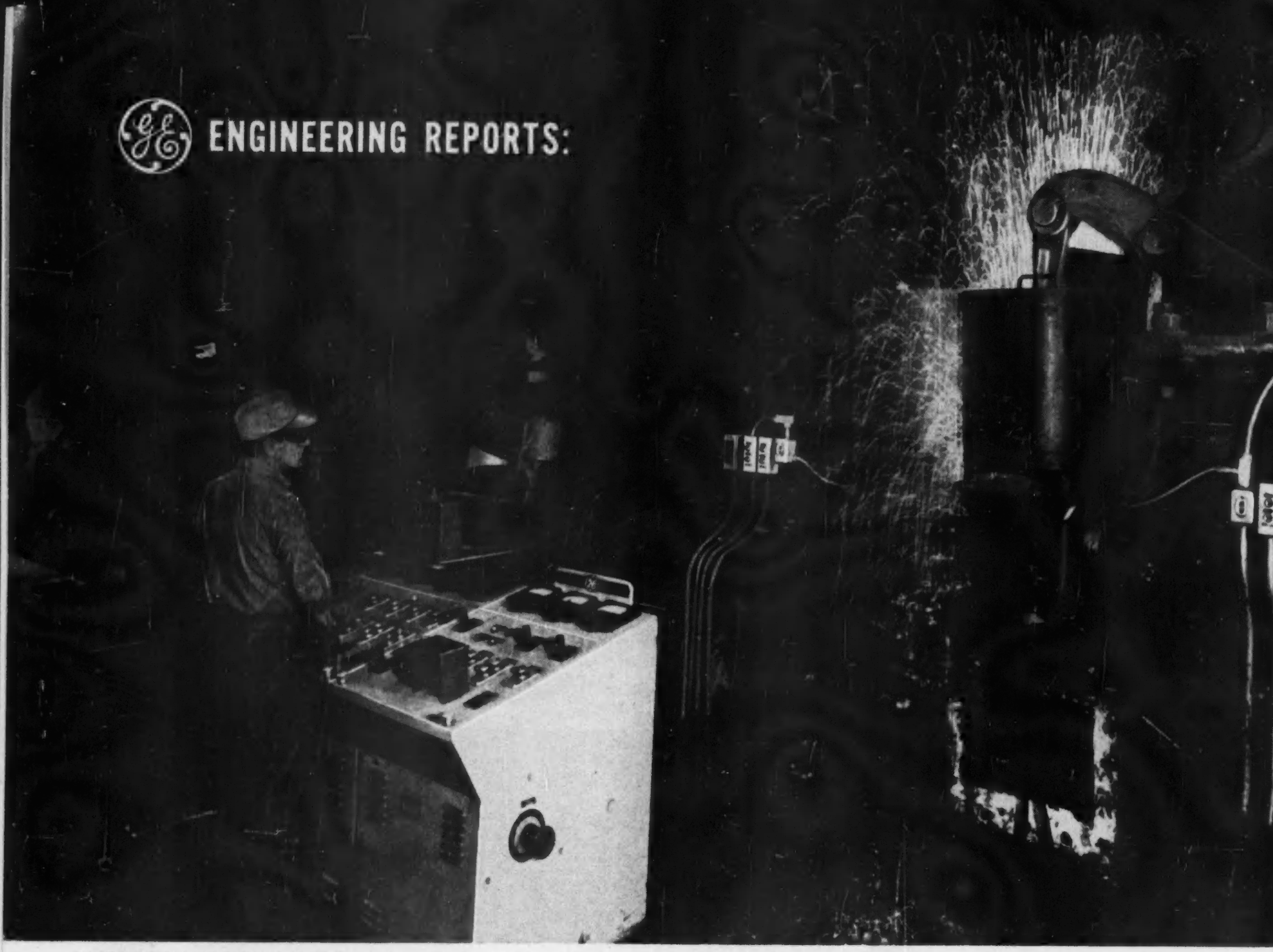


THERMOPLASTIC LENS IS ELECTRICALLY HEATED TO DEFROST AIRCREW GOGGLES.



LARGEST ELECTRICALLY HEATED COVER; BLANKET (*BELOW*) IS USED IN ROLLING MILLS.

ENGINEERING REPORTS:



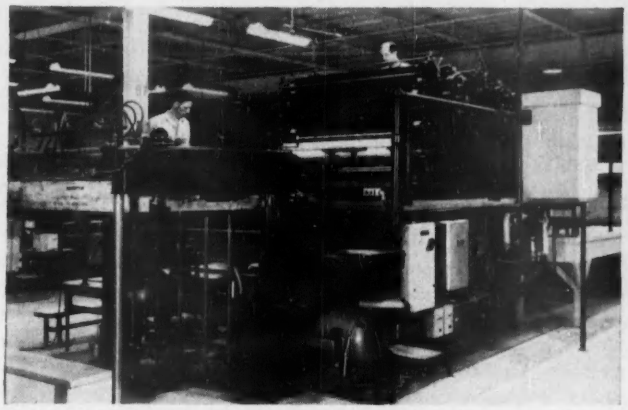
FASTER STEEL PROCESSING. G-E engineers helped increase strip output at Weirton Steel, division of National Steel, by applying the first amplistat loop control for reliable control of steel strip in pickling tanks. Lines now deliver a more uniform product.

Engineers amplify tiny signals to

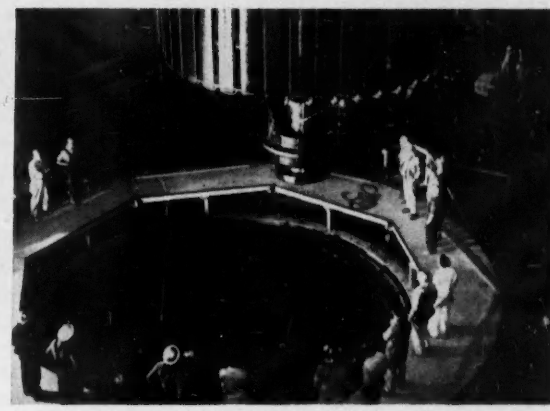
MORE YARN PER BEAM is the result of automatic tension control. G-E engineers have installed an amplistat in the control system of a textile slasher drive, helped lower production costs.

G-E ENGINEERS H. M. Ogle, General Engineering Laboratory, Dr. H. F. Storm, Industry Control, and W. L. Wilmer, printing application engineer, discuss some amplistats' uses in industry.

CLOSER AIRCRAFT CONTROL. To give added reliability to the Douglas A3D-1—U.S. Navy's most powerful attack plane—G-E engineers have used amplistats in the electrical systems and to regulate speed and temperature of aircraft power plants.



GREATER PRINTING-PRESS OUTPUT. To simplify maintenance of press drives, G-E engineers often design amplistats into the control systems. The device also permits widest practical speed range on job runs.



MORE AUTOMATIC VOLTAGE CONTROL. G-E engineers applied amplistats in the voltage regulator system for this giant alternator, being positioned at a hydro-electric installation.

harness America's giant equipment

G-E engineers help you cut operating costs by using magnetic amplifiers in control systems

The amplistat is another example of how General Electric application engineers take advantage of new product and engineering developments to build dependable, sensitive electrical systems. This remarkably reliable and maintenance-free power-control device—a static, magnetic amplifier—was investigated by G-E engineers over 40 years ago. Today, using an improved amplistat, G-E engineers can instantly multiply a tiny control signal's strength as much as 1,000,000 times to make your heavy equipment work faster and more smoothly, with greater ease, safety, and economy.

For example, G-E engineers have used the amplistat to help maintain uniform tension of steel strip in rolling mills and processing equipment, simplify operation and maintenance of printing press drives, reduce maintenance on electrolytic cell lines in copper refineries, and to build more reliable control and regulating systems in modern military aircraft.

You can put this engineering skill to work for you by specifying "G.E." when you buy electrical systems. G-E application engineers will draw on this engineering leadership in working closely with you and your consultants. Contact your local G-E Apparatus Sales Office early in the planning stage. General Electric Company, Schenectady 5, N. Y. 672-10C

Engineering Leadership gives you better electrical systems from—

GENERAL ELECTRIC

AMERICAN SOCIETY FOR TESTING MATERIALS

By ROBERT J. PAINTER

The critical importance of materials—especially engineering materials—was demonstrated forcibly time and time again during World War II and then later in Korea. Not only were there vital military problems, but civilian as well. It is a tribute to our economy and to the thousands of technical men in industry and government and others that somehow we were able to solve the critical problems. We produced huge quantities of high-octane aircraft fuel, perfected antitank guns, built our atomic plants, and made available the many special items needed, without any great hardship on our people.

Although many of these problems called for new thought and new data, a foundation for their solution rested largely in having available a great amount of scientific data on the properties and tests of materials; and also being able to develop specifications for quality, and quality-control methods that permitted production in sufficient quantities.

Critical problems will continue to challenge us, so all concerned should constantly assist in determining our needs far ahead and insuring that we shall meet them. We must conserve our resources; one way is to use our materials as efficiently as possible.

ASTM—A National Technical Society

The American Society for Testing Materials is a national technical society that has been characterized by over 50 years of collaboration with leading technical men representing the consumer and producer of materials; our armed services; municipal, state, and federal governments; and many other interests.

While the 11,000 members and committee members of the Society are concentrated in the United States and Canada, the membership is world-wide. The publications are distributed on every continent, and the standards and data are used in virtually every country.

From its very inception there was an international aspect to the Society—from 1898 to 1902 the organization was an American Committee of the International Association for Testing Materials. These various national groups were most anxious that some order come out of an admittedly critical situation with respect to evaluating materials. All the countries recognized the need for adequate tests, but the American group was also vitally concerned with adequate purchase specifications. It was largely because of this American emphasis (it didn't receive the support it deserved in foreign countries because of their own pressing problems) that the leaders here decided to incorporate the American group as a national technical society. This was done in Pennsylvania in 1902.

The charter states that the corporation was formed "for the promotion of knowledge of the materials of engineering, and the standardization of specifications, and the methods of testing." The seven incorporators were outstanding American technical leaders including Henry M. Howe, Charles B. Dudley, Edgar Marburg, Robert W. Lesley, Mansfield Merriman, Albert Ladd Colby, and William R. Webster. Edgar Marburg became the first Secretary of the Society and continued from 1902 to 1919 when he was succeeded by C. L. Warwick, who served until 1952. Charles B. Dudley—first President of the Society—was the only man to head the ASTM for more than one year; he served from 1902 to 1909.

Although minor modifications have been made twice in the Charter, ASTM has concentrated its work in this field of *research* and *standards.*

Because the Society's work is far broader than testing, suggestions have repeatedly been made that its name be changed. But the historical significance of the name, the extremely widespread use of the standards, and the tremendous effort that would be involved in making the change has justified the continuation of the present name.

ASTM is a materials society—really a society for materials. And its reputation has been achieved not in one field alone—for example, ferrous and nonferrous metals—but across a wide range of materials and products.

Importance of Technical Committees

It is not correct to say that ASTM is a group of technical committees for obviously the Society, like any other technical or scientific group, is comprised of men and—in increasing numbers—women. Yet, the Society's purposes are achieved largely through the activities of the hundreds of ASTM's technical committees. These groups are responsible for sponsoring and carrying out much of the extensive research and development work necessary to provide sound data on the properties and tests of materials. Moreover, the committees are charged specifically with the development of the standards, specifications, and tests which provide our economy with a basis of quality for so many materials and products. These standards provide the consumer with information on the basis of which he can make a choice as to which material is best suited for his purpose, and provide him with a brief designation with which he can call for the desired material. Some idea of the fields of materials covered by ASTM technical committees is given in the Table.

Widespread Representation

The founders recognized one basic concept in the work: If the standards were to come into widespread use, three chief interests would need to have adequate representation in the work—the consumers of materials; the producers of the raw materials, semifinished and finished products to be covered; and a third group that would include scientists, testing experts, research workers, and often, government men. Accordingly, an adequate balance be-

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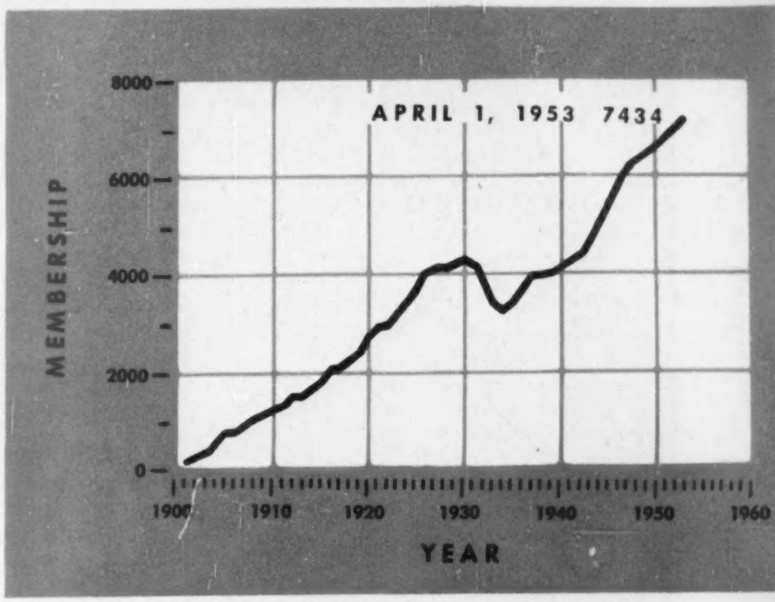
After serving as Assistant Secretary of ASTM for six years, Mr. Painter was appointed Executive Secretary in 1952. He is also serving as Treasurer.



ASTM HEADQUARTERS ON RACE STREET IN PHILADELPHIA; MEMBERSHIP CURVE SHOWS THE SOCIETY'S GROWTH SINCE ITS FOUNDING.

tween the consumer and producer groups is a requirement for the operation of the ASTM technical committees.

Another basic fact recognized in the work is this: A specification, to be sound, must be based on the latest and best information available. Obviously, a purchase specification must include adequate tests; therefore, the technical committees and other interests constantly carry on many testing projects. These are frequently of a round-robin nature—committee members carry out tests under prescribed conditions in their laboratories, and report their results to the committee and the Society.

To reiterate: sound and carefully analyzed data must be the basis of adequate materials specifications. Industry and federal, state, and city governments provide us with considerable technical data. The time of many men and their laboratories is devoted to round-robin testing or controlled field testing to make sure that our tests are adequate. It is difficult to estimate the cost to industry and government of the tremendous amount of work which they do for the Society, but it would be a high figure. From it come valuable returns: programs of this kind give assurance that a proposed test is sound and, particularly, is reproducible.

Much of the data coming from such research is published in the Society's *Proceedings*, *Bulletin*, or special symposiums, making available the valuable data that have been contributed.

AREAS OF ASTM TECHNICAL COMMITTEES MATERIALS TESTING

Metallic Materials	Cementitious, Ceramic, Building Materials	Miscellaneous Nonmetallic Materials
Ferrous	Cement	Paint, varnish lacquer
Steel	Magnesium oxychloride cements	Petroleum products and lubricants
Wrought iron	Chemical-resistant mortars	Gaseous fuels
Cast iron	Clay pipe	Road and paving materials
Corrosion of iron and steel	Fire tests	Coal and coke
Magnetic properties	Lime	Paper and paper products
Malleable iron castings	Refractories	Wood
Ferro-alloys	Concrete and concrete aggregates	Waterproofing and roofing materials
Iron-chromium-nickel alloys	Manufactured masonry units	Electric insulation
Nonferrous	Gypsum	Shipping containers
Wires for electrical conductors	Glass and glass products	Rubber and rubber-like products
Nonferrous metals and alloys	Mortars for unit masonry	Soaps and other detergents
Corrosion of nonferrous metals and alloys	Concrete pipe	Textile materials
Electrical heating alloys	Building stones	Cellulose and cellulose derivatives
Copper and copper alloys	Thermal insulation	Adhesives
Die-cast metals and alloys	Asbestos-cement products	Engine antifreezes
Light metals and alloys	Structural sandwich constructions	Industrial aromatic hydrocarbons
Electrodeposited metallic coatings	Acoustical materials	Laboratory apparatus
Metal powders and products	Ceramic whitewares	Naval stores
Metals and Related Testing	Porcelain enamel	Soils
Chemical analysis of metals	Building constructions	Industrial water
Absorption spectroscopy		Plastics
Emission spectroscopy		Floor waxes
Spectrographic analysis		Quality control of materials
Mass spectrometry		Appearance
Metallography and x-ray diffraction		Atmospheric sampling and analysis
Radioactive isotopes		
Nondestructive testing		
Fatigue		

Almost from the first, the Society has had excellent support from many of the leading companies in the electrical manufacturing field. Outstanding technical men in this industry have actively participated in all phases of the work. And several of the Society Presidents, Directors, and officers of leading technical committees have been from the electrical field.

Membership

Broadly, there are two classes of membership—individual and company. Individual memberships include persons, scientific societies, colleges or departments, libraries, government bureaus, and others. A company membership consists of a firm, industrial or trade associations, and related organizations. There is also a sustaining membership class and the student and junior membership. Currently there are about 7500 members which include some 5000 individuals (with juniors), about 2225 companies, and about 275 sustaining members. In addition, there are almost 4000 committee members serving on ASTM committees as additional representatives of their companies or associations.

Meetings

The Society's bylaws require that an Annual Meeting be held where reports of technical committees with their recommendations are received and approved. Another feature of this week-long meeting held late in June is the large number of technical papers. Many papers are frequently grouped as symposiums on pertinent topics concerned with materials. Throughout Annual Meeting week, and during the Spring Group Committee meetings and other annual meetings held in the spring, there are hundreds of meetings of technical committees. In recent years the Spring Meeting has had an average of about 300 meetings, the Annual Meeting over 500 meetings—in addition to main technical associations and other events. Frequently, as many as 40 meetings will be running simultaneously.

Constantly under way throughout the year are sessions of the various technical committees; several are held during meetings of other technical and trade groups. The amount of technical business transacted at all of these meetings is enormous, as a result of very intensive efforts put forth by the technical men present.

With ASTM membership cutting horizontally across all professions and industrial activities, it has not been feasible to organize the men locally in the form of chapters or sections. However, some 14 districts have been organized and they serve somewhat the same purpose as do the chapters of professional groups—promoting the work of the Society. Each district covers considerable area and is administered by a Council nominated and elected locally. Two or three yearly meetings are sponsored by districts, with papers and reports presented on subjects pertinent to the field of materials.

Publications and Standards

The Society publishes thousands of pages of material yearly. The regular publications include the *Year Book* (list of members and committee members, and related data); the annual *Proceedings* (1200 to 1500 pages yearly of technical papers and reports); *ASTM Bulletin* (eight times yearly, consisting of technical papers, news, laboratory apparatus advertising); the *ASTM Standards* (issued triennially—current 1952 edition in seven parts, totaling about 10,000 pages); a combined *Index to ASTM Standards* (about 300 pages), and numerous special technical publications, symposiums, reports, bibliographies, abstracts, and charts. These publications make possible wide distribution of the data coming from the vast amount of research and testing work; they particularly promote the use of the more than 2000 ASTM Standards. In addition to the book of *ASTM Standards* there are numerous special compilations: petroleum, textiles, plastics, electrical insulating materials and steel piping—about 20 such books. Each of these standards is available in separate pamphlet form and has world-wide distribution.

Officers and Awards

The officers of the Society include a President, two Vice Presidents, 15 Directors, and an Executive Secretary. This group, excepting the Executive Secretary, plus the three immediate past Presidents constitute the Board of Directors. Five Directors representing various industries are elected each year for a three-year term.

Among awards presented by the Society are honorary memberships, awards of merit, special lectures, and medals and awards for outstanding technical papers or other achievements. Two commemorative addresses—the Edgar Marburg Lecture and the H. W. Gillett Lecture—bring outstanding leaders in the field of engineering materials to the Society's Annual Meeting.

Co-operative and Joint Work

Because of the widespread interest in materials it is natural that the Society should have the close co-operation of a large number of technical societies and trade associations. The interest of these other groups is beneficial to ASTM, and many of the standardization and research activities are sponsored jointly with other bodies. For a 50th Anniversary luncheon of the Society held in 1952, more than 250 other societies and trade groups that have co-operated in the work were invited to attend, and many were represented. ASTM has enjoyed the close co-operation of many of the important branches of city, state, and federal government, including all branches of the armed services.

Headquarters Building

For the first 20 years the Society's headquarters was the office of Professor Edgar Marburg at the University of Pennsylvania. Later, offices were rented in the Engineers' Club Building in Philadelphia, and then in an office building in the same city. Since 1946 the Society has occupied its own building at 1916 Race Street on Philadelphia's Benjamin Franklin Parkway. The building was financed by contributions from members and friends of the Society. The present staff of 60 requires additional space, and so expansion is under way.

Contribution to Progress

While there is widespread use of the ASTM specifications and tests, it is difficult to completely appraise the value of the Society's work in standardization and research. Many industries base their quality requirements almost entirely on ASTM Standards. Also, many standards are incorporated in building, plumbing, fire codes, the boiler and pressure vessel codes, and in countless other applications to designate desired quality. The research work provides industry with the latest information on the properties of materials.

The continuing growth of the membership, standards, and publications—and the evidence on every hand of increasing use of the ASTM output—indicate that the contributions of the Society are continuing. Ω

MODERN TV LIGHTING offers flexibility and efficiency. Contrast the highlights on hair and shoulders of performers in the Fred Waring program (*above*) with the lighting of an early installation at WRGB, Schenectady (*right*). Overhead lighting with fluorescent lamp banks and Fresnel lens spotlights combine to effectively provide base, back, and key lighting, replacing water-cooled mercury lamps.

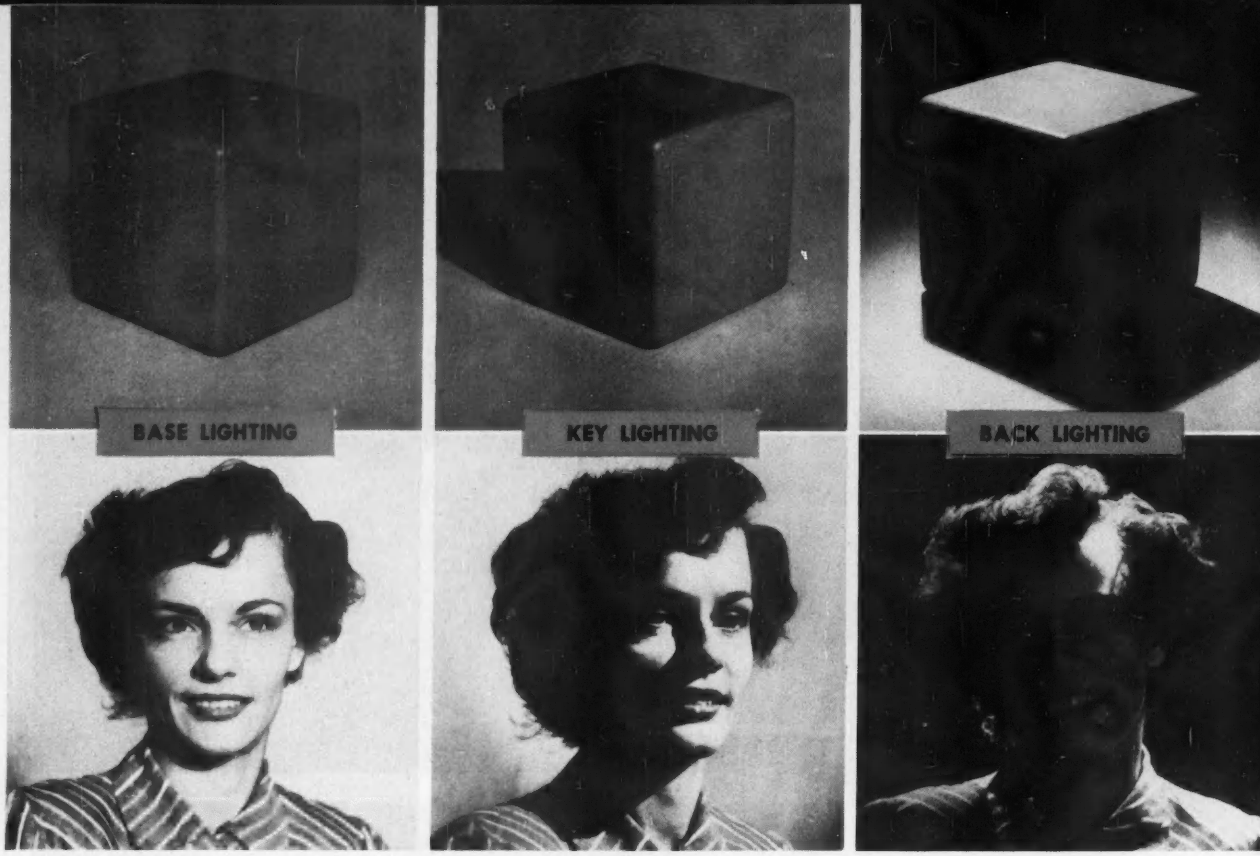
Good Lighting—A TV Problem

By RICHARD BLOUNT

Night after night as you sit before your television screen, you probably take little interest in the lighting of the various programs. That's the way it should be, for TV program lighting is meant to supplement the over-all effect rather than become the center of interest. Well-planned lighting can make the good programs better, and it can make the others appear to be better than they actually are.

Early Obstacles

In the early stage of the business, TV lighting directors were harassed by inefficient cameras. Prewar cameras just weren't very sensitive, and the director's main job was to pour light onto the set from every possible angle until he had the 1000 or more foot-candles required. Banks of filament lamps were used, but they caused mutterings among the actors because of the resulting high temperature. Some studios solved the heat problem by using water-cooled mercury arcs (photo, bottom). While these certainly cut down the heat in the studio, the color of their light accentuated skin blemishes and put heavy, dark shadows under the eyes. The mercury lamps didn't solve the problem of how to get good lighting; they merely passed it over to the make-up department. Also, the mercury lamps



were too short-lived for this service, and the water jackets often leaked.

Because the required light levels were so high, no attempt was made to use lighting to enhance a program. The director was thankful when he had enough light on the set to obtain any kind of a picture.

By 1945, new camera tubes required slightly more than 200 footcandles in the picture area. Although this was far better than the 1000 or more footcandles previously required, the new cameras had undesirable infrared sensitivity; later models were oversensitive to blues. Today's cameras have sensitivities that more nearly approach that of the human eye, and they require lighting levels from 25 to 100 footcandles, depending on the speed of the lens.

The color sensitivity of the new cameras is such that with filament or fluorescent lamps colors are reproduced in shades of gray with natural brightness. This means that yellow-greens, which appear brightest to the eye, are reproduced as white on your TV set. As the limits of eye-color sensitivity are approached in the blue and red regions, the colors are reproduced as progressively darker shades of gray. Ultraviolet and infrared "light," which cannot be seen, produce only a limited response in these new TV cameras.

Basic Factors

To light a television program successfully, the lighting director must know how to use light to achieve effective pictures. The camera substitutes for the eye—so, ideally, it should respond in the same manner. This is indeed a large order because visual characteristics include depth perception, color, and brightness response. Since brightness response is the only one inherent in a TV system, form, pattern, and depth perception must be conveyed by means of brightness differences.

Of the three, pattern is hardest to control. Because pattern is frequently associated with color, and because the light sources and camera-color sensitivity establish the response of colors in grays running from white to black, the lighting director frequently pretests a variety of colors. Those that produce pleasing brightness differences are standardized and used in sets, drapes, and stage properties, and as a basis for suggestions regarding costumes. Since costumes can't always be controlled, some materials occasionally aren't reproduced as effectively as the director would like.

Form and depth perception go together, and the same techniques are used to produce the illusion of three dimensions. For example, the object shown at the top, left, is obviously a block, yet we can show it more effectively by lighting its various planes separately rather than by one light near the camera. In the next picture the light has been moved from the vicinity of the camera to a point off to one side and above the camera level. This is now called the *key* light because it's the dominant light; its location can be definitely established. The effect of key lighting is to create a brightness difference between the two vertical planes and to establish their boundary.

In the next illustration the same light has been shifted to a point above and to the rear of the block. In this position it is called *back* light and serves to

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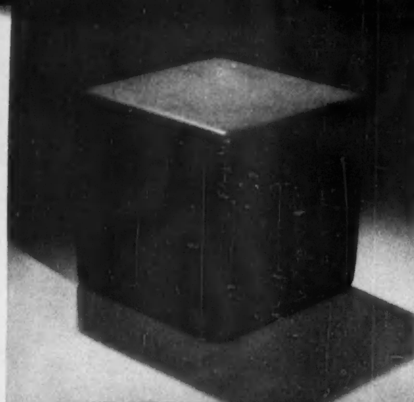
Mr. Blount is with the photographic light group, Application Engineering, Lamp Division, Nela Park, Cleveland and is responsible for lighting television, still- and motion-picture studios. His 14 years with GE, beginning in 1939, was interrupted by a five-year leave with the Naval Ordnance Laboratory. He is chairman, TV Studio Lighting Committee, Society of Motion Picture and Television Engineers.



COMBINATION

separate the horizontal and vertical planes by creating brightness differences between them. In addition, the top surface is separated from the background. In the final illustration all forms of light are used—base, key, and back lighting. You'll note that the total effect is to establish the boundaries of the various planes so that the eye "sees" a solid object on the two-dimensional viewing screen. In addition to the three light sources, a fourth might have been used to illuminate the background—a fourth brightness value to insure separation of all edges of the block from the background. With this subject, however, the difference in distance between the lights, the block, and the background, together with the differences in texture, produced the desired separation.

Lighting Techniques

Although the lighting in the block sequence has been oversimplified to show the basic concept that underlies good TV lighting, the same techniques apply to the human face. In the first picture of the girl, opposite page, you can see the effect of a single light near the camera; note the scarcity of highlights and shadows to play up her facial contours. The following picture shows the effect of key light alone. When back lighting is added to the next picture, the girl's dark hair is separated from the background, and her head seems to stand out away from the plane of the paper. The spotlight is mounted above and behind the girl, allowing little direct light to fall on her face. Because highlighted areas appear larger than they actually are, it's necessary to keep the back light well to the rear of the acting area so that as the actors move about the set, few intense facial highlights appear. And the last picture demonstrates the results that can be obtained with all three forms of lighting. Note the use of brightness differences to bring out the form of the girl's face, as well as to separate her head from the background.

As long as the subject is static and the camera position is fixed, as in these photographs, the lighting can be relatively simple requiring only a few pieces of equipment. But in a TV studio, where one shot must be followed immediately by another from a different angle, the lighting problem becomes more complex. The stage must be lighted in such a way that acceptable pictures can be obtained from almost any location. The intensity of key and back lighting sources must be so carefully controlled that as an actor turns toward the key light, his face is not washed-out. If highlights become too bright, the camera tube saturates, and the screen on your set whites-out in the immediate area of the highlights. This condition may also introduce transient distortion that produces black streaks on either side of the saturated area.

In practice this condition is avoided in two ways: Minimum key light is used and, the base light is unbalanced by about 20 percent from one side of the stage to the other. Picture quality suffers when these practices are used, but it can be partially remedied by following the theater technique of lighting specific areas of the stage. With adequate preplanning, cameras can be positioned to take advantage of the better lighting when the actors move into these areas. While such shots may each last only 15 seconds, six or seven of them during the course of the program can be very effective.

The range of brightness values that can usually be reproduced seldom exceeds 20 to 1 from maximum to minimum. If it does, the director must choose between saturation and loss of details in the brightest portions of the picture, or a similar loss in the shadow areas.

Equipment and Arrangements

Equipment used to light TV studios consists of two general groups: floodlights and spotlights.

Floodlights usually include fluorescent banks and filament lamps in 15- to 18-inch-diameter ellipsoidal reflectors. Filament lamps are most frequently used because of their small size and the ease with which they can be dimmed. But working under their heat is not too pleasant; that's where fluorescent lamps have the advantage. And fluorescent lamps with preheated cathodes can now be dimmed with the same ease as filament lamps; unlike the latter, the color quality of the light remains almost constant throughout brightness changes of 100 to 1 or more.

The second group of lighting equipment includes Fresnel lens units, as well as elliptical spotlights. The former are extremely flexible in that they can be adjusted to flood a large area or "spotted" to light a limited area. Often used in conjunction with a dimmer board, their extreme flexibility allows them to be used for base, key, and back lighting.

Elliptical spots are used where the shape or pattern of the light beam must be precisely controlled.

Lighting arrangements aren't standardized; they vary not only from station to station but from studio to studio. For example, a homemakers' show televised daily uses a set that is more or less permanently located in the studio. Action takes place in three areas—around the work table, sink, and electric range—and good lighting is set up for all three. The demonstrator moves so quickly from one to another that only general lighting is required for the spaces between these areas. Once set, this lighting pattern is seldom varied.

On the other hand, a once-a-week variety show needs its lighting tailored for each program. Even though basic lighting techniques are followed, extreme flexibility is required to meet the needs of the constantly changing program. The lighting equipment for the first program may not therefore be entirely satisfactory for the succeeding program.

Demonstrating Various Systems

To demonstrate a number of different lighting systems, a TV Lighting Clinic

TV LIGHTING SYSTEMS DISPLAYED LAST YEAR AT TV LIGHTING CLINIC, NELA PARK, CLEVELAND.

TV LIGHTING EFFECTS ARE OBTAINED BY COMBINATIONS OF WELL-DESIGNED EQUIPMENT.

was held at Nela Park in Cleveland in October 1952. The lighting systems (photo, top) included many more units than would normally be used. Eighteen-inch diameter "scoops" using 1000-watt lamps provided 100 footcandles across the stage. For uniform lighting throughout the depth of the stage, reflector floods with 150-watt lamps supplemented the scoops. These were operated at reduced voltage to keep from overlighting the upstage regions.

The fluorescent lamp banks, each using four 64-inch slimline lamps, provided about 75 footcandles and were supplemented by the same reflector lamps. The Fresnel lens spotlights with 750-watt lamps were capable of providing more than 175 footcandles at full voltage. These units were suspended from the ceiling at a height of about seven feet. This enabled them to be aimed *into* the set rather than down onto it. Because TV cameras "see" vertical surfaces primarily, the lighting must be designed to illuminate these surfaces. Supply cables were run in overhead, to keep the floor clear for camera action.

Key lighting was supplied by two 2000-watt Fresnel lens spotlights, each covering half of the stage. The back lights consisted of alternate 2000- and 1000-watt spots; normally, a single system would be sufficient.

In the Fred Waring Show, fluorescent lamp banks have been used for base light, as shown in the bottom photo. You'll note that a number of these are mounted on pantographs so that the height can be easily adjusted, and tracks are provided to move them upstage or downstage. Fresnel lens spotlights are mounted overhead and aimed downstage to provide back lighting. You can see this effect on the shoulders and heads of the actors. On the right are three additional spotlights for key lighting. Although the individual lamps are not visible, separate units are used to light the background. With the exception of cables running to the cameras, the floor is clear.

Importance of Flexibility

Flexibility of lighting is of paramount importance in TV studios; for this reason few fixed rules can be established to aid in the original design. Electric power load per square foot, however, is frequently used as a cross check. For example, in a studio handling many types of programs, a lighting unit will be needed for every 25 square feet. The wattage in any one fixture will range from 500 to 1000, thus producing a load of from 20 to 40 watts per square foot. The lower figure is often used at the beginning, but as the station grows, the load increases. For comparison, lighting in a modern office varies from two to five watts per square foot.

Curiously enough, the illumination level in both a modern office and a TV studio runs from 50 to more than 100 footcandles. Aside from differences in equipment efficiencies, the difference in power loads lies in the fact that all equipment is used all the time in an office, while only a part of that available is used on any one TV program. But with the tight schedule a TV station must follow, lighting may be arranged and ready to be switched on two programs in advance of the one on the air.

Such tight scheduling is common and limits the time that can be devoted to lighting. Seldom can the lighting director accomplish all he would like to; as a result he dreams of the day when he can sit in the control room and push buttons to create the lighting effects he so earnestly wishes to achieve.

For a few lucky men, the day is coming when motors will aim and focus the lighting equipment. But for the majority, the step ladder and hooked pole will continue to be tools of the trade. Ω

7:30 AM: A CAR-POOL COMMITMENT MEANS THAT AL GETS BREAKFAST FIRST. IT'S THE BEGINNING OF ANOTHER DAY FOR AN . . .

Engineer's Wife

Review STAFF REPORT

Anne Buckley Coggeshall, 29, has no definite philosophy of life. "I'm too busy with life to do much wondering about it," she says.

"And, I have no advice for any girl about to marry an engineer. I don't see that being an engineer's wife is basically any different than being the wife of any other professional man."

Anne married Almy D. Coggeshall in 1946. They met at a young peoples' group at Trinity Methodist Church in Schenectady. "I invited Al to a square dance because we needed another man and he had a reputation for being a good square dancer. Next, he invited me to go skiing."

Anne attended Oberlin College and Columbia Teachers College and has lived in several cities of New York State.

Al, a graduate of Middlebury College in Vermont, is a chemical engineer in the Material and Processes Laboratory of General Electric's Turbine Division in Schenectady.

"He leaves his work at the office," Anne says with a grateful smile, "although I often find him thinking about it around the house."

During 1950 they built in West Hill, a community of modern homes on the outskirts of Schenectady. John M. Johansen, architect of New Canaan, Conn., designed their home. "Of course it's modern," Anne says, "it's the only type of house that could give us complete freedom in developing a living pattern to suit our family."

They laid their tile floors, did most of the interior and exterior painting and wood finishing, and practically all the planting and grading. "And there's a lot more to do, both inside and out," Anne states.

"I'd like to have another child, maybe two. Children prevent a couple from being 'adult-centered.' I prefer that term to 'self-centered.' But centering your life on your children can be just as harmful as centering your life on yourself if you have *no* children."

For some of the events that make up Anne's life, follow photographer George Burns on the next six pages . . .

Engineer's Wife

CONTINUED

BREAKFAST TIME begins with the milk (consumption: 23 quarts a week) being brought in by Anne (*above*) and reaches a climax with Al's last glass of milk (*preceding page*). Sometimes Martha, 4, and Robert, 6, eat with their father, but normally they take their turn after he's gone (*upper right*). After the children are at play, Anne gets a chance for breakfast and catches up on her reading (*Harper's, New Yorker, Atlantic Monthly, Time*, or last night's *Schenectady Union-Star*).

OMNIPRESENT telephone aids Anne in her Home Bureau and other activities; usually proves a bane during an afternoon nap.

BRIDGE CLUB at West Hill is a monthly affair. "I'd like to entertain more if I could only catch up with myself," says Anne.



"I don't mind housework too much but the most unimaginative chore of all is doing



dishes. Ironing is next. And 'picking-up' is a job that never seems to end . . . I wish



my home stayed neat, but it just doesn't . . . I enjoy fixing things around the house."

CONTINUED ON NEXT PAGE

"My children are not my life. They're important, but there are other things in life that are important, too. But no marriage can be completely happy without children."

Engineer's Wife

CONTINUED

"Any manufacturer who makes toys that a mother can't fix should go out of business . . ."

ONE-HALF ACRE gives Anne enough room to concentrate on her extensive gardening activities. She likes plantings in large masses that emphasize the modern lines of her home and take advantage of the natural terrain. "Sandsea" (*lower right*), age 6 and "childproof," is exercised often but at other times is kept on leash. "I know only too well what dogs can do to gardens and lawns," says Anne.

CONCLUDED ON NEXT PAGE

"YOU CAN'T BEAT a station-wagon" says Anne, "whether you use it for hauling groceries, concrete blocks, furniture, or kids."

VISITING NEIGHBORS is a typical late afternoon pastime at West Hill, after naps are over and the children are clean once again.

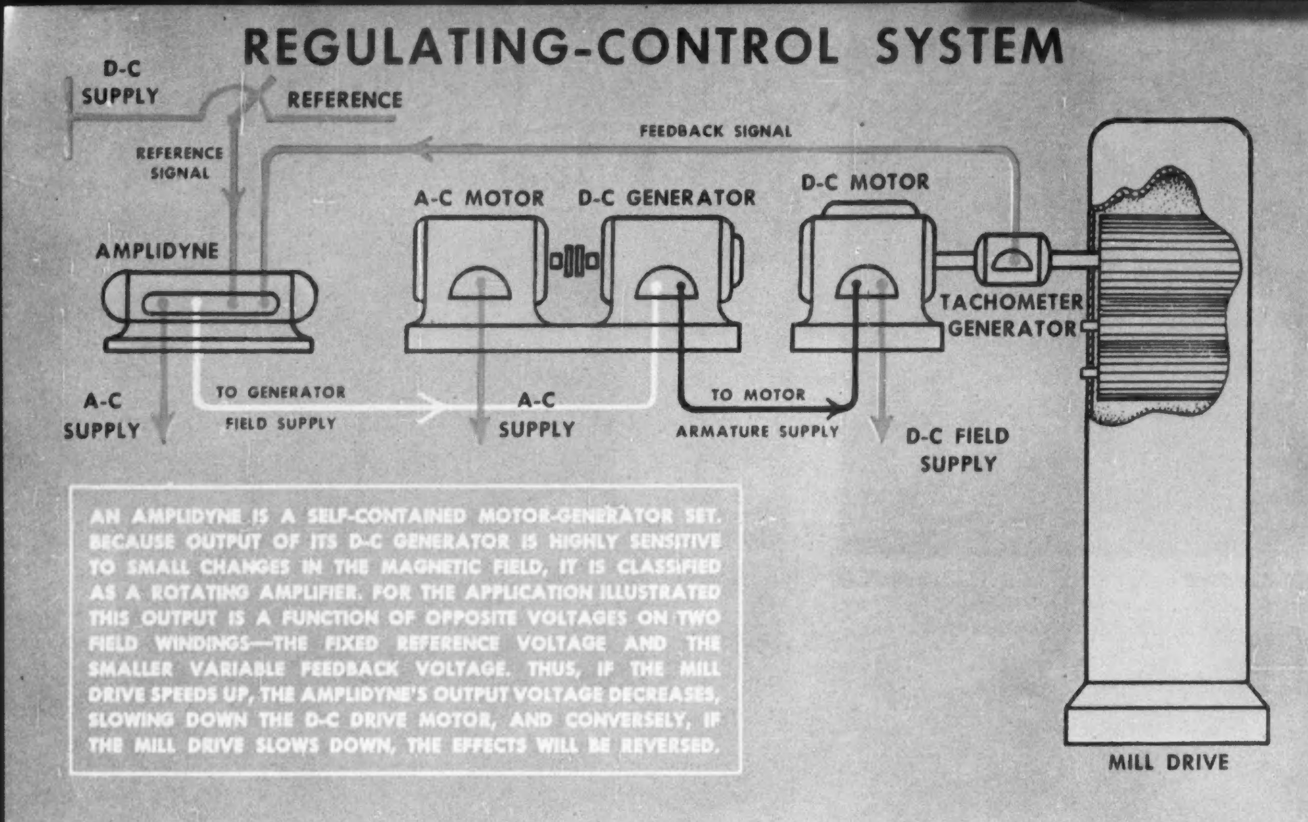
Engineer's Wife

CONCLUDED

ART CLASSES at West Hill, taught in artist Ted Batzell's home, are frequently attended by Anne. "I just wish I had time to do more things like this."

CORRESPONDENCE and the usual bills take up a good portion of the evening after the children are in bed.

"AROUND NINE-THIRTY, WHEN THE DISHES ARE DONE AND THE KIDS ARE IN BED I MAY GET A CHANCE TO RELAX AND DO SOME READING."



A FAR CRY FROM JAMES WATT'S FLYBALL GOVERNOR, THE AMPLIDYNE IS ONE OF THREE BASIC TYPES OF AMPLIFIERS AT THE HEART OF . . .

Control in Industry

By A. W. SCHMITZ and H. L. PALMER

What makes American industry hum? Its abundant use of electricity. Billions of kilowatt-hours are poured into our factories, powering electric motors that drive machinery through complicated processes. But all this energy would be useless without the ability to control it, for control acts as the nerve center of our industrial life.

Since 1938 we've had a tremendous growth in industrial processes and machinery, largely because of the impact of World War II. Higher speeds, faster rates of acceleration, closer operating accuracy, and faster response are demanded to increase our productivity.

These demands put the spotlight on swift self-regulating control systems. When measuring a variable output—such as position, speed, current, or voltage—the systems act quickly to limit deviation from a preselected reference quantity. Typical of regulating-control systems in use today is the one shown above, utilizing the rotating type of amplifiers.

Role of Amplifiers . . .

At the heart of every industrial control system is an amplifier: the rotating amplifier, or amplidyne; the magnetic amplifier, or amplistat; the electronic amplifier, or tube. Sometimes they are used singly and sometimes in combination. On the opposite page a comparison is made of the three types; on page 50 typical applications of each are shown, plus a combination amplidyne-electronic control application.

There's a continuous stream of tools available to the control engineer—the latest one being the magnetic amplifier.

●

Mr. Palmer joined GE in 1925 on the Test Course. He is now Manager of Electronic, Regulator and Aircraft Engineering, Industry Control Department, Schenectady. With the Company for 30 years, Mr. Schmitz is Manager of Equipment Engineering, Industry Control Department, Schenectady. He received the Coffin Award in 1950.

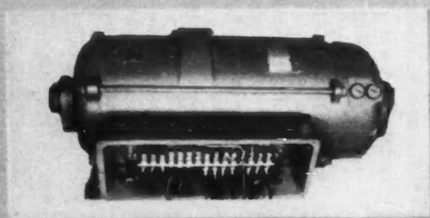
(See March 1953 Review, pages 22 to 24.) One of its important components, the metallic rectifier, is a big factor in its economic consideration.

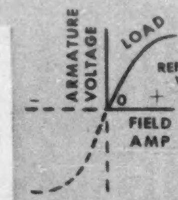
To further improve upon the properties of metallic rectifiers, laboratories and manufacturers have looked into the rectifying qualities of germanium crystals. At present they are up against some practical operating difficulties that must be solved before germanium can be universally used. Meanwhile, the advantages of a germanium rectifier's high efficiency and unlimited life are sufficient to spur them on to a solution.

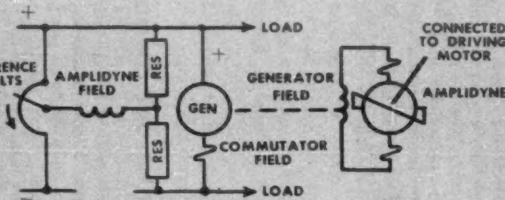
An outgrowth of the germanium rectifier is the transistor. For adding a control lead to the germanium rectifier makes possible control of current in much the same way as the grid of a vacuum tube controls current. Therefore, the solution of the problems using germanium as a rectifier will also make available a control rectifier. The latter will be small, won't need filament

HERE'S A COMPARISON OF AMPLIFIERS USED IN CONTROL SYSTEMS . . .

Amplifier — Load Characteristic — *Generator Voltage Regulation Simplified Circuit Diagram

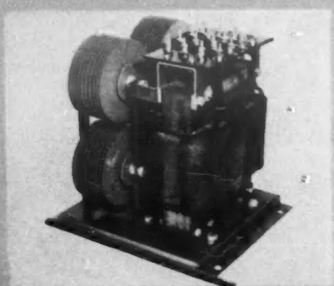


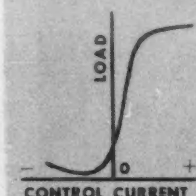


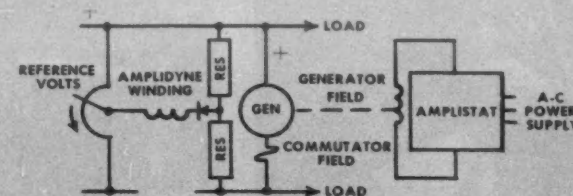


AMPLIDYNE—ROTATING

AN ADJUSTABLE GENERATED VOLTAGE DEVICE USED FOR CONTROL AND POWER AMPLIFIER



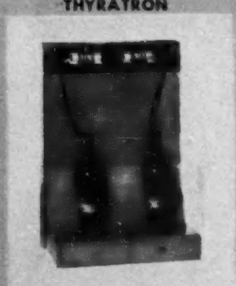


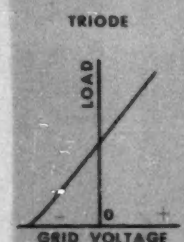


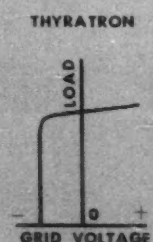
AMPLISTAT—STATIC

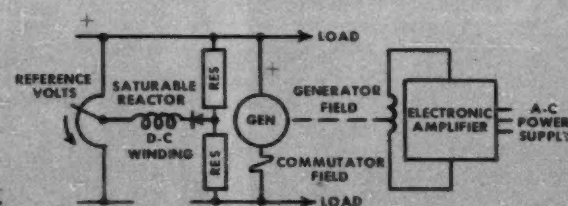
AN ADJUSTABLE INDUCTANCE DEVICE USED AS CONTROL AND POWER AMPLIFIER

THYRATRON









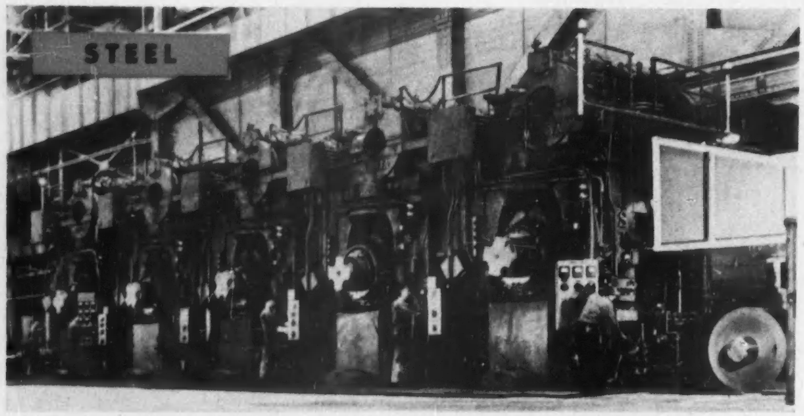
TUBES—ELECTRONIC

AN ADJUSTABLE RESISTANCE DEVICE—A THYRATRON AS POWER AMPLIFIER AND TRIODE AS CONTROL AMPLIFIER

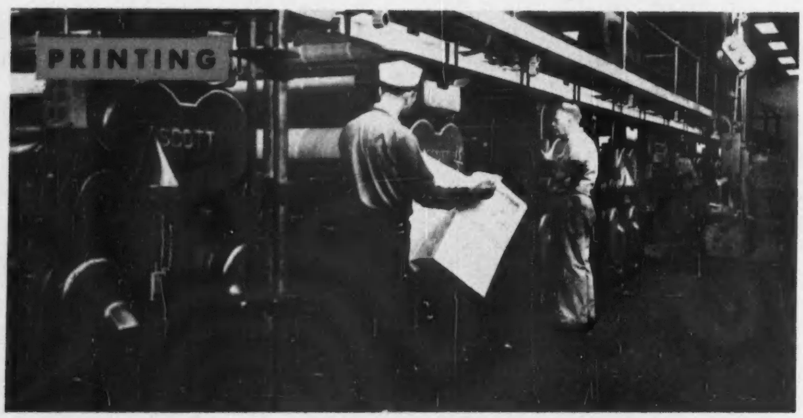
Amplifier	Electrical Data								Mechanical Data				
	Operation	Speed of Response	Amplification	Operates from MV Signal	Absorbs Power by Regeneration	Sensitive to Changes in Power and Frequency	Electrically Insulated Signal Windings	Minimum Watt Rating	Easy to Mount on Panel	Resistant to Shock	Requires Maintenance	Warm-Up Time Necessary	Requires Starter and Push Buttons
AMPLIDYNE—ROTATING	REVERSIBLE	MODERATE	MODERATE	NO	YES	NO	YES	300	NO	YES	PERIODIC	NO	YES
AMPLISTAT—STATIC	NONREVERSIBLE	MODERATE	MODERATE	YES	NO	YES	YES	40	YES	YES	NO	NO	NO
TUBES—ELECTRONIC	NONREVERSIBLE	FAST	HIGH	NO	NO	YES	NO	2.5	YES	NO	REPLACE TUBES	YES	NO

*Circuit shows amplifier used as power amplifier only. Data are basic, and may vary with different applications.

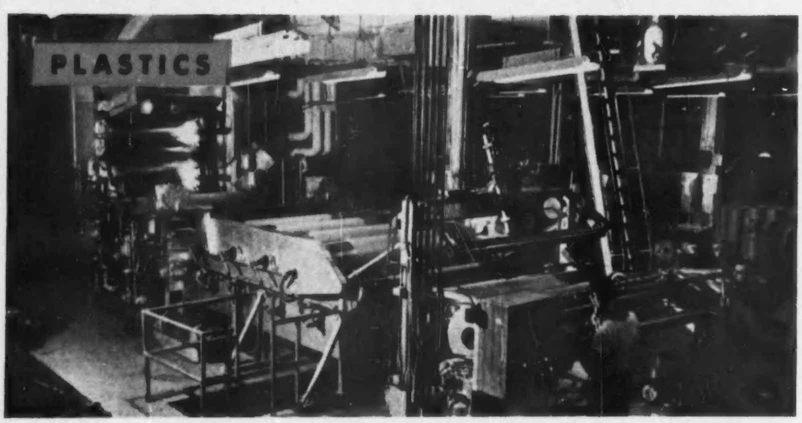
INDUSTRIAL APPLICATIONS



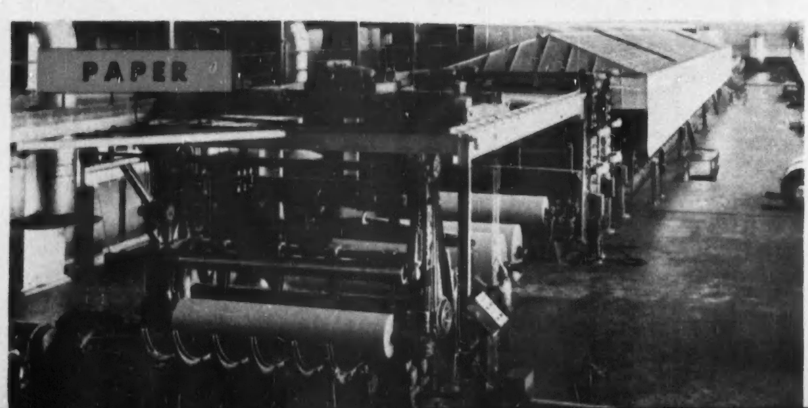
AMPLIDYNE CONTROL—In the steel industry the amplidyne controls motors and generators representing hundreds of thousands of horsepower. One tandem cold-reduction mill—with a total of over 22,000 horsepower—utilizes 34 amplidynes to carry out the mill operator's commands. Only 10 seconds are needed to accelerate the steel strip from a dead stop to 80 mph. Mill speeds have increased to this figure from less than 9 mph 20 years ago.



AMPLISTAT CONTROL—The amplistat, or magnetic amplifier, is an integral part of the control for ignitron rectifiers—rated 150 kw and 300 kw—used to supply power for electronic press drives. Controlling the rectifier's output voltage, the amplistat makes possible a 50-to-1 speed range of the d-c press-drive motor. It also supplies power to the drive motor's field coils. Pictured is a high-speed printing press that turns out 50,000 newspapers an hour.



ELECTRONIC CONTROL—Modern calender-drive trains for plastics film turn out finished material at speeds over 150 yards per minute. This is in contrast to a production rate of only 40 yards per minute just five years ago. Here, electronic control solved the problem of winding-up films at high speeds while maintaining the required degree of accuracy. Dozens of electronic controls have been furnished the plastics and rubber industry in the past 10 years.



AMPLIDYNE-ELECTRONIC—To increase the amplidyne's ratio of amplification, a stage of electronic tubes is introduced. With this arrangement the operating speeds of paper machines have increased substantially since World War II. Tissue paper, for example, is produced at speeds 50 percent higher. Amplidyne-electronic control has made a notable contribution in the paper industry because its reliability and precision permit continuous production of high-quality paper.

power, and should have unlimited life. These features make it a much sought-after device.

. . . And Computers

There are many circuit variations of amplifiers to cover all conceivable conditions and operations encountered in the industry. Obviously, the use of regulating controls in place of manual operation requires well-engineered and well-built control equipment. It makes necessary the analysis of system accuracy and stability to determine beforehand whether the system will perform satisfactorily.

At one time cut-and-try methods were applied during installation to adjust the control for accuracy, response, and stability. Often, this required excessive time and further modification in design—all at the expense of getting the drive into operation. Today, analogue computers solve these and other problems in advance.

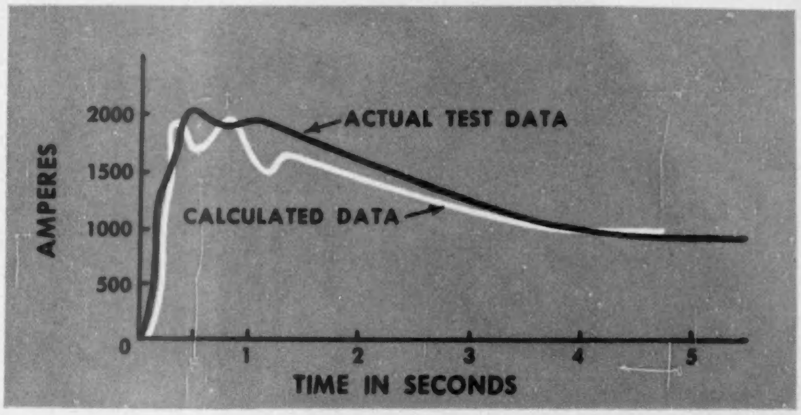
Mechanical Analogues

During the past several years mechanical-analogue computers have been developed to solve differential equations. They are usually arranged to express the answers in the form of curves. These differential analyzers, as such machines are called, have become a necessity to the control engineer.

For example, a differential analyzer was used to study a two-dimensional tracer control. This is a device utilizing a stylus that "feels" around the contours of a templet, or pattern, and transmits the motion to a machine tool. The analyzer determined effects—on the system's accuracy and stability—of variations in circuit and component time constants. It also made possible the investigation of the stylus' mechanical backlash—normally a difficult problem to handle by mathematical methods.

Another example of the use of the differential analyzer is the investigation of a color-register control system for a multicolor rotogravure press. (Function of the control is to maintain register between successively printed colors.) In such a system there are several electrically independent feedback loops. Interaction among them results when paper tension varies as it winds through the press.

To investigate the problem, known mathematical relationships were set up on the differential analyzer and tests were made to determine their validity.



CURRENT IN SHOVEL CONTROL DIFFERS SLIGHTLY FROM VALUES FOUND WITH COMPUTER.

They showed response characteristics identical to those previously observed on the presses—with and without register control. As a result the best control circuits for a variety of press conditions were determined. Also, the effect of varying press size, speed and quality of the paper, and the rate and method of register correction were readily analyzed.

Electric Analogues

There are now available many electronic-analogue computers that are faster, easier to set up, and easier to operate than mechanical computers. With them, results can be recorded on oscillographs or observed on oscilloscopes. Because they make use of electric circuits, they can be employed to synthesize large complex machines and systems in the laboratory. Thus, "breadboards" and development samples can be tested without the expense of tying up production machines. Factors showing the effect of wear and other practical considerations on the accuracy of performance can also be introduced.

The technical validity of this type of analysis—whether by mechanical or electrical analogy—has been proved many times by actual tests. Again, for example, oscillographic records were taken of the armature current in an amplidyne shovel-control during a special operating cycle. Then after determining the time constants of the motors and amplidyne control, the system was set up on an analogue computer and the test repeated. The plot of these and the actual test results (graph, above) corresponded closely.

Automation

Everyone is aware of the part computers play in automatically controlling guns. Among other things they continuously calculate the target's velocity and distance as indicated on the radar screen. There's little doubt that this same basic technique can be adapted to industrial and process problems to insure a satisfactory end product—regardless of changes in raw material or operating conditions. (See July 1953 REVIEW, pages 13 and 14.)

Many forms of program controls are already available today: contouring or tracing controls, for instances where the program is stored in a templet. Also, a line-follower control that accurately follows a scale drawing of the part to be produced. For this device, the program or intelligence is stored in a specially prepared drawing.

During the past two years two new forms of information storage have been developed. They are particularly adaptable to machine tools, but may find even broader use as soon as their possibilities become known. One uses punched cards or punched tape as a storage medium; the other uses a magnetic recording-tape.

The punched-tape kind of information storage utilizes the digital or exact information as read from a drawing of the part. Information from the drawing is coded by punching a series of holes in the tape. The machine to handle this information must have a mechanical "reader," or sensing element, to interpret the information in terms of position and speed of the various parts of the machine tool or process.

In the second type of information storage a magnetic tape records the actual speed and position of the work or tool holder of a machine tool while the part is being produced manually. After completion of the full machining cycle, the magnetic recording is rewound

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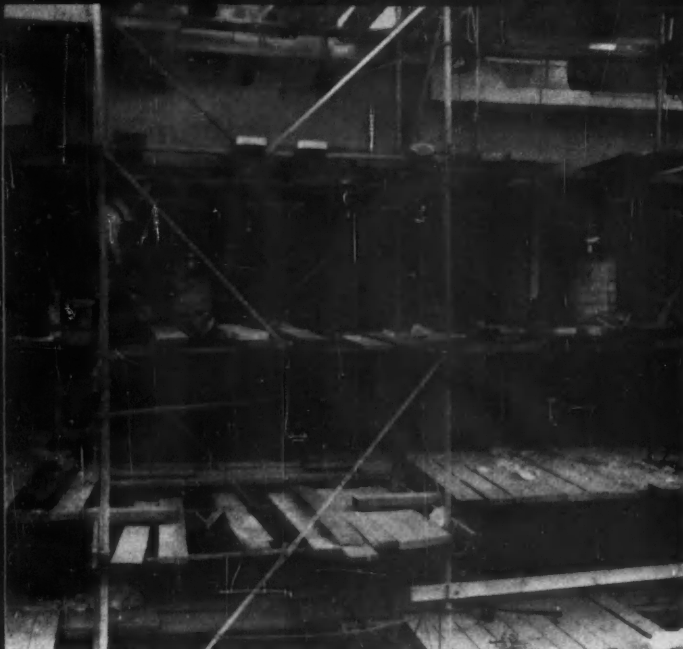
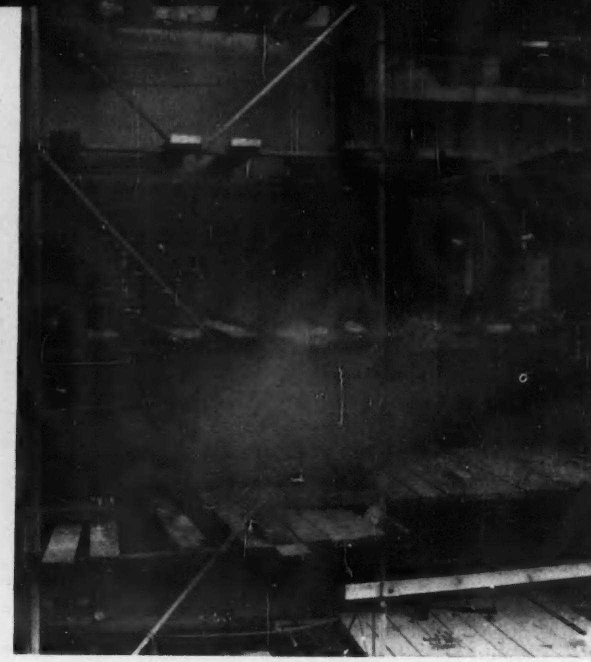


1 Filling blister voids of an aircraft carrier—14 feet above and below water line—with phenolic foam. Electric mixer beats air into the liquid resin, then catalyst is mixed in. Ten seconds later the mixture is sent down wooden chute and workers move away, as . . .



2 Mixture, generating its own heat, expands to 300 times its original volume. Carbon dioxide and steam given off in reaction blow up resin to a lightweight, cellular material. Expanded resin replaces balsa, once used at a much higher cost.

Story of Expanded

By J. D. NELSON

3 Cover plates removed to show how plastics foam assumes shape and fills void spaces. Highly buoyant foam keeps carrier from listing in event of a shell hit.

Not so long ago the Navy was using balsa to fill blister voids along the water line of small aircraft carriers. Balsa imparted buoyancy to the ship and prevented listing in the event the hull was pierced by shells.

Because voids vary in size and shape, the balsa had to be hand-tailored in place. And before a cover plate was welded over the void, the tailored balsa had to be removed, fireproofed with a special impregnant, and replaced again—a costly process.

Then the Navy switched to phenolic foam. A highly buoyant plastics material, phenolic foam is transformed from a liquid resin to an expanded solid state in two or three minutes (photo sequence). The results? Actual fabrication time was reduced tremendously, the fireproofing step was no more, and the over-all cost per cubic foot of void space shrunk to one-quarter its former value.

In one carrier installation involving 40,000 pounds of phenolic resin and a void volume of 8100 cubic feet, for example, the foaming-in-place technique was used under the most adverse weather conditions. Yet, the job was completed with minimum difficulty in a matter of some 70 dry-dock days. Total cost was $6.88 per cubic foot of space. In contrast, a similar installation using balsa to fill only 4900 cubic feet of blister voids took 167 dry-dock days to complete and cost $27.62 per cubic foot.

But even with their unusual self-fabricating characteristics, phenolic foams aren't limited to aircraft carrier application. They're also used as low-temperature and acoustical insulations, structural reinforcement for tail sections of airplanes, buoyancy media for boats of all types, and, among other things, as packaging materials. Perhaps one day your house will be insulated with phenolic foam just as simply as the oil dealer now fills your fuel-storage tank.

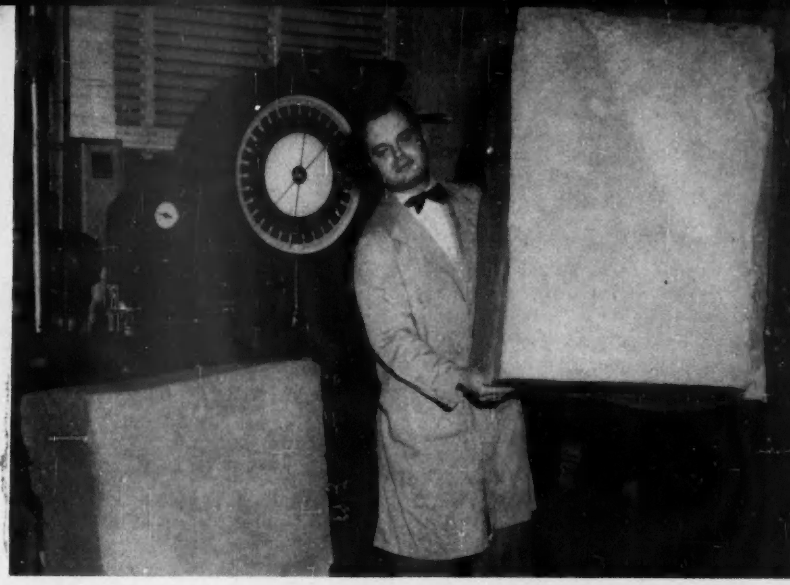
•

Active in developing standards for ASTM, Mr. Nelson is recognized as one of the nation's authorities on industrial adhesives. He joined GE in 1937. Presently he is in charge of product engineering activities for resin and varnish products made for industry at the Chemical Division Laboratory, Pittsfield, Mass.

How They're Made

Foams are made from liquid phenolic resins by a chemical blowing process that expands the resin up to 300 times its original volume. (Incidentally, phenolic resin is the "workhorse" of the plastics industry. Ordinary carbolic acid and formaldehyde are reacted together to produce it. This resin has excellent thermosetting characteristics—hardening with heat—and good over-all properties.) When a catalyst, usually acidic in nature, is added to the resin, a heat-liberating reaction is initiated. Two things will happen: 1) the catalyst reacts with bicarbonate of soda in the mixture to produce carbon dioxide gas, and 2) the heat generated turns water in the mixture to steam. Thus, two gases contribute to the resin's expansion.

Sometimes, additional ingredients are added to assist in control of density and to help cell formation of the foam. For certain applications, as in the photos,

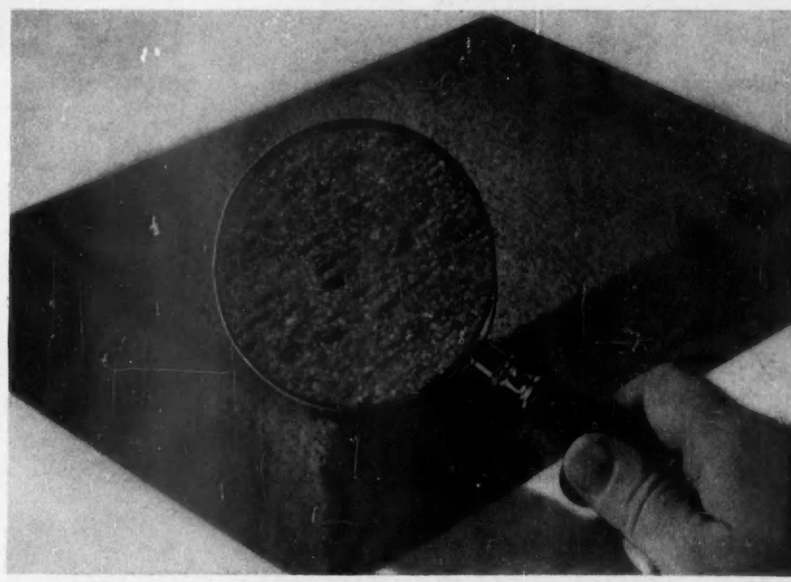


TWO-FOOT THICK slab of expanded foam is easily moved about the testing laboratory by author. Density of the slab, however, is what determines its mechanical properties.

Plastics

left, air is beaten into the resin before the catalyst is added. The air functions as seeding nuclei for the expansion process, as well as an additional source of blowing agent. Although reducing its compressive strength proportionately, air will generally produce foam with a more resilient texture.

Converting a liquid resin to an expanded solid in a matter of two or three minutes without external heat or pressure is unique among expanded plastics. The process makes possible the foamed-in-place technique—the expanding resin assumes the shape and completely fills the cavity that it forms in. Because the reaction generates its own heat, and because the equipment for foaming is so simple, the foam lends itself particularly well to field applications. All you need is an open pot or kettle to hold the liquid charge, and a mixer to agitate it.



AIR POCKETS enclosed by solid resin films make up the expanded phenolic foam. About two-thirds of these air pockets are independent cells—the others are interconnected.

Myriad Cells

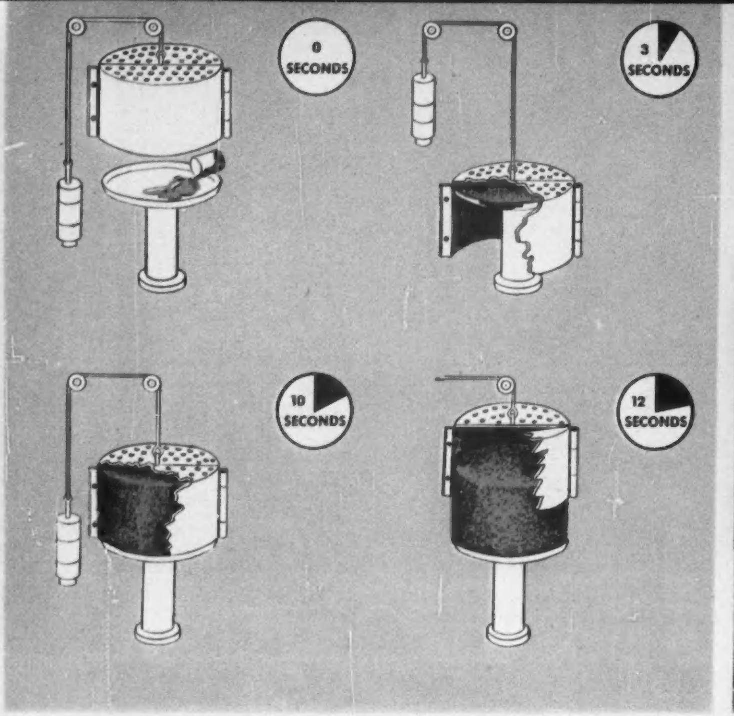
Foam is composed of both interconnected and independent air pockets (bottom photo) that are enclosed by solid resin films. Our tests indicate that about two-thirds of these cells are independent.

The cured, or hardened, resin is inherently a brittle material. Coating all its surfaces is a heavier-density layer—a sort of built-in protective skin—even where the boundary surface is against air. This layer considerably improves the foam's rigidity and nonsettling characteristics, especially in foamed-in-place applications. And naturally, properties of the foam are closely tied in with this protective skin, as well as with its cellular structure.

Controlled Expansion

Where the resin is not foamed in place, it is expanded in a special setup to form slabs that are cut or shaped for specific purposes (photo, top).

In this connection we recently developed a new foaming process that economically produces low-density slabs. With this counterbalanced apparatus (sketch, next page) you can form large blocks of uniform-density slabs, while at the same time efficiently utilizing the resin. The device, as you can see, is simple and economical to construct. It is best-suited for foam slabs in the density range of a half-pound per cubic foot or lower. These, incidentally, are the densities showing considerable promise in packaging and related fields.



COUNTER-BALANCED apparatus for expanding catalyzed resin with a minimum amount of friction. Mold moves upward during expansion, does away with voids, tears, and blowholes in foam.

INTERCONNECTED cells of phenolic foam make it an ideal acoustical insulation. In closely grouped offices, the clatter of office machines is deadened by slabs of foam placed between partitions and ceiling.

TABLE I—MECHANICAL PROPERTIES OF EXPANDED PHENOLIC FOAM

Property	1/3 to 1 1/2 Pounds per Cubic Foot Density	2 to 5 Pounds per Cubic Foot *Density	7 to 10 Pounds per Cubic Foot Density
Compressive strength, psi	0.8–5	9–31	45–130
Tensile strength, psi	—	4–35	35–75
Flexural strength, psi	—	24–40	75–230
Shear strength, psi	—	8–30	40–135

* Density range most common for foamed-in-place applications.

TABLE II—THERMAL CONDUCTIVITY COMPARATIVE PROPERTIES

Material	Density (Pounds per Cubic Foot)	Mean Temperature (Degrees F)	Conductivity (Btu per Inch per Degrees F per Square Foot per Hour)
Phenolic foam	1.7	73.7	0.24
Phenolic foam	7.9	72.7	0.28
Corrugated paper	1.9	75.0	0.26
Glass wool	2.3	75.0	0.26
Cork board	7.0	75.0	0.28
Rock wool	6.0	75.0	0.26
Rock wool	2.0	75.0	0.27
Fiberboard	12.0	75.0	0.31
Fiberboard	18.0	75.0	0.34
Hair felt	9.0	75.0	0.36

By referring to the illustration again, you'll see that the catalyzed resin is poured into the pan and the restraining mold lowered in place. Within a short time the foam begins to expand, exerting an upward force against the mold. Because the mold is counterbalanced, it takes only a slight force to start it moving upward. Foam is deposited against the mold as the resin blows up, and thereby eliminates most of the friction. It is this absence of friction that prevents formation of voids, tears, and blowholes. The result is a uniform-density slab from top to bottom.

After 10 seconds the foam reaches its maximum expansion, the mold is swung open, and the block removed. Usually the mold is lined with paper prior to foaming. This way sticking is eliminated and the foam's surface is protected during handling. When the foam is ready for use, the paper is easily stripped away.

Some Properties

Mechanical properties of phenolic foam are a function of density. Some average values obtained on sections with their higher-density outer skins removed are given in Table I. These strengths are adequate for many applications and the strength-weight ratios are fairly good. Still, they aren't particularly outstanding for applications where structural strength is a major factor.

A similar tabulation of moisture resistance clearly shows the effect of interconnected cells—as density increases, moisture absorption decreases. For while the cured resin is itself unaffected by water, the cellular construction does permit penetration of moisture. You can eliminate this, however, by use of suitable coating materials.

The effect of the interconnected cells also shows up in buoyancy data. For the foam has much greater buoyancy when immersed just under the water's surface compared with immersion under 20- or 30-foot heads. Here, apparently, the increased hydrostatic pressure is high enough to partially break down the cell walls, permitting some moisture infiltration.

Cellular construction of phenolic foam, together with its lightweight and rigidity, makes it an excellent heat insulator. In Table II its thermal conductivity is compared with that of common insulating materials. Note that the lower density foams are among the best insulators. Other data show that for best thermal properties there is a minimum foam density at or near one pound per cubic foot.

Versatility Plus

Interconnecting cells are undesirable from several points of view but not where acoustical insulation is concerned. Cell formation in phenolic foam is ideal for sound deadening. Sound waves enter the open portion of the foam structure and are trapped within. This is borne out by an acoustical test with the sample sealed in an opening between two rooms, one of which contains the variable sound source. For frequencies from 100 to 5000 cycles per second, the average transmission loss is 14.8 decibels. (As a comparison, the transmission loss for hair felt in this frequency range would be five to six decibels.)

In this test the sample of phenolic foam still had its higher-density outer skin. If the skin had been removed to expose a higher percentage of porous openings, you could expect even better results. At any rate it indicates that phenolic foam is an effective sound deadener over a wide frequency range.

The expanded foam has other characteristics that are inherent to phenolic resins in general: namely, a high degree of resistance to heat and chemicals. Usable continuously at temperatures up to 300 F, phenolic foam is classified as self-extinguishing: it won't burn when the source of flame is removed. And with the exception of certain alkalies, alcohols, and acetones, its resistance to chemicals is excellent.

To date, foamed-in-place applications constitute the largest use of phenolic foam. Its lightweight, rigidity, stiffening qualities, buoyancy, and ease of fabrication, make it a natural for filling irregular voids and cavities. Where spaces are of irregular contour, the savings in fabrication labor alone often justify its use.

The aircraft carrier mentioned at the outset has been at sea under extreme service conditions for over two years. Periodic inspection of the phenolic foam in her hull has shown no after-shrinkage or tendency to settle. This, coupled with the possibility of increased defense efforts, indicates future large-scale use of foam in similar applications.

In the aircraft industry foamed-in-place phenolics are finding their place as structural stiffeners for wing assemblies and absorbers of resonant vibration. Also, plastic dies used in drawing aluminum parts for aircraft—such as skins, cowlings, instrument panels, and so on—are strengthened with higher-density foam because of its lightweight. The same is true of jigs.

The economical production of low-density foam slabs by means of the counterbalanced apparatus described earlier has opened up many new applications for phenolic foam. Of these, one of the most promising is its use as a packaging material for fragile objects. It has several advantages over conventional packaging materials. For one thing, its lighter weight—shredded paper or excelsior are more than six times heavier—reduces shipping costs. And when properly used, it minimizes breakage, particularly of lightweight, fragile objects. There's also indication that packing time and workers' fatigue are reduced.

Thermal insulating properties of the foam are used to advantage in packing perishable goods. Foam is also helpful when fire retardance of the packaging material is a factor to be considered. Finally, the counterbalanced apparatus can be set up in the shipping room itself. Thus, a steady supply of foam is insured, and valuable shipping-room space saved.

These are some of the factors that are important in consideration of phenolic foam as a packaging material. It isn't a revolutionary cure-all for the packer. It definitely has its limitations. Yet, it should find good volume use where its properties can be of advantage.

Dual Personality

Low-density slabs of foam show promising results as thermal insulation. Of particular interest at present is their combination with honeycomb core material in lightweight building panels. For you can press expanded slabs of less resilient foam into the honeycomb structure with only a slight degree of compression. Then, if suitable skin panels are bonded to either side of the honeycomb-foam core, you have a lightweight panel board. It's structurally strong because of the skin-honeycomb structure, and it's a thermal insulator because of the foam inside that structure.

Such panels should eventually find a volume use in prefabricated houses and in partition-panel construction. For those applications where additional structural strength is needed, the resin can be foamed in place within the honeycomb cells at a much higher density. This does, however, raise costs and doesn't seem to hold much promise.

On the other hand, individual batts of thermal insulation can be made from certain types of low-density slabs. By carefully compressing a one-third pound-per-cubic-foot slab to about 3¼ times this density, you get a resilient batt with low thermal conductivity. (Compressing the batt breaks down interconnected cells so that air can't get through by convection.) In addition, it produces an economic product that is easy to handle.

The use of phenolic foam for sound-deadening purposes (photo, opposite page) has barely been touched to date. Its sound-absorption properties are as good or better than conventional acoustical materials. Once installed, it is permanent because of its resistance to fire, heat, and most chemicals.

Phenolic foam's use as home insulation has always been an intriguing one. The idea of shipping a drum of resin to a house under construction, and then installing a permanent foamed-in-place insulation, has stirred the imagination of many a person. The resultant product certainly has most of the desired requirements: good insulation against heat and cold, fire resistance, nonsettling, ease of installation, and permanence. But unfortunately, costs are out of line with the techniques and materials as we know them today. This is not to say, however, that in the future we won't

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Railroadin' South of the Border

By LUTHER B. ROGERS

Whenever Service Engineers get together, they swap tall tales of their adventures in foreign lands. The incidents recounted here by Mr. Rogers are typical of the anecdotes that are fast becoming legendary in the annals of service engineering. He joined General Electric in 1923 and spent his entire career with the Locomotive and Car Equipment Department, Erie, supervising the installation of electric and diesel-electric locomotives in all parts of the world. Last year he retired and is now living in San Juan, Puerto Rico.
—EDITORS

THE RUNAWAY TRAIN

In the southern section of Brazil the meter-gage Sorocabana Railway winds its way westward for more than 560 miles from Sao Paulo to the Parana River.

Leaving its terminal in Sao Paulo it passes through old, sedate towns and cities with histories dating back to the beginnings of Brazil. There you'll find old Portuguese names like San Antonio and Sao Roque, and tongue-twisting Indian names like Botucatu and Itapetinga. Then the line plunges into the vast coffee country, which is ever moving westward, where one may travel a day and a night without seeing anything but coffee trees stretching away to the horizon. In some places the coffee has been planted among the great logs of fallen trees that were left after the virgin forest was cut down and the jungle burned away. Here the towns are very new. They bear such names as Presidente Prudente and, at the end of the line on the east bank of the Parana River, Presidente Epitacio.

One of these towns, then only 18 years old, had paved streets, modern stores, and 16 banks.

The heavy haulage over the Sorocabana Railroad is coffee, lumber, and beef on-the-hoof from the Matto Grosso.

When electrification of the first section of the Sorocabana from Sao Paulo to San Antonio—about 90 miles—was planned the steam locomotives were burning wood. This fuel was becoming scarce and increasingly expensive, Brazilian coal was of poor quality, and oil had not been developed so hydroelectric power looked attractive.

Twenty 133-ton 3000-volt d-c locomotives were ordered for the initial electrification. All cabs and trucks were built at General Electric's Erie Works, and 10 locomotives, completely equipped there, went into service in 1944.

At this stage of a new operation there is usually a group who decides that this is a good time to demand a raise in pay and the Sorocabana was no exception. The engine crews went out on strike.

In Brazil the fire departments are a part of the military. Within the Sao Paulo Fire Department, there is a body of men trained to take over any situation and perform any kind of work necessary in an emergency. And a strike is considered an emergency.

When the engine drivers and their helpers served notice that they would not run the electric locomotives without an increase in pay, a detachment of these *bomberos*, or special firemen, was dispatched to take over the engine house at the Bara Funda yards in Sao Paulo.

After about 30 minutes of instruction in the mysteries of electric locomotive operation, the firemen were given several soldiers for protection and sent out with trains.

The first train was operated by a captain of the *bombero* company. And let me say to his credit that he delivered his train safely and without too much damage to San Antonio—then the point where the electrification ended.

It was on the return trip that he came to grief.

West of the Ipanema substation, going toward Sao Paulo, there's a long downgrade with a sharp curve at the bottom just a few hundred yards from the substation.

It is not known exactly just what went wrong—whether it was lack of experience, bad judgment, or the captain putting on a show for the soldiers. In any case, he allowed the speed of the train to reach such proportions that he was unable to regain control.

When the train hit the curve at the bottom of the grade, the locomotive held the rails, but the first car derailed, broke away, taking down three concrete trolley poles as it jumped the westbound track, and went down over a 25-foot embankment.

At 60 mph the locomotive went by the Ipanema substation with neither power nor brakes, because the substation had tripped out when the trolley poles went down.

It was 2½ miles to the next station, all upgrade. The locomotive lost its momentum after going about two miles and came to a stop.

This would make a happy ending if I were to stop here, but my story continues.

Not having been instructed in the operation of the hand brake, and having no power to apply the air brakes, the captain was helpless. The locomotive began rolling backward down the grade, gathering speed as it went. The soldiers wanted to jump but the captain ordered them not to. Three finally did, and they were badly mauled in the ballast of the roadbed. Again they passed the Ipanema substation at high speed and ran head-on into the wreckage of the train.

As soon as the echoes of the crash had died away the captain said, "Well, we are stopped! Let's get out and see what happened."

While I was having breakfast that morning, a messenger from the Engineer of Maintenance of Way came to the house and said there had been a wreck. The Senior Engineer was waiting at the station with a gasoline rail car and wanted to know if I wished to go with him to the Ipanema substation.

The locomotive was still upright even though it had passed over two lengths of broken rails. A freight car truck was under the front end. The pilot was gone; otherwise the locomotive seemed undamaged.

Three freight cars had gone across the outside track and down the bank—one car of lumber, one refrigerator car of meat, and a car of potatoes. Their contents were scattered about the countryside.

Up on the right-of-way stood two boxcars crosswise on the tracks—one car of corn and one car of beans; both had burst open. Corn and beans were everywhere. Most of the train was still on the track, although some of the cars had derailed.

The strike was settled that night.

HORSEPLAY

Dark rain clouds hung low over the water just offshore to windward and gave promise of some relief from the glaring tropical heat. The town back of the docks, with its closely built houses of brick and plaster and narrow paved streets, threw back the heat like an oven. The mountains covered with heavy jungle growth rose abruptly behind the town to 3000 feet and sheltered it in a great pocket.

There never was very much wind in Puerto Cabello, on the Venezuelan coast. In fact, that was how it got its name, so the story goes. *Cabello* is Spanish for "hair." In the old windjammer sailing days some sea captain said, in describing the seaport, "There's so little wind there you could dock a ship with a hair." And so it became known as Puerto Cabello.

It was in August 1951 that we were at the Puerto Cabello dock. We had just placed on shore the last of the eight 67-ton 840-hp diesel-electric locomotives built at GE's Erie Works for the Venezuelan State Railways.

One of the boys from the floating crane had climbed up on the roof of the locomotive to clear the slings as the crane operator took them away. Stepping into the loops of the slings, he signaled the operator to take him up. The boom on the crane was 100 feet high, and the slings hung 50 feet below the hook. It was not customary for anyone to ride on the slings, but it looked like a good stunt and the operator obliged by taking him all the way up. He came in for a lot of razzing from his friends on the dock, but he took it in good part and waved back.

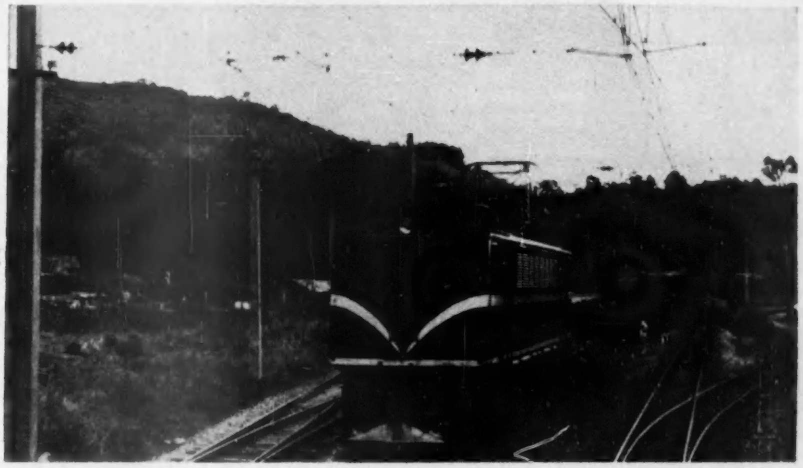
When the operator began swinging the boom back over the deck of the floating crane, he kept right on going until it was far out over the water. Then running the hook down, he dunked the boy three times in the bay amid loud cheers and laughter from the dock.

It was a humorous touch for the conclusion of a successful unloading operation. Everyone was in good spirits.

THE BARREN LANDS

The strangest land I have ever visited was the nitrate pampas in Northern Chile.

Located high up on the Pacific slopes of the Andes, these pampas, or plains, are absolutely devoid of natural life. There is almost no moisture and the annual rainfall is recorded as zero. Once in 25 or 50 years it rains for a few hours, or for as long as three days at a time. But this only happens when the wind changes—a rare event. One may find many people in the small towns along the coast who have never seen rain.



TYPICAL SCENE ON THE SOROCABANA RAILWAY WHERE RUNAWAY TRAIN WENT BERSERK.

Also, for a thousand miles there is almost no fresh water. Whatever streams wander down from the high Andes soon disappear in the sand. The people drink water distilled from the Pacific Ocean. One important reason for the electrification of the railroad that brings the nitrate down to the coast was the high cost of pumping water for the steam locomotives up to the tanks along the right-of-way. This in itself presented a problem because pump pressures ran as high as 1500 psi.

Northern Chile is in the trade wind belt and, with few exceptions, the wind always blows from the west. This creates a condition that makes it impossible for rain to fall. Located near the Tropic of Capricorn, its climate is warm, but the Humboldt current with its cool waters flowing up the coast from the antarctic tempers the air as it moves inland off the ocean. This air, sliding up the arid slopes of the Andes, warms up in the sun. As it warms it absorbs what little moisture exists. After the sun sets and the temperature in the pampas begins to fall rapidly, clouds start forming along the coast range, but the relative humidity never gets to the point where rain falls. Temperatures range from more than 100 F in the daytime to freezing at night.

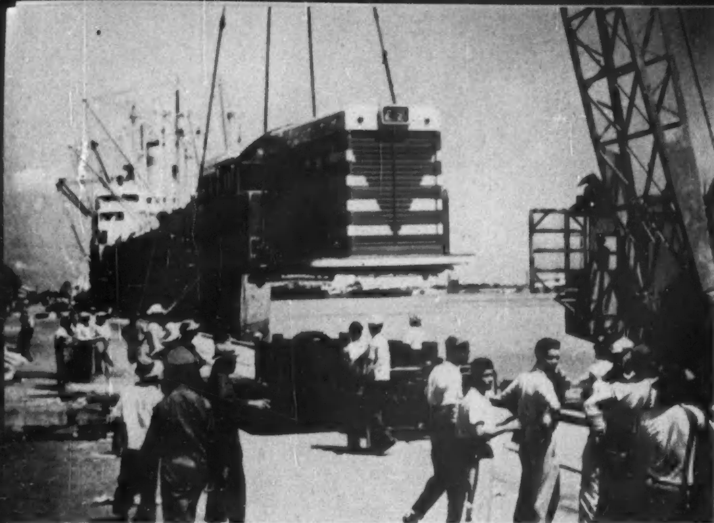
Along the coast a few cacti and some hardy plants live on the moisture from the fogs that form at night, but beyond the coastal range there is nothing—no vegetation, no animal life, no birds, and no insects.

At the seacoast all Chilean dogs have fleas. However, at the nitrate plants in the pampas there are no fleas. The natives say that when the trains stop at Barriles, where the pampas begin, the fleas all get off and take the next train back!

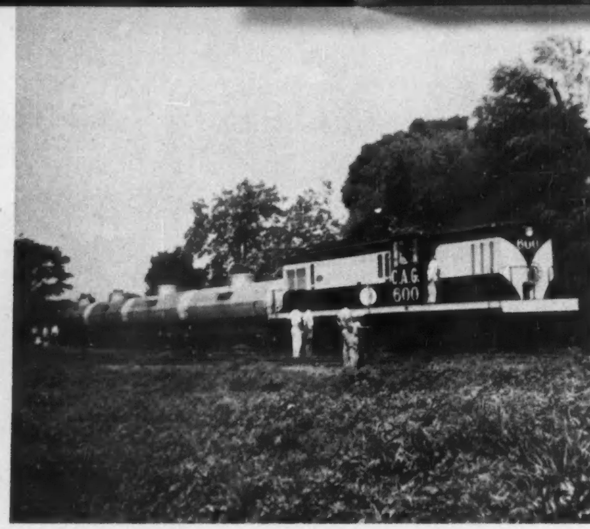
The cool waters of the Humboldt current teem with fish of many kinds and sizes. These supply abundant food for the millions of water fowl that thrive on them. One of these birds, about the size of a sea gull, is called the *garoma*. During the nesting season it flies up to the edge of the pampas and lays a single egg in the sand. Every morning it flies down to the ocean and dives for fish. Late in the afternoon it goes back up to the pampas and sits on the egg until the next morning when the sun is warm enough to take over. There are thousands of birds in this area, and the ground will be nearly covered with eggs. The mother bird seems always to know her own egg. After the young birds hatch, she will come down out of the sky, land beside her own offspring and feed it by disgorging fish she has taken into her stomach from the ocean.

The *garomas* fly back and forth in great clouds. Sometimes stragglers get lost in the night fogs and wander around making the night hideous with their cries.

There's only one place in the world where sodium nitrate can be mined from the ground in the form of ore, and that's on the Chilean pampas. Just how the nitrate got there is not definitely known, but it's generally be-



SUCCESSFUL UNLOADING of diesel-electric locomotive took place in Puerto Cabello, Venezuela, at scene similar to this.



GUATEMALAN BANANA PLANTATION like this one was where the snake-in-the-grass incident occurred.

lieved that millions of years ago, when the pampas were just emerging from the ocean floor, these mud flats were inhabited by millions of birds who fed on the fish that thrived in the cold waters of the current flowing up from the antarctic. The droppings from these birds mixed with the silt and were washed by the rains into the hollows to form the nitrate ore beds as they are found today.

Sodium nitrate was discovered in Chile entirely by accident. An Indian was camping one night in the pampas and to keep himself warm he built a fire against an outcropping of grayish white stone with a few pieces of dead cactus that he had brought with him.

To his surprise the stone began to burn fiercely with a bright flame. In the morning he broke off a piece of the outcropping and took it down to the coast where he gave it to a missionary, telling him it was "devil rock."

The missionary wasn't particularly impressed and finally one day he became tired of having the stone around and threw it into his flower garden. After a few days he noticed that all the flowers in the vicinity of the stone were growing at a tremendous rate. He sent a sample of the stone back to England to be analyzed. The report showed a high percentage of sodium nitrate.

This report ushered in the very lucrative sodium nitrate industry. Some of the old British companies paid from 50 to 100 percent dividends.

For more than 50 years Chile held the monopoly on sodium nitrate until synthetic nitrate began to cut into the market. To meet this competition, more efficient processes of production and transportation had to be introduced.

On the Anglo-Chilean Nitrate Railroad running from Tocopilla to Maria Elena, the 24-mile section between Tocopilla and Tigre Yard, known as the "Bank Section," was electrified with 1500 volts d-c. Seven 85-ton 42-inch-gage locomotives were built at the Erie Works. These locomotives, which were equipped with regenerative braking, went into service in 1927.

Nothing in the nitrate pampas ever changes unless it is done by the hand of man. There are old river beds and dry water courses that may not have seen water in a thousand years. In one place a cataract at some time must have plunged hundreds of feet down into the valley. At another place one sees tracks where someone on horseback rode out across the desert. The tracks may have been made yesterday or last week—more likely it was 10 years ago.

In the early days the nitrate ore came down to the coast over a winding road in two wheeled carts drawn by horses. Fifty years ago the English built a railroad to transport the nitrate. The railroad grade cut across the old wagon road, but here and there sections of the old road remain intact. One still clearly sees the wheel ruts and horse tracks in the sand almost as if the road were still being used. Occasionally, wind squalls kick up a little dust, but with no frost, and almost no rain everything remains unchanged.

Nearly a hundred years ago the Indians left their dead sitting up in the pampas wrapped in homespun cloth and surrounded by a low stone wall. These mummies can still be found in little burying grounds in some parts of the pampas.

Standing at a road crossing on the bank of the Rio Loa, a salt stream that runs down into the pampas, I saw a mummified horse that had been dead for some time. Someone had stood him on his feet, braced him up with pieces of wire tied to stakes, and placed on his back a *carabinero's* uniform stuffed with straw. In the *carabinero's* hand was a wooden sword held at attention, and on his head a *carabinero's* cap.

At the nitrate plant in 1927 I asked one of the men how long he had been there. "Oh," he said, "ten years that I know of." I have often wondered if the *carabinero* and his horse are still standing guard at the river crossing.

Nothing ever changes in the pampas.

THE SNAKE IN THE GRASS

The United Fruit Company's plantations in Guatemala are located at Tiquisate on the Pacific slope of the Andes about 40 miles south of the Mexican border. These plantations include 30,000 acres of bananas from which the annual yield is 2,500,000 stems. All of this fruit must be transported to the Atlantic coast over the narrow gage International Railway of Central America which climbs up the slopes of the Andes to Guatemala City at an elevation of 5000 feet.

From Escuintla to Palin, 17 miles, the grade is 3.6 percent and at one point for a few hundred yards it is 3.7 percent. This is the limiting grade and with steam-locomotive operation constituted the bottleneck that held down the annual production of bananas to 2,500,000 stems.

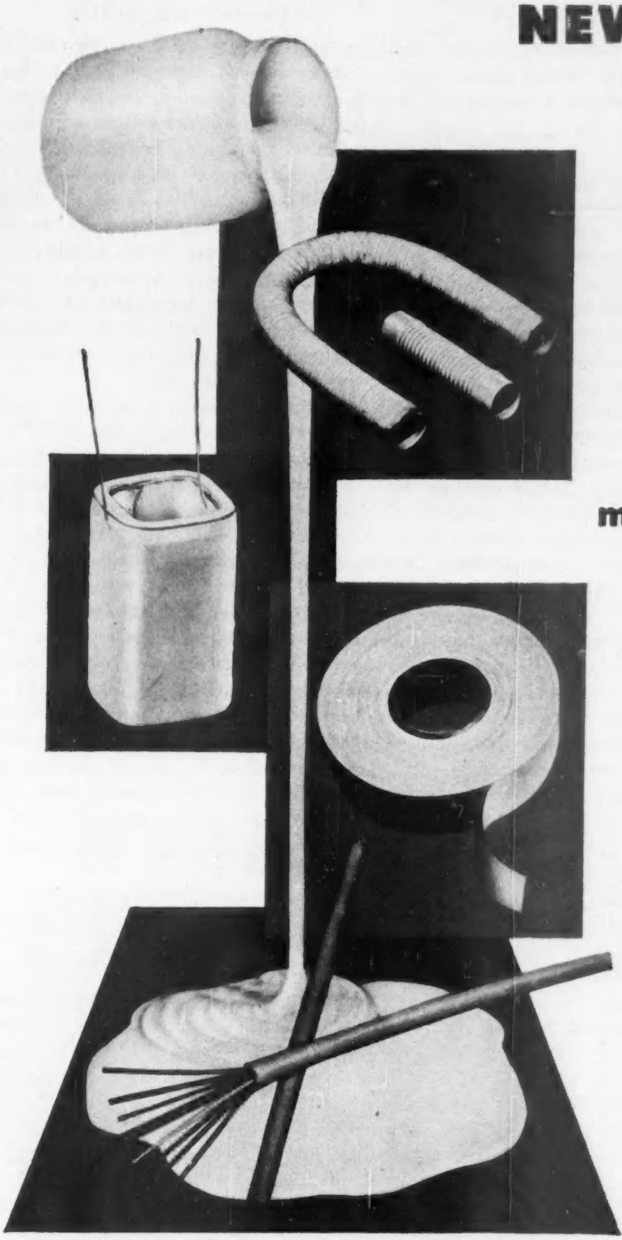
Substituting diesel-electric locomotives for steam on this grade seemed to be the only practical solution, and so six 120-ton 1200-hp diesel-electric locomotives were ordered from General Electric.

When these locomotives were assembled and put into operation in 1950,

CONCLUDED ON PAGE 60

NEW (GE logo)

SILICONE RUBBER COMPOUND



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Power System Primer—

(*Concluded from page 25*)

the 480-volt secondary load at the load center can be switched to the secondaries of the other transformer.

The Summing Up

In essence, then, the electric power system of the Evendale plant consists of: 1) a source of power—the dual 66-kv incoming lines from the electric utility; 2) a primary distribution system—the arrangement of 13,800-volt medium-voltage circuits that feed the load-center substations; 3) a secondary distribution system—the 480-volt utilization feeder circuits emanating from the load-center substation secondaries; and 4) a motor-center double step-down transformation—the 6900-volt utilization voltage for large motors transformed directly from the 66-kv incoming line, including an additional step-down for the associated 2400-volt motors.

Power systems of plants in other industries will have these same elements. And designed in each, though perhaps not apparent at first glance, are *simplicity*, *reliability*, and *economy*.

Simplicity means a readily understandable arrangement of circuits that are easy to operate, with no complicated switching; an arrangement where in time of emergency—even under strain—an operator can make the right decision and quickly take action to keep power flowing. Maintenance is seldom needed on such a system, and when it is, takes little time.

A major step toward accomplishing reliability is to use existing designs of good equipment. For a fully reliable system, you provide alternate sources of power without sacrificing simplicity.

Economy goes hand in hand with simplicity and reliability. For example, to get the most economical system, you study motor horsepower ratings versus voltage levels so that you can pick standard equipment. But rarely, if ever, would you consider *nonstandard* voltages or equipment selected on purely theoretical grounds. Best results are achieved by utilizing, in sound basic arrangements, advantages of modern equipment.

Skillful application—another way of saying "common-sense use"—of tried and proved engineering know-how can solve, without exception, the problems encountered in electric power system design. And most of the decisions, in the final analysis, are based on the system's over-all economics. Ω

Railroadin'—

(*Concluded from page 58*)

it was quickly demonstrated that the bottleneck could be broken and the goal of five million stems a year could be realized.

Unfortunately, labor troubles soon developed and the diesel-electric locomotives were taken out of service. For seven months I went to Tiquisate at least once a month, started up each locomotive, and ran it long enough to bring the batteries up to full charge.

Finally an agreement was reached with the union and the diesel-electric locomotives went into operation again. But further troubles developed and the locomotives were tied up indefinitely.

One day I was at Tiquisate starting up the locomotives. It had been raining steadily for three days, and water stood around in little lakes wherever there was a depression in the ground. This was the fourth day and the total fall for the day was five inches.

The long line of volcanoes that stand like sentinels guarding Guatemala's Pacific coastal plain was shrouded in heavy rain clouds. Even the thick jungle only a few yards away showed dimly through the downpour.

Beginning with the first locomotive I was going down the line, starting up the engines as I went along. I had just started the engine in the fifth when I happened to look back along the locomotives. At about the center of the second locomotive there was considerable commotion in the grass where something black was moving. My first thought was that it was an iguana, a big lizard that is common around the plantations. This one looked like an extra large one, and to get a better view I jumped down and ran back to the second locomotive. The iguana turned out to be a big black snake. When he saw me coming, he headed back under the locomotive. The track gage is 36 inches and, as he crossed over the tracks, parts of him hung over both rails.

Instead of crossing the track, as I thought he was going to, he went up over the brake rigging and disappeared in the frame of the locomotive. I never saw him again, and I didn't make any further investigation. Where there is one quite often there is a mate. Of the 80 types of snakes in Guatemala, about 50 are poisonous. The chances are two to one against you if you don't know your snakes. Ω

Submarine Power Plant—

(*Concluded from page 27*)

so that they are more effective and so that less fuel is required, 3) a coolant, 4) structural material, and 5) controls. All these items fight for space within the primary shield. To be nuclearly efficient, the reactor must be small. The result is a tight design in which enough heat for a relatively large power output is taken from a very small volume. That the heat-transfer rates must be high is obvious. As is usual in engineering structures, the heat is not generated uniformly, and the problem is thereby complicated.

Another problem peculiar to liquid-metal reactors is that of thermal shock. Liquid metals have high thermal conductivities that give large temperature dislocations in the structure with sharp load changes such as "scram" (emergency shutdown), or even with rapid load changes.

Control can be effected most readily by the insertion of nuclear poisons. Unfortunately, these poisons must be inserted with reasonable uniformity of distribution throughout the core. Operation must be handled either through mechanical seals, or by mechanisms contained in the primary fluid. The accuracy of positioning and speed of motion required is similar to that on steam turbines.

Another important factor is that the success of a reactor is directly dependent on the reloading means. Even if the initial loading is made for the lifetime of the equipment, unloading is needed in the early stages of the development program to determine just how the fuel elements are getting along. The problem is further complicated by the fact that the heat from the fuel elements can't be shut off completely after they have operated for some time. Therefore, the designer must decide whether he will reload in one piece, or piecemeal. With a water system, he must provide proper closures of a heavy pressure vessel; with sodium, he faces the added complication that he must maintain an inert-gas atmosphere over the work.

The design of a nuclear power plant for a submarine involves problems that are extensions of old and time-proved techniques. The designers recognize that unforeseen problems will arise, but they're fully confident that these new power plants will be successful, and that they will provide a new level of performance for submarines. Ω

Control in Industry—

(*Concluded from page 51*)

and made ready to play back all recorded motions and operations. Thus, the recording can readily be stored and re-used whenever the machined piece is needed in the future.

Punched tapes or magnetic recordings can be made to cover the machining cycle for any number of intricate parts of a unit.

By adding either type of control to a general-purpose machine tool, tapes or recordings may be prepared that will permit its operation as an automatic special-purpose machine tool.

What's Ahead

Today's high production speeds require controls with swiftness of response that can no longer be supplied manually. Self-regulating controls are the answer. At the same time, there's a constant evolution of control principles and amplifying means to obtain even faster speeds of response, and more accuracy of performance.

In the 1930's, the amplidyne—or rotating amplifier—was applied in industry where the sensitive capabilities of electronic tubes weren't needed, and where there was reluctance to use such fragile equipment. In subsequent years, however, control equipments were designed using the electronic tube and amplidyne in combination. Today, by contrast, the trend is toward replacement of both types with the static, or magnetic, amplifier.

Of tremendous help to the engineer in solving the complex control problems that lie ahead will be mechanical and electronic calculating machines. For in addition to solving mathematical equations, they can be used to simulate the electric machinery for which the control is designed. Thus, a more thorough test of the control can be made in the factory prior to installation at the customer's plant. This new technique has already reduced installation and tune-up time to a high degree.

Controls of the future may well include computers and information-storage devices to permit measurement and integration of operating factors in a process. That is, the control itself will make necessary calculations and automatically correct the process to get the desired end product. When we reach this stage of control, our nation's industrial productivity will have no limits. Ω

Expanded Plastics—

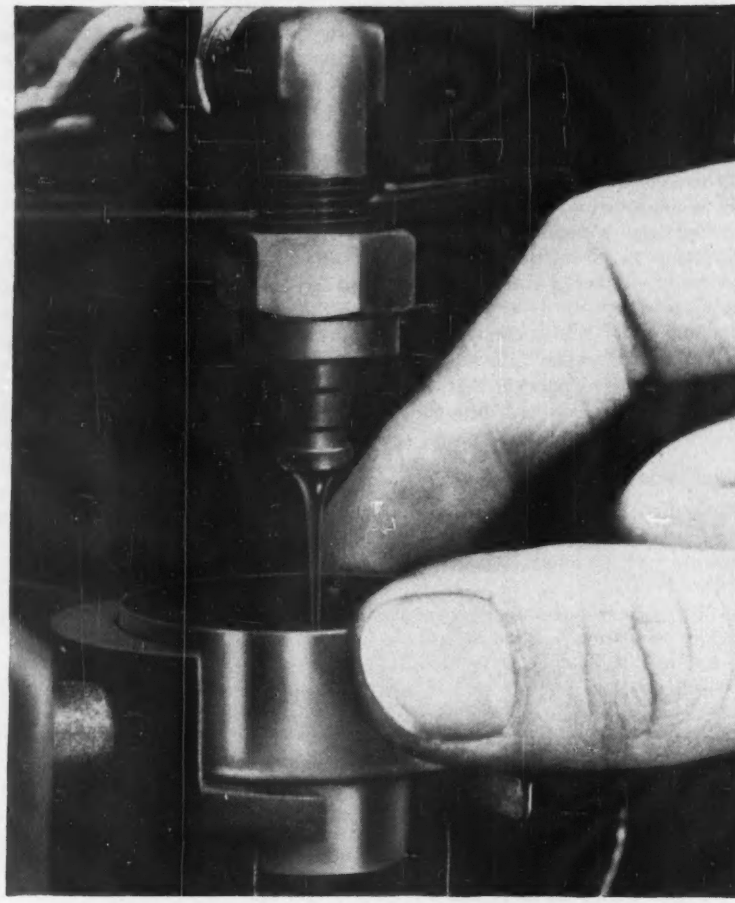
(*Concluded from page 55*)

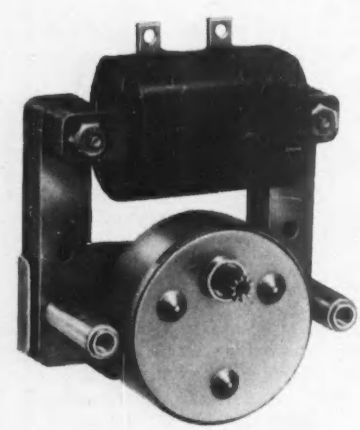
devise some means of changing the picture entirely.

The Summing Up

You can classify expanded phenolic foam as a somewhat brittle material composed of a combination of independent and interconnected cells. It has remarkable self-fabricating properties, fair mechanical strength, good buoyancy and thermal insulating properties, excellent sound-deadening ability, strong resistance to heat and chemicals, and moderate cost.

Few new products, however, initially possess every characteristic you might desire. And this is certainly true of expanded plastics, whose brittleness and interconnected cells somewhat limit its application. But every new product, and particularly those of the chemical industry, goes through an improvement phase almost before it is introduced on the market. Present development efforts are already producing foam varieties with extra toughness and good cellular formation. When these are marketed, expanded phenolic foam will indeed be a material to be reckoned with. Ω





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