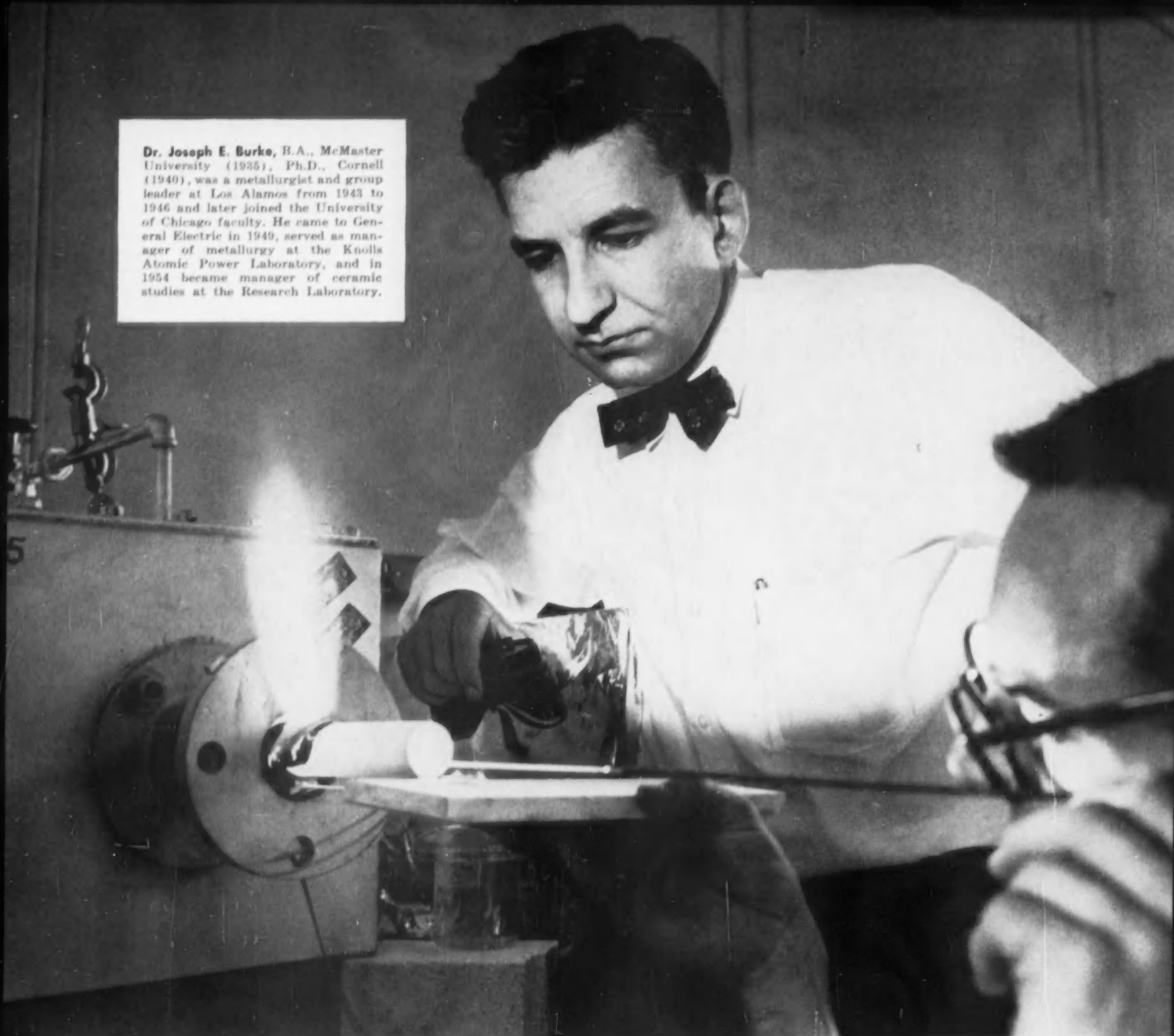
GENERAL ELECTRIC Review

SEPTEMBER
1956



Dr. Joseph E. Burke, B.A., McMaster University (1935), Ph.D., Cornell (1940), was a metallurgist and group leader at Los Alamos from 1943 to 1946 and later joined the University of Chicago faculty. He came to General Electric in 1949, served as manager of metallurgy at the Knolls Atomic Power Laboratory, and in 1954 became manager of ceramic studies at the Research Laboratory.

Ceramics for the jet age

General Electric's Dr. J. E. Burke seeks better ceramic materials by studying their microscopic structure

During a decade as a "practicing metallurgist," Dr. Joseph Burke contributed to the knowledge of structure and kinetics in metals. He also developed an interest in the crystalline cousins of metals: ceramics. Recognizing the potential of ceramic materials, Joe Burke turned his talents toward increasing and exchanging the mutually useful information produced by research in both ceramics and metallurgy. Now he is leading an intensive effort at the General Electric Research Laboratory to learn more about the *structure* of ceramics — and the effects of structure on mechanical, electrical and magnetic properties.

At General Electric, ceramics research already has created unique insulators for vacuum tubes, new ferrites for electronic uses, and transducers whose applications range from hi-fi to ultrasonics. As the day of "non-brittle" ceramics comes ever nearer, Joe Burke and his associates expect their non-metals may be the answer to many high-temperature problems of the jet age.

Progress Is Our Most Important Product

GENERAL ELECTRIC

SEPTEMBER 1956 • VOLUME 59 • NUMBER 5

GENERAL ELECTRIC Review

EVERETT S. LEE • EDITOR

PAUL R. HEINMILLER • MANAGING EDITOR

COVER—Missile test vehicle, part of Project Hermes, was designed by General Electric for the Army Ordnance Corps. From such missile operations came much of the information now contributing to the success of the earth satellite program (see page 10). A special camera takes 12 frames a second on 50-foot 5x5 Eastman Aerial Ektachrome film. Arrow and cross hair locate exact center of frame. With such transparencies, General Electric engineers analyze missile takeoff characteristics.

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, NY.

General Electric EM* Pumps . . .

Move liquid metals with greater safety and continuity

. . . OPERATE WITHOUT MOVING PARTS, SEALS, OR BEARINGS

General Electric electromagnetic pumps, first designed for radioactive and high-temperature systems, are now used in liquid metal laboratories and industrial processes where minimum leakage and continuous operation are important.

Now designed to pump liquid metals at temperatures up to 1500 degrees F and to move up to 10,000 gallons per minute with accurate control of flow, General Electric EM pumps can be used to move such metals as sodium, sodium potassium, lead, bismuth or mercury.

** Electromagnetic*

General Electric offers complete liquid metals pumping systems including EM pumps, magnetic flowmeters, liquid level indicators, pressure transmitters, induction heaters, cold traps, plugging indicators and sodium oxide control stations.

For more information on liquid metals pumping systems and components, contact your nearest G-E Apparatus Sales Office, or Section 193-1, General Electric Company, Schenectady 5, New York. Outside of the U.S. and Canada write to: International General Electric Company, 570 Lexington Avenue, New York City, N. Y.

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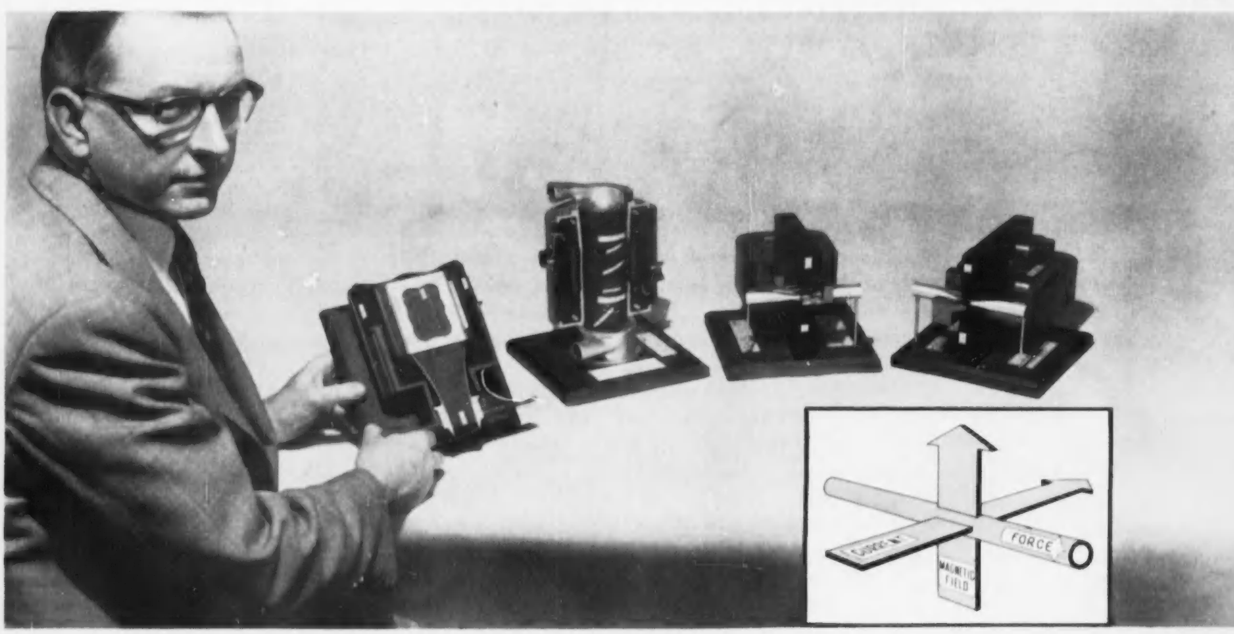
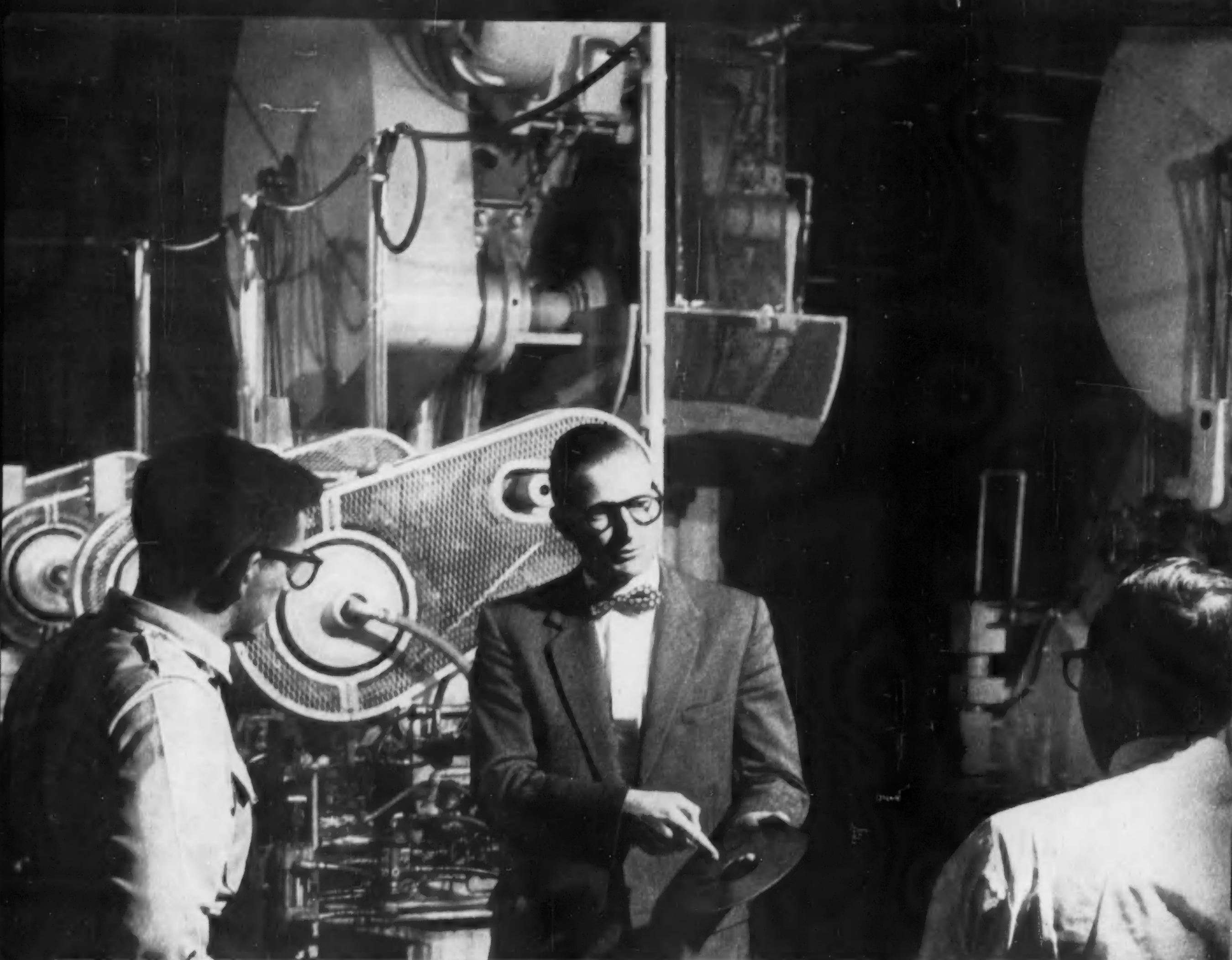


FOUR GENERAL ELECTRIC EM PUMP MODELS are shown by J. F. Cage, Manager—Component and Coolant Systems Engineering Operation, Atomic Power Equipment Department, (l. to r.): linear induction, helical flow, d-c, and a-c types. Diagram shows pumps' operating principle: Force is exerted on current-carrying liquid in magnetic field.

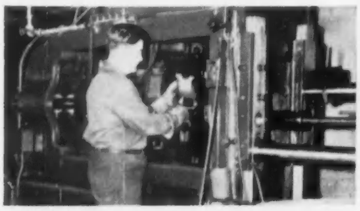
LIQUID METAL LOOP tests sodium potassium (NaK) in a G-E electromagnetic pumping system for use as heat-transfer agent. Loop's a-c EM pump (below) operates at 600 degrees F with capacity of 30 gallons per minute. Magnetic flowmeter (left of pump) measures flow externally, providing greater safety.



New trends and developments in designing electrical products . . .

Why General Electric Magnets clad in die-cast aluminum sheaths offer important design and cost advantages over the conventional methods of fabricating magnetic assemblies

THE MAN in the picture below is removing a section of a radar magnetron tube magnet from a piece of equipment that goes by the imposing title of "Lester-Phoenix Horizontal Cold Chamber H-HP-3X 400-Ton Die-Casting Machine."



This machine is in our Edmore, Michigan, magnet plant, and its sole function is to cast aluminum sheaths on General Electric Alnico Permanent Magnets.

These alclad magnets offer designers seven major advantages over conventional methods of fabricating magnetic assemblies.

1. Die casting strengthens the magnet structurally.
2. Whole assemblies can be designed and built as a single "package," speeding the final assembly job at the plant.
3. Design of mounting arrangements is simplified because pins, holes, and screws can be cast into the sheath, instead of the magnet.
4. Responsibility for the entire assembly is centered in a single source, simplifying purchasing procedures, and eliminating costly in-plant assembly operations.
5. Complete magnetic assemblies can be purchased premagnetized and/or pretested.
6. Die casting provides a consistent, more attractive finish for applications where appearance is important.
7. Die casting is a convenient, low-cost mass-production technique for magnetic assemblies that eliminates the problem of attaching crystalline cast magnets to other components.

The following examples will illustrate how these advantages can be turned to practical use.

Figure 1 is a relay drag magnet assembly, typical of those used in the meter and instrument industry. Before the manufacturer switched to this casting, it was necessary to cast a magnet against a piece of steel, bend the steel into the proper shape, and weld the ends together.

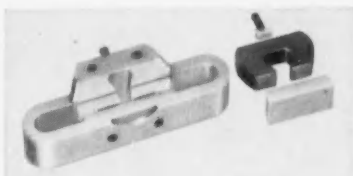


Figure 1

Now, however, magnet, mounting pin, and steel return path are assembled in a single operation—eliminating the difficult 3-stage fabrication job. This assembly—one of the most complex handled by the die-casting machine—illustrates the equipment's tremendous versatility.

Figure 2 is a generator rotor, consisting of eight G-E Alnico magnets held in position on a camshaft by the cast-aluminum matrix.

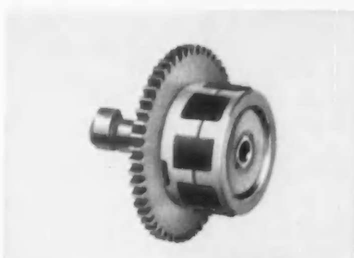


Figure 2

The casting supplements the strength of the magnets (which are subjected to high rotary speeds). And it eliminates difficult grinding, assembly, and banding operations.

The four radar magnetron tube magnets in Figure 3 give some idea of the wide range of sizes the machine is capable of handling. The smallest magnet (bottom, right) weighs only 1 lb., while a quarter section of the largest magnet weighs more than 11 lbs.

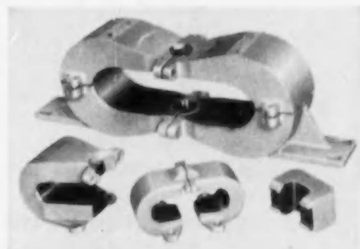


Figure 3

Here, the aluminum sheath improves magnetic stability by preventing direct contact between magnet surfaces and steel objects. In addition, the mounting brackets cast in the sheaths eliminate inserts normally cast in the magnets which would weaken its energy and structure.

Aluminum-sheathed magnets are often far less expensive than conventional magnets . . . especially on long production runs. And, in many of the cases where the unit cost of alclad magnets is higher, the tremendous advantages gained by die casting have more than offset the price difference.

The one best way to find out whether or not die casting is feasible on your application, is to check with a General Electric Magnet Engineer.

You can do this—or obtain information on any other problem in the realm of permanent magnets—by dropping a note to: *Metallurgical Products Department of General Electric Company, 11201 E. 8 Mile Blvd., Detroit 32, Michigan.*

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THE SPLENDOR OF COURAGE

I well remember in 1903, when I was a boy in Wilmette, Illinois, reading in the newspaper about the General Electric steam turbine-generator installed in the Fisk Street Station of the Commonwealth Edison Company in Chicago. It was 5000-kw capacity and was, when installed, the largest steam turbine in existence. To me it was as exciting as is the space ship to the boy of today. I had to see it.

So some of us in the New Trier High School asked our mechanical drawing teacher if he would take us to see the big machine. He did, and we saw it in all its magnificence. We also heard it, for it made a whale of a noise.

Little did I know at the time the story behind this accomplishment, just as today few people know the stories of the achievements of industry which have brought them the things they use and enjoy. But when I came to Schenectady in 1913, I found that same steam turbine-generator enshrined in the General Electric plant there as a "Monument to Courage."

Later I came to know the men who were responsible for the machine and the story behind it. I have loved that story for all these years, and have kept it constantly before me. It combines beautifully the fundamentals of engineering progress: having an idea or plan of something new with a vision of its future; evaluating the usefulness and worth of the idea; developing a sample step by step into a pilot unit; manufacturing an operating unit and installing it; operating it—seeing it grow into the fulfillment of the original vision and even beyond.

A condensation of John Hammond's account of the Commonwealth Edison machine, from *Men and Volts*, appears on the opposite page. May others be inspired and guided by it as I have been.

It is called a Monument to Courage. In all industrial progress, courage is a word of splendor. It comes both from the mind and the spirit of man. It is vision to see a need; it is the ability to accomplish that need; it is firm in determination to succeed. It is undergirded by faith and has untold perseverance in the face of obstacles. It knows no defeat; it is dynamic to move forward. It is the essence of progress. It is the very necesssary ingredient for success in all the realms of industry.

Just a few weeks ago there was unveiled in Schenectady what is believed to be the world's most modern factory for the manufacture of induction motors. Built at a cost of approximately $7 million, the new motor plant—highlighted by many new and revolutionary manufacturing processes—has made possible producing motors in 24 hours that formerly took two weeks to produce. The increased production output has brought more employment in the plant than ever before.

Another Monument to Courage.

Jim Olin, Superintendent of Manufacturing, said:

> "Here in our new motor plant we have seen our long-range dreams come true. We have built a plant with capacity for the future. We have built flexibility to meet changing customer requirements for various motor types. We have achieved the ultimate in mechanization for the kind of motors we are making. And we have realized new standards of employee comfort and morale."

To be with men of courage in a company of courage is to know the exhilaration of an expanding life of usefulness.

EDITOR

MONUMENT TO COURAGE*

Early in 1897 a tall young man entered the office of E. W. Rice, Jr. Mr. Rice was then technical superintendent of the General Electric Company at Schenectady, and later became its president. The young man announced himself as Charles G. Curtis of New York. In his traveling bag he brought the plans and the description of a steam turbine.

It was new. Rice had the imagination to believe that it would work. He examined, analyzed, appraised the drawings. He made an agreement with Curtis that he was to have the best facilities of the Schenectady Works to carry on the experiments necessary to make the turbine practical.

Then followed trying days—days full of troubles. After two years of experimenting, a recommendation was made to Rice that the tests should be abandoned.

Rice turned to an engineer, William LeRoy Emmet, who had distinguished himself by his handling of the problems of alternating current. Emmet investigated Curtis' turbine and studied the results of the tests. Emmet saw something in the turbine that made him think that it required further experimenting to bring out unsuspected possibilities. Emmet recommended that two machines be built for commercial usage: one of 500-kw capacity, the other of 1500.

Rice gave Emmet charge of the design and manufacture of the trial turbines. Within 24 hours he was down in the shops, immersed in the tremendous question of the future of the new turbine.

Within a year the first Curtis-Emmet turbine was completed and ready for testing under service conditions. It came up to every expectation. A few months later the 1500-kw unit was well advanced.

Emmet and Curtis next designed a vertical 5000-kw turbine and offered it to the Commonwealth Edison Company for its new Fisk Street Station in Chicago. Rice had his hands full to win his board of directors to an undertaking so beset with difficulties. But he did. And all the while Emmet was busy with engineering data, which he finally took to Chicago. Assured by Emmet that the turbine was possible, Commonwealth Edison designed the new generating station for it.

That was in 1901. The Fisk Street Station was to begin operating in the fall of 1903. The year 1903 dawned and with it came anxiety and apprehension. When would the first factory test of the big turbine be made? A tentative promise was given. It had to be postponed, then postponed again.

Early in February 1903, George Emmons, manager of Schenectady Works, called Bill Madigan, a factory foreman, and gave him the job to meet the March promise.

It looked hopeless, but as Madigan studied the job, his fighting spirit rose to the challenge. Like a general, he marshalled his men, organizing their difficult operations. He kept the work going without pause. Repeatedly he stepped in and worked with his own hands. Everything he did was planned ahead.

Word was sent to Chicago that the turbine would receive its factory test March 7. March 1 arrived. Rice came down and asked when the turbine would be steamed. Madigan, grimy with dirt and grease, replied: "On March 5!" His eyes were red from lack of sleep but his head was as clear as ever, his smile as reassuring. The big turbine was almost assembled, towering four times as high as a man. A few more days of intensive, unflagging work followed, and on March 4, Madigan told the test men to let in steam. The turbine performed excellently at the official test of March 7.

That steam turbine-generator required only one tenth of the space and weighed only one eighth as much as the reciprocating engines it replaced. But still Emmet's problems were not settled—the unit had yet to be installed in the Chicago powerhouse. For months things kept going wrong. Construction men had to stay there and watch the turbine as it ran. They fairly lived in the generating station. But after three months no more unfavorable reports were received. The turbine ran steadily day and night, month after month.

Now Emmet busied himself with new experiments and new designs, for a clamor was going up from other central station executives for turbines of their own.

And as the General Electric shops hummed in the effort to supply the turbine demand, the engineers improved both turbine and generator, year after year, eventually reverting to the horizontal type, until the machines grew in efficiency beyond the rosiest dream. And that work of engineering progress still goes on.

*Condensed from John Winthrop Hammond's *Men and Volts*, New York: J. B. Lippincott Company, 1941.

SPIRALING HURRICANE forming over Texas on October 5, 1954 was photographed from 100-mile-high two-stage Navy Aerobee rocket with 16

What the Future Holds for the Earth Satellite

By R. P. HAVILAND

On July 29, 1955, the White House in Washington made this announcement: "The United States, as part of its contribution to the 1957–58 International Geophysical Year, will launch a small, unmanned earth-circling satellite vehicle."

Primarily a research vehicle, the satellite—an initial attempt at prolonged flight through space—will gather data concerning our earth and sun. Until now, the more than 100-mile layer of atmosphere that blankets our planet has kept us from obtaining this information. With the satellite, however, instruments can function outside this insulating envelope. Sustained observations in space and time will be possible for the first time.

But the satellite project involves even more than research.

As a long-term project with eventual everyday advantages, the satellite naturally needs much development before all of its uses are realized. Still, some of its useful applications are so simple that they'll come almost immediately.

Celestial Mechanics Primer

Elementary physics books teach that when you throw a stone from the earth's surface, its path—or trajectory—forms a parabola. But this is only an approximation. Sufficiently accurate for a short distance, the law becomes progressively more inaccurate as distance increases.

•

Coming to General Electric in 1947, Mr. Haviland is now Flight Test Planning Engineer, Special Defense Projects Dept., Philadelphia. Author of numerous articles and papers and holder of five patents, he was Project Engineer of the Bumper Two-Stage Rocket program that sent a two-stage rocket to a world-record altitude of 244 miles in 1949.

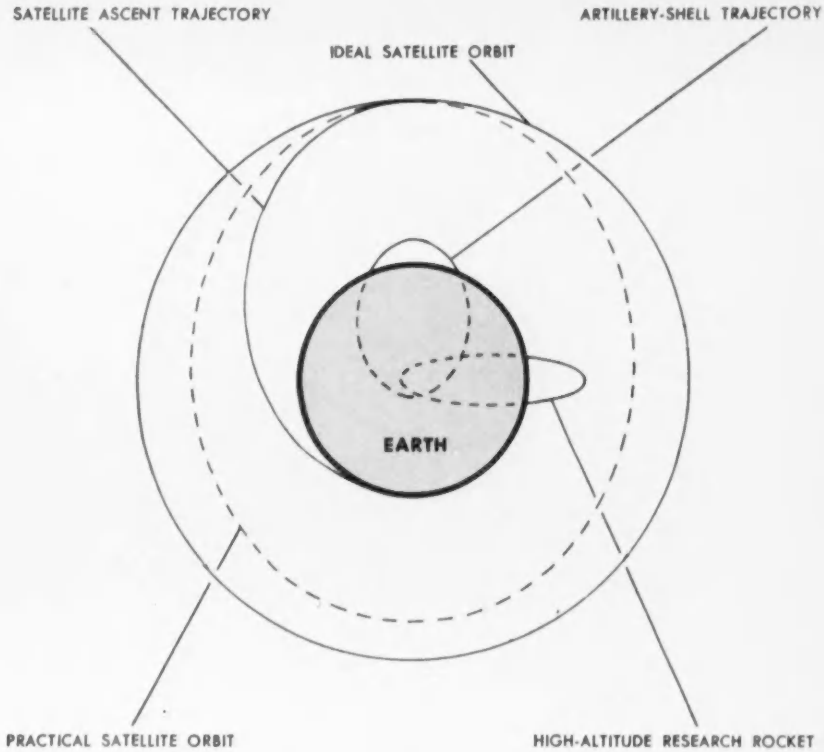
At great distances the curve of the stone's trajectory forms a section of an ellipse. Part of this curve—the part that the stone follows—is outside the earth. The rest lies within the surface with one focus of the ellipse at the earth's center.

In the 16th century, Johannes Kepler, a German mathematician and astronomer, showed that celestial bodies conform to the same laws of motion that govern a stone. Each planet, he pointed out, travels an elliptical path, or orbit, with the sun at one focus. Just as the moon is a satellite of our earth, these planets are satellites of the sun.

Thus an artificial satellite would have to duplicate the motion of a natural moon in the same orbit—mainly a problem of speed, direction, and position at the time of launching (illustration, top, opposite page).

To launch the earth satellite, a three-stage finless satellite-bearing rocket with gimbal-mounted motors for guidance

h… 16-mm movie camera.



TRAJECTORIES of bodies fired from surface of earth follow elliptical paths with one focus at earth's center. Planets also orbit elliptically but with the sun at one focus.

will be used. Let's assume here that the satellite can be placed in any orbit.

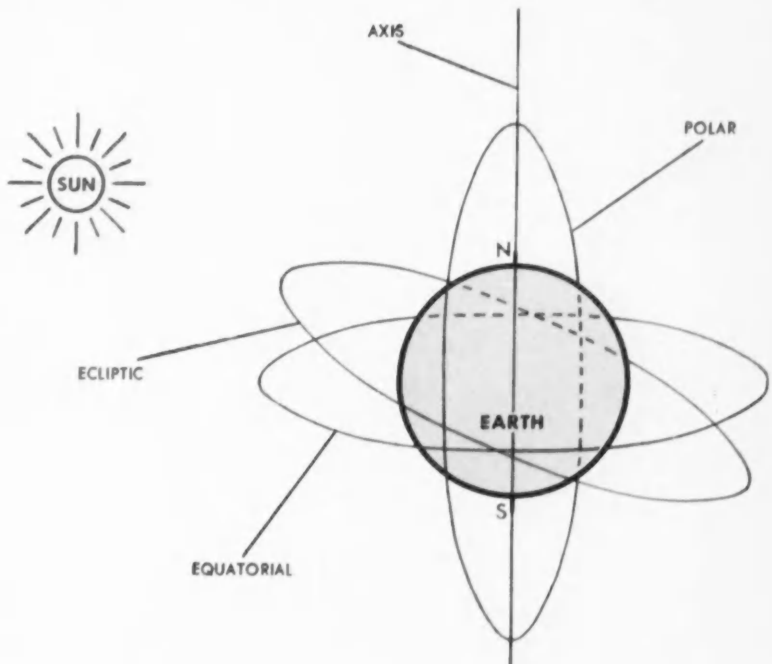
Orbits Around the Earth

For specific applications of the satellite, you need to understand its motion relative to the earth. Here the plane of the satellite's orbit, always passing through the earth's center, plays an important part.

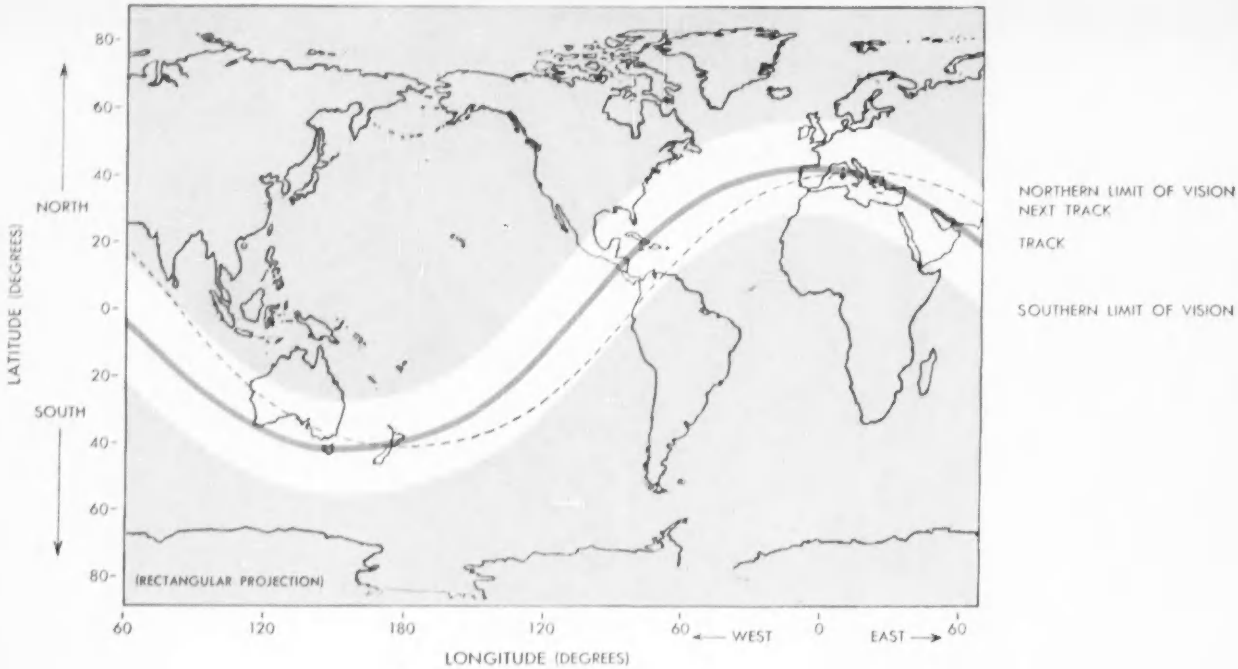
Orbit possibilities include: those with the plane passing through the earth's equator or through the earth's poles and one that inclines at an angle to the equator and coincides with the plane in which the planets move around the sun. These are called the equatorial, polar, and ecliptic orbits respectively (illustration, lower right). Still others incline at an angle to the equator and are known as the inclined orbits.

Besides the plane of the orbit, the satellite's motion must be considered. Height and velocity of the satellite also enter into this (Table I).

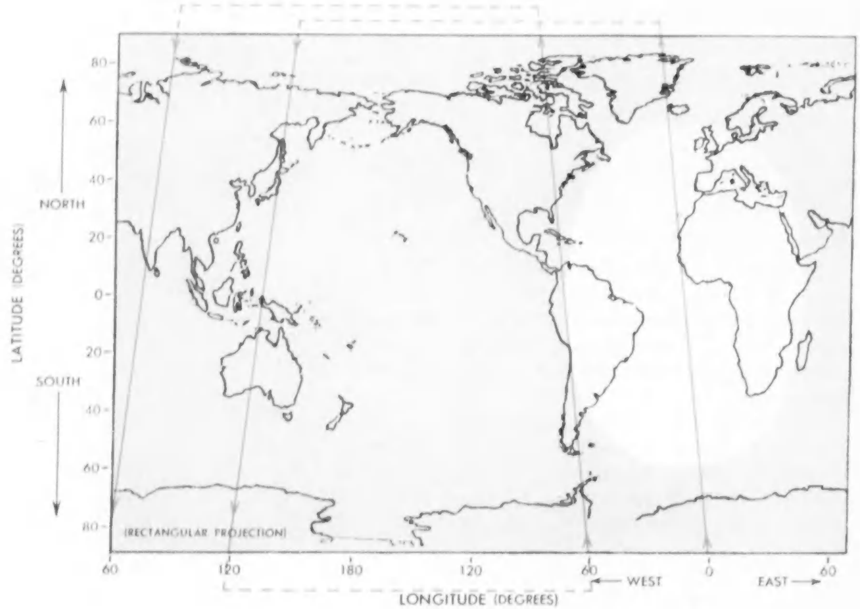
At the satellite's great height, you can view an appreciable portion of the earth (Table II). But the visible portion continually changes because of the earth's rotation while the satellite moves around it.



ORBITS of future earth satellites each possess distinct advantages. For example, on the equatorial orbit a 22,300-mile-high satellite would be stationary relative to the earth.



Earth mass as seen from a satellite 300 miles high and traveling eastward in its orbit changes with each successive track (above). Twice in 24 h urs, every point on the earth's surface would be visible from a 1200-mile-high satellite orbiting around the poles (right).

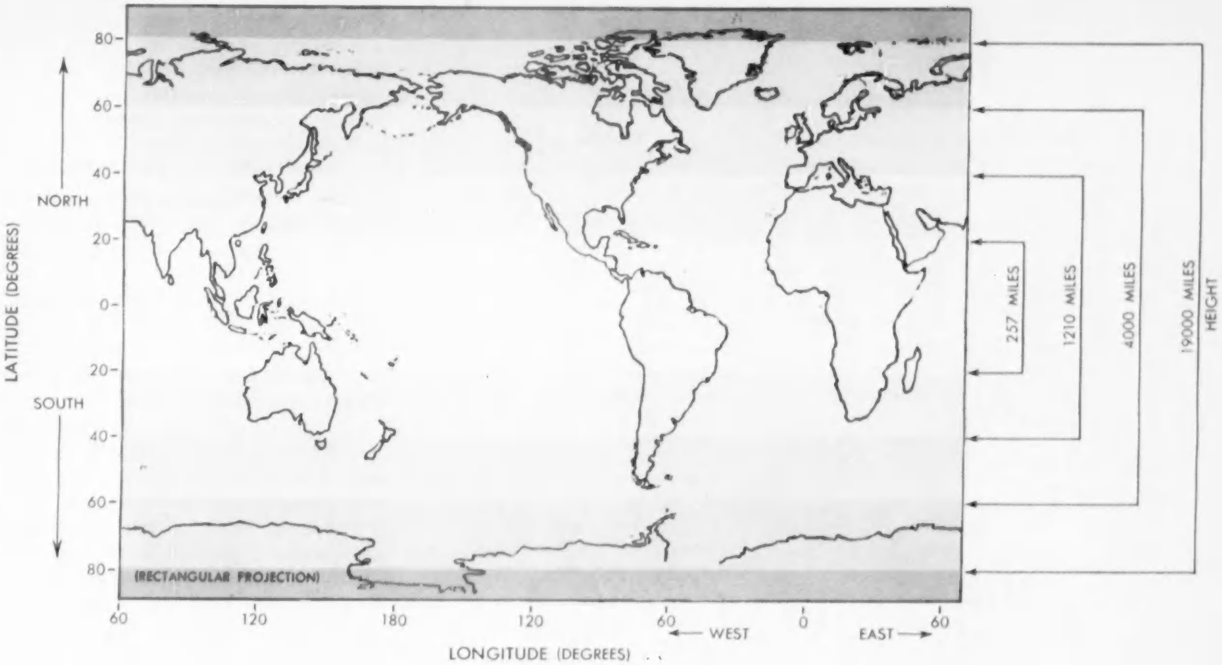


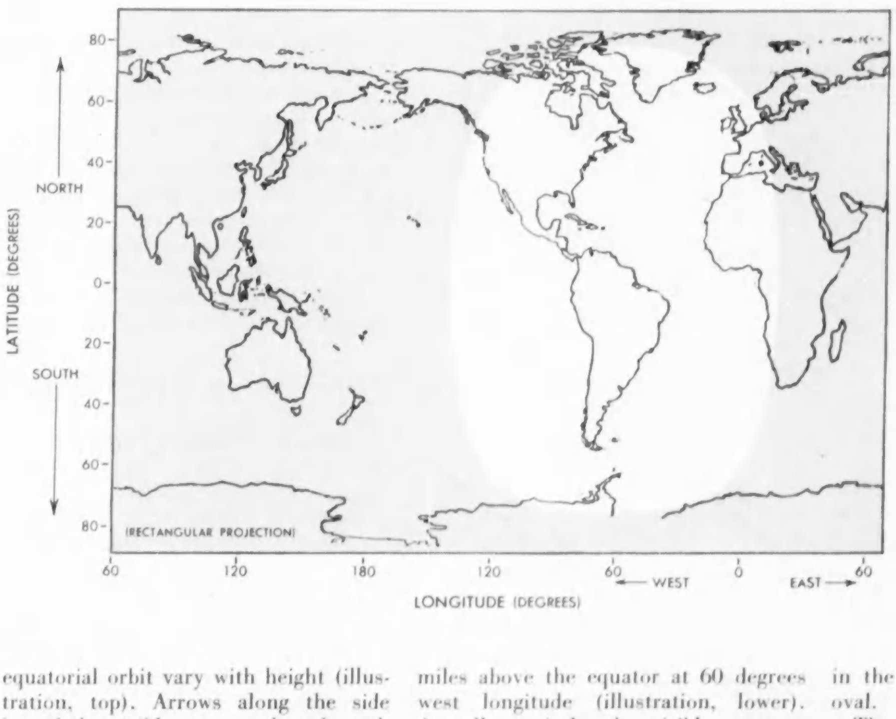
Two successive tracks of a satellite 300 miles out in space, moving west to east on an orbit inclined 40 degrees to the equator, can be graphically shown (illustration, top). Actually, the satellite travels in space about 96 minutes. But when viewed from the earth—also moving west to east—its *apparent* period is about 104 minutes.

In the illustration the shaded areas lie outside the north and south limits of vision for a single revolution of the satellite. These limits move as the tracks move. During a 24-hour period, all parts of the earth's surface between 63 degrees north and 63 degrees south latitude have become visible once.

Successive tracks of a satellite 1200 miles up, and orbiting about the earth's poles every four hours, would make every point on the earth's surface visible at least twice in 24 hours (illustration, lower). The shaded areas again denote limits of vision for a single revolution; the oval shows the area visible at instant of crossing equator.

Areas visible from a satellite on an



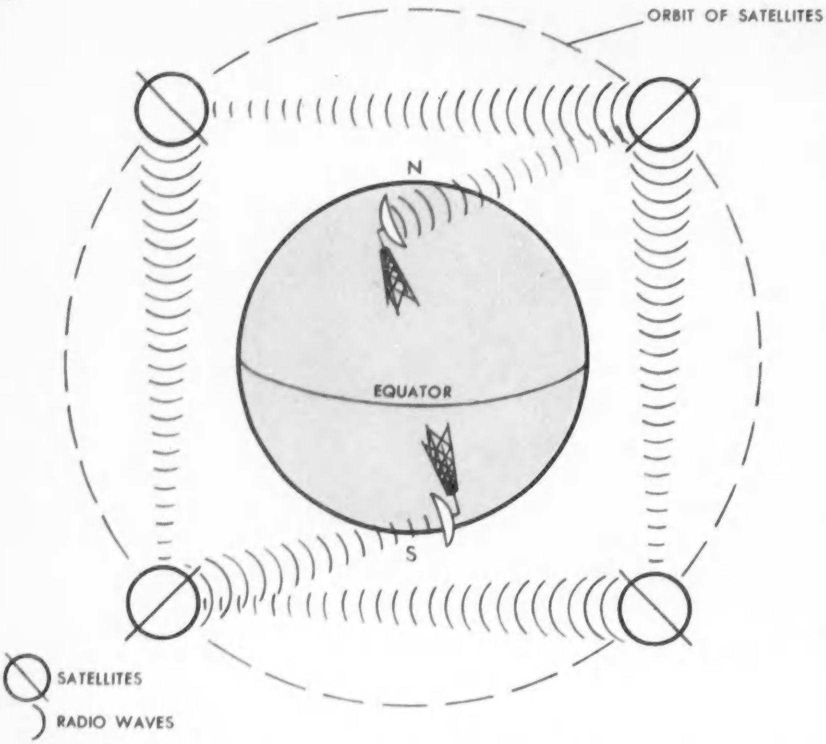


Visual limits of a satellite on an equatorial orbit vary with its height; at 4000 miles, the satellite covers an 8400-mile expanse of earth (above). A single equatorial satellite 22,300 miles up could relay signals across the Atlantic or between the North and South American continents (left).

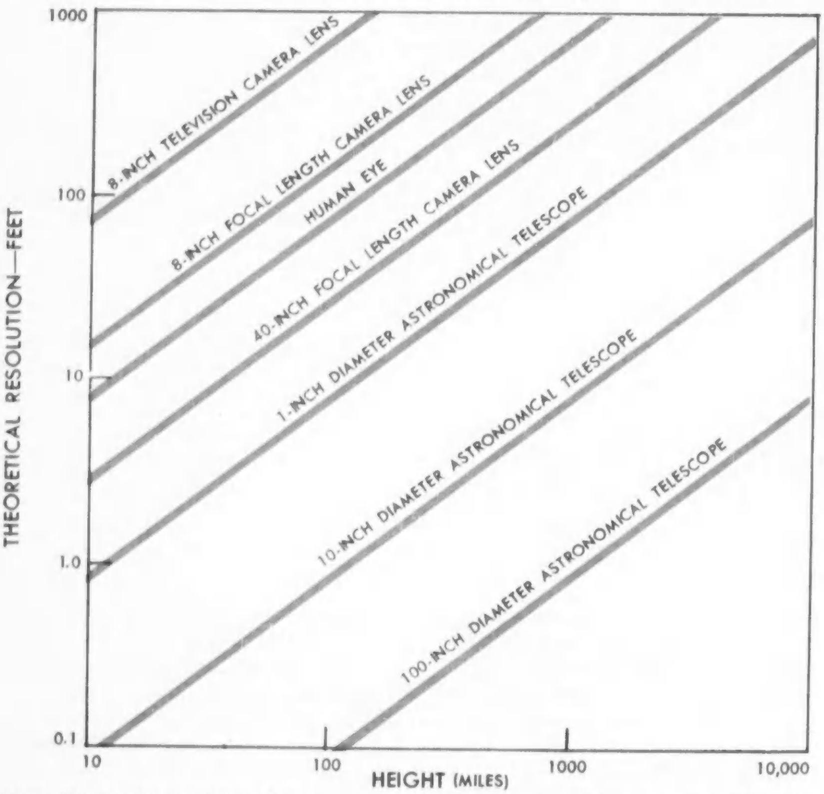
equatorial orbit vary with height (illustration, top). Arrows along the side bound the visible area north and south of the equator. At 4000 miles up, for example, the band extends from 60 degrees north to 60 degrees south latitude—a distance of 8400 miles.

Here an oval represents the earth's surface observable from a satellite 22,300 miles above the equator at 60 degrees west longitude (illustration, lower). Actually a circle, the visible area appears as an oval because of map distortion. Revolving synchronically with the earth, the satellite has a period of 24 hours at 22,300 miles. Because the satellite always appears to stay over the same place, you would see it at the same point in the sky from anywhere within the oval.

The satellite's inherent characteristics suggest early application in three major fields: mapping and geodesy, weather charting and forecasting, and communications. With the foregoing information as a background, let's now move into these areas.



FOUR SATELLITES equally spaced on a 4000-mile-high equatorial orbit provide an excellent communications link. Signals transmitted from earth can be relayed around the world.



LENS SYSTEMS limit ability of cameras to resolve detail at great distances. The eight-inch focal-length camera lens is representative of the type now used to make aerial surveys.

Mapping and Geodesy

Presently you can accurately make maps of the earth's surface in two ways: triangulation or aerial photography. Mapping with an earth satellite parallels both in principle.

Triangulation—In the triangulation system, you accurately measure the length of a base line; towers are located at opposite ends of this line. At various intervening points you then measure—with a transit theodolite—angles to each of these towers. Knowing two angles and the included side for a given triangle, next calculate its remaining sides with trigonometry. By repeating this process for all the triangles, each tower point can be accurately located. Several such triangulations, incidentally, have been carried across the United States.

Surveying by triangulation, though accurate, is slow and expensive. Each tower put up must be taken down, each measurement must be made several times, and the best "fit" must be calculated. Also, the towers must remain stationary, ruling out a survey across a large, undulating body of water.

With the aid of an earth satellite system, the triangulation method would give greater accuracy and coverage than it now does.

To start, first determine the satellite's orbit with great accuracy. This can be done by making simultaneous, angular observations at three successive instants from the ends of the same base line used for the triangulation survey. For a period of several months repeat these measurements when the satellite is visible. While in principle the first three pairs of measurements define the orbit exactly, you'll

TABLE I—VELOCITY AND ORBITS

SATELLITE HEIGHT (Miles)	SATELLITE VELOCITY (Miles per Second)	SATELLITE PERIOD (Hours)
257	4.8	1.59
620	4.6	1.76
1210	4.3	2.06
2222	4.1	2.64
4000	3.5	3.95
7650	2.9	6.95
19000	2.1	19.30
22300	1.9	24.00

need additional measurements to reduce error.

Determination of the orbit makes known the length and position of the satellite's path over a given period of time. Thus angular measurements, made as before, measure the distance between any two points on the earth's surface—with the satellite's path as the base line. (Actually the projection of this path on the earth forms the base line.) Finding the distance between these two points then becomes a matter of relatively simple trigonometry.

With many such distance measurements, you can establish the earth's size and shape—the science of geodesy.

Though the earth's size and shape is fairly well-known at present, observation of the satellite would greatly reduce errors in the calculation. The resultant increased accuracy would significantly serve such groups as astronomers and navigators.

Aerial Survey—An aerial survey simply maps a picture of the earth's surface from a high altitude with a good-quality camera. With certain exceptions, the technique utilizing a satellite in place of an aircraft will remain unchanged. For instance, the camera would be several hundred miles high rather than the usual two to four miles.

Also, the camera itself would be somewhat different. In any camera lens the resolution, or ability to distinguish small objects, decreases at greater distances. Increasing the resolution sacrifices the lens' field of vision.

The resolutions obtainable with present camera systems can be charted (illustration, lower, opposite page). The eight-inch focal-length camera lens represents a type used for aerial surveys. At the heights normally employed, it resolves objects about three feet in diameter—slightly greater than the width of your office desk top. From a satellite 300 miles in space, however, it would just be able to resolve earthly objects 500 feet in diameter. In more physical terms, at this height the camera couldn't distinguish a 423-foot World War II Liberty ship at sea.

Although this resolution would handle an area map, for instance, it wouldn't do for a city map involving resolution of objects three feet across. Photographing a city from a 300-mile height requires an astronomical telescope with about a 10-inch lens opening.

Until further development of the satellite system allows recovery of camera film, early systems will have to avoid this problem. They can use such techniques as television to return aerial photographs to earth.

Resolution with an eight-inch focal-length television camera lens in a satellite 300 miles out in the atmosphere would be about 3000 feet. (Length of the SS *United States* is 916.8 feet.) Not too good you'll agree, but it would suffice for mapping mountains, shore lines, large rivers, and similar masses.

Facsimile, or wire photo—a better technique—takes full advantage of the resolving power of its lens system, whereas a television camera does not. Requiring less equipment, facsimile mapping will probably be used in satellite systems.

Having the satellite reasonably close to the earth assures maximum accuracy and resolution with any surveying system. On the whole, a satellite traveling a polar orbit at an altitude of about 400 miles appears the best compromise for surveying any area on earth.

Considering all these factors, you can reasonably assume that mapping with the aid of an earth satellite will proceed gradually. Some mapping of the triangulation type will no doubt be done with the first successful satellite launching. It will be directed primarily at determining the earth's shape. Future satellite programs using TV or facsimile systems will initiate detail mapping. Eventually, cartographers will complete a world map with the aid of the satellite.

Weather Charting and Forecasting

At any given time, clouds cover from a third to a half of the earth's surface. Photographs taken from research rockets make this strikingly evident.

Knowledge of the extent and type of clouds furnishes much information about the weather. Because the satellite can view cloud coverage over extremely large areas in a short time, it could prove helpful in forecasting future weather, too.

An excellent example of this occurred recently. Photographs taken from a Navy Aerobee rocket launched over New Mexico were assembled into a single composite view that encompassed the lower Rio Grande Valley in southwestern United States. The composite (photo, page 10) showed an unsuspected, fully developed tropical disturbance—similar to a weak hurricane. The storm covered a 1000-mile-diameter area, centered near Del Rio, Texas.

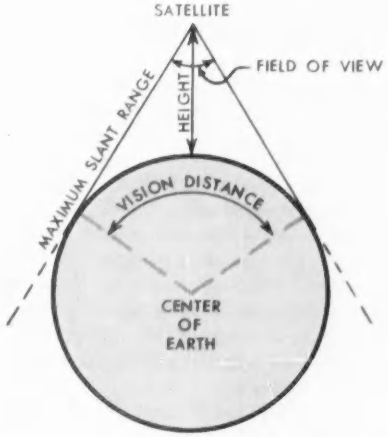


TABLE II—VISION FROM THE SATELLITE

HEIGHT (Miles)	VISION DISTANCE (Miles)	MAXIMUM SLANT RANGE (Miles)	FIELD OF VIEW (Degrees)	EARTH'S SURFACE VISIBLE (Percent)
257	2800	1445	140	17
620	4200	2310	120	25
1210	5600	3350	100	32
2222	7000	4750	80	38
4000	8400	6920	60	43
7650	9800	11000	40	47
19000	11200	22700	20	49
22300	11600	26800	17	49.5

"Three satellites would provide world-wide communication."

A satellite's value in weather service can further be increased by carrying instruments: their readings can be transmitted to the earth. Some instruments could measure the temperature of the earth's surface and atmosphere, the amount of radio static produced by thunderstorms, meteoric dust, the earth's reflectivity, and the intensity of solar radiation. Often made in research rockets with little difficulty, measurements of this type assume importance in long-term forecasts of the weather and its effects.

Because weather forecasting presents no problem of camera lens' resolution, you can select the satellite's orbital altitude for good coverage of the earth's surface: the 1200-mile-high polar orbit should be satisfactory. During the day, extended coverage of the earth could be obtained with one satellite on the polar orbit and another on the equatorial orbit at about a 4000-mile altitude.

Probably a second satellite project, carrying TV or facsimile equipment plus some instruments, will mark the beginning of weather charting and forecasting. As techniques progress and become less experimental, the project will supersede some present-day undertakings—Iceberg Patrol, Atlantic and Pacific weather ships, and hurricane-hunter flights.

Continued attempts to control the weather will bring an increase in the scope and accuracy of weather forecasts. The result: greatly reduced loss of life and property through unexpected weather conditions.

Wireless Communications

High radio frequencies propagate along nearly straight lines, as do light rays. And so, to be usable in communications, each transmitting and receiving station must be within a line-of-sight range. But despite this, the great demand for communication circuits forces more and more services into the higher frequencies. Television, particularly, requires a wide spectrum of operating frequencies.

At present, some high frequencies used for long-distance communication utilize a number of relay stations between the sending and the receiving points. Microwave systems provide a workable example: each relay tower picks up the signal from one station and transmits it to the next. Still, the system requires a large amount of costly and complex equipment and is practical only over land or narrow bodies of water.

Recently, you may have seen several live TV programs originating in Cuba. They were transmitted to the United States by a relay station mounted in an aircraft. The airplane's height increased the line-of-sight distance between sending and receiving points. This same principle proposed for satellite communication systems would increase by many thousands of miles the line-of-sight distances between stations—the satellite's height being much greater than that of the airplane.

As an example, suppose you stabilize four satellite stations on 4000-mile-high equatorial orbits (illustration, top, page 14). Assuming they are equally spaced about the earth, one of these stations will be visible at any instant from any point between 60 degrees north and 60 degrees south latitude. A signal can then be transmitted from any ground location to the nearest satellite and relayed from satellite to satellite. At the proper location, the signal can be retransmitted to a receiving station on earth.

The principle is straightforward: For a single channel of communication, you need a receiver of good quality and a low-power transmitter aboard the satellite. Ground equipment would be more complex, the major item being a large directional antenna that can be pointed toward the satellite.

But if the satellite were 22,300 miles high, you could do without this movable ground antenna. Relative to the earth, the satellite would then be stationary. A properly located single satellite could relay signals across the Atlantic or between the Americas. Three satellites would provide world-wide communication. The equipment needed at this great height would be somewhat more complex but shouldn't pose too serious a problem.

By increasing the power of the satellite's transmitter, the complexity of ground equipment could be reduced to the simple receivers used for home television and FM radio. It appears practical, for example, to provide a wireless signal equal in strength to that now required for cities in every part of the United States. (The Federal Communications Commission requires a greater signal strength in urban than in rural areas.) The satellite station in the 22,300-mile orbit would carry a transmitter output of about 15,000 watts and use an antenna 320 feet in diameter.

Both of these requirements are certainly possible. And additional stations in the satellite orbit could utilize the same antenna, forming a sort of Radio City comparable in extent to the antenna installations that are atop the Empire State Building.

The amount and type of communication from the satellite presents a problem involving both technical and economic factors. To justify the cost of this satellite system, it would have to furnish a new, greatly improved service or a less expensive one. So far, the few preliminary studies of the problem aren't conclusive because a good cost estimate of a large-scale satellite system can't presently be determined. Until better estimates are available, the satellite's future in communications remains unpredictable.

Full use of the satellite as a communication medium probably won't occur until manned operation of the satellite becomes practicable. Television transmission will no doubt be the satellite's first major communication service. And the 22,300-mile equatorial, or synchronized, orbit will probably find greatest use.

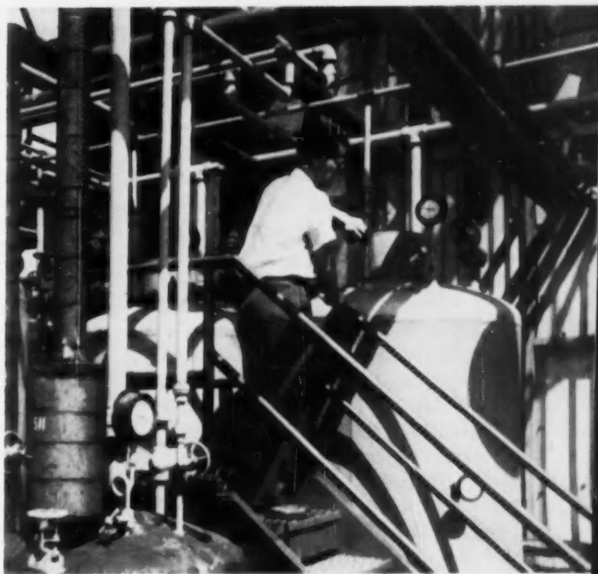
Truth Stranger Than Fiction

Applications of the earth satellite could be projected further and further into the future but that would take us into the science of astronautics. For truly the satellite represents a first step in man's attempt to make a prolonged flight through space. However, the applications of the satellite that have been pointed out here are those attainable within the present limits of our technical knowledge.

Thinking back, you may recall that only as short a time as 10 years ago an earth satellite was generally considered science-fiction material. In fact, only a few years ago many lacked faith in its practical applications.

But progress has accelerated rapidly, and the earth satellite program—Project Vanguard—is now under way. Soon the first flights will be attempted. Considering the wide range of the satellite's potential, you can certainly expect additional programs.

In the not-too-distant future, earth satellites, like modern airliners, may be part of our everyday life. Ω



Self-tracking radar antenna with integrated electronic system (left) is typical of the "systems" thinking that confronts technological teams. Manufacturing engineers handle increased quantities of intermediates used in the production of gum for silicone rubber (above)—meeting another of the industry's demands.

The Electrical Industry Challenges the Engineer

By W. SCOTT HILL

Why has a fairly simple generator-switch-lamp-motor business evolved into a great multipurpose electrical manufacturing industry?

This extensive change involves far more than simple population growth and a general demand for better working and living conditions. One significant influence stems directly from the engineering talent that staffs the industry's technical work force and supplies a substantial part of its management. The energy, ingenuity, and stimulation that come from these engineers and scientists continually improve and enlarge the range of products and equipment. All this in turn stimulates further improvement.

The process of this industrial evolution follows a natural sequence. Knowledge of the steam turbine enabled the electrical manufacturer to move directly into the gas-turbine and jet-engine fields; the vacuum tube plus rapid expansion of the radio industry preluded all of today's high-frequency-spectrum endeavors—still only in their infancy.

Scientific developments originate basically in the fields of physics, chemistry, and metallurgy. Naturally then, countless applications utilize a wide range of chemical products—insulation, plastics, silicones—and the electrical industry not only uses but also produces and sells these products.

Metallurgical developments for the industry's own needs also find wide use elsewhere. New alloys for permanent magnets or cemented carbide cutting tools, for example, become key products in a nonelectrical area. Major appliances and improved lighting as well as the equipment necessary in mass-production industry evolved from the technology that expanded the entire electrical field.

Disciplines in the Industry

Over the years, some industries remain fairly static; others disappear completely. In conservative financial circles today you will find industries having great growth potential described as dynamic. The electric equipment industry—one of those most frequently cited for growth potential—owes its dynamic characteristics to several policies . . .

- Undergirding a program of scientific and applied research with the objective of creating funds of understanding
- Hiring personnel whose creative ideas produce improvements that stimulate the development of new products
- Encouraging the greatest possible freedom and opportunity for the individual to develop these ideas
- Providing team cooperation to carry the ideas through the difficult and often discouraging days of development and into the reality of a profitably saleable product.

Traditionally, the electrical engineer has been a cornerstone in the development of power generation, and its transmission and distribution. To this he now adds the entire field of electronics including control and instrumentation.

Does it surprise you that the electrical industry needs as many—or more—mechanical engineers as electrical? Refrigeration and air conditioning, machine design, and fluid-flow and combustion problems enter into an increasing number of the several hundred thousand products associated with this industry.

Supersonic propulsion problems including missiles and jet engines absorb more and more aeronautical engineers and scientists. And the nuclear power field for aircraft also seeks these men.

Throughout nuclear areas, wide need exists for engineers trained in the metallurgical and chemical engineering fields. They also work in the laboratories and chemical divisions of the industry.

The graduate with a basic engineering degree and a special interest in the manufacturing process itself as well as one with a degree in Industrial Engineering, Production Engineering, or Engineering Administration can move in the manufacturing function. Here he produces products that evolve from the minds of development and design engineers.

Graduates in engineering physics or science should adapt well to the technological work of the future. In the realm of science, physicists and chemists—formerly devoted exclusively to research and the laboratory—now work as important partners of the team.

In this era of computers with its close relations to analysis and design, the mathematician—particularly the applied mathematician—finds a rapidly growing demand for his abilities.

Although smaller in number, additional scientific and technical groups, such as the biochemist and biophysicist in nuclear work and those with a radiological physics degree, fill specialized needs.

Also don't overlook the civil engineer who has a well-rounded background. Industry needs these engineers because of the knowledge of structures that they contribute.

And already automation calls forth engineers with intense creative talents.

Team Approach

Modern technology finds its roots in the basic concept that the most effective progress results by combining the pieces of technical knowledge, as in building blocks, to create a successful industrial unit. Combinations of the foregoing academic disciplines are exercised in many of the steps that form the evolutionary life cycle of a typical technological development.

Basic research occurring in the research laboratory contributes new scientific knowledge that precedes specific application. Then in the next two stages engineers and scientists use their mutual abilities most effectively: in work commonly identified as applied research, utilizing the new scientific knowledge in specific applications; and again in the development stage by the imaginative thinking that produces experimental models to prelude practical usage.

Using creative ability, design engineers convert these models into products, proved and ready for manufacturing. Product engineers act as liaison between designers and manufacturing engineers who encounter production problems.

Important technical work manifests itself in each phase of this manufacturing process—planning, evolving of the equipment, and supervising and coordinating the functions of the skilled workers who operate the machines that convert the materials to finished products.

Once manufactured, the equipment needs a satisfied customer. To him, installation and field service become paramount. Unless the product meets his expectations, he may well question its value. To this end the engineering team functions. It contains the field force so vital to the marketing and servicing of complicated electric products manufactured today. Sales and application engineers perform a great public service. They bring the designers' ideas to the men who utilize them in utility, industrial, or transportation companies.

Because of the great range of technology today, you can be an expert in only a few of its aspects. Consequently, engineers and scientists must choose some phase of the team activity and then become so proficient in it that they can make a genuine contribution—either by their own efforts or by their administrative ability.

Complexities of Growth

New problems—such as "systems" thinking and others now visualized in dim outline—will confront tomorrow's technological team. In the defense area, the application of systems thinking takes on the form of highly complicated missile control or the self-tracking radar antenna with integrated electronic system. Leaders in the mechanical field anticipate not only greatly improved hydraulic control systems for nuclear reactors but also the possibility of combining solar energy with a heat-storage system and a heat pump for domestic heating. Integrated drives in steel mills, on paper machines, or on large power shovels are current applications of the systems approach involving power and control in the combined electromechanical field. The future promises continued development of other systems ideas.

Already computers are provoking another technological revolution, at least for the engineer and scientist. Bigger and faster models solve problems in motor or transformer design and heat-rate or bucket design for turbines, calculate jet-engine performance, and act as engine simulators to save months of model building and testing—only a hint of things to come.

A device that gives the engineer answers to 10 differential equations in 10 unknowns frees him from much empirical experimenting. With analog computers, today's engineer can trace the transient heat-transfer characteristics of some electric machine so that actual design replaces empiricism—one of tomorrow's routines. These and other new tools give the engineer of the future unusual opportunities, easily recognized as computers draw out the performance curves for the interrelated factors of electric power-system problems or electric furnace operation with its associated voltage control.

In this entire area the reliance on chemistry for composition and physics for structural behavior brings sharply into focus the experience of these disciplines as components of the engineering team.

Insulation for new temperature and stress limits of rotating equipment, lubricants for fantastic operating conditions, as well as propellant fuels and combustion chambers for rockets draw heavily on such knowledge. Solid-state physics contributes new knowledge of boundary layers. Transistor development follows with its concentration to obtain a stabilized wide-frequency-response device capable of being mass-produced. From this comes the miniaturization of all types of electronic devices and attendant circuitry redesign, with ulti-

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Mr. Hill, a previous contributor to the REVIEW, *has been associated with General Electric for 33 years. He is Manager, Engineering Recruiting, Engineering Services, Schenectady.*

". . . the engineer must do the broad, creative thinking . . ."

mate consequences that only the most visionary can perceive today.

Will the material limitations that constitute one of the great frontier problems be any less a barrier tomorrow? Operating tomorrow's atomic power plant will require more and better knowledge not only of nuclear fission fuels and their enclosures but also of the behavior of shielding or structural materials under radiation. Turbine generators have increased from 75,000 to 192,000 kva at 3600 rpm in the last 10 years. They can now be built for more than 300,000 kva and will be projected to 500,000 kva in another 10 years. Though all these require great technical knowledge in stress analysis, heat-transfer, and fluid flow as related to coolants, metallurgical problems of materials at high temperature or stress loom as large as any.

Look at any field—electromagnetics or dynamics, heat-transfer or fluid flow, electronics or elasticity—and you'll realize that knowledge of systems, materials, and computers will have still greater importance tomorrow. Analysis indicates that much of the knowledge needed is founded on science, clarified by understanding mathematical relations developed through engineering science, and finally carried to the useful product stage through the engineer's work.

The Changing Educational Concepts

Engineering colleges for the past 20 years have tended to turn out graduates equipped with the practical knowledge to begin work immediately in some specialized field. This seemingly meets the needs of many industries at the moment, but only a slight backward glance shows that many of the technologies of even a few years ago are already superseded.

This realization led to a search for programs that would not be obsolete by the time the senior student took his degree in hand and accepted a job.

Certain basic technical material underlies most technical work. From this search evolved a greater emphasis on these common understandings. They begin with physics and chemistry, build up to the engineering sciences, seek the true meaning and understanding of mathematics, and end with some concentrated study experience in one or more of the engineering fields.

Most of the advanced colleges have revised their thinking: delay specialization until the individual reaches the very end of his undergraduate work; keep it relatively minor in character even then. The truly specialized knowledge will come later—either in graduate school or through some advanced education process associated with work experience.

Senior engineering students often ask, "Should I start work immediately, go to graduate school, or get a little work experience and return to academic work later?" The answer depends more on the individual than on any formula. Usually the greatest contribution to society will be made if those with outstanding capabilities prepare themselves academically to the highest reasonable level of competence. The doctorate implies specialization in depth for the esoteric, but the percentage of those who can achieve this will probably always remain low. Graduates increasingly look on the master's degree as providing that extra year for gaining specialized knowledge to supplement the bachelor's degree. And company educational programs also help the graduate to acquire extra knowledge.

For many students immediate work experience is indicated. Probably some would not meet the qualifications of an accredited graduate school. Their interests or objectives may be better realized by using these first years to gain experience. Perhaps the stimulation and competition of the industrial world more actively motivates them than would academic work.

Undoubtedly the engineer or scientist will pursue education in one form or another throughout his lifetime. Obtaining this at maximum efficiency requires planning and direction—often possible through participation in classroom work at the graduate levels at neighboring universities, or through company-operated education courses.

A great difference between undergraduate preparation and industry experience lies in the area of problem solving. For this reason industrial educational courses have a twofold purpose: to assure the individual's knowledge of mathematics plus the engineering sciences and then to build both competence and confidence in his own ability to solve engineering problems.

The developmental nature of the electrical industry places a high premium on creativity among its technical personnel. To this end, courses teach the young engineer how to improve his creative ability and turn out significant original ideas in new fields.

Seeking Professional Stature

What range and perspective does the electrical industry display to the technical man? Early in his professional career, he will be involved in its technical operations almost exclusively. As he grows in experience, clarifies his objectives, and has his abilities challenged, he'll discover that his choices have led to several careers. Broadly, these divide into two categories: professional leadership through application of technical knowledge or administrative leadership through directing the work of others. Few know in their early years which one they will develop the most aptitude for or which will be more rewarding or satisfying. Before making a final commitment, some often try both. The more versatile have combined them to a remarkable degree, earning outstanding recognition in both technical and executive pursuits.

Unfortunately, technical men often find it difficult to relinquish portions of their work to engineering or laboratory technicians. The individual who learns to utilize others of less technical competence for supplementary work enhances his own professional stature. As industry moves more toward the use of computers or systems concepts, the professional engineer must do the broad, creative thinking and leave the details and repetitive work to others.

Rigorous Problems Ahead

Over the years the electrical manufacturing industry has solved deep and challenging problems. And because of its growth potential, subsequent problems will be even more rigorous. To overcome them will require the finest brains from all the varied engineering and scientific disciplines. Ω

CREDITS

Page	Source
10	U.S. Navy Research Laboratory
27 (upper and lower right)	Burns Photography, Inc.
47 (lower right)	American Management Association
48 (right)	Underwood Corp.
52–57	Jay Seymour

Unique Phosphors That Amplify Light

By D. A. CUSANO and DR. F. E. WILLIAMS

The intensity of the cathode rays that scan the screen of your television picture tube is modulated in proportion to the electric signals received from the television station. Because the amount of light generated in this phosphor screen depends on the intensity of the bombarding beam, a visible picture is reproduced. Thus the beam's primary function is to transmit information to the viewing screen. If this were the only function of the beam, such an operation could be achieved efficiently and inexpensively with a small tube operating at low voltage and current. Unfortunately, the same electron beam that contains the picture information must play a second role—that of generating a high brightness in large television screens. This requires operating the picture tube at a much higher voltage and current, which necessitates expensive equipment.

A better television system would utilize the electron beam merely to control, not to provide, power for the generation of light. This can be achieved by using a light amplifier, which takes a faint image and with inexpensive low-voltage power produces a much brighter picture. For example, with a suitable lens arrangement, a weak image from the face of a small low-voltage television tube would be fed to a large-area light amplifier and there increased in brightness many times. Briefly, a good amplifier would permit the separation of the information role from the light-generation role, permitting each job to be done more efficiently and inexpensively.

A similar situation exists in x-ray fluoroscopy. The x-ray beam penetrating your anatomy must not only emerge with the information about your ulcer but also be intense enough, unfortunately, to excite a sufficient amount of light in the fluoroscopic screen.

Because of the small electroluminescent background of present light-amplifying phosphors, this observation was made at an x-ray dosage higher than ordinary medical dosages. In actual practice the x-ray dosage is determined not by the intensity necessary to get the information into the emerging beam but by the power necessary to make the information visible to the radiologist. To minimize the dosage, the radiologist suffers the inconvenience of becoming dark-adapted. At these low light levels the eye does not perceive images clearly. Again, a light amplifier would separate the role of communicating information on your ulcer from the role of generating light at the fluoroscopic screen. A faint image would thus be amplified in brightness, with only the information requirement determining the x-ray dosage.

During the past decade, electronic methods of light amplification utilizing special vacuum tubes and circuits have been extensively explored. Particular emphasis has appropriately been on fluoroscopic image intensification. Closed-circuit television systems and image tubes, although moderately successful in a few large radiological installations, have not become widely used. However, development work on these systems is continuing. One inconvenience of the electronic methods for general fluoroscopic examinations: the radiologist must work at some distance from a patient, because the image is reproduced on the face of a cathode-ray tube. Cost prohibits the electronic methods of light amplification for home television. Thus x-ray fluoroscopy, television, and other image display devices are in great need of a simple light-amplifying screen.

Luminescence of Crystalline Solids

Phosphors are crystalline solids capable of light emission without heating when suitably excited. In a fluorescent lamp, ultraviolet photons from the mercury discharge excite the phosphors. Because the excitation is by photons, the phenomenon is called *photoluminescence*. With the best lamp phosphors, one visible photon is emitted per incident ultraviolet photon. X-ray photons also excite photoluminescence. Phosphors can also emit light when bombarded by cathode rays; hence the term *cathodoluminescence*. In the past few years the excitation of luminescence by a voltage applied to the phosphor has received much attention. In this phenomenon we see a direct conversion at room temperature of electric energy into light—thus the term *electroluminescence*.

Solid-State Light Amplification

We have recognized for some time that if electroluminescence could be initiated and controlled by incident light, image amplification in phosphor screens would be feasible. We reasoned that amplification might be achieved by the incident light affecting either the electric field in a phosphor or the density of mobile electrons because these quantities determine the electroluminescent intensity.

Two years ago we announced and demonstrated light amplification in a simple phosphor film (illustration, left, page 22). Amplification of radiation with a simple phosphor involves a basically new phenomenon—*photoelectroluminescence*—indicating not only that the incident radiation initiates and controls the light emission but also that the power required for this light emission comes from voltage applied to the phosphor. Phosphors exhibiting this phenomenon are appropriately termed *light-amplifying phosphors*. The way the amplifier works is described on the opposite page.

Recently, several laboratories including ours have described another type of solid light amplifier. It does not involve a new phenomenon but instead utilizes two well-known solid-state elements to achieve radiation amplification (illustration, right, page 22). In its simplest form this method involves a photoconductor and an electroluminescent layer in series sandwiched between two electrodes—one transparent. Alternating voltage is supplied to the electrodes. The impedance of the photoconductor—for example, cadmium sulfide—is arranged so that in the dark the voltage applied

TEXT CONTINUED ON PAGE 22

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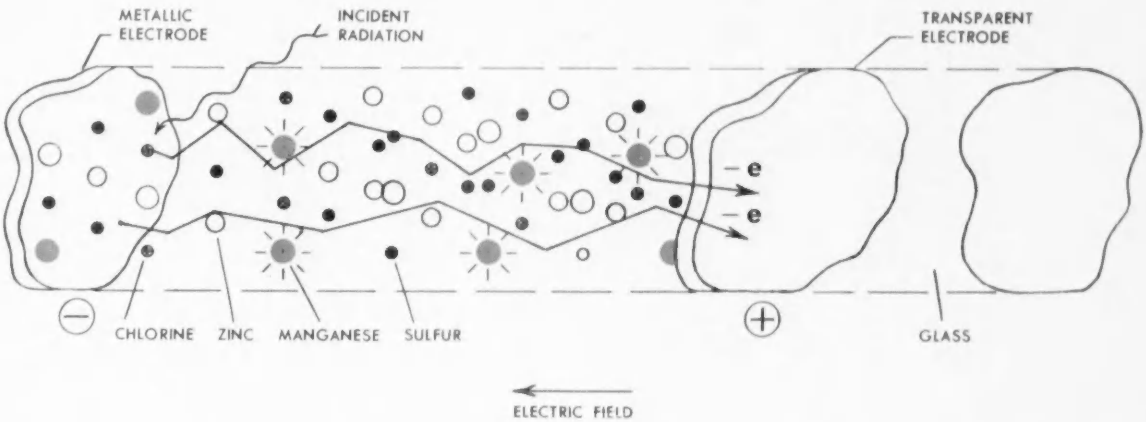
Mr. Cusano and Dr. Williams are both with the General Physics Research Department, General Electric Research Laboratory, Schenectady. Joining GE in 1949, Mr. Cusano—research assistant, Light Production Studies Section—carries out development of transparent phosphor films and experiments in cathode-ray excitation of phosphors, electroluminescence, and the solid-state amplifier. With the Company since 1948, Dr. Williams—Manager, Light Production Studies Section—was an invited speaker at the Cambridge (England) Symposium on Luminescence in 1954.

HERE IN SIMPLE TERMS IS HOW LIGHT-AMPLIFYING PHOSPHORS WORK

MECHANISM OF PHOTOELECTROLUMINESCENCE



Activator Systems

Impurities largely determine the luminescence of phosphors. The impurity atom and its neighboring atoms in the crystal comprise the activator system. The properties of the activator system dominate photoluminescent excitation and emission.

Pure zinc sulfide is transparent to radiation in the near ultraviolet. The introduction of chlorine as an impurity yields an activator system that strongly absorbs radiation in the near ultraviolet. The chlorine atoms actually substitute for sulfur atoms. The excited chlorine activator system is versatile: it can emit blue light; it can transfer energy to another activator system; or it can ionize to form a mobile electron and a stationary positive charge. The relative probabilities of these events are influenced by temperature, local electric field, and the presence of other activator systems.

The introduction of manganese as an impurity has a barely perceptible effect on the absorption of radiation by zinc sulfide. The manganese atoms substitute for zinc atoms. The manganese activator system makes up for failure to absorb radiation by its astonishing facility for acquiring energy from other activator systems. The manganese activator is particularly effective in acquiring energy that is originally absorbed by the chlorine activator system. As a result of the energy-transfer process, the manganese activator finds itself in an excited state with no choice regarding its future—it can only radiate yellow light.

Thus the chlorine and the manganese impurities serve two distinct roles in photoelectroluminescent zinc sulfide: the chlorine is responsible for the absorption of ultraviolet; the manganese, for the yellow emission.

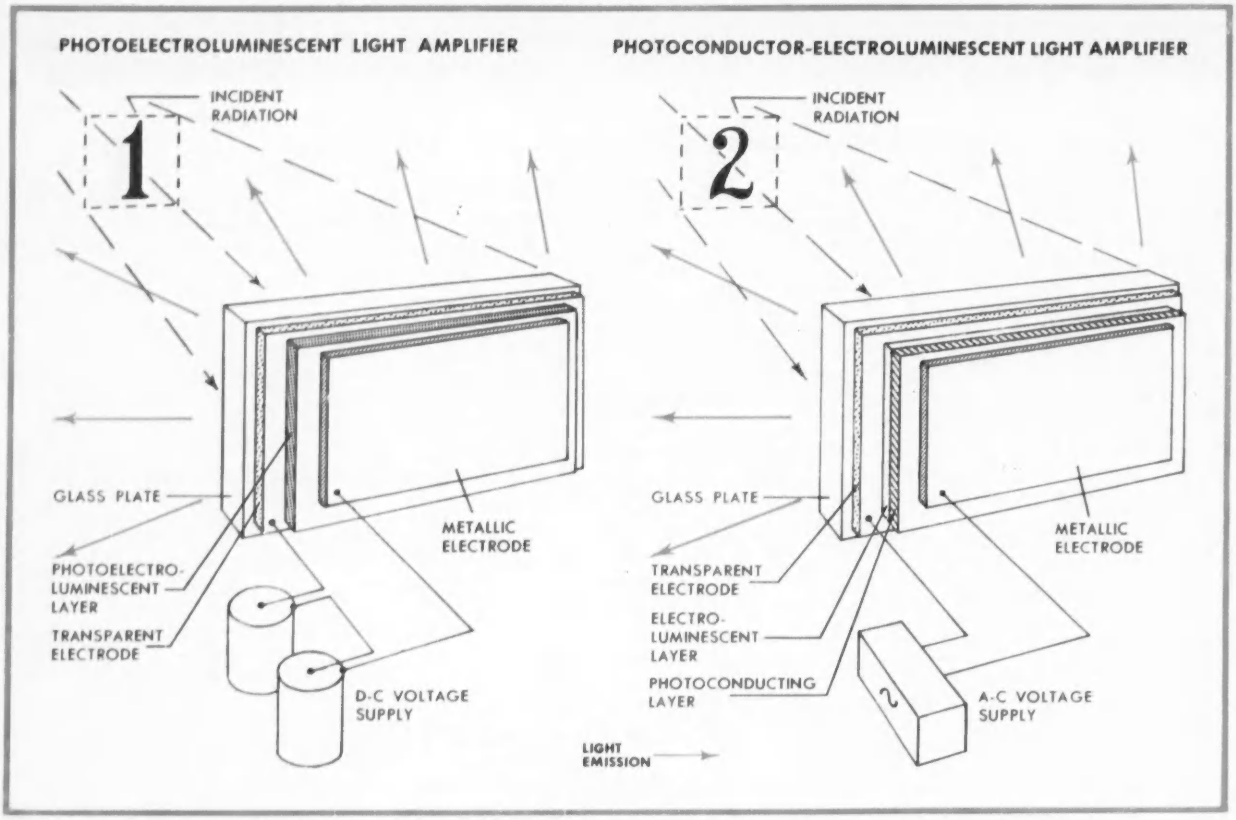
Mechanism of Light Amplification

The photoelectroluminescent process is responsible for the light amplification observed. Obviously, the applied voltage must provide the energy for the emitted light; otherwise we could never hope to realize more energy radiated than falls on the phosphor. Therefore, each photon of ultraviolet must somehow control the electroluminescent production of several photons of visible light.

The control is achieved as follows: Consider the same absorption of ultraviolet light that we did a moment ago, but also consider the absorption taking place while the phosphor is subjected to a strong electric field. The excited chlorine activator system now invariably becomes ionized, precipitating a series of propitious conditions and events. The stationary, positive-charged activator system increases the electric field locally. The positive space charge increases the field near the cathode from 10^5 to 10^6 volts per centimeter. The enhanced electric field facilitates penetration of the cathode barrier by electrons from the metal electrode. In addition, the ionization of the chlorine activator system has also provided a mobile electron in this high-field region. Finally, additional mobile electrons are created by inelastic collisions of mobile electrons with bound electrons in the high-field region. Dielectric breakdown is avoided by the termination of avalanches before they attain catastrophic size. The limited distance over which the high electric field extends limits the size of the avalanches. The combined efforts of charge-carrier formation by ionization of the chlorine activator system, barrier penetration, and collision ionization of bound electrons insure that many mobile electrons arise from each ultraviolet photon. Also, the conditions for electroluminescence now exist.

The electroluminescence of zinc sulfide requires the formation of a region with a high electric field and also the creation of mobile electrons in the high-field region. The mobile electron can then be accelerated to sufficient velocities so that inelastic collisions with activator systems may occur, thereby exciting the activator. In ordinary electroluminescence the high-field region is formed by thermal ionization of weakly bound electrons, whereas the mobile electrons are created in the high-field region by electric field ionization of more tightly bound electrons.

In photoelectroluminescent zinc sulfide, however, the high-field region and the mobile electrons result from the excitation of the chlorine activator system by the incident ultraviolet. The excitation of the manganese occurs both directly through inelastic collisions by high-velocity electrons and indirectly through transfer of energy from collision-excited chlorine activator systems. The manganese then emits yellow light that is well in excess of but controlled by the incident ultraviolet.



INCIDENT RADIATION initiates and controls light emission. Amplifier (right) utilizes two well-known solid-state elements.

to the electrodes is almost completely across the photoconductor. Because there is very little voltage across the electroluminescent layer, no electroluminescence occurs. When exposed to radiation, the impedance of the photoconductor decreases, more voltage appears across the luminescent layer, and light is emitted. If the incident radiation forms an image, it can be reproduced and amplified in the screen. If this or any other screen responds to its own emitted light, some means such as an opaque layer between the two elements may be used to prevent light feedback.

Our primary concern here is the preparation, properties, and theory of light-amplifying phosphors—appropriate because of the important new physical phenomenon involved, as well as their promise for practical image intensification.

Preparation

Phosphor coatings such as those used in fluorescent lamps, television tubes, and fluoroscopic screens are made up of different materials and in these applications are excited to light emission by different forms of energy. All these coatings are composed of layers of phosphor powder—that is, microcrystalline phosphor grains of irregular shape and size. To achieve light amplification in phosphors, it is important to have an electrically continuous and homogeneous phosphor layer without grain-to-grain contacts. Such a layer permits intimate contact with broad-area electrodes and supports the high electric fields involved in this new phenomenon. Fortunately, the development in our laboratory of the vapor-deposition method, originally for making high-resolution cathode-ray-tube screens, provided us with phosphor layers having the desired characteristics. After extensive research on diverse phosphors amenable to vapor deposition, zinc sulfide containing manganese and chlorine impurities was found to exhibit photoelectroluminescence.

To coat a glass plate with this phosphor, the plate is placed in a quartz coating chamber heated to a temperature of 600 C (illustration, top, opposite page). A mechanical pump connected to the outlet tube at the top of the chamber exhausts the air and maintains this exhaustion. Hydrogen-sulfide gas is then permitted to flow into the chamber at the bottom and out through the top, maintaining a hydrogen-sulfide pressure of one millimeter of mercury. The formation of zinc sulfide on the plate begins as soon as a mixture of zinc, zinc chloride, and manganese chloride is injected into the hot chamber. This provides a constant source of the vapors, which intermingle with the hydrogen sulfide and react with it when they reach the hot glass plate, producing zinc sulfide that has manganese and chlorine as impurities. The layer continues to increase in thickness until the injection of powder is halted.

In the fabrication of the light-amplifying screen, the zinc sulfide must be formed directly on one of the conducting electrodes. The glass is precoated with a layer of titanium dioxide. This transparent layer, originally nonconducting, becomes conducting during the vapor deposition of zinc sulfide. Finally, application of a second electrode completes the amplifier construction. This electrode is a metallic layer, which can be deposited in a variety of ways—most commonly by vacuum evaporation. Thus the phosphor sandwiched between two electrodes—one transparent for light emission—forms the amplifying screen.

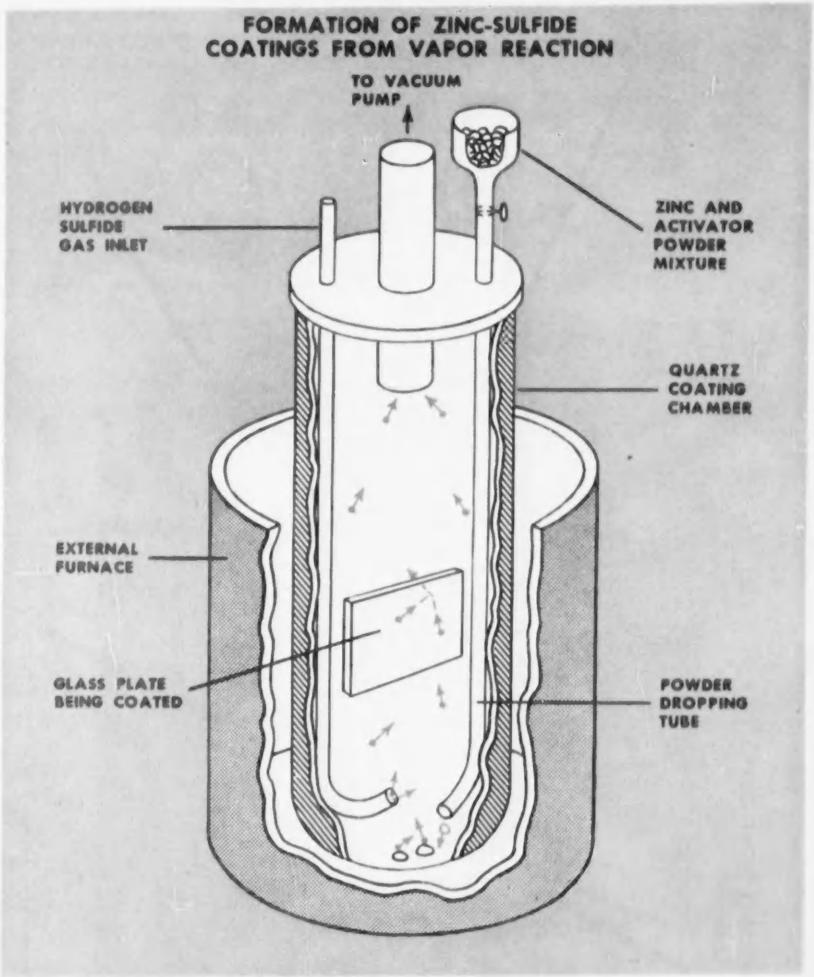
Properties

The screen can be examined simply by applying voltages to the electrodes, with ordinary batteries. Because of the simple geometry of the screen and the homogeneity of the phosphor, the application of voltage subjects the phosphor to an electric field. Dividing the voltage by the thickness of the phosphor layer gives the average value of the field. The layer is as thin as one thousandth of a centimeter; consequently, we can obtain a high field by applying only 100 volts. The phosphor layer will break down if a voltage greater than 100 volts is applied to it.

Even these high fields in the phosphor produce only feeble light emission. In other words, the phosphor does not electroluminesce well in the absence of external radiation. But irradiating the screen with either x rays or ultraviolet rays while maintaining the applied voltage produces a marked increase of light emission. In fact, an analysis of the intensity of the emitted light discloses as much as seven times the energy in visible emission as the energy incident in the ultraviolet beam. The photons multiply elevenfold. The difference between the seven and the eleven arises, of course, because an ultraviolet photon is more energetic than a visible photon. In other words, the incident radiation has initiated, or "triggered," electroluminescence—the ability of the phosphor to extract energy from the applied voltage and to convert that energy into light.

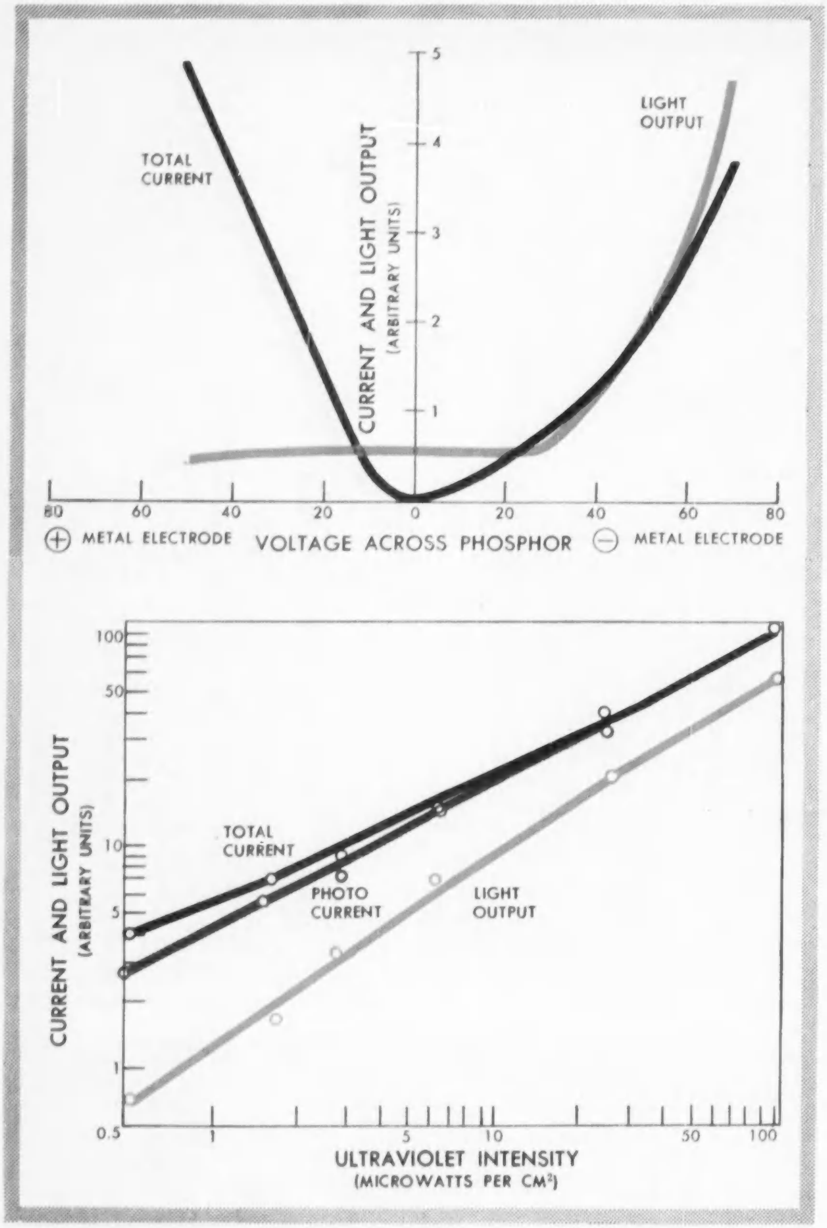
Let's examine the behavior of light output with voltage, noting the requirement that the metal electrode be negative (illustration, top, next page); otherwise, no increase of emission is observed. The light output at zero voltage is, of course, photoluminescence of the phosphor with ultraviolet excitation.

Before considering light-amplifying phosphors for image reproduction, it must be shown that the ultraviolet or x-ray beam is more than just a switch to turn on electroluminescence. Increasing the intensity of the incident radiation yields more light emission. By means of the screen the incident radiation controls the amount of electroluminescence. Because the incident beam contains the information to be reproduced and amplified, image reproduction, let alone amplification, could never be achieved without this additional



VAPOR-DEPOSITION METHOD produces phosphor layers having desired characteristics.

LIGHT-AMPLIFYING phosphor cell is examined by authors Cusano (left) and Williams.



LIGHT OUTPUT AND CURRENT depend on voltage across the phosphor with constant ultraviolet irradiation (top) and on ultraviolet intensity with constant voltage (lower).

property. The amplification is nearly linear (illustration, lower). Thus good contrast is maintained during amplification.

If sudden changes are made in the intensity of irradiation, the light emission requires finite times to adjust itself to new values. These times range from a few hundredths of a second to several seconds, corresponding respectively to high- and low-irradiation intensities. These time constants put an upper limit on the rapidity with which an image can change.

In the light of the mechanism of photoelectroluminescence (discussion, page 21), these properties are understandable.

Applications

The most probable application of light-amplifying phosphors in the near future will be intensified fluoroscopic screens. This application is attractive not only because of its importance to human welfare but also because the requirements are less stringent than for most other applications: the useful brightness level is modest; a response time of a tenth of a second is satisfactory for most fluoroscopic work; and the color of the emitted light is not critical.

Radiation-amplifying phosphors can be used in fluoroscopy in two ways . . .

- The simplest method utilizes an amplifying phosphor sensitive to x rays. We have observed photoelectroluminescence with x rays exceeding in brightness the response of the best photoluminescent fluoroscopic screens. To attain further intensification with x rays and also to fully utilize the information in the x-ray beam, we must devise thicker phosphor layers so that most of the impinging x-ray energy will be absorbed.
- A somewhat more complex method utilizes a light-sensitive amplifying phosphor in conjunction with an ordinary fluoroscopic screen. In this system the x-ray photons are absorbed by an efficient fluoroscopic screen, and the light emission from this screen is amplified by the contiguous light-amplifying phosphor.

The application of light-amplifying phosphors to television belongs to the more distant future. The brightness level, response and afterglow times, and color requirements for television receivers demand pronounced improvements in light-amplifying phosphors. In principle, these phosphors have attractive possibilities for color television. For example, color switching could be achieved by switching the modest voltages on three contiguous light-amplifying layers responding to the emission from a cathodoluminescent screen. In this way, both brightness amplification and color switching are achieved.

In general, light-amplifying phosphors should be considered for application to any visual information display system in which brightness is a problem or in which adequate brightness has been attained inefficiently. The practical application to most problems awaits further improvements in light-amplifying phosphors. Modifications of the response and emission characteristics are being pursued in the light of our improved understanding of photoelectroluminescence. In addition, investigations of these unique phosphors are yielding interesting information on many aspects of the physics of solids. Ω

Breathing the thin air of upper altitudes, an advanced turbojet engine thrusts Lockheed's needle-nosed F104A *Starfighter* (above) at high supersonic speeds. Such an engine is the product of much imaginative research and development. The plastics compressor blades (right) that exhibit no wear after running through a 100-hour test of endurance are an example of present development.

Flight Propulsion—Out of Thin Air

Review STAFF REPORT

"Air power is like poker. The second-best hand is worse than none at all."

Gen. George C. Kenney
Former Commander, Allied Air Forces
Southwest Pacific

America's aircraft industries, up to the present time, have followed a cyclic pattern: they wane in peace and produce near miracles in war. Will history continue to repeat itself?

The pattern began with World War I. Ironically, the nation that pioneered powered flight was caught with only a handful of pilots, balloonists, and obsolete planes on hand. Yet by the war's end, United States Air Service had developed up to 1200 trained pilots and 45 squadrons of aircraft, plus supplying large numbers of aircraft engines to our European allies.

However, when the armistice came, public pressure forced a wholesale canceling of contracts with America's fledgling aircraft industries.

World War II and associated events are still vivid. Using her high productive capacity, America built up the mightiest air force the world had ever known. But again, when hostilities terminated, contracts with aircraft industries were canceled. The giants of aeronautical technology found themselves with no business to support or justify their existence.

During the early postwar years, air frame manufacturers tried as best they could to preserve their nucleus of knowledge. One, the Boeing Airplane Company, even commenced construction of 50 large transport planes without orders. These subsequently became civilian counterparts of the military KC97 *Stratotanker*.

Manufacturers of aircraft propulsion systems followed a similar course, seeking out refinements that would give their engines greater output and reliability for less weight and cost. In September of 1948, a North American *Sabre Jet* powered

TEXT CONTINUES ON PAGE 28
OVERLEAF: PROPULSION SYSTEMS

HONEYCOMB SANDWICH of stainless steel and lightweight core has 80 percent more strength than solid structural members. Used developmentally for casings, tail-pipes, and nozzles, it also withstands high bending loads and temperatures.

JET ENGINES are subjected to simulated altitudes

OUT OF THIN AIR (Continued)

PROPULSION SYSTEMS:

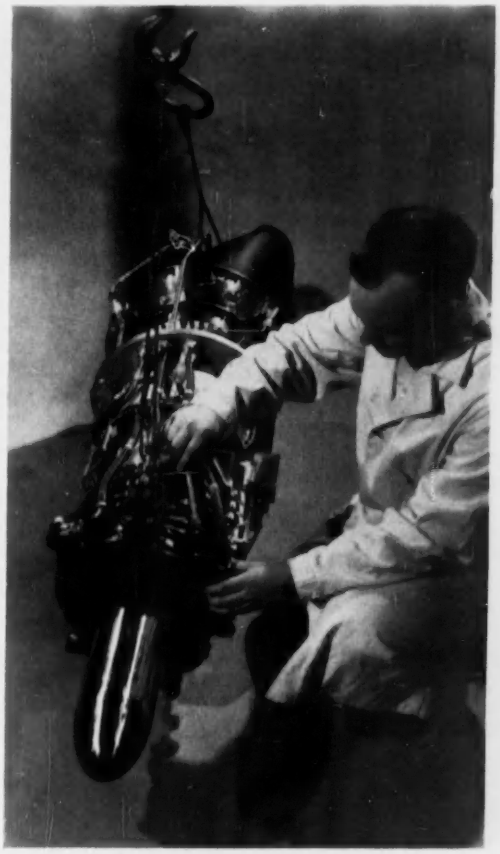
Flight-propulsion systems may seem simple, but their applications rank among the most advanced and difficult branches of technology.

Subjected to great temperatures, pressures, and forces, a jet engine must remain in perfect balance while operating under severe environmental conditions.

To meet today's exacting standards of quality, flight-propulsion systems require thousands of hours of research, development, and testing.

ORDINARY FLAME, key to greater thrust, gets intensive study in laboratory (photo, above). Technologist (photo, right) analyzes action of noz-

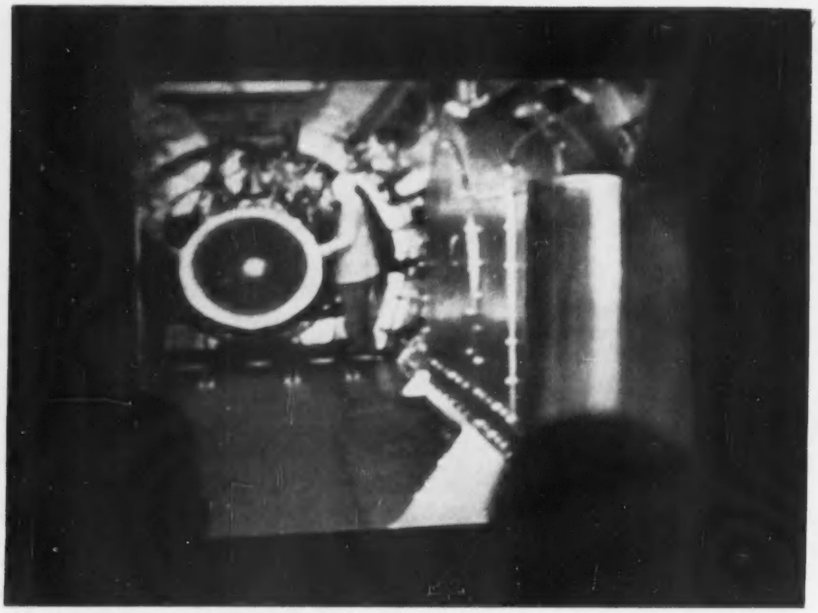
and low temperatures in a steel test chamber located at Lynn, Mass.



HELICOPTER gas turbine puts out about 1000 hp.

Products of Diversified Research and Development

zle on a custom-built 60-pound-thrust rocket motor. When pressure at nozzle equals that of surrounding medium, the efficiency is greatest.



CLOSED-CIRCUIT TELEVISION shows viewers at Evendale, Ohio, a jet-engine test being conducted in Lynn, Mass. A digital computer at Evendale quickly calculates the test data.

by General Electric's J47 turbojet engine set a world speed record of 670.98 mph. Then, in 1949, an experimental Boeing bomber propelled by General Electric J35 engines flew coast to coast in 3 hours, 46 minutes. The bomber was a prototype of today's B47 *Stratojet*, backbone of the United States Air Force (USAF) Strategic Air Command. Later that year, the General Electric J47 became the first jet engine certified by the government for commercial aircraft.

With the outbreak of the Korean conflict in 1950, America's aircraft industries weren't thunderstruck by the sudden demands made upon them. They were accustomed to the cycle.

In that year, America had a total of 8000 combat aircraft. Arrayed against this force, potentially, were 20,000 Russian first-line planes and an equal number in reserve. But, characteristically, within two years our aircraft production rate tripled. Research and development brought about new types. Engine power grew steadily.

A Shift in the Cycle . . .

Open warfare in Korea ceased with the signing of the truce agreement between the United Nations and the Communist delegates of North Korea and the Peoples Republic of China at Panmunjom in July of 1953. But this time America did not revert to its usual peacetime procedure of total disarmament; nor has it since.

Jet aircraft first came into extensive open conflict in Korea. Our planes were forbidden to cross the Yalu River, Korea's northern boundary. But USAF North American F86 *Sabre Jets* with advanced General Electric J47 engines established a 14:1-kill ratio over enemy fighters—principally the Russian-built MIG15. Experts attribute this lopsided ratio not to superiority in numbers but to the superior quality of American planes and pilots.

America's aircraft industry achieved this quality through persistent research and development. Today it is wholly committed to this course. To remain a great nation—economically or otherwise—a country's aircraft industry must be efficient and up to date. Thus it concentrates on quality rather than quantity, on continual improvement rather than a crash program of production.

The industry pursues a twofold challenge: a business rivalry on a competitive scale nationally and a contest for survival internationally. American manufacturers spur competition from within; foreign manufacturers—notably the Sovient Union—provide outside stimulus.

. . . and Responsibility

It may surprise you that this nation's leading electrical manufacturer, General Electric, also leads in the manufacture of aircraft propulsion systems. A pioneer in the industry, General Electric built America's first turbojet engine in 1942. Since then, the company has produced more than 31,000 turbojet engines. And one of them, the General Electric J47 turbojet mentioned earlier, is flown more than any other engine in the world.

Earlier this year, military officials—including the USAF vice chief of staff—aviation journalists, and reporters from all over the country visited General Electric's Aircraft Gas Turbine Division (AGT) headquarters plant in Evendale, Ohio, a few miles north of Cincinnati. Even to someone accustomed to such events, the meeting proved unusual. Billed simply as "a tour of development facilities for flight-propulsion progress," the affair was more than that: a large privately owned company, with 50 years' experience in aeronautical technology, displayed its achievements in flight propulsion.

In another sense, the meeting gave testimony to the freely competitive economic structure of America. In addition to exhibiting facilities that made past advancements possible, AGT's general manager, J. S. Parker, disclosed plans for building a supersonic test facility. The cost for the first phase will be roughly $20 million—a considerable private investment in research and development.

You grasp its significance more readily from the words of USAF's vice chief of staff, General Thomas D. White, spoken at a dinner highlighting the Evendale meeting: "Our great corporations can best volunteer efforts in the area of research and development," he said. "Research, especially basic research, is best accomplished by unfettered initiative working in an environment of complete freedom."

And so, the meeting sounded the arrival of what may mark a new era in America's history of flight: a shifting of a large share of responsibility for basic research and development from the government to private industries.

Many-Sided Technology

Understandably, many of the journalists present at the meeting wanted to know about General Electric's activities in guided missiles, aircraft nuclear propulsion, and the earth-satellite launching—some of the more glamorous activities.

The full spectrum of aircraft propulsion alone, however, includes such things as advanced turbojets, rocket motors, new types of gas-turbine engines, and unique concepts of propulsion. To these, you can add other types of engines that you hear more of each day: ramjets, turboprop, and turbofan engines—for fixed wing, rotary, and pilotless aircraft. Generally overlooked, too, are the turbine-driven accessories so vital to flight, notably: engine starters, fuel pumps, electric alternators, and turbosuperchargers.

Electronics—or "avionics," to use popular terminology—has become another vital segment in aeronautical technology. Expressed in terms of dollars, you immediately grasp the significance of this field. Every single watt of electric power consumed by electronic equipment now under design increases an aircraft's cost by nearly $20.

General Electric's J79 turbojet caused much conjecture among aviation writers. After much research and development, it went into production this year and now powers Lockheed's needle-nosed F104A *Starfighter*, the world's fastest fighter plane (photo, top, page 25). (According to Lockheed the plane compares to " . . . putting a saddle on 60,000 hp and flying it as fast as a 16-inch shell.") A commercial version of this engine, incidentally, will power the Convair 600, America's fastest jet airliner. This turbojet will produce more thrust per pound of engine weight than any other in its class.

Undoubtedly, the General Electric J79 turbojet represents one of the greatest advances to come out of existing facilities. Yet plans for future engines indicate as great a gain over the J79 as this engine now shows over its famous older brother, the General Electric J47.

BELL P59 AIRACOMET, propelled by two of the first American-built turbojet engines, zipped through the air on October 2, 1942. Each of its engines delivered 1250 pounds of thrust.

Glimpse Ahead

You can plan and organize till doomsday, but progress doesn't come about automatically. Creative research and development are essential. Accordingly, the proposed supersonic propulsion facility will play a large part in perfecting engines of the future.

Engineers will be able to "fly" large jet engines at simulated high altitudes and speeds to 2300 mph while duplicating conditions encountered when a jet aircraft dives or climbs. Temperatures generated by wind friction at high velocities create many mechanical and metallurgical problems. But with the new facility their solution will be accelerated. The result: engines can be handed over for production in a shorter time. In this area, some think that the United States has been losing ground to Russia.

Compressor blades of plastics (photo, right, page 25), a product of present facilities, impressed people on the tour. Used in five stages of a General Electric compressor rotor, they test operated successfully for 100 hours. They are limited at present to a maximum temperature of 500 F; in more advanced engines, operating temperatures run higher. Still, with the myriad developments in materials you hear about today, who can say that plastics compressor blades won't someday be a practical reality?

A giant digital computer, housed in a building all its own, also gave visitors a glimpse of things to come. Design data on a theoretical jet engine were programmed into the computer. Onlookers then selected a desired speed and altitude. Once these values were cranked in, the computer quickly calculated thrust, fuel consumption, pressures, temperatures, and other data on the engine's performance. All this information was electrically typed and tabulated on a single sheet of paper.

Besides "flying" an engine in the design stage, the computer has still another function. For example, as officials and journalists watched on a closed-circuit TV screen (photo, opposite page), a jet engine was tested 600 miles away at another General Electric plant in Lynn, Mass. Simultaneously, test data were transmitted from Lynn to the computer at Evendale. It then made calculations on the data and displayed test results on the face of a cathode-ray tube for all to see.

Interest also centered around a honeycomb sandwich material—80 percent stronger than solid materials—used experimentally for lightweight jet-engine structures. Brazed together, stainless-steel or special alloy skins one hundredth of an inch thick sandwich a lightweight honeycomb core. The resulting metal laminate contains excellent properties, functions in temperatures to 1900 F, and withstands high bending loads.

A laboratory, the only privately owned of its kind, operates as part of AGT's facilities for developing new fuel applications. The government owns the few others in operation.

Some of the fuels will power high-performance engines now in the planning stage; others will probably find their way to rocket applications. However, simply developing new fuels with greater energy content per unit volume is not enough. Before they can be applied, their availability and reliability need to be well established. There must be a compromise between what research finds useful and what development deems practicable.

Thin Air

The approach to research and development can be compared with two roads that diverge in a wood. If you take the lesser traveled one, it may make all the difference—as it did for Dr. Sanford A. Moss.

In 1901 Dr. Moss, a young man fresh from graduate studies at Cornell University, joined General Electric. His ambition: develop a workable gas turbine. The

"jet propulsion . . . best means of increasing an aircraft's speed."

trick was to burn fuel in a chamber under pressure, then use the expanding gases to turn a turbine wheel. Despite the lack of high-temperature materials in those early days and the fact that it had never been done before, Dr. Moss persisted. And in 1903 he succeeded.

Although the turbine wheel turned, it lacked sufficient power output to do useful work—other than to provide compressed air. But at that time compressed air was needed. In the ensuing years, General Electric built up a world-wide reputation as a manufacturer of air compressors for industrial use.

For 16 years Sanford Moss gathered an impressive knowledge of air compressors and turbine combustion problems. And in 1917 the National Advisory Committee for Aeronautics called him to Washington. They asked him to develop an aeroplane engine booster—originally conceived by the French engineer, A. C. E. Rateau. This booster compressed the thin air of high altitudes to sea level pressure and then pumped it into the cylinders of an aircraft engine. The denser mixture of combustion gases naturally burned with more energy, and the engine's power output greatly increased.

Dr. Moss' redesign of the aeroplane engine booster came to be known as a turbosupercharger. It proved its mettle on Pikes Peak—14,100 feet above sea level—in central Colorado. There Moss ran tests on the turbosupercharger to simulate the thin air an aircraft meets at that altitude.

He used a Liberty aircraft engine, which had a sea level output of 350 hp. Atop Pikes Peak, its output dropped to 230 hp. But when Moss connected his turbosupercharger, the engine's horsepower jumped to 356—six more than at sea level.

In spite of this success, the turbosupercharger didn't receive complete acceptance until 1920, two years after the close of World War I. Then a supercharger-equipped La Pere biplane—the most advanced of its day—reached 36,000 feet. (The plane's pilot passed out from lack of oxygen at that altitude. He came to at 4000 feet, pulled the plane out of a steep dive, and landed safely.) A year later the same plane reached 40,000 feet. Soon afterward, the United States Army Air Corps ordered 150 turbosuperchargers.

A more colorful dramatization of the turbosupercharger's prowess occurred on July 21, 1921—a drama familiar to some.

In the face of much military opposition, Gen. Billy Mitchell set out to prove that air bombardment could sink the German battleships *Frankfort* and *Osfriesland* more effectively than naval gunfire. To do this, a plane had to fly at 15,000 feet—beyond the reach of naval antiaircraft shells—and carry 2000-pound bombs. At that time, bombers weren't capable of transporting such heavy bombs at so high an altitude.

But when Mitchell installed turbosuperchargers on his squadron's new twin-engine Martin bombers, they easily made the run. At 15,000 feet they unloaded their bombs on the battleships. The *Osfriesland* sank in less than three minutes—her hull caved in by concussion and her deck smashed. In less than a half hour, the *Frankfort* joined her.

Even with the minimum of high-altitude flying during the 20's and early 30's, General Electric maintained its interest in superchargers.

As a result, a General Electric supercharger geared to the engine of a TWA commercial airliner in 1937 made possible the first flight "over weather" between two distant cities. The following year, large installations of turbosuperchargers were applied to the Boeing B17 *Flying Fortress*. And their application was subsequently extended to many of the Air Force's high-performance fighters and bombers—ultimately to the Boeing B29 *Superfortress*.

Jet Propulsion—a Reality

For years, engineers the world over—particularly a British engineer named Frank Whittle—believed jet propulsion to be the best means of increasing an aircraft's speed. But not until 1939, at the outset of World War II, was the first flyable jet engine secretly produced in Germany. In 1940, Italy built and publicly demonstrated a jet-propelled plane.

These incidents apparently prompted the British Air Ministry, after years of indifference, to take seriously the turbojet design of their own Frank Whittle of the Royal Air Force. In 1941, they flight-tested Whittle's engine.

Gen. H. H. "Hap" Arnold, the United States Deputy Chief of Staff for Air—visiting Britain at that time—heard of this highly secret test. He asked for and received permission to build the engine in America.

The many years spent by General Electric refining the turbosupercharger made the Company a logical choice to build America's first turbojet engine. Using Frank Whittle's design, General Electric, with the cooperation of the British Air Ministry and the United States Army Air Force, constructed the first engine within six months. While the engine had to be built in accordance with the British design, General Electric engineers—notably the project engineer, D. F. "Truly" Warner—made many improvements. Cracking of the compressor's impeller blades under centrifugal force stumped the British. From his store of supercharger experience, Warner produced an immediate remedy. British engines subsequently used some of these American-built impellers.

Roughly speaking, a pound of thrust is equal to 1 hp at 375 mph. The American-built turbojet of British design, the IA, delivered 1250 pounds of thrust. And on October 2, 1942, two of these engines powered a Bell P59 *Airacomet* (photo, page 29)—the first American plane propelled by jet thrust.

Before long, General Electric produced new, more powerful engines: the I-14, I-16, I-20, and I-40, so called because they put out 1400, 1600, 2000, and 4000 pounds of thrust, respectively. But the fast pace in turbojet technology made an engine obsolete before it reached mass production.

With the war's end in 1945, plans painstakingly laid were torn up. Having experienced a similar transition before, General Electric nevertheless persisted in developing jet engines. But here the story takes up where it left off.

Race for Quality

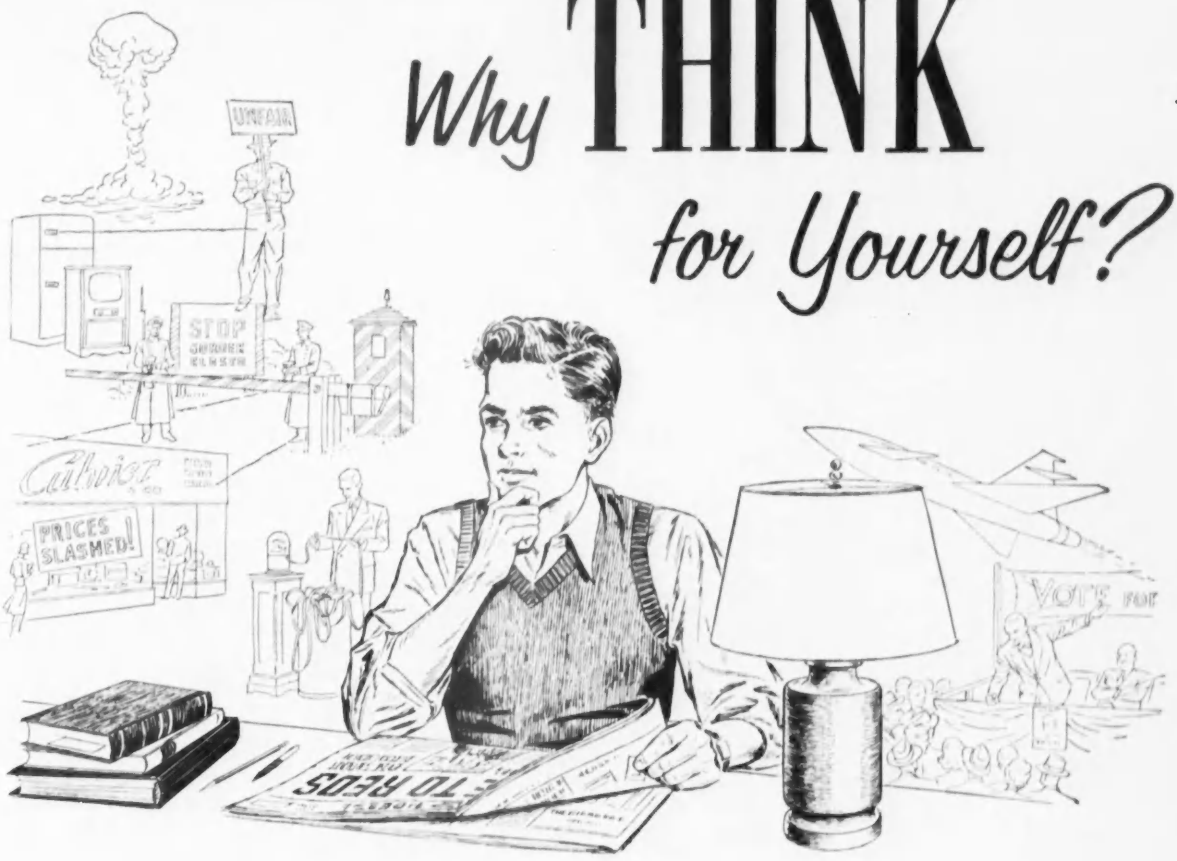
A high military official pointed out that Russia had long ago passed the United States in quantity of air power. According to him, the Soviet attempt to close the quality gap by greatly increasing their research and development effort now presents a real concern.

In this article, you've glimpsed the present, past, and future of a large aircraft-propulsion-systems manufacturer. Actually, its efforts reflect those of America's aircraft industry as a whole—working together so that we will never again face an aggressor nation unprepared.

The current battle is one of progress. Winning no longer becomes a question of being first with the most but of being first with the best. —JJR.

GENERAL ELECTRIC'S ANSWER TO . . .

Why THINK *for Yourself?*



WE have to take a lot for granted these days. Civilization has made so much progress in the past hundred years that we just can't keep up with all the angles any more. The more complicated things get, the harder it is to understand them.

In the old days, anybody could understand the ice box. Nowadays the electric refrigerator does a better job, but it's not so easy to understand.

It's the same way with candles and kerosene lamps. When they were used for lighting they were easy to understand. But electric light is much better—and more complicated.

We're living in an age of specialists. It's just about impossible for one person to know everything about everything, so he concentrates on one thing—he specializes.

Yes, more and more we're finding that even everyday subjects are not as simple as they used to be, or we thought they were. And for that reason, we have to depend more and more on other people—the specialists, that is—for the facts.

Is that good? Well, it isn't bad. And in one respect it's very good indeed. For if the specialists work as a team, they can do a better job than any one of them could do alone. And by the pooling of knowledge, we can carry on to much greater accomplishments than we could as lone wolves.

Building on Foundations

For we build on the foundations laid down for us by our ancestors. Edison and other pioneers provided such a foundation in electricity. Others following in their footsteps, built better and better machines and devices, worked out better and better ways of doing things electrically.

It's the same thing in all fields of knowledge—physics, chemistry, metallurgy, medicine, law, civil engineering, math, and so on. By pooling his knowledge, man sets himself apart from animals and uses the brains which God gave him.

Yes, we have to take other people's word for things. We can't know everything ourselves, so we accept what others tell us.

But, on the other hand, we can't just swallow *everything* that anybody tells us. Or we can't be like those people who believe whatever they see in print.

All right, you say; then what *are* you to believe? You know you can't accept everything anybody tells you as fact. And when you hear conflicting reports about something, which one do you believe—if any?

The answer, of course, is that you have to do some thinking for yourself. And that brings up another problem: How can you be sure you use the best judgment?

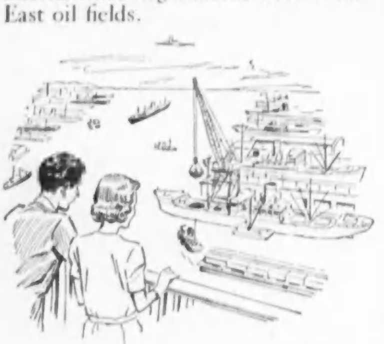
Probably the best answer to that one is general education, in addition to the specialized kind. Not only do you have to specialize in your own field if you want to compete with the other fellow, but you also have to get a good background of general, all-around education so you can use the best judgment in everyday life. With such a background, you can use the intelligence you were born with to decide when to believe one thing, when to believe another, or when to decide that the truth is somewhere in between.

Importance of Economics

For instance, let's take economics. Although there are a lot of subjects we ought to have some kind of general knowledge about, economics is one of the most important. Some of the toughest arguments are in this field.

You don't have to be a brain to know something about economics. It doesn't have to be hard to understand. It can be very simple, and very interesting. And everybody should know something about it.

For economics deals with the *things* we need or want in life—what the economists call goods and services. It goes into such matters as how many of these goods and services there are, how they get from where they grow or are made to where they are used, what it takes to make them valuable to us, how much they cost, and so on. Economics can be as close to you as buying an automatic electric toaster, or it can be as remote from you as international negotiations over Near East oil fields.



Much of the fundamental disagreement between the free world and Russian communism is over questions of economics. Most of us think of it as a question of freedom versus slavery—and we're right—but that's not all it is. One of the roots of the disagreement is the question of how goods and services will be produced, who gets them, and who does what. Many of us believe that those subjects have brought about much of the trouble in other matters like the right of free speech, the right to think as one pleases, or the right to worship God in one's own way.

Most of the controversial issues in local and national politics are economic issues. A depression, for example, is a matter of economics, and one party may make a political issue out of it by saying that another party caused it. Another subject which involves economics is public ownership versus private ownership. And economics has a great deal to do with such things as taxes, minimum wages, and good schools.

Still another very important subject of argument these days is the question of industry or business on the one hand, and organized labor on the other. If labor leaders say industry is making too much profit and should pay higher wages instead, whereas management says it can't afford to pay higher wages, it comes down to a question of economics again. And if you don't know anything about the economics involved, you wonder who's right.

So, as we said before, the only way you can really think for yourself on such matters is to learn more about them. If you don't get some fundamental education in economics, you'll never know whom to believe. When an economic subject is being discussed, your views won't be worth much unless you know something about it.

Some Examples

That doesn't mean that each of us has to become a specialist in economics. But at least you can learn *something* about the subject—enough to help you think for yourself when you need to.

For instance, do you know what money really is? Do you, like so many other people, think that money is valuable for its own sake? If you do, then you don't know much about economics. You can't have a really good understanding of money without learning something about economics.

Or, to take another example, consider the profits of a business. Do you know what they really are? Do you think profit is what the owners take out of the business for themselves? Do you think profit is all the money the business takes in over and above the cost of running the business? Or do you think it's something in between those two? If you just don't know, you ought to learn something about economics, for the subject of profit is a very important one in this country today.

Other Subjects, Too

What's true of economics is also true of other subjects. By making yourself acquainted with some of the fundamental things about science—say astronomy—you don't have to take it completely on faith when, for example, the astronomers tell you that the stars are really suns like our own, but much farther away. You can understand in a general way how the astronomers know this, even if you don't go through all the business of proving it yourself, every step of the way.

For it really doesn't take much familiarity with technical subjects to give you enough general understanding of them to make it easier for you to think for yourself. And once you have that familiarity, and can think for yourself about subjects, you'll have a better understanding of how scientists and engineers can provide us with so many wonderful things in our modern civilization—things like radio and TV, synthetic materials, and silicones; construction miracles in giant dams and mighty bridges; the wisdom to solve problems with uncanny computers; the research that promises to harness the power locked in the atom; the techniques in automation which are producing for us more and better things for less money—and which employ more people in doing it.

INDUSTRY PROMOTES THE STUDY OF THE THREE R's (Part VI)

You may want extra copies of this article titled "Why Think for Yourself?" to help you guide the young people with whom you come in contact. They can be obtained free by writing to the GENERAL ELECTRIC REVIEW, Bldg. 2-107, General Electric Company, Schenectady 5, NY. In your request, please ask for publication PRD-97.

The challenge of a growing suburbia...

and one practical solution

If you've ever watched a residential area evolve from houses into homes, you know that these new communities are — in the final analysis — people. You see brick and wood begin to reflect personalities and dreams. At dusk you see warmth shining from windows that only yesterday were vacant and lifeless.

To America's electric utilities, these thousands of lighted windows present a challenging problem: how to meet greatly increased power demands at continuing high standards of reliability. General Electric Super Coronol* preassembled aerial cable has helped electric utility companies find one answer. With this aerial cable there is less chance of storm damage, maintenance costs are lowered, service continuity is improved. Residents benefit, too, from better appearance because crossarms and unsightly open wire lines are eliminated.

The use of this preassembled aerial cable also means that in many instances larger areas can be covered than with open wire construction in voltage-limited distribution lines with these results:

1. Reduction in number of feeders required.
2. Use of larger substations.

Both of these advantages result in lower cost per kva of installed substation capacity.

G-E Super Coronol preassembled aerial cable is one of many G-E products that are helping electric utilities supply new residential communities with the greatest convenience of all—electric power. Construction Materials Division, General Electric Company, Bridgeport 2, Connecticut, Section W186-1537.

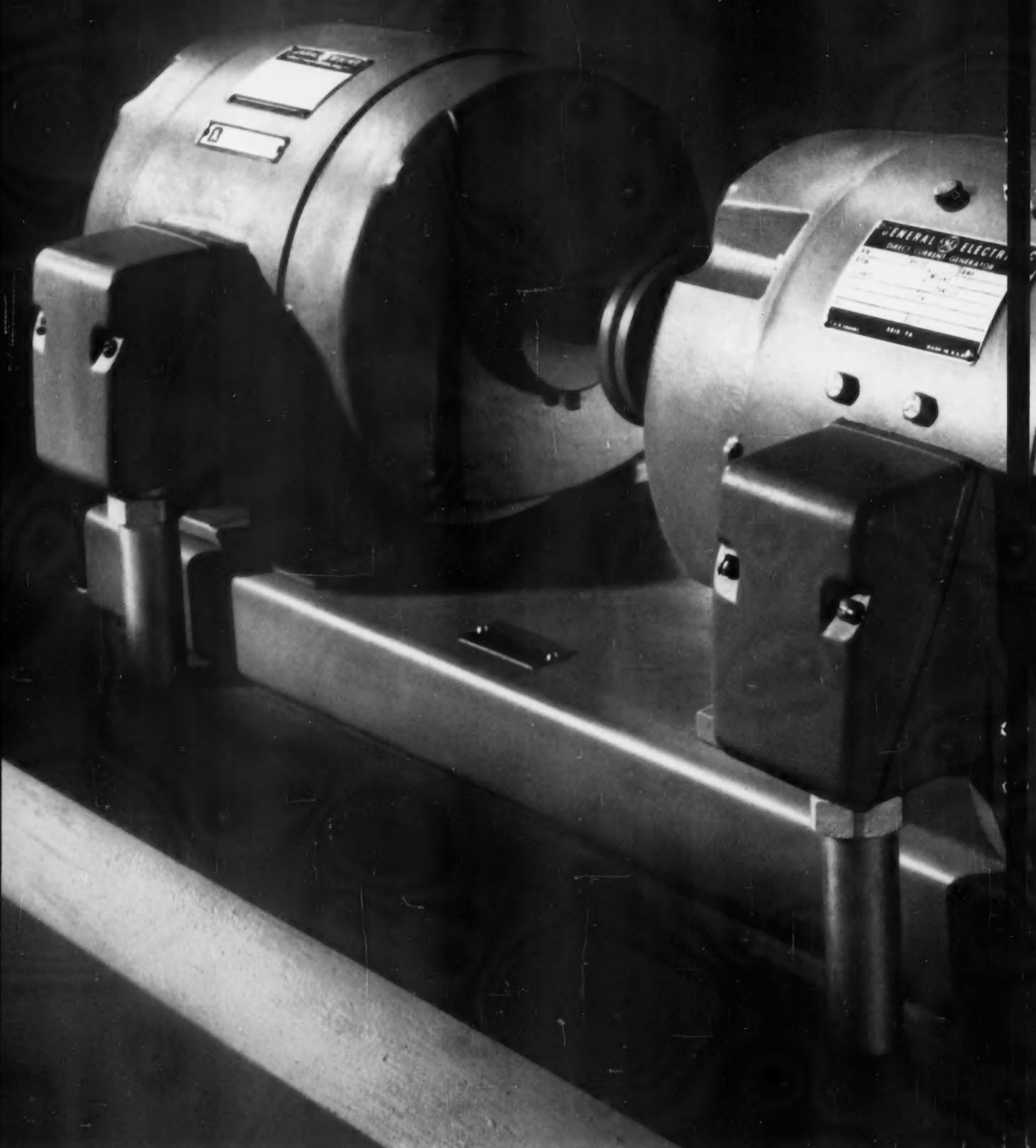
* Registered Trade-mark General Electric Company.

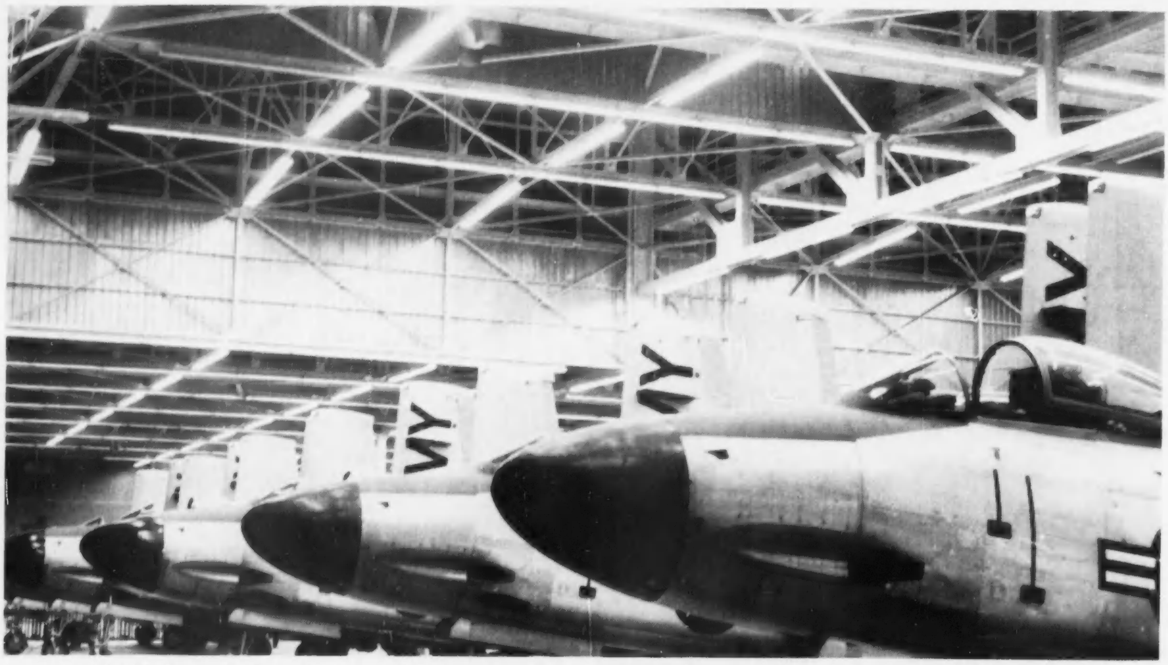
Progress Is Our Most Important Product

GENERAL ELECTRIC

To help you cut production costs . . .

NEW General Electric





At the McDonnell plant, St. Louis, light level in pre-flight area more than doubled as a result of group relamping.

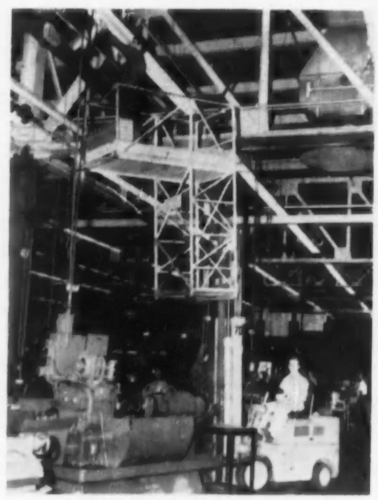
McDonnell Aircraft saves over $7,500 a year by Group Relamping with G-E Lamps

MAINTAINING 36,000 fluorescent lamps on an individual basis was a major item on the McDonnell Aircraft Corporation budget. High labor costs, inaccessible fixtures and the congestion brought on by expanded production compounded the problem and the expense.

WITH THE HELP of a General Electric Lamp specialist, McDonnell worked out a systematic Group Relamping Plan. Now they replace large groups of lamps periodically with new General Electric fluorescent lamps. Fixtures are cleaned when lamps are replaced. Lighting maintenance is scheduled for periods when production is low. And because the schedule is set up to allow only a maximum of 3.8% burnouts, the high cost of individual replacement is completely eliminated.

"WE ESTIMATE our total savings in lighting maintenance costs from group relamping at $7,500 per year." writes Leon P. Bowers, Utilities Supervisor at McDonnell. "In addition to money savings we're getting a needed, much higher level of light throughout our plant, and there's less interference with production due to lamp changes. Our labor costs would surely run at least 100% higher were we to replace lamps as they burn out and regularly wash fixtures in a separate operation."

IT'S THE UNIFORM PERFORMANCE of General Electric lamps that makes Group Relamping work here and in many other plants, offices and stores. Group Relamping can save *you* at least 50% of your lighting maintenance labor dollars. You can find out all you need to know by sending for the new booklet, "Group Relamping Pays Dividends." Write General Electric Large Lamp Dept. GE-9, Nela Park, Cleveland 12, Ohio.

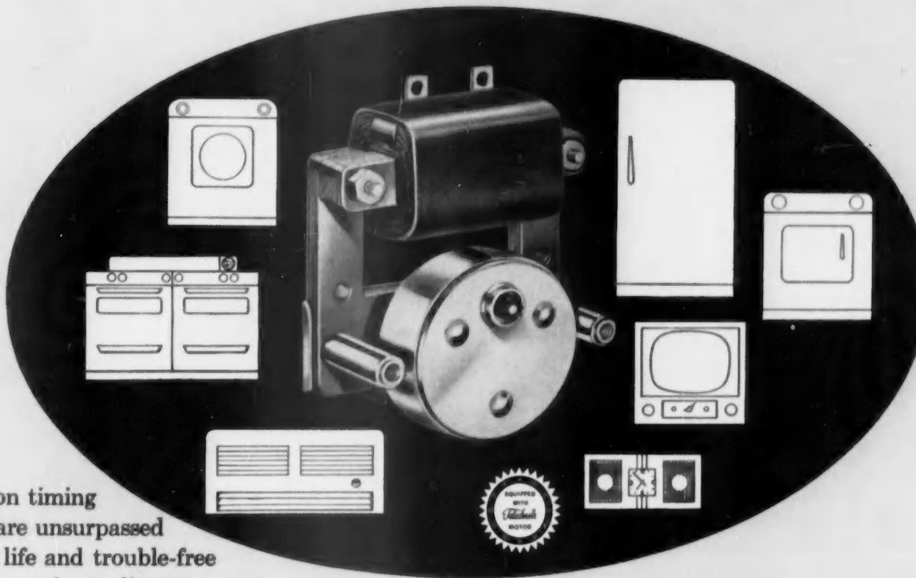


Special equipment like this platform on a lift truck enables maintenance crew to change lamps quickly and easily.

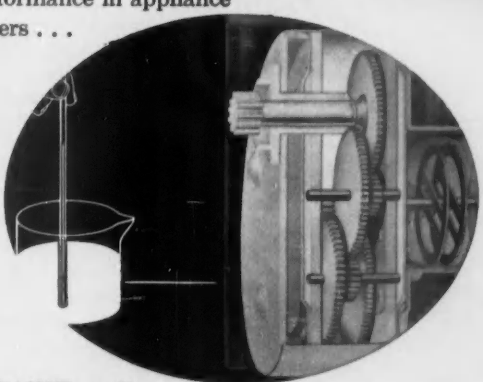
Progress Is Our Most Important Product

GENERAL ELECTRIC

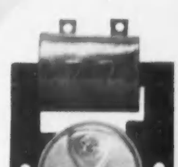
Why America's leading appliance timers are powered by the leader in timing motors!



Telechron timing motors are unsurpassed for long life and trouble-free performance in appliance timers . . .



BECAUSE capillary action feeds oil to moving parts. The oil, drawn up between the plates, furnishes a continuous source of lubrication for all bearings.



Telechron timing motors come in a wide range of speeds and torque ratings . . . rating for rating, a Telechron timing motor will outlast and outperform any other synchronous timing motor made.

BECAUSE rotor is so light it floats on water . . . lightness gives faster starts and stops without bearing wear. In operation, rotors virtually float in the magnetic field, with the rotor shaft supported on the film of oil in which it rotates.

For full information, simply write to or phone Telechron Timers and Motors, Clock and Timer Dept., General Electric Co., 229 Homer Ave., Ashland, Mass.

Telechron motors make sales easy—automatically

Planning

". . . we began to think about Waynesboro. We looked at maps and travel folders. We knew that it is in the mountains and that the camping should be good. During the winter of 1953-54, we had a lot to talk and think about and a lot of planning to do."

Moving

"On March 18, the moving vans arrived. It was a cold, dreary day with snow in the air. The Department had made all the arrangements, and the movers packed everything completely and efficiently—even to the last picture on the wall."

Going from Blizzards to Blue Ridge

By MRS. KIRK SNELL

A new plant opens and your company asks you to move. You wonder: Will your house be sold before you move? will your children be upset being pulled out of school at mid-term? will your wife be happy setting up a new household?

You've read reports such as the American Management Association's "Company Practices in Employee Transfers and Relocations." Your next-door neighbor may have moved to a new job many states away. You saw the real estate agents bring people to his house, you talked with him about the move in a general way, and your wife told you some more things she had heard. Perhaps the day after a neighborhood farewell party, the moving van backed into the yard. You received a few postcards or maybe a letter. "Things are working out OK," they wrote.

But how does it *really* feel in a new town, with different faces and a new routine of day-by-day living to establish: What dairy do you recommend? where's the best place to get my car serviced? where's the closest drugstore? who's a good baby sitter? And perhaps you're living in a motel while trying to find a house to buy and working 8 to 10 hours a day getting the new plant into production.

During the spring of 1955, General Electric's Specialty Control Department completed its move from Schenectady, NY, to Waynesboro, Va., some 550 miles away (September 1955 REVIEW, page 44). To bring you a firsthand account of the human side of a move, the REVIEW asked the wife of an engineer from the Department to give you her story. She's Mrs. Virginia Snell, known as Ginna. Her husband Kirk, a supervisor in development engineering, has been with General Electric for 15 years.

The Snells are both from Marion, Iowa (population 6000) and have been married 10 years. They have two boys—Tommy, eight, and Peter, four.

—EDITORS

About three years ago we received the first indications that perhaps we wouldn't be staying in Schenectady much longer. You know how those things get around in a company.

It was the summer of 1953, and General Electric's Control Division had just been decentralized into three departments. Soon after, Kirk told me that a study team was looking into the future business prospects of the Specialty Control Department. He had a pretty good idea of what was going on; men from the planning study often came to him for opinions. He also told me that it looked as if the study team was going one step further than just a business forecast—a new plant at another location was in the wind.

Rumor and speculation ran high during the summer of 1953. I heard it from other wives, and it was a common topic in the men's car pools. For a time, Michigan seemed the most likely location, and some of us began looking forward to good fishing and swimming. Then Pennsylvania cropped up. Soon after, Virginia was mentioned more and more often and, specifically, the town of Waynesboro. We gave a lot of weight to that rumor because unless the town actually had been considered, who had ever heard of Waynesboro?

Just about every night when Kirk came home, I'd ask him, "Has it been announced yet?" On the night of November 13, his answer was yes. That day the manager of each section had called his people together, announced the location to be Waynesboro, and revealed a tentative schedule for the move.

Naturally, Kirk and I had talked in a general way about what we would do if we had to move. The idea of a move had sort of lurked in the background, with us hoping that like a mildly bad dream it would go away. But now that it was official, it was a little hard for us to believe. That night both of us were dejected. We weren't interested in leaving our friends in Schenectady, our new home in West Hill, or the Adirondack Mountains where we had taken many fine camping trips. And we were just beginning to enjoy the home we had built during the past four years.

But after a few days we faced reality and began to think about Waynesboro. We looked at maps and travel folders. We knew that it is in the mountains and that the camping should be good. And then, we liked the idea of raising children in a small town, population about 14,000.

During the winter of 1953-1954, we had a lot to talk and think about and a lot of planning to do.

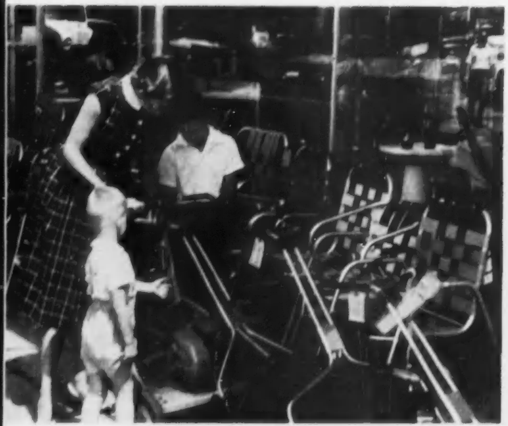
We attended all the orientation meetings that Specialty Control management held for the families. We saw colored slides and movies, received volumes of printed matter, asked questions, and learned what policies would apply to the move. From a wife's viewpoint, I thought that General Electric was doing everything possible to make it easy for all of us. For instance, each husband and wife could take an all-expense trip to Waynesboro to look for a new home, and the Department would pay for boarding expenses or baby sitters for children.

By spring 1954, we were looking forward to the move. Some of our neighbors from West Hill would be going with us; it was fun planning together what we would do. We wives were pleased that our men were going to work in a new plant. The place would be air conditioned, with no soot, noise, or overcrowding; and we could pick up our husbands after work without being stopped by guards or a traffic jam.

On Memorial Day weekend 1954, Kirk and I decided to take a trip on our own to Waynesboro—little more than a day's drive. The blooming roses and lush countryside made this a perfect time to see Virginia. (Spring is just getting under way in Schenectady by the end of May.) The people in Waynesboro were extremely friendly and seemed pleased that General Electric planned to locate there. Rumors also being thick in the town to which a new plant is moving, we were asked as many questions as we asked: About how many families would be moving in? about how many children?

During that weekend we had a good chance to look over the area. We were so impressed that we bought a lot—

TEXT CONTINUED ON PAGE 41
OVERLEAF: STARTING LIFE IN A NEW COMMUNITY



"The service establishments and local stores give us the kind of service we rarely received in the North."

". . . Sherando Lake is only a few miles away . . . . Nags Head and Hatteras are near-by for ocean swimming."

"Waynesboro has an excellent municipal swimming pool . . . . There's tennis and golf and good Scouting activities . . . . We found an AAUW chapter here and groups interested in bridge, gardening, canasta, books, and square dances."

New Home "Late last June the contractor broke ground . . . ."

"We moved in right after the New Year."

"We wives were pleased that our men were going to work in a new plant . . . we could pick up our husbands after work without being stopped by guards or a traffic jam."

BLIZZARDS TO BLUE RIDGE (Continued)

Starting a New Life in a New Community

"Kirk is happy, and so are the boys . . . . I'm so thankful for what we have."

about a half acre on a hillside facing the Blue Ridge Mountains. Now the move seemed real, and we spent our evenings drawing up the plans for our new home.

On Labor Day we made another trip to Waynesboro for a week's vacation. We talked to contractors, surveyed our lot, and took colored slides to show friends in Schenectady. We looked into the school and church situation and found many good youth groups. And we looked forward to taking advantage of the range of cultural activities at Charlottesville, home of the University of Virginia, only 24 miles away.

By this time we knew that we would be moving early in March 1955. And so, we had to get our house ready for the market. Neither of us was happy about the financial situation. For we soon found that winter isn't the best time to sell. Further, we were in a fading market in Schenectady and faced boom conditions in Waynesboro. But the house was sold before we left.

On March 18 the moving vans arrived. It was a cold, dreary day with snow in the air. The Department had made all arrangements, and the movers packed everything completely and efficiently—even to the last picture on the wall.

Because our contractor was so rushed that he couldn't start our home until summer, we lived in a Waynesboro motel while we looked for a house to rent. We finally found one and settled down to living in a new town.

Hospitality was emphasized in Waynesboro. The people were genuinely glad to see us and went out of their way to make us feel at home. Now, more than a year later, I can say that they are just as friendly. Both the townspeople and the people at Du Pont, who have been here for years, did everything to absorb the General Electric people into the community's activities.

The service establishments and local stores give us the kind of service we rarely received in the North. For instance, one of my friends phoned for groceries and then went out for the afternoon. She left her house unlocked—we all do. When she returned home, she found no trace of the groceries. She happened to look into the refrigerator and there they were—the delivery boy had neatly put everything away.

We found the schools in Waynesboro are different from those in the North—more organized, more homework, and firmer discipline. Tommy likes it, but it took him a while to get adjusted. Here, they stick to the routines of the three R's. As one schoolteacher told me, "It's difficult to be progressive with 37 kids."

There were, of course, some things we had to adjust to. For a wide selection in shopping you must go to Richmond, 93 miles away; and there aren't any discount houses here. There's a personal property tax; state income taxes are on a par with New York; and gasoline is higher. Food prices run about the same. Some of our ideas about architecture and building construction weren't accepted at all. A concrete-block house is all right if you face it with brick, we were told.

Our first spring and summer were wonderful. Waynesboro has an excellent municipal swimming pool, and Sherando Lake is only a few miles away. There's tennis and golf and good Scouting activities. Nags Head and Hatteras are nearby for ocean swimming and fishing.

Two of us General Electric wives started a Cub Scout den in the neighborhood early this year. We found an American Association of University Women chapter here and groups interested in bridge, gardening, canasta, books, and square dances. Baby sitters are plentiful.

Because we moved in as a group, we introduced different foodstuffs—now you'll find lasagna, for instance, and a wide variety of cheeses and seafoods in the markets. At the same time, we've learned to like black-eyed peas and kale.

Late last June the contractor broke ground for our new home. Kirk decided to do the wiring himself; so he took an hour's test before the local Examining Board and was licensed as an electrician. We moved in right after the New Year. Building the house took a lot more time than any of us, including the contractor, thought. Getting materials was the biggest problem, for they're just not used to a boom. Then too, all house builders traditionally take off during the hunting season.

Last Christmas I directed a play at the Main Street Methodist Church. On Christmas Day it was 75 F; several transplanted Northerners stood around in light shirtsleeves discussing the weather and other Christmases. I got homesick for West Hill and their afternoon Carol Sing on the day before Christmas.

We're fairly settled in our new home now and like it more and more every day. Kirk is happy, and so are the boys. I soon forgot a lot of the difficulties because I'm so thankful for what we have. We're making new friends and busy starting life in a new community. Ω

MECHANICS OF A MASS MOVE

***Review* STAFF REPORT**

Specialty Control moved 133 families including 55 engineers from Schenectady to Waynesboro.

Department policy on the move: An initial trip for both husband and wife to look for housing, plus one or two other expense-paid trips for the husband to clear any final details. The Department paid all expenses for the entire family.

Living expenses at Waynesboro were paid for a reasonable length of time while new housing was being secured. In addition, each employee was reimbursed for the expenses of refitting drapes and carpets, installing appliances, legal fees for the purchase of his home, and other incidentals.

If you were unable to sell your house through normal real estate channels, the General Electric Realty Corp. bought it at a price determined by an appraisal of its market value.

If these policies didn't cover everything, management considered the employee's case on its own merits.

A Department spokesman said, "A move like this costs about $200,000. What are a few dollars here or there if it keeps an employee and his family happy? We know that the sooner a man gets set up in a new location—and the fewer worries he has—the sooner he's going to settle down and begin contributing."

According to Harry L. Palmer, Specialty Control's Manager of Engineering, 95 percent of the engineers who were asked to go made the move. Those who didn't move had good personal reasons: one engineer declined because his handicapped child required a special type of medical care.

To inform the families about the move in detail, the Department distributed 28 reports in 13 months on housing, schooling, and policies. Other reports answered questions submitted by the employees . . .

- Is Waynesboro in an asthma or hay-fever belt?—*No.*
- How is television reception? —*Good. The area offers four channels.*
- What is the price of a man's haircut?—*Eighty-five cents.*

According to Dr. Louis T. Rader, General Manager of the Specialty Control Department, the school situation is the most important feature to consider in locating a new plant, in addition to the usual factors of transportation, location of market, and labor supply. "We found in our surveys," he reports, "that if the schools are good, other factors in the community are desirable."

Rader claims that Waynesboro schools are equal to, and sometimes better than, the Schenectady area schools he is familiar with. And as a Schenectady school board member for four years, he knows. "If the schools are good, the children are happy and so is the wife. And that *is* important."

With the plant in operation for more than a year, relations between General Electric families and the townspeople have been extremely smooth. Rader likes to tell this story: "A local merchant accused me of bringing only hand-picked people down here. I told him, 'No, they're just representative of General Electric families everywhere.'"

We Did Not Know What Watts Were...

By PAUL N. NUNN

In these days of 330-kv transmission lines, 25-million-kva circuit breakers, and electronic protective relays, it takes imagination to visualize what the early, practical adventurers faced in the field of power generation. One of these pioneers, the late Lucien L. Nunn, together with his brother, Paul, planned, built, installed, and operated for the first time in the United States a commercial alternating-current hydroelectric transmission system that utilized high voltage for power purposes. Destined to set the pace in power generation for years to come, this development supplanted the former low-voltage direct-current type of electric power generation. Their accomplishment occurred in 1890, even before engineers tapped the great power resources of Niagara Falls.

As a note of interest, the Nunn brothers later became the engineers for the first development at Niagara Falls, made for the Ontario Power Company. In 1903, Paul Nunn designed and engineered their huge electric plant—then the largest in the world.

Serving for several years as Chief Engineer of the Telluride Power Company located in Colorado, Paul Nunn became its president upon the death of his brother, Lucien, in 1925. Out of the Nunn brothers' interest in education and engineering training grew the Telluride Association for training students in engineering under a scholarship plan. Paul Nunn—a life member of the American Society of Civil Engineers, American Institute of Electrical Engineers, and American Society of Mechanical Engineers—died October 27, 1939, at the age of 79.

Recently, the REVIEW obtained some of Paul Nunn's reminiscences—remarks he made in 1927 in Salt Lake City at the first joint meeting of the Utah Society of Engineers, AIEE, and the Electrical League of Utah. Edited excerpts appear here in article form.

—EDITORS

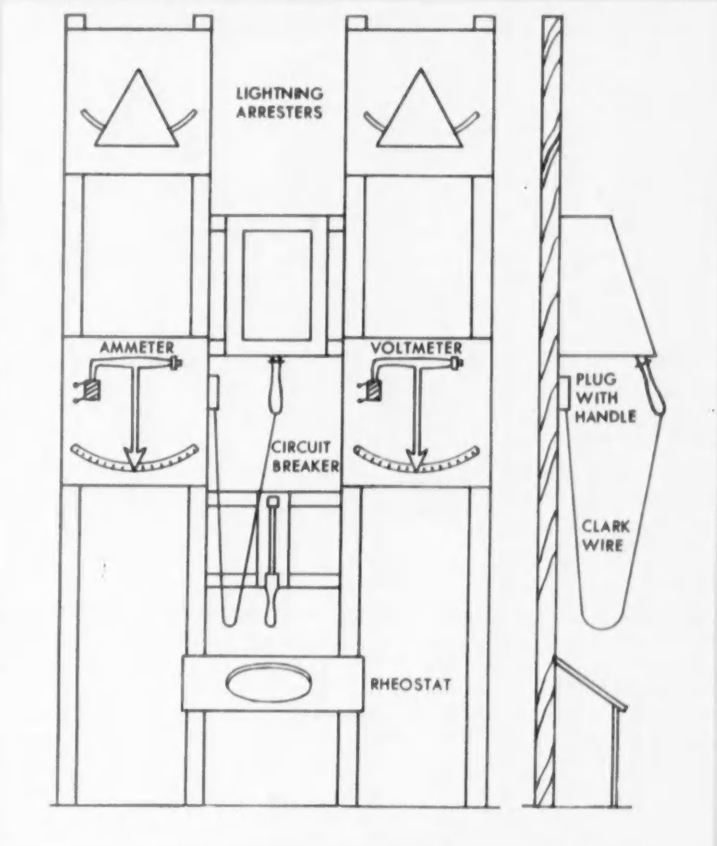


FIG. 1. AMES SWITCHBOARD—1890

At Niagara Falls 37 years ago [1890], an International Commission—presumably the ablest engineers and scientists in the world—met to discuss a great problem. Millions of dollars had been subscribed to an undertaking at Niagara Falls: developing power from the water.

I suppose that most of you have seen around in the country districts of Utah the remnants of a little old water power. In the United States, water power to any large degree was recognized at only two points, both located in Massachusetts: Lowell, the great center of looms; and Holyoke, the paper-producing center. The idea of developing water power had just taken hold . . . .

The Commission was sitting at Niagara Falls to decide how to transmit the power developed from the water wheels of Niagara Falls to Buffalo—a distance of 25 to 30 miles. Alternative proposals suggested were wire-rope drive, compressed air, liquid air, circulating oil, and electricity. And back in 1890, electricity was very much in doubt.

About that time, the concern that employed my brother, Lucien, as its counsel struck it rich in a little mine above the timber line in the San Juan country of Colorado. It was way above the timber line, hence above the line of fuel. To transport coal to that point would have cost $40 a ton, perhaps $50. A mill was necessary, and power was necessary to drive the mill.

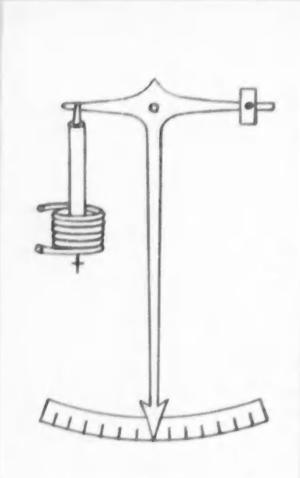


FIG. 2. AMMETER OR VOLTMETER

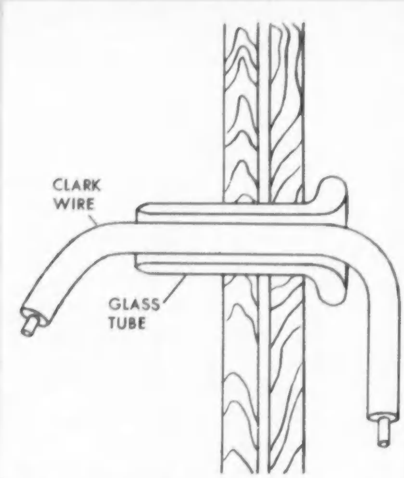


FIG. 3. WALL INSULATOR

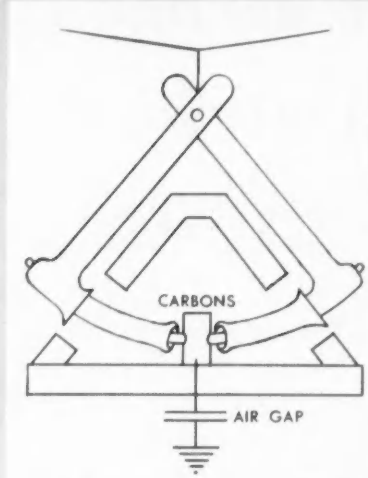


FIG. 4. PICKAX LIGHTNING ARRESTER

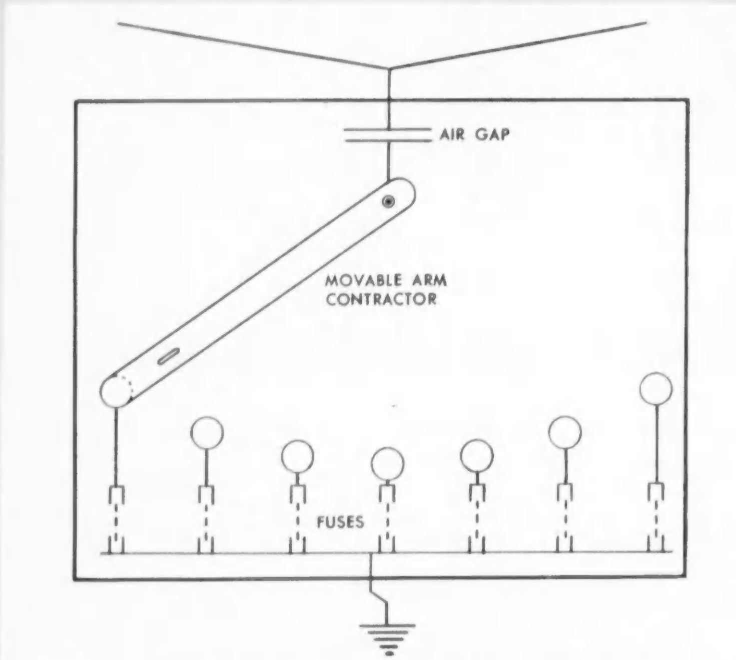


FIG. 5. FUSE LIGHTNING ARRESTER

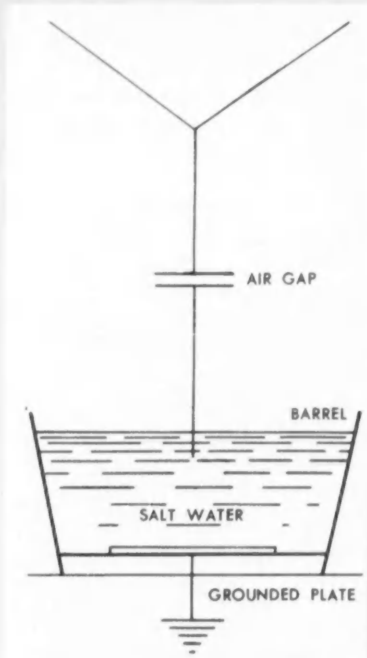


FIG. 6. TUB LIGHTNING ARRESTER

My brother wrote and asked me how we could utilize a mountain stream, three miles away, to furnish power for the mill. That was the beginning of the first hydroelectric power transmission in the United States, if not in the world. There may be some question about the world.

Our plant sounds pretty insignificant nowadays. Your local company operates single units that produce more power than a string of ours a mile long would have produced; and they think nothing of it. But there is a difference in location, too. Our machines could be carried by mule-pack wherever we had to take them.

The switchboard (represented by Fig. 1) was beautifully made of oak, 2×4's and 1×3's, the oak being paraffined. We had a very oppressive sense of the usefulness of high voltage. The uprights were connected by cross strips. Upon this board were erected a couple of instruments.

In the center of the board, though you wouldn't recognize it as such, was a circuit breaker. With not much need for them, there were at the time no circuit breakers. Still, we had to have one. It was automatic only in the sense that when a man wanted to operate it,

"Nobody raised any questions, and nobody answered any."

he might faint and pull the plug out. Otherwise, it was manually operated.

The plug was an affair with a paraffined wooden handle protected by a hard rubber disc, to keep the hand from slipping onto the bare copper at the end. Sort of a receptacle was pinched down on it to make good contact and keep it from falling out. When the circuit was to be broken with the power on, the operator took hold of the plug and pulled it out. Perfectly simple. But it was usual that the circuit had to be broken when a motor had just dropped out of step. You people understand what a synchronous motor out of step means today in the lag of the current tenacity of the arc.

The flexible conductor was six feet long to give plenty of room. As the size of the units became somewhat larger, the cord proved too short. And so it had to be extended to eight feet. You can imagine, I fancy, how you would feel pulling out a plug like that—running back eight feet—and finding the arc still holding. That was unusual.

The technique of the situation was to wiggle the plug to put out the arc. If that did not work, a cap or a hat was used to fan it out. I don't remember that an operator ever failed to get it broken in some way; but I do remember a careless operator pulling the plug and letting it swing close to his leg. He got off pretty well with only the cost of a new pair of trousers.

A single-pole switch closed the circuit, the circuit breaker opened it. The rheostat looked like the manual of a pipe organ: it was full of fence wire, curled up.

You people are accustomed to good-looking instruments that measure accurately and are portable. If they get out of order, you send them back to the factory. Probably most of your portable instruments are now made either by the General Electric Company or by the Weston Company.

One of the first instruments was a good-looking black-walnut box, with some window glass in front of it (voltmeter and ammeter shown in Fig. 2). Inside was something constructed like an assayer's balance. On one end of the balance was a bundle of loose iron wires, with the counterweight on the other end. The telltale swung back and forth on a scale. This describes the rudimentary instrument for alternating current. Theoretically, it is correct. The only difficulty lay in the losses set up in the iron core and they were not great. But when anything happened to tip the instrument or shake the switchboard, the calibration was all off. We did not know much about calibration in those days. We set up a thing as we thought right and then took as gospel truth whatever it said.

The only difference between a voltmeter and an ammeter lay in the winding of the solenoid and the addition, back of the instrument, of a supplementary resistance. A wattmeter? We had none. We did not need any. We did not know what watts were, and we would not have known what to do with them . . . .

During the early days of alternating-current work, volt-amperes were a measure of power. And if anything happened so that the power did not get into the volt-amperes—well, that was the manufacturer's fault; it had nothing to do with us. Nobody raised any questions, and nobody answered any.

When I look at the expensive glass plates that you build in your powerhouses now, and through which the conductors lead in or out, I think sometimes of our early efforts. The only thing we had to use in the way of a wall bushing was a piece of glass tubing cut to the requisite length and prepared by heating and bending the ends back (Fig. 3). Through that, we ran a piece of wire, insulated as well as could be.

You are familiar with high-grade insulated wire. You now have conductors good for 20,000 or 30,000 volts; in fact, I recently saw a piece of rubber-covered conductor tested up to 60,000 volts; and it was not any larger than some wire we used to have and called good for 10,000 volts.

Back in those days, only one concern in the United States pretended to make a rubber-covered wire that withstood more than 100 volts—that is, just one concern made high-voltage wire—and that was Clark. But two manufacturers—Okonite and Habirshaw—made house-wiring wire good for 100 volts. It was rubber covered even then but guaranteed only for 100 volts, because standard voltage for house wiring in those days was 52 volts.

The high-grade very fine Clark wire was made in Cambridge, or Boston, Mass. Electrical manufacturers could not afford to use much of it, though in special places they did. When one wanted something especially fine for an experimental laboratory or in the construction of machines, he would go to the extravagant length of using Clark wire.

Clark wire was made in a little old shack of a place under the supervision of this man Clark, who had been a farmer. Peace to his ashes! For he went long before this. He didn't know anything about rubber; he didn't know anything about business. But he loaned some money to a man who made some kind of a rubber product, and he had to take over the works to get his money out of it. A shop employing about 10 hands turned out Clark wire. It had no braided covering, but it did have pure rubber insulation.

Refer again to the circuit breaker (Fig. 1). The loop of conductor hanging down was considered a rather formidable sort of thing to be so familiarly hanging in sight where it could be touched. And so, in addition to a piece of Clark wire, we slipped over it a piece of ordinary rubber tubing. True, it was pretty good tubing; but how much do you suppose that tubing would stand electrically? I haven't any idea, but I doubt that it was good for 500 volts. It was the best we knew . . . at the time when that great Commission was sitting at Niagara Falls, discussing this grave question of the best means to transmit the power to Buffalo, whether by wire rope or electricity.

We had a simple, single transmission. For we wanted to drive only one mill. Therefore, our apparatus consisted of two identical machines, nominally 100 hp. It sounds a little funny now—100-hp generator, 100-hp motor. We still say horsepower for motor, but back in those days it was also horsepower for generator. Why? We didn't know what kilowatts were. We hadn't made their acquaintance yet. And so we rated everything in horsepower.

The two machines operated at the opposite ends of the transmission: one driven by a Pelton water wheel, the other driving the mill. They were identical, interchangeable, and had 12-pole iron-clad tee-tooth armatures—an invention of his Satanic majesty. You don't see them any more. The reason is

" . . . sometimes lightning strokes came four or five a minute."

that generators will break down once in a while; and when they do, you want some chance to repair the winding, some chance to put in a new coil. With a tee-tooth machine it is practically an impossibility because the coils must be wound at the factory. Highly insulated, they were difficult to get into a machine without so distorting them as to break the insulation.

We had no transformers because, without commutators, a sufficiently high voltage could be generated for our purposes—3000 volts—and that voltage was handled directly on the machine. It was rather nervy. It was 3000 volts that we broke with the automatic circuit breaker.

Our particular part of the country was a great location for lightning. One point had an altitude of nearly 13,000 feet; another, 7000 feet. That difference in altitude has a bearing on the atmospheric disturbance. In those days we didn't know about atmospheric disturbance. That term had not been invented. With us, it was just plain lightning. But it came along with great frequency; I might even say with great regularity.

We used a marble box, with two holes in it, through which the pickaxes dropped (Fig. 4). Do you see anything about this that looks like a lightning arrester? The points of the pick were equipped with pieces of arc-lamp carbon. The theory is very simple—beautifully simple. The explosion of the discharge would kick out the pickax and break the arc. Of course, there wouldn't be any explosion without an arc, and there wouldn't be any arc until the pickax lifted. The contraption may have worked sometimes when we didn't even know it.

Lightning was the bane of our existence. After replacing the generator coils a few times, we had a very fine motive for avoiding their breakdown. We took up our generator and motor and placed under them insulating platforms made of 4×4 oak pieces, boiled in paraffin.

I have been told a great many times that you can't paraffin oak, that you can only plaster the paraffin on the outside, that you can't drive it in. But we *had* to drive it in. So our situation paralleled the elephant's. You have heard the old question: "When does an elephant climb a tree? When he *has* to."

By running paraffin at a little above the boiling point of water for 24 hours, we drove out the water vapor from the sticks. The vapors that followed were condensable and would condense when chilled. We kept the sticks under the surface of the paraffin until it cooled and also until the sticks were cold all the way through. A vacuum formed within the fiber of the wood and soaked in the paraffin to a depth of several inches—clear through a three-inch plank. And that, I think, is the secret. We had no difficulty in paraffining oak or almost any of the nonfat woods. Using oak as a foundation under the machines greatly reduced the difficulty from lightning.

Still we had lightning. Finding some means of handling it taxed our ingenuity. The most successful lightning arrester ever built was a very complex mechanism (Fig. 5). It consisted of a perfectly plain commutator switch, with each terminal of the commutator connected to a fuse. The operation though delightfully simple required two attendants to operate it: one held a paraffin stick to push the tongue of the switch at every lightning stroke; another replaced the fuses.

At one time we operated 60 points, necessitating a third operator. Now, that is no joke. And it was no joke to the boys. For they had to work very fast because sometimes lightning strokes came four or five a minute. Of course, that was not lightning—only atmospheric disturbance. But, as I have explained, we didn't know the difference!

We tried many schemes to find something that would be automatic, or at least would not require so many operators. One scheme had some merit. It was a half-barrel, with a metal plate in the bottom, grounded (Fig. 6). We brought a shunt from the line across the gap and laid it perhaps one sixty-fourth of an inch into the liquid, simply a salt solution.

Theoretically, as the discharge enters the solution, the spit of lightning into the water blows the water away and breaks the arc. And it works. But it is rather exacting in its disposition. The water must be just at the right height and, for best results, must contain just the right amount of salt. In our extremely dry country the exactions annoyed us. Evaporation forced us to add water four or five times a day to keep the surface exactly right.

I remember an amusing incident. Outside the station down in the flat at the river, we had placed one of these arresters where the grass grew luxuriously. A herd of cattle came down one day. And one boisterous old bull took a fancy to it and wanted a drink of that water. At just that instant we were having a little thunderstorm. The effect on his abdominal muscles or his diastolic action was that the curve was very straight!

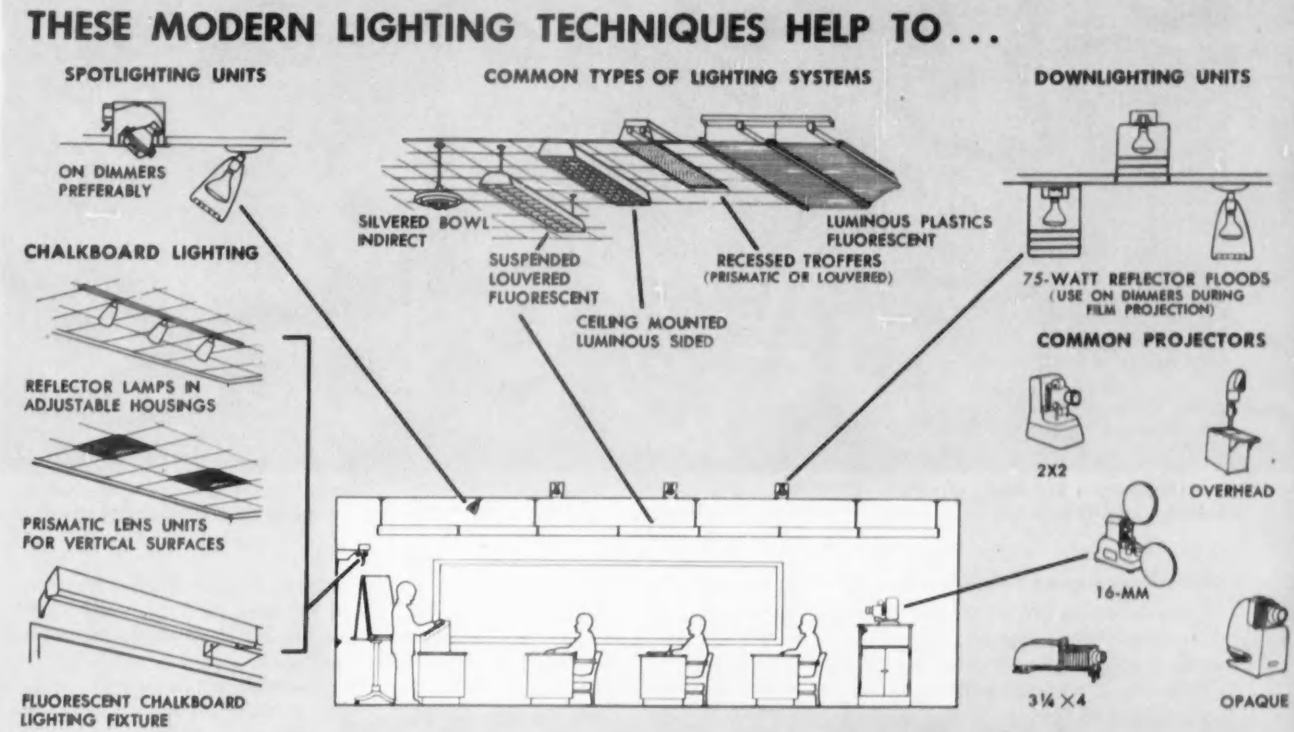
Going in for stone construction presented quite a problem: how to carry 3000 volts, and a little later 10,000 volts, through a stone wall. We had none of the insulators that you have now. Nor did we have porcelain tubing; it wasn't made at that time.

And glass was very friable. Often glass insulators would stand on your desk and crack, all by their lonesome, just from sheer internal stresses. For many purposes glass was the best we had.

But, there again, we used oak, a 6×6 oak piece, with a hole bored through it and paraffined. You see, boring a 1½-inch hole through a 6×6 oak piece will perhaps give you just about two inches of solid oak that, when carefully and thoroughly paraffined, will generally stand up to something like 100,000 volts. We did not know that then because we didn't know what 100,000 volts were. We knew only that it withstood our voltage. Inside the bored hole we put some hard-rubber tubing, which was obtainable, and inside the tubing, Clark wire.

This incident illustrates the ingenuity we had to exercise: One day we received a larger motor—a 200-hp motor—and it came without a collector ring. Having to operate it at once forced us into building a collector ring. We took four or five pieces of oak plank, 2 inches thick and paraffined, laid them cross-grain, and pinned them together with oak pins. We put them in a little old lathe and turned them down to round, with grooves. Then we wound copper wires in the grooves, flattened the wire down with a hammer, and filled it up with solder. It ran so well that we didn't bother to take it off when our collector rings finally arrived. It ran for two years.

Wonderful things can be done with a little ingenuity, together with paraffin, oak, and patience. Ω

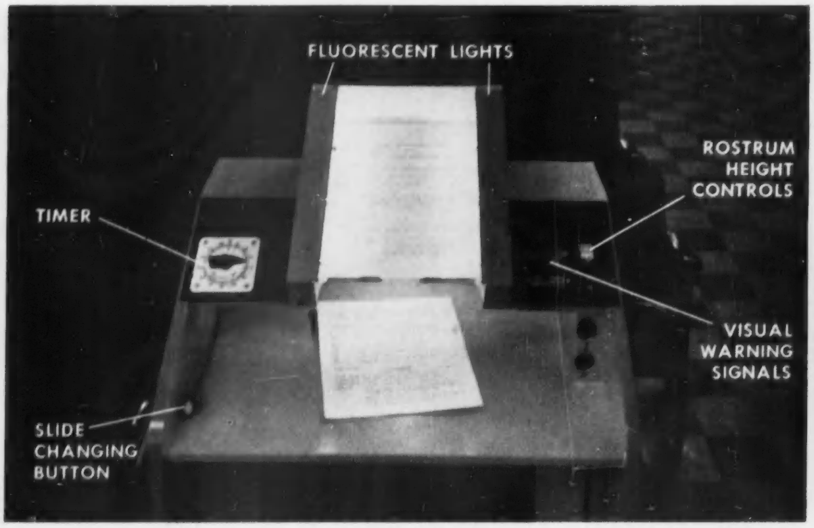


How Lighting Serves Education in Industry

By CARL J. ALLEN

Increasingly employee education becomes a major activity of management. It takes on several forms: orientation courses for new employees, staff meetings, technical forums, sales conferences for the more experienced employees; and advance-study managerial seminars for top-management personnel. All these point up industry's need for suitable rooms, designed and equipped to efficiently handle various educational activities.

Lighting performs an important service to education. A valuable teaching aid obtained at low cost, lighting contributes to more efficient teaching and more effective learning. In public schools the cost of good lighting in the classroom represents only about one percent of the total over-all cost of education. But considering the salaries of the class members who attend industrial educational programs, the cost of providing good lighting for such purposes becomes insignificant.



WELL-EQUIPPED ROSTRUM includes both lighting and mechanical aids that enable a speaker to deliver a smooth, poised presentation; illuminated speech prompter (right above) complete with an adjustable-speed control resembles those that are used in television studios.

Classroom Size and Equipment

Groups of 25 to 30 people should have classrooms at least 24 feet wide and 32 feet long—the usual size of a public school classroom. In classrooms longer than 35 feet the leader tends to lose personal contact with persons on the fringe of the group. Equipping the room with movable tables and chairs facilitates various seating positions: block arrangements for round-table discussions; several small groups for individual workshop discussions; rows or T or U groups for conferences.

Flexible seating demands comfortable lighting when viewed from all angles—for persons seated in the conference-type classroom can easily face in any direction.

Windowless industrial classrooms need not be a handicap. Indeed, they can be highly successful when furnished with good comfortable lighting and cheerful light-color interiors. Moreover, they eliminate the need for any shielding from sun and sky brightness or darkening when projecting slides and movies—problems that accompany windows.

Modern teaching techniques are designed to appeal to the visual sense. A good instructor constantly uses visual aids—chalkboards, tackboards, display panels, models, projected motion pictures or slides, and others. Each of these requires special lighting treatment for maximum effectiveness.

General Lighting

Conditions within specific classrooms vary widely. Thus recommendations for lighting a typical industrial classroom appear here as alternates, or options, to facilitate choosing the best arrangement to meet a specific condition.

Good general lighting must be visually comfortable and nondistracting. Most educational areas use fluorescent lighting because of its high lamp efficiency and utilization. But silvered-bowl incandescent lighting can sometimes be lower in over-all cost—for example, in locations having a power rate of about two cents per kilowatt-hour and using less than 500 hours of lighting per year. Under these conditions the savings in lower initial cost of the incandescent system, as compared with an equivalent fluorescent system, are more than the savings in lower operating cost of the fluorescent system. Silvered-bowl incandescent lighting may be the economical choice for lighting training classrooms or conference rooms not in constant use.

Of the common types of lighting systems, suspended louvered fluorescent equipments are the most widely used as they are relatively simple to install. Suspended fixtures perform well on ceiling heights of more than nine feet; for ceilings nine feet or less or where recessed lightning is not possible, the equipments can be surface or ceiling mounted.

New installations frequently utilize recessed troffers and luminous plastics ceilings. These two types can also be applied where high ceilings are to be lowered or unsightly overhead structures concealed by dropped-ceiling constructions. For general lighting in classrooms the trend moves toward 50 to 100 footcandles.

Supplementary Lighting

While general lighting is a primary consideration, supplementary lighting on the chalkboard, display easel, and demonstration table also makes a major contribution (illustration and photo, page 47). Accent lighting on these teaching areas sharpens visual details—to a person seated in the rear it may make the difference between seeing and not seeing an essential point under discussion. More importantly, the use of dramatic supplementary lighting creates a strong visual impression of the teaching point, giving it a better chance of being remembered. Usually the lecturer switch-controls the spotlights, but the smoothest spotlight performance comes when dimmer-operated and controlled by an assistant.

Because most speakers or instructors in industrial classes are specialists in their field rather than trained instructors, they generally rely on notes or outlines. Thus they find helpful some of the recent aids for the speaker: good lighting

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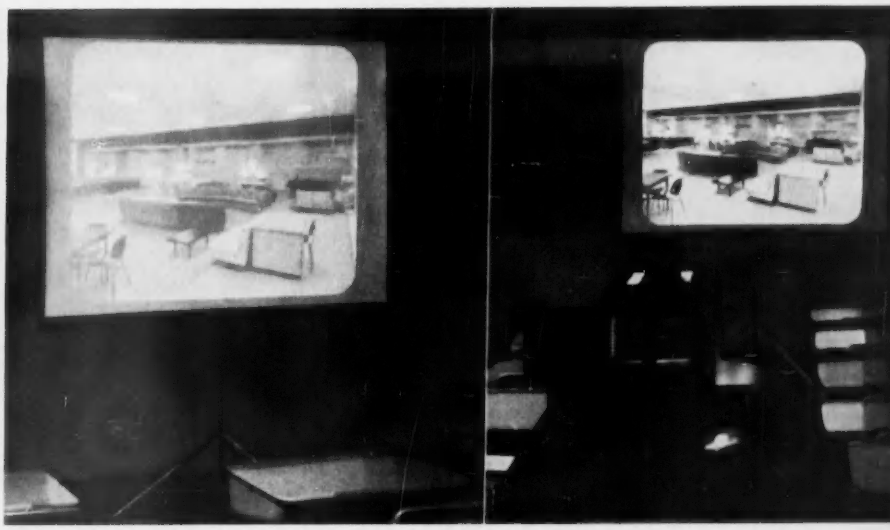
For eight years Mr. Allen, a previous contributor to the REVIEW, *has worked exclusively with lighting for educational institutions. School Lighting Specialist, Large Lamp Department, Nela Park, Cleveland, he has specialized in illuminating engineering since joining General Electric in 1936.*

FLUORESCENT CHALK creates dramatic and effective presentations in a dark room.



CLARITY OF PICTURE on a beaded screen depends on seating location; it appears washed out to a person seated at the side (left) but the projectionist sees a clear picture.

at the rostrum, illuminating the notes from both sides and an illuminated adjustable-speed speech prompter, first used for TV performances (photos, opposite page). The rostrum is also motorized to adjust to differences in speaker height.

Overhead spotlights ideally located on a line 55 degrees above horizontal from the speaker's face serve to concentrate the audience's attention on the speaker. This location is low enough to give pleasing facial shadows and yet high enough not to produce any undesirable glare in the speaker's eyes. These spotlights plus illumination on the speaker's notes cast a pleasant glow onto the speaker's face. Lighting only from the rostrum would produce unnatural effects. Two spotlights, one slightly stronger than the other and located about 90 degrees apart in the horizontal plane, give the desired results.

The chalkboard, a principal visual aid, needs the best lighting. With only general lighting, illumination on the chalkboard is usually about one half that on the desks—a good reason for supplementary illumination.

Today, chalkboard lighting fixtures come in a variety of incandescent and fluorescent forms. The increasingly popular fluorescent chalkboard lighting unit raises the illumination on the board to about 100 footcandles from a single fluorescent lamp in a good controlling reflector. This lighting unit not only makes chalkboard writing stand out clearly but also serves as a magnet that captures the visual attention of an audience.

Sometimes an instructor may want to write in the dark while material is being projected on a screen. On such occasions, replacing the regular fluorescent lamp in the chalkboard fixture with a 40-watt black-light fluorescent lamp equipped with the black-light filter makes fluorescent-chalk writing visible in the dark. Using chalk in various brilliant colors gives unusual and effective results, creating a dramatic presentation—long remembered by an audience (photo, left).

Visual Aid Projectors

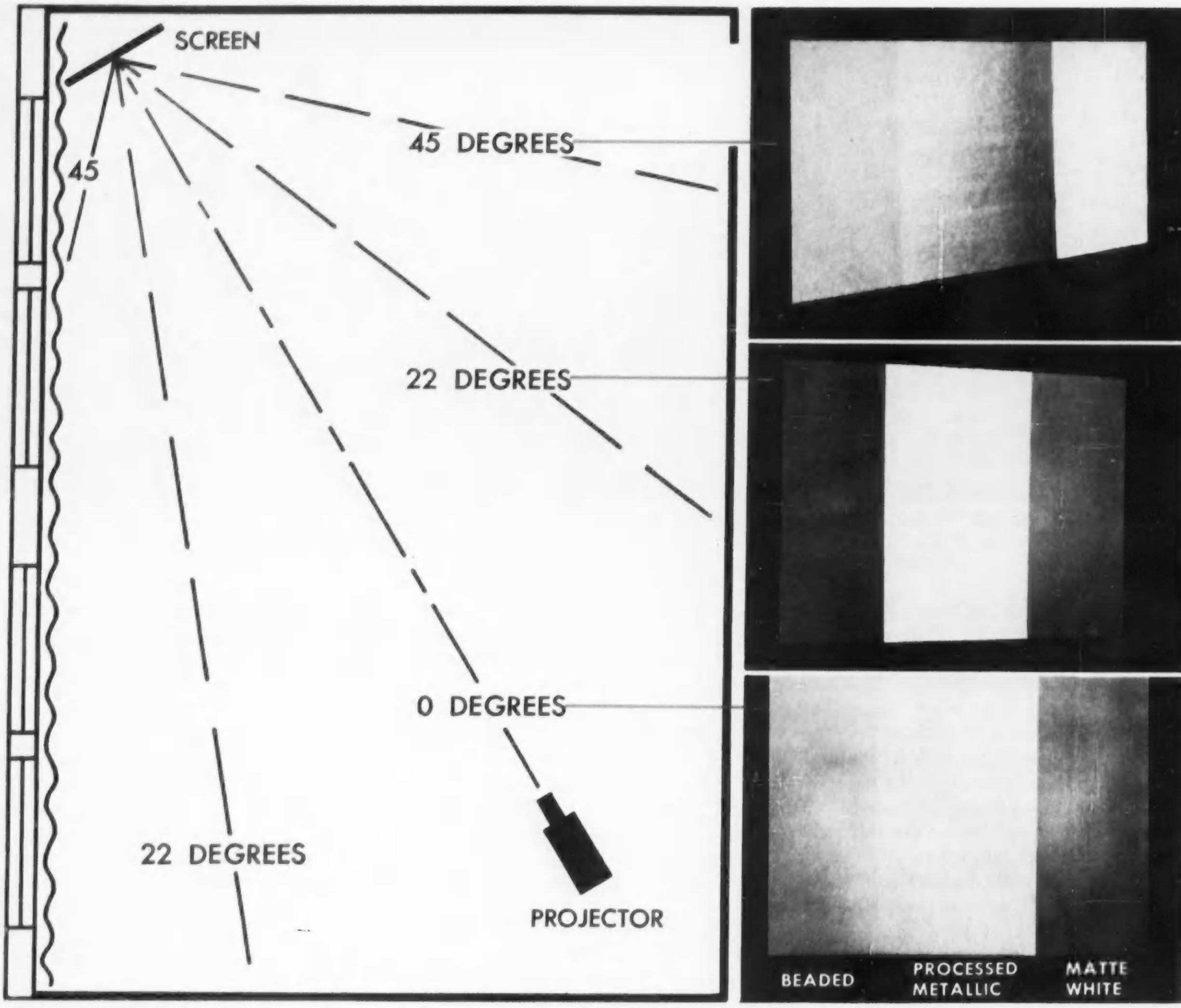
Research repeatedly shows that properly used audio-visual material—such as educational motion pictures—improve understanding and retention of material. Some fields of industrial education have a wealth of 16-mm motion-picture material; others use locally prepared 2×2-inch slides; and still in wide use is $3\frac{1}{4} \times 4$-inch slide material—especially for hand-colored slides.

In addition to the 16-mm, 2×2-inch, and $3\frac{1}{4} \times 4$-inch projectors, there are opaque and overhead projectors—useful where material is not readily available in film or slide form. The opaque projector though useful in projecting, say, open book pages up to 10 inches square, operates on the principle of reflected light. This makes it less efficient than those that project the light through transparent film. With an opaque projector, stray light on the screen must be kept to a minimum. In one test, for example, the image washed out at about one-quarter footcandle of stray light with a 500-watt opaque projector. But with an efficient 500-watt $3\frac{1}{4} \times 4$-inch projector, four footcandles of stray light were permissible on a screen before the projector image washed out—a 16 to 1 difference.

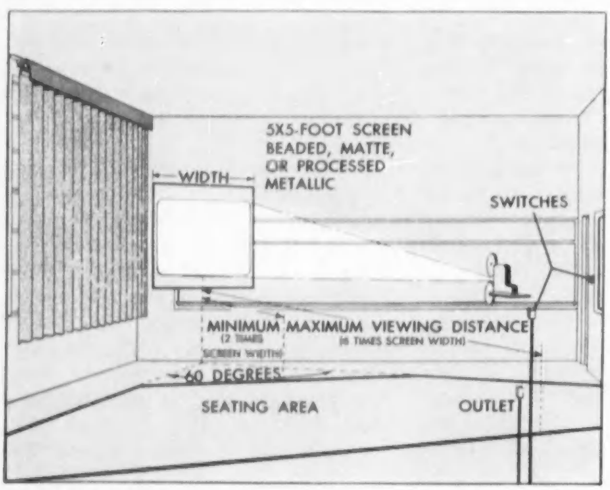
The overhead projector has this advantage: It can use hand-prepared illustrations made on large sheets of transparent material, eliminating the photographic processing. Machines that accommodate material 10 inches square can be readily obtained and used in considerable room illumination when projecting black-and-white line illustrations.

Closed-network television, rapidly becoming an educational tool, will probably be a common teaching technique in many industrial training programs. It is currently being used in college and high school teaching to show a class anything too large or small, too delicate, or too dangerous to directly present in front of a group.

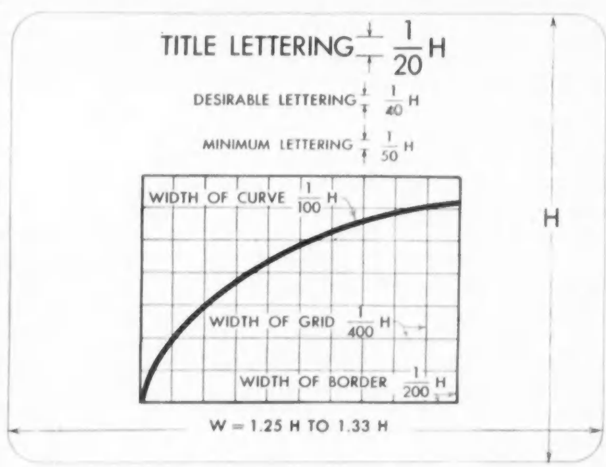
With modern TV cameras at least 50 footcandles of general lighting should be provided on the televised scene to assure reasonably good black-and-white pictures with good depth of focus. Viewing a televised picture differs from viewing the same scene on a motion-picture screen. The blacks in a televised picture come from the black glass that covers the face of the tube. Because the black glass absorbs most of the stray light, room illumination is not a serious limiting factor. On a motion-picture screen the blackest part of the picture can be no darker than the brightness of the



DEMONSTRATION SCREEN composed of three types of materials effectively indicates their differences. When viewed from the usual angles found in audience seating arrangements or from the projector position, the degree of brightness will depend on the type of screen.



GOOD AUDIENCE VIEWING in a classroom 32 feet long requires a 5-foot-wide screen—about one sixth the maximum viewing distance.



SCREEN READABILITY of printed matter requires specific letter sizes and line widths in relation to their projected reduction.

screen with whatever stray light shines on it. The TV screen is electronically activated, and typical screen brightnesses will be 10 to 15 times that of a typical 16-mm motion picture.

Screens

Reflected light screens fall in three categories: beaded glass, processed metallic, and white matte screens—each with its own properties.

The beaded screen directs light back on the axis from which the light came originally. Thus with the greatest amount of light coming from the projector, the most brilliant image is seen from the projector position. Because stray light from the window also reflects back on itself, someone seated with his back to the windows will be the most disturbed by these reflections. The combination of these two effects explains why one person may see a faint washed-out picture on the screen while the operator standing beside the projector sees a brilliant, clear picture (photos, right, page 49).

The relatively new, processed metallic screen, designed to reflect the light within a narrow vertical angle, disperses the light in a rather wide horizontal angle—a desirable property, considering the usual audience seating arrangement (illustration and photos, top, opposite page). Processed silver and finely ribbed aluminum screens used for this purpose come only in flat panels. Beaded and white matte screens have the advantage of portability; they can be rolled up for storage or transportation.

The recommended screen width of one sixth the maximum viewing distance makes small details readily visible; the 24×32-foot classroom would require about a 5-foot-wide screen (illustration, lower left, opposite page). With no critical visual detail, as in a pictorial motion picture, this ratio can be increased. Reduction in screen size increases screen brightness: a 30-inch screen will be four times brighter than a 60-inch screen with the same light on each.

Projection-Room Lighting

Projector-lamp efficiency, projector performance, and the reflectance characteristics of screens are all recent, significant improvements. Even so, a small amount of stray light still dilutes typical projected images to the point where they lose enough detail to be unsatisfactory. A test showed reasonably good results if stray light on the screen did not exceed one-half footcandle; at the two-footcandle level, loss of detail became objectionable.

Windowless rooms provide the best projection areas. With windows, opaque roller shades that overhang about six inches or have light-tight side channels adequately darken the room. Many schools use opaque draw draperies that can be pulled on curtain tracks over the entire face of the window. Light-tight side and bottom channels on Venetian blinds with redesigned slats and tapes permit a blind to close tightly with little light leakage.

For comfortable viewing, avoid contrast between a light screen and completely dark surroundings. However, too much surrounding light distracts from the projected images; if it fell on the screen, the picture sharpness would be diluted. An average general lighting level of about one footcandle—enough to make notes and identify persons—usually gives not more than one-half footcandle on the screen.

Low-level lighting for audio-visual presentations can be provided by 75-watt reflector flood lamps in well-louvered downlights operated on dimmers and located just over the seating area. At full voltage such units will provide 5 to 10 footcandles; at reduced voltage they provide one or two footcandles for note taking. Confining the light principally to the seating area prevents wash-out effect of stray light on the screen.

At one time, fluorescent lamps could not be dimmed. But now the rapid-start lamp permits dimming on special ballasts and dimming circuits. Thus the general fluorescent lighting level can be lowered to provide a satisfactory lighting level for good projection.

Dimmer-controlled indirect incandescent floor lamps may be used in a room already provided with lighting. This type of indirect lighting can be integrated into the design of portable projector carts (photo), using commercially available fixtures and a 300-watt reflector lamp.

Operating two incandescent lamps of like wattage in series will also provide low-level lighting. Such series operation of incandescent lamps equals lamp operation at 50 percent of rated voltage, resulting in about 10 percent normal light output. In silvered-bowl indirect lighting, two fixtures can be connected through a double-pole double-throw wall switch and operated at full line voltage or in series.

PROJECTION CART has an indirect dimmer-controlled light and other accessories for more efficient visual presentations.

Visual Display Charts

Often slides or charts are lettered too small to be read by an audience. Specific letter sizes and line widths can guide the person preparing charts for projection purposes (illustration, lower right, opposite page). Letter sizes and line widths are given in terms of the illustration's height. The smallest lettering height of 1/50 H is based on a minimum projected letter height of 1 inch for each 30 feet of viewing distance—assuming that the audience will not be seated farther away than six times the screen width. The American Medical Association bases its eye chart on a person with 20–20 vision being able to see 1-inch-high letters at 50 feet. Thus the 1/50 H ratio takes into consideration people who have lesser vision; for them the letters need to be larger.

Effectiveness of general and supplementary lighting in industrial classrooms depends on several related factors. These include the classroom's size and adaptability to projection requirements, type of projectors and screens used in presenting visual aids, and the quality of visual material. When properly used in the industrial classroom, good lighting supplemented by helpful visual aids makes teaching and learning more efficient, more effective, and more interesting. Ω

Plan Team tosses in ideas, discards some, sorts out, and develops the best.

Produce Script, props, approvals are all part of wearing schedule.

Present A commercial that appears natural and easy to an audience owes its smoothness to weeks of planning and final coordination of activities.

Producing a Three-Minute Spectacular

Review STAFF REPORT

On Sunday evening, March 4, from 9 to 9:30 o'clock in the East, approximately one out of every five Americans saw and heard Paul Muni and Polly Bergen in a television play called "A Letter from the Queen."

Each of the 33-odd-million viewers paid nothing for this entertainment, except a few pennies worth of depreciation on his TV set (assuming he wasn't at the neighbors) and a tiny fraction of the month's power bill.

General Electric, on the other hand, paid a handsome sum of money for the services of the people needed to produce a complex collection of electronic impulses and distribute them to 152 stations throughout the land.

And for this weekly outlay, General Electric has the opportunity to talk about itself for three minutes—all the Federal Communications Commission allows for each half hour of program time.

If all 33-million people watch and listen—and understand—the program is a tremendous bargain. Reaching this audience, say, by direct mail would cost many times as much in postage alone.

If only a few watch and listen—and if they should fail to understand—the program is a colossal waste of money.

And just because 33-million people watch the entertainment portion of the show—occurring both before and after

the three-minute commercial—is no assurance that they will be on hand during those middle three minutes. It's obviously an ideal time to go to the refrigerator, to make sure the kiddies are in bed, to prepare a quick Sunday-night snack, or to check the newspaper to see what will be on what channel at 9:30.

There's the problem. In only 180 seconds the commercial must tell in a dignified manner how and why, among other things, General Electric is a leader in research, engineering, and manufacturing skill. And because the audience would just as soon be doing something else, the presentation must hold their interest from its outset until the entertainment resumes.

The three-minute Progress Report for the March 4 program was devoted to electric motors, *The Universal Servants*. The steps that led from the conception of this commercial to its brief moment of glory beginning at 9:16:16 pm make an interesting story of the problems encountered in communicating a fairly intricate technical idea to a mass audience—and making it register.

Progress Reports are handled by a three-man operation—supervisor and two producers—in the Schenectady unit of General Electric's Public and Employee Relations Services. The New York advertising agency of Batten, Barton, Durstine, and Osborn (BBDO) provides the General Electric unit with a basic staff of five men: coordinator, agency producer, film producer, and two writers. The agency producer hires the directors, scene designers, cameramen, and talent, usually free-lance. This team of eight men plans, develops, and produces—week in and week out—180 seconds of entertaining education that will register the Company's message and draw above-average survey ratings.

Progress Reports are planned in 13-week cycles at a meeting with BBDO. The group presents ideas—always comes up with a surplus, relegates some to a future series, and immediately discards others.

Even approved subjects hurdle a long series of difficulties before being firmly scheduled. For instance, live commercials are usually coupled with live entertainment, film commercials with film shows. The difference in quality between film and live makes a mixture of the two noticeable to viewers. Money and time are other factors: a film commercial costs about three times as much as a live one and usually must be shot at least a month before the release date. While films lack the here-and-now spontaneity of live commercials, they do give some advantages. They offer the chance of newsreel coverage of an important event and can be rerun as many times as the sponsor chooses, thus amortizing the cost premium.

Timing introduces another problem: An electricity-on-the-farm commercial should be scheduled in the spring; the engineer's role in today's technology would tie in with Engineers' Week. Also commercials must give a balanced picture of General Electric's activities: research, engineering progress, manufacturing skill, and human relations, to name a few.

That educational and entertaining commercials are produced each week and receive high ratings—even allowing for the vast range of subjects offered by a company the size of General Electric—is a tribute to the GE—BBDO team.

Toward the end of November 1955, the group met and planned the second cycle of Progress Reports (January through March). They discussed—and scheduled—a live commercial on electric motors for March 4, bracketed by one on railroad progress and one on lightning research.

Soon after this team meeting, they released the production schedule: Charlie Keenan of General Electric would follow it with Al Book of BBDO as the writer.

Because 10 of General Electric's product departments manufacture motors, each justifiably proud of its products and prerogatives, Keenan knew that the job ahead would take an unusual amount of patience and understanding. And so late in January, he slated a meeting with the primary contact, Harry E. Smith, Advertising Manager of General Electric's Medium Induction Motor Department, Schenectady. Other Company advertising men would be reached by additional communication lines.

One morning early in February, Keenan and Book met in Smith's office. MIM, as his department is called throughout the Company, produces 7½- to 3000-hp motors—sold by General Electric under its registered trademark of Tri-Clad motors.

Keenan roughed out the objectives of the Progress Report: explain how an electric motor works; point out progress in electric motors; show some significant motors of today; tell how motors benefit everyone.

Quickly, talk turned to the first objective—just how *does* an electric motor work.

"Make it simple," said Book. "I'm a typical layman. I'm a sounding board. I pass on what I hear to the audience. The simpler it is the better for our purpose."

Smith explained that a motor basically converts electric energy received over lines into rotating motion to drive machines. He suggested a simple demonstration: Put metal filings into a beaker of water, then place the beaker inside a rotating electric field. "For the transition," he said, "take out the beaker and replace it with the motor's rotor. It's that simple."

As the discussion warmed, such terms as stator, lines of force, magnetism, a-c

Sunday 11 am Lifeless Studio 56 awaits action.

2 pm Men complete staging details, arrange motors, and line up tools.

2:40 In upper reaches of Hall, group meets for final script conference.

and d-c, automation, dynamometer, and synchronous motor flowed freely. Keenan, sensing that the objectives were fading rapidly, called a halt, urging that they discard these technical terms. "I know they sound simple. But just because we use them doesn't indicate that we know their meaning or can even explain them. Remember, this must be understood by a *mass* audience. You're not talking to an AIEE group. And leave out automation. We'll cover that in a later commercial."

After the meeting in Smith's office, Keenan circulated a letter that read, in part: "The next meeting on our research activities concerning the upcoming Progress Report on electric motors will be held in New York City on Tuesday, February 14. We're going to get together with Don Herbert with a view toward developing some simple demonstration that will help get this story across better."

Don Herbert, General Electric's Progress Reporter, is known to small-fry viewers—and many adults, too—as Mr. Wizard, star of a half-hour weekly television show seen on more than 141 stations. There are hundreds of Mr. Wizard clubs, and his technique of "teaching science painlessly" has been cited in a score of special awards and scrolls now hanging in his office. Herbert is an expert at performing graphic demonstrations for television cameras. This ability plus a fine combination of a businesslike mien and an ingratiating air got him the job of General Electric's Progress Reporter.

Prism Productions, Herbert's office-workshop on 23rd Street in New York where the group met, has large airy offices and a well-equipped workroom.

Shortly after 10 o'clock, Al Book read his first rough to the group. Into the script he had written Billy Quinn—a 10-year-old actor who had served as the "questioner" on many of the Progress Reports. The commercial would open with Herbert and Billy demonstrating the way that a motor works, followed by Billy guessing the number of motors in his home. This, Book said, would show the importance of motors in the home. And then film clips would emphasize the importance of motors in industry.

"For the opening shot they could be examining a fan," Book suggested.

Someone doubted whether a fan was dramatic enough and asked, "How about an erector set?"

"Can't use that," Keenan remarked, "we used it last week."

"How much time do I have to show how a motor works?" Herbert inquired. Before anyone could reply, he laughingly answered, "Yeah, I know, 22 seconds. This will revolutionize physics teaching!"

"That looks too complicated." The agency producer nodded toward a small demonstration motor whirring in front of Herbert. "Can't we show how a motor works without all this . . .?" He pointed to the exposed magnets, core, and wires.

"You're just like my wife," Herbert said, smiling. "She's always saying to me, 'Can't you tell me how atomic energy works without going into all those details?' "

Because the commercial had no opening, Keenan steered the talk in that direction. He again outlined the objectives, suggesting that they concentrate on something difficult when done by hand but easy with a motor.

One approach had Billy polishing a chair, with an electric buffer finishing the job. Reflections from the chair made this idea impractical. Then, too, not enough people in the TV audience own buffers.

"Why not have the kid sawing a board? I could finish the job with a power saw," Herbert volunteered. There were nods of agreement.

More discussion followed concerning the demonstration motor and whether three-phase 110- or 220-volt power would be available in the studio. Then the meeting moved into Herbert's office to wrap up the sequence of the commercial's elements.

One item brought to the group's attention was Book's concern about having the boy in the script. "If he blows a line, then Don has to cover. It means that Don must learn not only his own lines but also the kid's. I know the kid is good, but he's only 10. That's a lot of responsibility for a 10-year-old."

"I agree," Keenan said. "It's something we've considered from every angle. But the advantages of having the kid on the show far outweigh any fluffs. He's got audience appeal. He's got a likable face—wholesome. The audience puts itself in the boy's shoes. They say to themselves, 'If that kid can understand it, so can I.' And it works, too. This is nothing new—only an adaptation of what the Greeks did centuries ago. It's the Greek chorus all over again.

7:15 Discarding the film clips forces some hurried revisions in the commercial.

8:42 Herbert returns and once more walks through the commercial with Billy. The Director recommends suggestions for improving the audience's visual impressions.

During a play the chorus became the 'audience,' registering the reactions of an audience. The boy does the same thing: he's the Greek chorus; he's the audience. Okay?"

At 12:25 the group broke up for lunch. Book now had a better idea of how to proceed: Billy would open sawing on a piece of wood and Herbert would complete the job with a power saw; an electric motor demonstration would follow, plus some discussion about motors in the home, film clips on motors in industry, and a windup showing today's General Electric motors. Book promised a script in a couple of days.

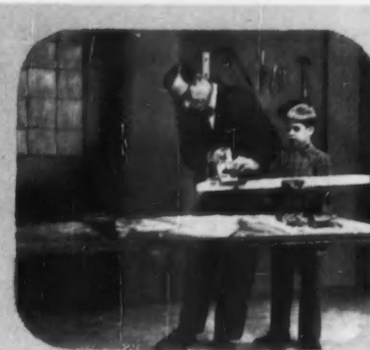
In the $2\frac{1}{2}$ weeks between the meeting at Herbert's workshop and March 4, Keenan maintained a wearing and abrasive schedule. He was closely following not only the electric motors commercial but also seven others that were in various stages of development.

Script changes were usually of a minor nature—a constant effort to get a more informative and polished presentation. At the same time he remained aware of the three-minute limitation on the copy. Words and phrases were altered: Billy's "Whews" were changed to "Wows," his "Gees" to "Boys," and his "Yep" to "Yes." "General Electric" was placed in front of the word "motors" at the proper places, and "washing machine" became "washer."

In one instance it was decided that Herbert should wear safety glasses while he operated the power saw. As Keenan expressed it, "We'd have every safety man in the Company jumping

9:16:16 The impact of a carefully planned, thoughtfully executed three-minute commercial climaxes the group effort that extended over a strenuous 13-week period.

(As the commercial opens, audience hears sound of wood being sawed.)



Let's do it the easy way with an electric power saw. Watch.

See, the magnetic force between the two [magnets] makes this one turn.

In the average American home you'll find electric motors all over the house. . . .

General Electric has made a lot of progress in motors—work horses of industry.

This tiny one is the G-E Telechron electric clock motor.

HERE'S WHAT YOU SAW AND HEARD ON SUNDAY,

HERBERT
"Pretty tough work, eh, Billy?"

BILLY
"Sure is, Mr. Herbert."

HERBERT
"Let's do it the easy way with an electric power saw. Watch."

BILLY
"That looks easy."

HERBERT
"Well, that's because we did the hard work with electricity and magnetism."

BILLY
"Electricity and magnetism?"

HERBERT
"Uh, huh, because that's what makes an electric motor work, and, of course, an electric motor is what made the saw work. Come over here, and I'll show you. You see, here are two permanent magnets, one mounted so that it can turn—like this. Watch what happens when I bring them close together."

BILLY
"It moves."

HERBERT
"Sure. See, the magnetic force between the two makes this one turn. Now here's another one mounted so that it can turn, too. This is the core of an electric motor. When we send the electric current through these coils we create magnetism that does the same thing—watch."

BILLY
"Look at it go."

HERBERT
"'Course, that keeps on spinning and that's what makes the electric saw work."

BILLY
"Do all motors work like that?"

HERBERT
"Well, just about. Billy, I wonder if you realize how many electric motors are working for us all the time? Over here in the kitchen, for instance. You look around the kitchen and see how many electric motors you can find."

BILLY
"Well, there's a motor in the mixer."

HERBERT
"Yeah."

BILLY
"In the washer."

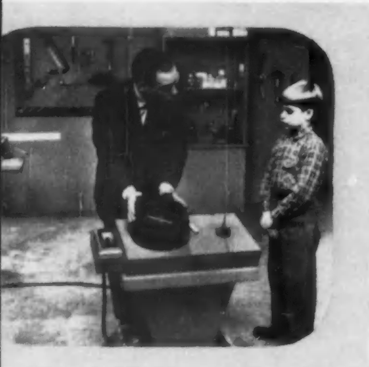
HERBERT
"Very good, any more?"

BILLY
"The refrigerator."

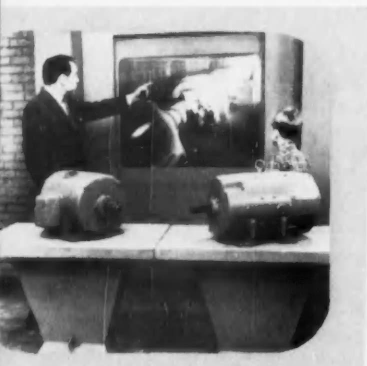
HERBERT
"In the refrigerator, in the automatic dishwasher, the automatic oven timer, the electric clock, and this is just in the kitchen. In the average American home you'll find electric motors all over the house from the basement all the way up to the attic. Of course, electric motors not only help mother do her work around the house, but they help dad, too, regardless of what his job is, whether he works in an office or plant or on the farm. In fact, G-E electric motors are important in every industry."

BILLY
"Gee, I never thought of it that way before."

HERBERT
"General Electric has made a lot of progress in the development of motors,



This is the core . . . we send electric current through these coils. . . .



And here is a motor drive for a giant wind tunnel.

MARCH 4

too. Today, they make thousands of different kinds. Here is the famous G-E Tri-Clad, and here is a new Kinamatic motor—together, the work horses of industry. This tiny one is the G-E Telechron electric clock motor. And here is a motor drive for a giant wind tunnel."

BILLY

"The motor is bigger than a man."

HERBERT

"It is, and every one of these motors makes—well—more muscle, more strength for all of us and for our country."

BILLY

"Electric motors sure are important."

HERBERT

"They're very important, Billy. G-E engineers are always trying to make them even better, to improve all of the things that make our lives richer, more satisfying, and more rewarding. In America, that's the way we measure progress, and as you know, at General Electric, progress is our most important product."

all over us if Herbert didn't wear them. And it might encourage some of the do-it-yourselfers in the audience to use them, too."

Another one of Keenan's duties was coordinating and ordering the various properties for the commercial: General Electric unit kitchen, clock, mixer, mural of a wind tunnel, and a pair of safety glasses. BBDO, meanwhile, looked for a power saw with a General Electric motor and a hand saw.

Five days before air time, scripts were distributed to interested General Electric operating departments for their approvals. By late that afternoon the approved copies began trickling in. The reactions were uniformly satisfactory except for the description of how an electric motor works. Immediately, Keenan began preparing a revised version of just how an electric motor *does* work.

On Wednesday, February 29, Book arrived from New York to work with Keenan on the electric motors commercial and others for future shows.

With some cardboard models he had developed with an engineer, Keenan showed Book the new idea for demonstrating the principle of an electric motor: A bar magnet brought close to one end of a magnet pivoting on a vertical shaft was either repelled or attracted. "Now," Keenan said, "we lift off this magnet that spins, place it inside the stator of a motor, turn on the power, and the magnet should spin.

"Herbert," he explained, "will say: 'When electricity is put through the stator.' Only the word 'stator' won't mean anything to the audience. What's a better word?"

Book thought a second, then said, "How about core?"

Keenan nodded. "Herbert will say something like: 'And when electricity is put through the core of an electric motor, it becomes a magnet and causes the other magnet to spin.' Then he'll turn on a switch, and the magnet should spin."

"You sure this is going to work?" asked Book. "Remember, this is live. We're on the air."

To cover all chances, Keenan planned to have two demonstrations written into the script. One would use the bar magnets; the other would use one of Herbert's science demonstration motors.

Next he tackled the problem of getting the "magnet" motor built and shipped to New York for the telecast. Harry Smith furnished the stator of a 7½-hp Tri-Clad motor, and a General Electric model shop assembled the demonstration. Getting the bar magnets proved to be a task. Finally, a physics professor at Union College solved this problem with two 6-inch demonstration compasses.

Book returned to New York to get the final version on paper and duplicated for the show. A meeting in New York at CBS Studio 56 on 58th Street between Park Avenue and Lexington was set for 2 pm Sunday—seven hours before air time.

CBS Studio 56 was once the Liederkranz Hall, acoustically one of the better halls in New York. It has since been chopped up into studios and today is used almost entirely for the production of live TV commercials.

A look inside Studio 56 on this particular Sunday morning reveals four gaunt walls plus lighting equipment and sundry gear associated with a TV studio. The pile of crates in the middle of the floor contains the General Electric unit kitchen, a refrigerator, and other props.

2 pm—The unit kitchen and refrigerator are in place, and all sets are erected. The four sets—workshop, kitchen, living room, and motor display—form an arc to make camera movement easier.

All the latent energy that the project quietly absorbed for five weeks now comes to the surface. Twenty-five people busily work on staging details: spraying wax on all the unit kitchen and refrigerator's shiny surfaces to reduce glaring reflections, or flare, in the camera; putting the demonstration motors in place; and lining up the tools for the workshop area.

The first time any self-styled reasonable man sees live television being produced, he says, "There must be an easier way." But logic—surrounded by pressures, authorities, conflicting talents, union regulations, and the relentless progress of the clock on the wall—can seldom be found in the mechanics of a TV studio. That the visible results are logical and coherent is a tribute to the performers who maintain equanimity through it all. Most people have the idea that men like Don Herbert are overpaid. But when the time arrives and responsibility for the job rests on his shoulders alone, not many envy him.

2:40—In the upper reaches of the Hall (photo, right, page 54), the show's director meets with Don Herbert (cen-

"... the commercial is the reason for the whole enterprise."

ter), BBDO representatives, including Al Book (second, left), and General Electric representative Charlie Keenan, opposite Book.

Herbert reads through the script for timing; the director takes the part of Billy who is rehearsing for another show. The first read-through clocks out at 2 minutes and 40 seconds.

The film clips don't agree with the script; it is rewritten.

3:45—The "camera fax" begins—a rehearsal using cameras that transmit pictures to the control room. Camera positions are plotted, and the director "blocks," or plans, the action for Herbert and Billy.

A union man clamps a 2×4 in the workshop vise. Which end should Herbert saw? If he saws the end that would give the best camera shot, it would offend all the home craftsmen in the audience, as well as not be quite safe. Keenan decides it should be done the safe and the most logical way; the director works with the cameras to get a satisfactory angle.

4:20—On the control-room screen, the position of the 7½-hp Tri-Clad motor looks awkward. To say that a motor is a handsome piece of equipment would be charitable, even though designers have tried to give it style and dignity. But with the distortions that occur on the tiny screen, conduit boxes suddenly grow to outlandish and grotesque proportions, and shafts project at odd angles. "If we show the General Electric monogram, then you can't see the shaft. Which is most important?" the director asks. Keenan says that it must look like a motor—never mind the emblem on the end shield.

5:15—Herbert goes through the commercial and an agency man takes the part of Billy. It times out to three minutes and six seconds. Number 3 camera conks out. The director calls a break.

There's a stir in the control room: The whirling magnets in the motor demonstration aren't visible enough; they blend into the background.

It is suggested they be painted white. No, someone else says that may ruin their magnetism. A technican solves the problem when he sticks a piece of masking tape on the magnets and trims the tape to size. The contrast looks good on the control-room screen.

Then Herbert complains that the power saw spews sawdust over his dark suit, giving it a tweedy appearance. Another piece of masking tape seals the exhaust port on the saw.

Next, the mixer on the unit kitchen can't be seen. Again, it's a question of a light color against a light color. Because masking tape or paint is out of the question, the director works in a close-up shot to identify the mixer.

5:45—The director calls an hour break for dinner.

6:45—Billy Quinn has arrived and walks through his part with Herbert. Billy is a quiet youngster who takes rehearsals and script changes in his stride. He gets along well with Herbert and readily follows orders from the director. Billy has performed on Hit Parade, appeared on Broadway in "The Remarkable Mr. Pennypacker," recorded for Columbia with Giselle McKenzie, and receives an allowance of $1 per week.

7:15—Rehearsals continue, each one becoming smoother as the actors fall into the rhythm of the pace and the cameramen and director integrate their routines.

Between 7:15 and 7:45 each run-through incorporates the film clips. The film—handled in another CBS studio—is seen on a monitor in Studio 56.

For the first run-through with the film, Herbert's commentary and the film sequence don't match. Reproduction quality is poor. Keenan shakes his head and calls the agency representatives together. They decide to eliminate the film clips, remove the living-room set, and rewrite the script to include electric motors in various industries.

7:45—At a CBS studio on the third floor of Grand Central Terminal, 16 blocks away, Paul Muni and Polly Bergen begin the dress rehearsal.

8:00—The commercial is integrated into the dress rehearsal and times out to exactly three minutes.

8:15—Herbert, anxious to get some "business" (eye-catching hand action) into the final scene with the two display motors, suggests giving one of the motor shafts a slight spin. This is accepted and a technician cleans off the gummy protective coating.

At the unit kitchen, more wax is sprayed on the cabinets to kill flares.

Herbert breaks his collar stay and replaces it with one borrowed from a BBDO man.

8:27—Herbert leaves to have make-up put on; Billy talks with his mother in a corner of the studio; others drift out for coffee.

8:42—Herbert returns and once more walks through the commercial with Billy. Billy's mother gives her son's hair a final combing.

9:00—The master screen in the control room shows the General Electric monogram, and the announcer says: "For General Electric here is Ronald Reagan."

In Studio 56, cameras warm up and the floor is cleared. The assistant director quips, "Isn't it true Muni did this show because he has some General Electric stock?"

But the problems of Paul Muni or Polly Bergen don't concern the men in Studio 56. Their only worry is the middle three minutes, the important part, the part that pays off. Admittedly, the men in Studio 56 agree that without good entertainment nobody watches the sponsor's message. But there is also the unexpressed attitude that it's tougher to get people to watch a commercial than to watch some make-believe story. And when you get right down to it, the commercial is the reason for the whole enterprise.

9:07—Herbert and Billy go through the commercial once again. During the motor demonstration, Herbert keeps calling the magnets "needles" (which, of course, they are). Keenan asks the agency producer to request Herbert to say "magnets."

9:14—In the control room the assistant director calls the one-minute signal. Someone scrapes a chair along the floor and tension mounts.

A phone rings. The assistant director answers, listens, puts his hand over the mouthpiece, and says, "Central control says they're running over. They'll appreciate anything we can give them." He uncovers the mouthpiece and to central control reports, "I relayed the message," then hangs up.

9:16—Ronald Reagan says: "Y'know, many of the jobs that we have to do at home and at work would be a lot harder if it weren't for General Electric motors—as you'll see in Don Herbert's Progress Report."

"'It was an instructive commercial, and people . . . could grasp it.'"

At exactly 9:16:16 the commercial begins (complete script, box, page 56), and 2 minutes and 50 seconds later Herbert concludes with, ". . . and as you know, at General Electric, progress is our most important product."

The members of the audience, assuming they hadn't gone to check the kids or get that sandwich, heard Don Herbert and Billy Quinn speak barely 500 words—mostly words of one syllable. As the professional performers they are, both carried it off in perfect fashion. The 2×4 was neatly sawed, the demonstration motor hesitated momentarily then spun wildly, no flare came from the unit kitchen, and the smallest General Electric motor looked small indeed in Herbert's hand.

The program, it was disclosed later, had a Nielsen rating of 33.5. This means that 33.5 percent of the 35-million television homes in America saw the program. Each of the nearly 12-million sets tuned to the General Electric Theater was watched by an average of 2.78 persons, making a total audience of 33 million. Both the Nielsen and the Trendex surveys put the General Electric Theater for March 4 among the "top 10" for the week.

Having spent the money for the program, it is not hard to justify spending a little more to see how much of an impact the first investment produced. For this purpose, General Electric and BBDO obtain the services of Gallup and Robinson, a well-known Princeton, NJ, opinion-survey organization. Gallup and Robinson submit a weekly "Television Impact Report," a 30-page mimeographed document describing in detail the results of their Monday survey.

The term "Remember Commercial" used in the report is considered by General Electric and BBDO to be the key factor. In this regard, the commercials on the General Electric Theater almost invariably have done well. Gallup and Robinson say that the Remember Commercial norm for all one-half-hour programs advertising one product (about three minutes devoted to a commercial) is 55 percent. The average for all General Electric Theater programs during the past season was 65 percent. On these commercials, men do better than women by a 71 to 54 score.

The electric motors commercial on March 4 achieved a score of 67 percent —above the norm for all programs and above the average for the General Electric Theater. Of the men interviewed who qualified as viewers of the program, 73 percent could recall the commercial with reasonable accuracy; for women the figure was 60 percent.

Of greatest interest to the novice reading a Gallup and Robinson Impact Report are the verbatim statements, recorded in astounding detail by interviewers.

The vast majority of recalls indicated that the audience understood the message and that a favorable impression of General Electric was created. Here are some samples . . .

"A man showed a little boy how a small, primitive motor operated. It had an armature and a magnet. The one thing they always say is, 'Progress is our most important product.' They showed all the different types of motors that GE makes; one was a huge thing. The commercial pointed out how important motors are in our daily lives and how different things would be if we didn't have any motors. I thought it was a good idea to use the little boy to explain the fundamentals of the motors. They had a reasonable approach and, the points were easy to understand."

"Don Herbert was talking to a kid about motors. He said that electricity and magnetism work together. He demonstrated how the magnetic field in the motor was activated. Large and small motors were shown. A Telechron clock was an example of a small motor. Motors can be any size and still be practical. They said, 'Progress is our most important product' and showed that they are more interested in progress than anything else. The commercial was done in the simplest manner. If the little kid could understand, then anyone could comprehend the way the motor worked."

"A man showed a little boy all the motors there were in the house. He pointed out everything electric in the kitchen that had a motor. They showed a motor bigger than a man in a tremendous room. Men were standing by it. They showed the coils and the magnet on the inside of a smaller motor and explained how it turned. It was very interesting. I had never heard the working of a motor explained. It was an instructive commercial, and people like me who didn't know anything about motors could grasp it. The commercials are not too long, and they are not always interrupting the story. They're not overdone. . . ."

And people who have the story all wrong still indicate a favorable impression of General Electric . . .

"They showed a cylindrical object on a platform. The little pin or needle in the contraption was spinning, showing how electricity was produced. They also showed some motors. I think the main idea was to show the centrifugal force of GE to produce electricity which is the main object of the country [Company]. The more electricity produced the more advancements there will be in the country. They also try to sell their products. The little boy added a family life touch to the commercial. Anything GE says is very true. They are a good company."

"It was a stupid commercial because the average person doesn't how too much about motors. It was just a way to bring the name of GE before the public. They showed the different types of motors they handle and talked about the sizes and the jobs they do. GE is a good name, and their products and the fields into which they go are vast. It is a big company with great resources, and they are in there pitching."

Constant analysis of these playbacks, or recalls, leads to two general conclusions . . .

- No matter how straightforward or oversimplified the presentation may be in the eyes of those preparing it, the average viewer cannot be expected to gain more than a general impression of what the message is all about.
- Complete comprehension of the details presented is not essential to creating favorable impressions of the sponsor.

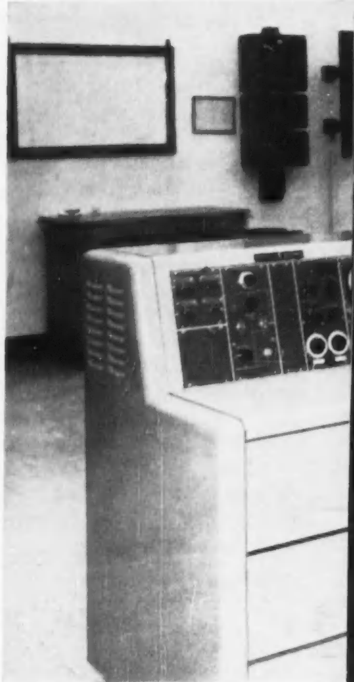
But was it worth the time, worry, and expense wrapped up in that brief interval of time from 9:16:16 to 9:19:06 p.m. on Sunday, March 4?

One factor explains the time and worry—and justifies the expense. This fabulous factor is the size of the audience: On this one Sunday evening in March, Paul Muni performed for more people than saw Sarah Bernhardt in a lifetime on the stage.

The correlation between *audience size* and *preparation effort* is an obvious example of human nature at work. It might be expected that *preparation effort* would reach an absolute maximum and level off at a point well below an *audience size* of 33-million people. However, the explanation for the maximum effort surrounding General Electric's Sunday night commercials rests in the fact that, if there *is* a *maximum preparation* effort, it isn't reached with an audience of a mere 33 million.

"You oughta see," one advertising man says, "how some poor guys stew and fret about the commercials for something like Peter Pan—when 60-million people are watching." —PRH

PENALTY-FACTOR COMPUTER applied to AG&E system saves over $100,000 a year compared to operating the system with transmission losses neglected.



AUTOMATIC DISPATCHING SYSTEM u
obtain the appropriate incremental cost s

How Modern Tools Improve Power System

By DR. L. K. KIRCHMAYER

Recent developments in analytical methods, computers, and load controls have saved the electric utility industry millions of dollars annually in operating costs. These techniques illustrate the challenging problems electric utility engineers are solving in cooperation with electrical manufacturers.

To establish a common basis, let's define the term "electric utility power system." A power system is an integration of sources of electric energy and transmission facilities designed to provide an adequate and economical supply of electric energy to a given area. Transmission lines of 100,000 to 400,000 volts interconnect the loads and sources of generation. For example, the system of the American Gas and Electric Co. (AG&E) provides electric service to about 1,300,000 customers in a 40,000-square-mile territory that includes parts of seven states. Altogether, the AG&E system operates 32 steam-electric and hydroelectric plants having a capacity of 4-million kilowatts. A network of 5560 circuit miles of 132,000- and 330,000-volt transmission lines interconnects these plants and the load centers.

The operating engineer, or load dispatcher, is responsible for providing reliable service at a minimum cost by coordinating the operation of the power system. Recently developed methods greatly aid him in operating the system more economically, with a resultant minimum fuel expenditure. Of particular significance are new methods of analysis, computers for undertaking these analyses, and load control systems that automatically and economically control the outputs of the plants.

Fundamental Principles

The dispatcher's analysis must recognize that the various power generating stations differ in thermodynamic and hydraulic efficiencies, cost of fuel, and proximity to the load centers.

The first step in the analysis determines the incremental production-cost characteristics of the various plants in the system. The incremental production-cost characteristic (illustration, page 62) simply means the increased number of dollars per hour that must be spent to produce an additional megawatt of output. Note that the incremental production cost increases with the output. If all generating plants were at the same location, operating all units at the same incremental production costs would achieve optimum economy.

However, in many systems the plants and loads are at different locations, interconnected by the transmission system. Transmission losses, which will occur in such system operation, must be considered in the analysis. Annual fuel savings of about $50,000 per 1000 megawatts of installed peak capacity have resulted from proper consideration of transmission losses in the scheduling of generation for widespread systems.

General Electric in cooperation with American Gas and Electric Service Corp. developed practical means of

M utilizes master-area and dispatching consoles that
st signal to be transmitted to controlled units.

Operations

appropriately evaluating and calculating transmission losses for various operating conditions. Through the use of a mathematical model of the transmission system, a loss formula is obtained that expresses transmission losses in terms of all source loadings. This formula involves the square of each source loading and the cross products of all source loadings.

This formula permits developing practical methods of coordinating transmission losses with incremental production costs to obtain maximum operating economy. Essentially, the loss formula is used to calculate penalty factors that modify incremental production costs to include the effects of transmission losses. Optimum economy—with the effect of transmission losses considered—is then obtained when the incremental cost of received power is the same for all sources. Reaching a generation schedule by this criterion requires the solution of a set of nonlinear simultaneous equations.

Pioneering work by General Electric in cooperation with the Hydro-Electric Power Commission of Ontario produced certain fundamental principles for the economic loading of a combined steam and hydroelectric power system. The incremental water-rate characteristic is considered in studying the performance of a hydro plant. It specifies the additional water flow in cubic feet per second required to generate an additional megawatt of output, the units of this characteristic being cfs/mw. To coordinate the loading of the steam and hydro plants, this incremental water characteristic must be converted into an equivalent incremental cost with a conversion coefficient. Thus schedules for the hydro plants can be determined much as those for the steam plants. The magnitude of the conversion coefficient determines the amount of water used by a given hydro plant. An increase in the conversion coefficient makes the hydro plant incremental cost appear higher in comparison with the remaining plants, resulting in less water being used. Conversely, decreasing the value of the conversion coefficient makes the equivalent hydro plant incremental cost appear lower, resulting in more water being used.

Analytical Tools and Computers

Determining or calculating the loss-formula coefficients associated with the mathematical model of the transmission system involves two steps: first, determine transmission-system data on a power system analog computer known as the network analyzer; and second, perform matrix operations on these data with a high-speed internally programmed digital computer. This method of attack has resulted in tremendous savings in time and effort.

The network analyzer provides an electric model of the power system that simulates the performance of a full-scale system. The combination of the General Electric No. 1 and No. 2 network analyzers (photo, page 63) permits representation of 36 generators, 300 transmission lines, and 106 loads. Essentially, the analyzer consists of variable resistance, inductance, and capacitance units representing transmission lines, transformers, and loads. These components can be connected in any desired manner to plug and jack panels to create the electric circuit model of a power system. Single-phase a-c voltage sources, adjustable with respect to angle and scalar magnitude of voltage, represent generating plants. By selecting on the keyboard the number associated with the circuit element, the electric quantities of interest in any analyzer element are read on a light-beam instrument at the central metering desk. Impedance measurements on the transmission network as well as power flow for various typical operating conditions are recorded from this anlayzer.

Next, the data are transcribed to standard punched cards for additional calculations to be performed by a high-speed internally programmed digital computer, such as the IBM Type 650 magnetic drum data-processing machine. Because a general programming deck for this loss-formula calculation is already available, the setup time is negligible after these data are punched. For example, the loss-formula coefficients associated with a system of 25 sources can be calculated in less than one hour compared with several weeks of hand calculation.

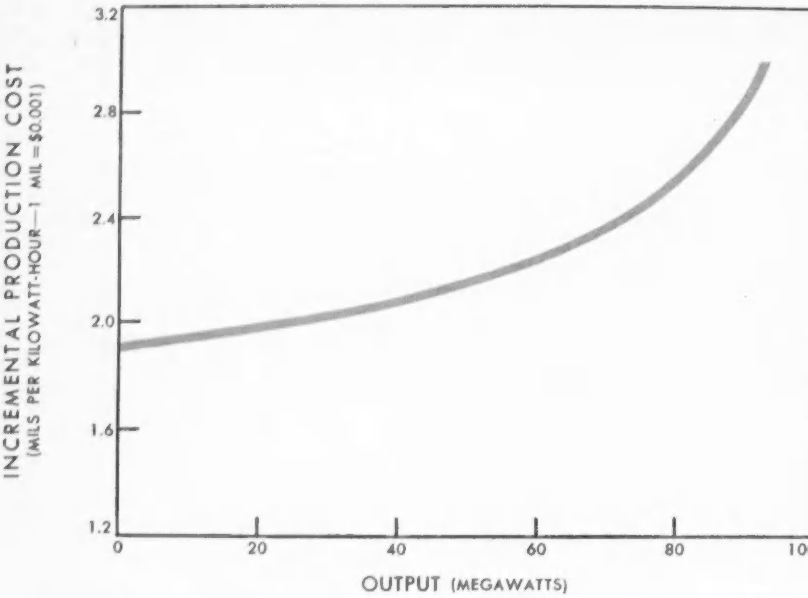
The main data storage for the Type 650 computer is a rotating magnetic drum on which storage positions for 2000 10-digit numbers with their sign are arranged. Instructions and constants used in a particular problem are read into this drum initially and called on when desired. The average time in which a number may be read from the drum is 2.4 milliseconds. The approximate operating times are multiplication, 12.5 milliseconds; division, 16.5 milliseconds; and addition, 3.5 milliseconds. The input device reads 200 punched cards per minute; the output device punches the results at the rate of 100 cards per minute.

This type of computer is as valuable for financial computations that involve large volumes of input-output data as for engineering computations that are characterized by a moderate amount of data and a long calculating sequence. Many organizations may justify its use on the basis of both financial and engineering calculations.

Application of Principles

As mentioned before, optimum economy in power-system operation for a given combination of units results when the incremental cost of received power is the same from each source. The fundamental data required and the theory of coordination can be applied in several ways to the hour-by-hour operation of a power system. . .

- Generation schedules that are precalculated.



INCREMENTAL PRODUCTION COST increases with each additional megawatt of output.

- Use of special computers built particularly for use of load dispatcher to calculate schedules as the need arises.
- Economic automation for automatically and simultaneously maintaining economic allocation of generation system frequency and net interchange. The net interchange equals the sum of the power flows over the transmission lines interconnecting a given power system with its neighbors.

Precalculated Schedules

Various general-purpose computers can solve the simultaneous nonlinear coordination equations, giving the optimum generation schedules for various preconceived system conditions. A newly developed iterative procedure is used most successfully on the IBM 650 computer. For a given total load, the computer calculates and tabulates the incremental cost of received load, total transmission losses, total fuel input, penalty factors, and received load plus the allocation and summation of generation.

A number of power systems have found it practical to precalculate tables or charts by this means for direct use by the load dispatcher. This method of determining precalculated schedules has also been invaluable in determining: 1) the importance of transmission-loss considerations in the operation of a given system and 2) the improvement in operating economy resulting from purchase of specialized computers or economic automation systems.

Use of Specialized Computer

Innumerable combinations of operating conditions can occur in large integrated systems because of varying fuel costs and frequent interconnection transactions. When the required number of precalculated schedules covering these conditions becomes very large, specialized computers particularly designed for the load dispatcher may be justified economically.

An analog computer, developed cooperatively by the American Gas and Electric Service Corp. and General Electric, calculates the previously described penalty factors for all plants and interconnections for various operating conditions. Installed in the Central Production and Coordination Office of AG&E early in 1955, this penalty-factor computer operates with an incremental fuel-cost slide rule that compares the incremental production costs of the system's various units. The slide rule consists of a logarithmically calibrated incremental production-cost scale, movable strips for each generating unit, movable fuel-cost adjustment scales, and a penalty-factor scale. Each movable strip for the generating units indicates the relation between the unit's incremental production cost and its output.

The application of the penalty-factor computer (photo, page 60) to the AG&E system saves over $100,000 a year compared with operating the system with transmission losses neglected. This computer consists essentially of adjustable power units that represent the various plant loadings and interconnection flows, a loss-formula network, and a central-penalty factor and incremental transmission-loss instrument. Once the power settings are made, the negligible computation time amounts to little more than that required to read the penalty factor from an instrument. The penalty factors are used to adjust the relative positions of the generating-unit strips on the slide rule, and the desired generation schedule is read from these strips.

Economic Automation

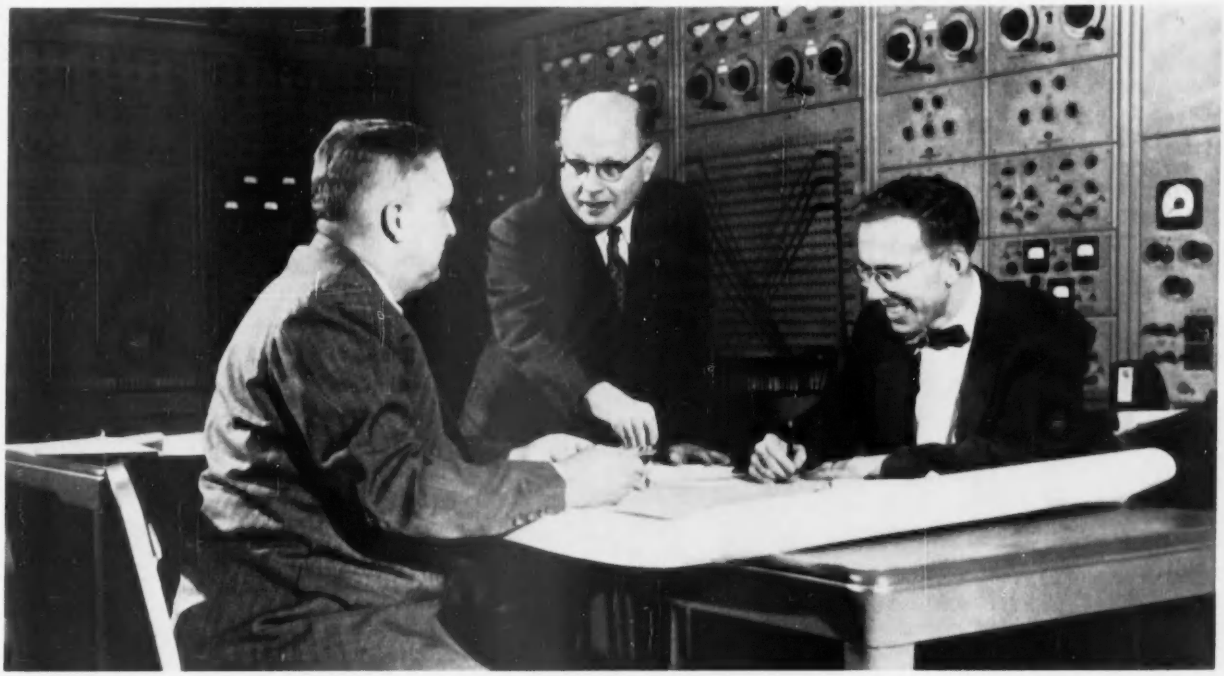
Use of an automatic dispatching system that supplies economic automation of the power system provides additional savings that result from. . .

- Improved fuel economy—the dispatching system not only calculates the desired generator outputs for the actual rather than forecasted conditions of a power system but also automatically executes the schedule, resulting in closer adherence to proper allocation of generation.
- Decrease in man-hours required to economically operate a system.

General Electric developed the first completely automatic dispatching system that automatically determines and executes the most economic loading allocation in addition to maintaining system frequency and net interchange simultaneously. Kansas City Power and Light Company made the initial installation of this equipment in 1955. Planning estimates indicate this new dispatching system will provide significant direct annual savings.

The master-area and dispatching consoles (photo, preceding page) are located at the load dispatcher's office. The master-area console develops a signal proportional to the integral of the frequency and net power interchange errors. This signal is interpreted as the incremental cost of received power. Means are provided in the dispatching console to manually or automatically modify this signal by the value of the plant's penalty factor, thus obtaining the appropriate incremental cost signal to be transmitted to each unit under control.

The master-station console and the machine console are both located at the station. The master-station console pro-



BASIC TOOL for all transmission studies, the network analyzer provides necessary circuit-loading information used in digital calculations. Dr. Kirchmayer (right) and G. Kron check results from the analyzer with S. B. Crary, Manager, Analytical Engineering (left).

vides all the adjustments for operating the whole station; the machine console provides adjustments for a given generating unit. In the machine console, the incremental-cost signal from the dispatcher's office is fed into a function generator representing the machine's incremental-cost characteristic. The function generator and servo comparison loops insure that the unit is loaded in accordance with incremental cost theory. The entire system operates continuously to specify an optimum division of output among all units in operation.

The master-area console that detects any deviation from desired conditions of system net interchange and frequency adjusts the total generation to match the area load. This deviation is used to correct the prevailing incremental-cost signal and restore the power system to balance.

The General Electric automatic dispatching system requires only a single control channel to each generating station. Automatic calculation and execution of transmission-loss penalty factors require a return telemetering channel from each plant output to the dispatching office. However, this usually imposes no additional communication burden because the dispatcher's office normally requires plant output readings for other reasons.

Future Development

New analytical, computing, and control techniques promise improved solutions for a number of problems. Existing economic automation schemes permit each area of a power system to automatically maintain its own frequency, a predetermined and preset net interchange, and economic allocation of generation. In the future, complete economic automation of power pools formed by several areas or companies will eliminate the need for manually determining and setting the most economic interchange of each particular company.

In economic operation of hydro plants, a number of problems require fundamental investigation: Probable occurrence of water availabilities; time required for water to flow between plants; and economic manipulation of annual storage. Although these problems are most difficult, the calculus of variations, plus probability theories, offers a helpful tool in seeking their solutions.

High-speed internally programmed digital computers will undoubtedly be applied to automatic interconnected-system energy accounting. Analog to digital converters would provide the required data input from the metered interconnection flows. The machine memory would contain significant information about sales and contracts. The program for the machine would provide the necessary instructions to automatically and continuously compute the interconnection energy accounting and billing.

As power systems expand, they become progressively complex. Also, increasing costs—particularly for fuel—emphasize the need for faster and better solutions to power system operating problems. With the electric utility operations doubling every 10 years plus the present and projected shortage of scientific personnel, engineering manpower problems become increasingly critical. Computers, together with people trained in analytical and computing techniques, provide a means of meeting these challenges. Ω

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Dr. Kirchmayer has been with General Electric's Analytical Engineering Section, Apparatus Sales Division, Schenectady, since coming with the Company in 1948. In April 1956 he became Manager of the newly established Power Systems Operational Investigations Unit. As a result of his research and achievements in power systems engineering as well as his participation in professional activities, Eta Kappa Nu awarded him honorable mention as one of 1954's Outstanding Young Electrical Engineers.

American Society for Metals

By WALTER MORRISON

Do you remember the heavy black cooking ranges of the turn of the century? In those days, size reflected strength. A large horse had a lot of strength—why not a large piece of iron?

During the early days of our industrial development, iron was simply iron—and the larger the piece the stronger. The pig iron went directly from the blast furnace to a foundry where it was cast into whatever size and shape the job required.

Fifty years ago, some technically trained men understood the physical and chemical properties of metal—such as the idea of treating steel to give it greater strength. But they did not pass this knowledge along to the men who selected metals for finished products.

What happened to close this gap between the science and the engineering of metals?

Early Organization

In 1913 a young man in Detroit, Billy Woodside, became disturbed over this lack of cooperation between the science of metals and their application to automobiles. Recognized as a clever toolsmith after years at a smith's forge, Woodside began selling the products he designed and made. Woodside had not worked long as a salesman before realizing that steel producers needed more knowledge, not only about product application but also about the structure and service qualities of their product. If the skilled worker and the metallurgist could be brought together in an exchange of ideas and experiences, he believed that the whole alloy steel industry would profit.

Woodside proposed the formation of a club that could serve as a forum for the people responsible for the design and application of finished products, particularly the parts used in an automobile. Known as the Steel Treaters Club, such a group was formed in Detroit, with Woodside outlining the general purposes and procedures.

Monthly meetings throughout the first year included discussions about improving steel serviceability through heat-treating. A need developed for more scientific information, and so technical metallurgists were admitted to membership. Because the Club rapidly outgrew its original quarters, a larger meeting place was secured. Presentation of papers and round-table discussions became a part of each meeting. As interest grew, membership reached 600 during the Club's first year.

In 1915 the group became known as the Steel Treating Research Club and in 1918 changed again to the Steel Treating Research Society. Separate chapters included groups in Detroit, Chicago, and other industrial centers. The Chicago group first thought about national organization. Its 200 members at that time paid dues to the Detroit treasurer. Detroit was also thinking of organizing nationally. Chicago, however, was the first to initiate definite organization plans.

And in 1918 they adopted the title of American Steel Treaters' Society and faced a national expansion program with a deficit. William H. Eisenman, a school superintendent from nearby Elmhurst, Ill., accepted the duties of organizing the Society. He not only completed the national organization but also personally organized 41 of the first 50 chapters and has continued to direct the affairs of the Society throughout the ensuing 38 years.

After World War I, Albert E. White—former colonel in the U.S. Army Ordnance Corps and then an Associate Professor of Metallurgy at the University of Michigan—united the Steel Treating Research Society and the American Steel Treaters' Society. He pointed out that on a national basis the two could jointly advance the purposes of all groups with definite benefits to industry. White was elected the first president of the amalgamated group, its compromise name becoming American Society for Steel Treating.

The newly formed national organization celebrated its unification during the week of Sept. 14, 1920, at the second National Metal Congress and Exposition in Philadelphia. Cleveland became National Headquarters.

In 1933 the organization adopted the title American Society for Metals (ASM). Its purposes have never changed. Although many details have been added to the Society's services, the principles laid down originally by Woodside still guide ASM—the unification of science, technique, and skill in the field of metals production, fabrication, and use.

Holding over 700 meetings a year, the 95 ASM chapters include over 26,000 members and are organized with complete autonomy in industrial centers of the United States and Canada.

National Headquarters of ASM serves both in an advisory capacity and as a clearinghouse for technical information developed at all levels. Educational courses organized by a chapter inform its membership on technical subjects of special interest and importance to that area. Society-published books offer basic information in these courses.

Coordinated efforts between the various chapters and the national organization stimulate interest in metallurgical careers for students in junior and senior high school and college.

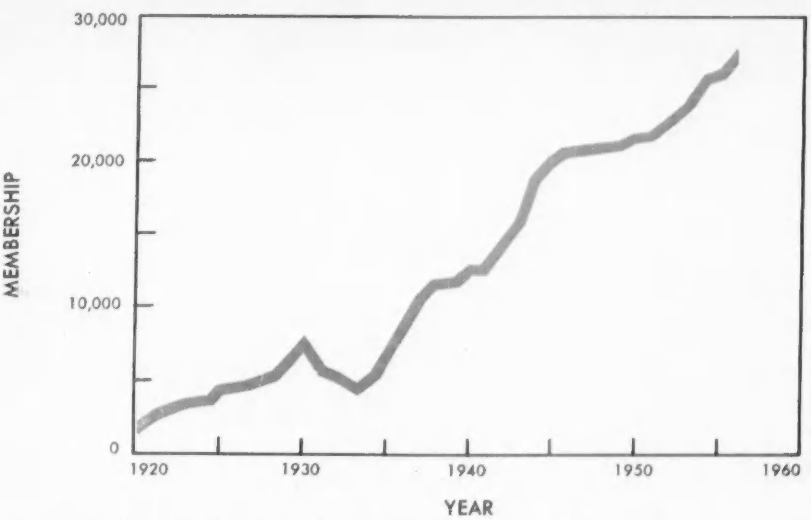
Publications

ASM has published a greater number of books on metals than any other company or organization, with 69 titles listed in its current catalog.

A basic tool of all metals engineers and technicians is the Society's *Metals Handbook*. Over 2000 members contributed material to this book, used throughout the world as the principle reference work in metals engineering.

Mr. Morrison is Director of Public Relations, American Society for Metals. He has held this position for the past eight years.

NATIONAL HEADQUARTERS in Cleveland serves as a clearinghouse for metals industry.



SOCIETY MEMBERSHIP has continued to increase along with its expanding services.

Each month the Society publishes the industry's engineering magazine, *Metal Progress*. This magazine goes to hundreds of engineers in all branches of the profession as well as its members.

To keep the Society well informed on ASM activities throughout the world, the monthly *Metals Review* reports membership news and annotates 10,000 articles about metals from over 800 domestic and foreign publications.

The Society annually issues a volume called *Transactions* that contains scientific papers and discussions presented at the annual Metal Congress, plus reports on the national and local activities of the Society.

A compilation shows that in one year ASM collects, edits, publishes, and distributes millions of pages of information on the subject of metals.

ASM originated and still owns and manages the National Metal Exposition—the largest annual industrial event in America—as well as the biennial Western Metal Exposition, which serves metals engineers in 11 western states.

The First World Metallurgical Congress held in Detroit in 1951, sponsored by ASM, attracted overseas conferees from 39 free nations for an international exchange of information on metals. The Second World Metallurgical Congress will be held in Chicago November 2-8, 1957.

Awards

ASM devotes much time and effort to promoting the metallurgical profession, giving awards and honors to students in all age groups and to teachers.

In conjunction with the National Science Teachers' Association, ASM sponsors Science Achievement Awards to junior and senior high school students throughout the country. More than 200 U.S. bond awards and special honors are awarded yearly; in addition, recognition awards are presented to high school science teachers.

ASM created the annual award to teachers of metallurgy in the United States and Canada. Ten $2000 awards have been made since the program was established four years ago.

Each year ASM sponsors Visiting Lectureships designed to supplement engineering instruction at the college level. The dean of engineering or an engineering department head requests an outstanding scientist as a visiting lecturer. ASM in turn invites this lecturer and underwrites the costs of his visit.

In 1952 the American Society for Metals established the ASM Foundation for Education and Research in the metals field with an initial grant of $650,000—the largest foundation fund ever set aside by an American technical society from its own resources. Through this Foundation, ASM annually sponsors 53 $400 scholarships for outstanding metallurgical students who have reached their second year in the metallurgy curriculum. A Fellowship grant of $4200 is awarded for graduate study in metallurgy.

Growth

Except for the lean years during the early 30's, Society membership has increased yearly since national consolidation in 1920 when membership totaled 1824. During the 40's, ASM membership doubled. The last official count in April, 1956 recorded a membership of 26,293 (illustration).

Membership growth reflects increased interest in and concern about the products and uses of metals. Men in all phases of metals production and fabrication realize that a free exchange of ideas and experiences makes for better opportunities. ASM serves as a forum where problems can be discussed objectively and where new developments, products, and services are revealed and adapted to different technical situations.

Increase in membership has determined the Society's progress. Knowing and accepting the other fellow's problem and viewpoint has given metals engineers their greatest opportunity to apply progressive ideas to their work in industry, education, and research. Better materials, greater incentive for research, improved methods, and modern equipment have resulted from the united efforts of the metals men.

Services

ASM services are designed to keep its members well informed on all activities and new developments in the metalworking field. Technical information includes technical articles, lectures, education courses, movies, free preprints of Metal Congress sessions, free placement service for engineering graduates, and counseling with experts from industry, government, and research organizations on specific metallurgical problems. ASM also translates the results of scientific investigation for its members.

The Society promotes industrial progress through its annual Metal Exposition where products, equipment, and services are often shown for the first time. Thousands of scientists, engineers, production men, and management executives meet in forums, seminars, and round-table discussions on current problems at the annual Metal Congress—held simultaneously with the Metal Exposition.

Because of ASM's basic interest in metals, similar activities have been started on a world-wide basis. In 1955 the Metallurgical Societies of the U. S. A., Great Britain, Germany, Belgium, France, and Sweden met jointly. ASM was well represented at the meetings of this international conference, held in various European centers during June.

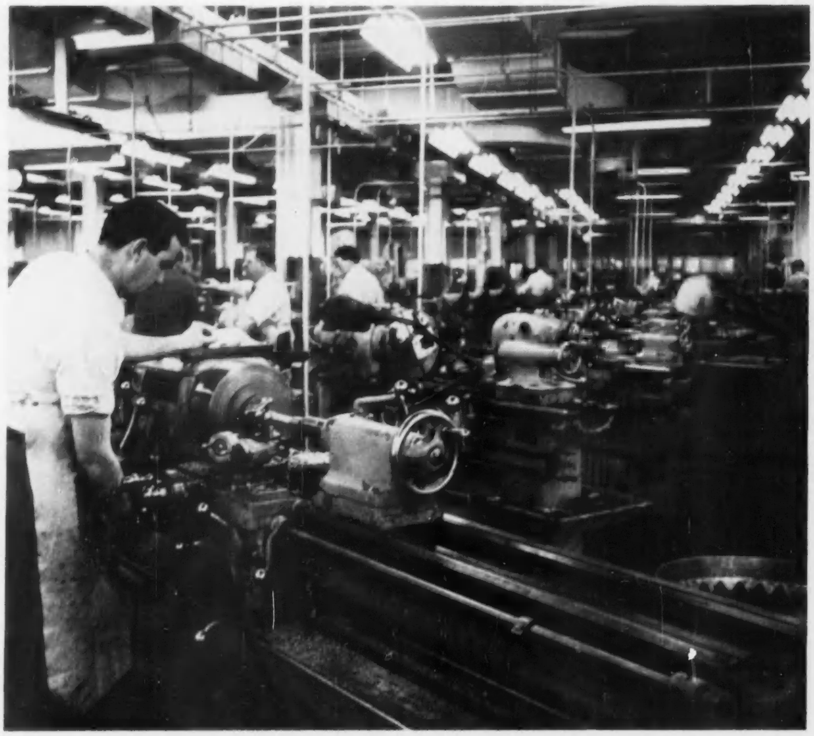
The Future

National Secretary Eisenman's long-range plans promise an even more significant future for the Society.

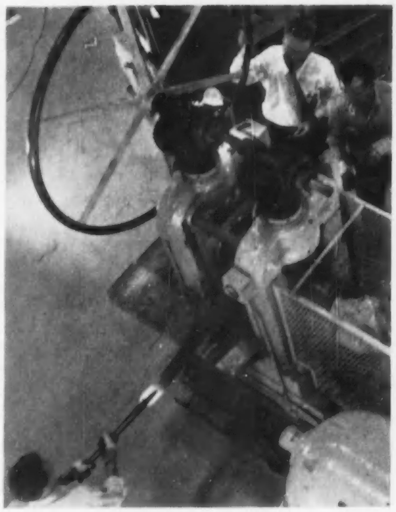
The Society's Board of Trustees have approved three of the five points in Eisenman's blueprint: erection of a new headquarters building; creation of a division—the ASM Metals Engineering Institute; and the formation of another division—the ASM Metallurgical Seminars. Points four and five include the development of two new divisions as circumstances and conditions warrant: the ASM Metal Research Laboratory and the ASM Metal Science University.

ASM has successfully given extensive service at a minimum cost to its members and to the metalworking industry, at the same time creating a firm financial structure. The ASM of tomorrow as envisioned by Eisenman will continue to grow in importance as it adds to the services for the Society's increasing membership.

ASM—bringing together all the interests touching on metals and metals engineering—received *Business Week* plaudits: "ASM is the metals industry's clearinghouse for basic know-how." Ω



MACHINING OPERATIONS require special tool tip materials in shearing through metal.



MODERN EQUIPMENT: hand-controlled rolling mill (left) and 1250-ton extrusion press.


ENGINEERING LEADERSHIP
KEY TO ATOMIC PROGRESS