GENERAL ELECTRIC Review

NOVEMBER 1954

ENGINEERS

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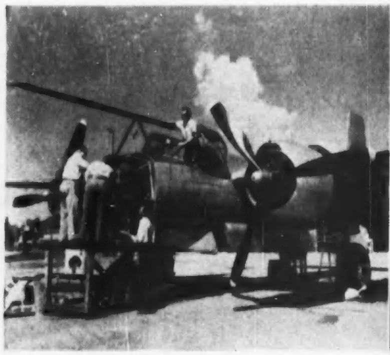
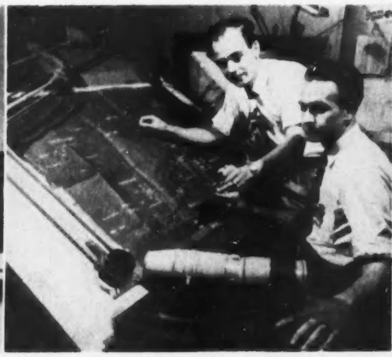


DEVELOPMENT ENGINEERING—Development engineers are continually obtaining and assessing new basic engineering and scientific knowledge to make possible new developments. They serve as consultants to help in the solutions of engineering problems, which often require research, experimentation, and the development of a new product or component.



DESIGN ENGINEERING—To maintain leadership in the electrical field, design engineers are constantly striving to develop new and better products. Their skill is largely responsible for the steam and gas turbines, motors, heat pump, control equipment, and many other products. In electronics, they design equipment for television broadcasting and reception, radar, and other electronic equipment.

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GENERAL ELECTRIC

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GENERAL ELECTRIC Review

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

COVER—On the northern fringes of the continent, "cat trains" steer lonely courses to distant sites where experimental radar stations were built by the Western Electric Company for the "distant early warning line." Special radio communications equipment was supplied by General Electric's Electronics Division. (Photo courtesy *WE* magazine of Western Electric.)

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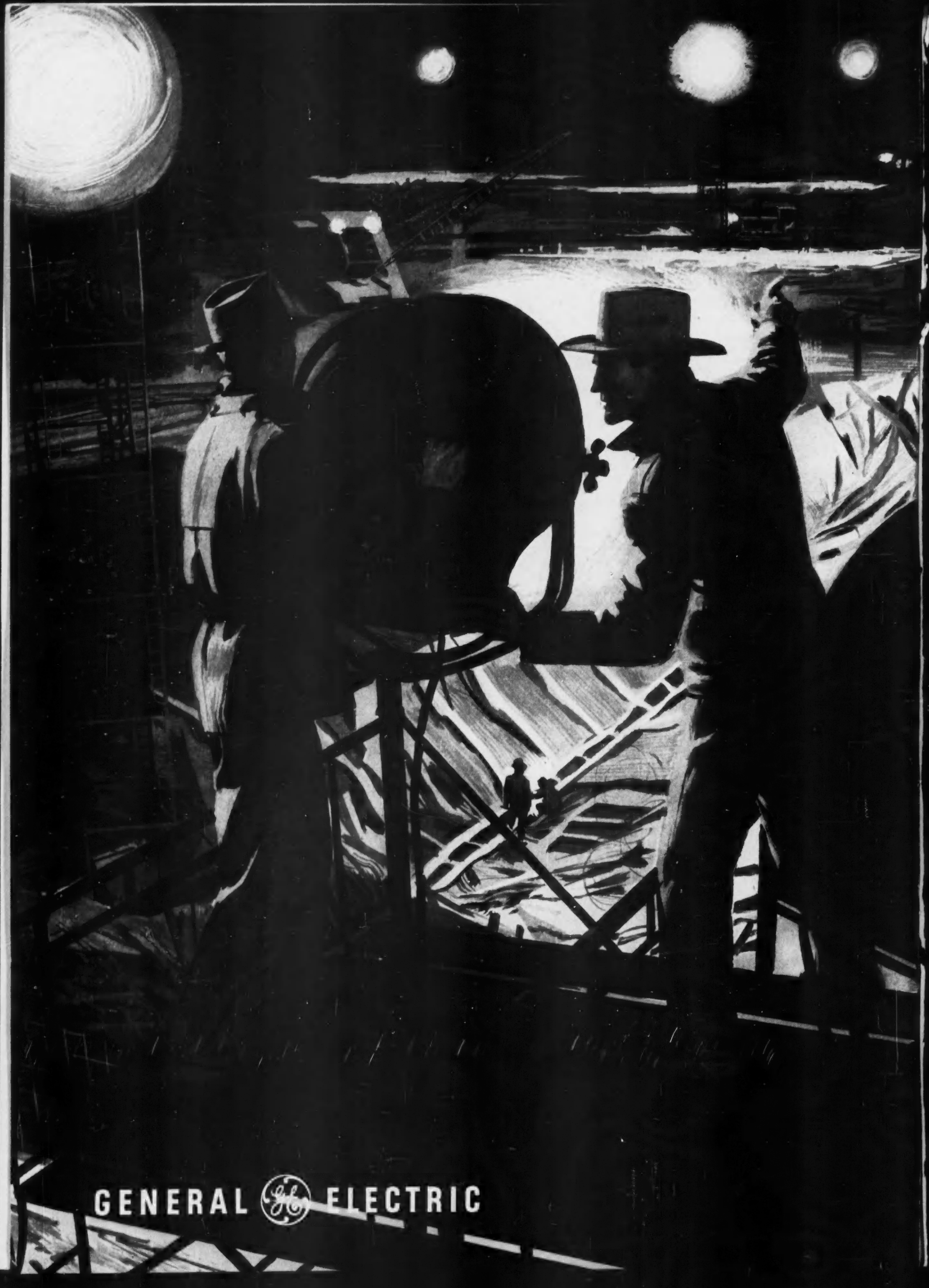
GENERAL ELECTRIC

Burned-out plant re-equipped fast to minimize production loss

A raging fire recently burned out a large industrial plant, reducing machines to rubble. Management's first concern was to resume production quickly in new quarters. What resources could General Electric's Apparatus Sales Representative marshal to help?

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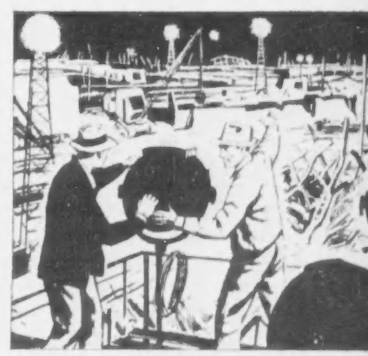
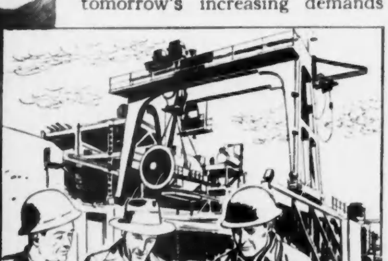


MAINTENANCE SERVICE helps keep your plant electric equipment operating at peak efficiency



PROJECT CO-ORDINATION simplifies purchasing, plans deliveries to speed construction schedules

FIELD-SERVICE ENGINEERING facilitates equipment installation, expedites start-ups, helps train personnel for proper operation

ANALYTICAL ENGINEERING solves complex system problems, cuts time used in system design

THE ENGINEER AND HIS ENGINEERING EDUCATION

The life of the student engineer in college is an ever-extending inspiration. That's where the continuous threads of his engineering activity first begin. That's where the forces of nature become alive to him in the revelation of all their power and potential. That's where the exactness of the mechanisms of nature becomes his serious business. That's where the detail of order becomes apparent. Surrounded by the new, that's where creativity can be born.

In his college life, work is the order of the day and night, not forgetting some time for play. And permeating that engineering life and motivating it are his teachers and his professors. For, as they teach the fundamentals of natural laws and bring to the classroom a knowledge of engineering, so they bring also a knowledge of living as exemplified in their own lives and experiences.

In my own college life I well remember Dr. Ernst J. Berg, at Illinois and later at Union. He loved his boys and worked hard with them to bring a realization of the wonders of nature and of the opportunities that lay ahead for those who could visualize phenomena and apply mathematics and skill thereto to achieve a final result of practical value. Working out original problems was always his delight.

One of the most fascinating of these problems was that of the short-circuiting of an a-c generator. I can see Dr. Berg to this day, as he stood at the blackboard, describing to us the phenomena of a short circuit: what happened during the transient period from the steady state of normal power operation to the steady state of short circuit, how the field current died down, how the flux decreased, what factors were affecting the induced electromotive force. The final step was a differential equation which, when solved, would give the instantaneous values of the armature current. Then, substituting in the final equation to find the values of the current for many different values of time and plotting these on squared paper, the results showed in all their beauty as the curves unfolded.

All this involved much work and application. It required knowledge of the phenomena, knowledge of mathematics to write the equation and to solve it, application and thought to evaluate the phenomena as they appeared on the squared paper, and experimental work in the laboratory for a complete understanding. This was engineering education.

Outside the classroom, Dr. Berg used to advise and admonish us in many things. "Join the country club," he always said. And then there was his famous savings curve:

$$S = 25t^{1.6}$$

embracing the Steinmetz hysteresis formula, where S was the sum of dollars to be set aside at six percent interest each year after graduation. When t was 1 year, the sum invested was only $25. But as t increased, S increased to much larger amounts.

We each of us drew a curve for our own use. Of course, Dr. Berg said, there might be some discontinuities in the curve at the time of taking a wife or the coming of the babies, but nevertheless there was the curve. And it impressed us greatly and made us think on those human things beyond engineering which are so essential to the complete success of the engineer. This also was engineering education.

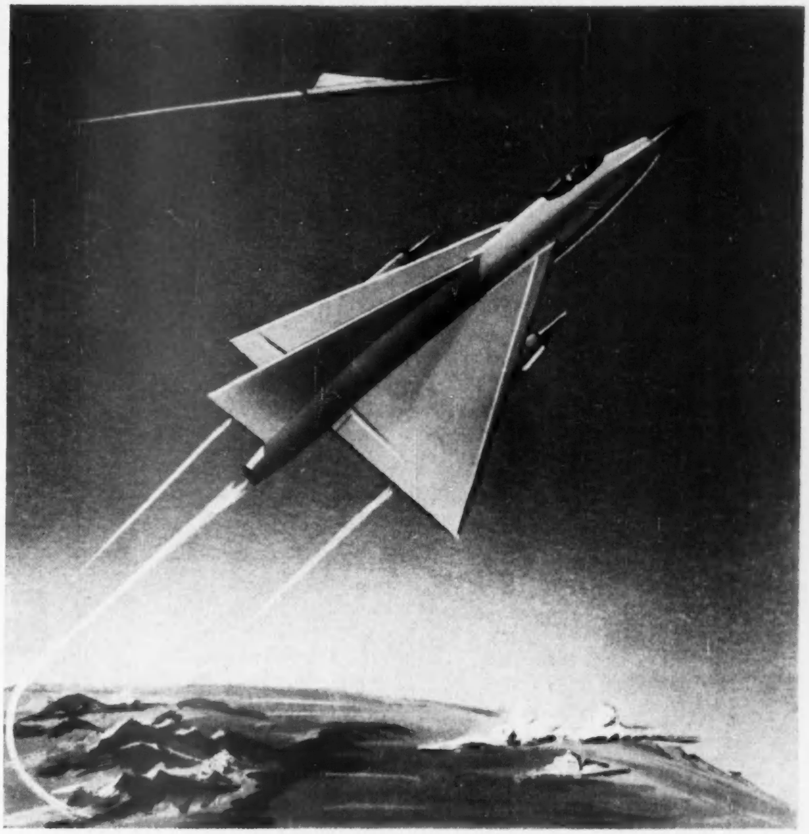
So in the life of every engineer there are the Dr. Bergs and other mentors. For college engineering education, in the last analysis, is the relationship between the professors and the student. This relationship carries on through life into industry, beyond the college, for engineering education in college is for the years to come. Thus it must have a continually growing expansion as industry grows.

As new knowledge from nature is brought into being by the scientists, so must the principles of physics expand as taught to the engineering student. As new materials are brought into being, so must these be included in the teaching of chemistry and metallurgy. As new concepts of mathematics come into being, their application must also be included. And as new knowledge is gained in engineering fundamentals, so must these advances be reflected back to be incorporated into the educational picture.

The phenomenal growth of the electrical industry has been supported by the many loyal teachers in the engineering schools who are building men—building engineers. Each year their graduates enter industry to grow in the experiences of practice and to contribute to the opportunities ahead. These opportunities are ever-expanding in magnitude and scope, in technical and management content, in human endeavor and understanding. In the midst of all of these, may there always be a proper recognition of the engineering teacher.

Everett S. Lee

EDITOR



HIGHER AND HIGHER flight speeds into the supersonic range impose stringent design requirements on both aircraft and engine. Confronting the designer are the problems of the thermal barrier, thrust efficiency, high temperature, and pressure ratio.

Turbojets for Supersonic Flight

By J. S. ALFORD and E. L. AUYER

The intense development effort applied to turbojet engines during World War II has continued with undiminished vigor. For a long time the primary problem in the aeronautical art was to have airplanes break through the sound barrier. Once supersonic flight was achieved, research airplanes have gone on to Mach 2 and 2.5—2 and 2½ times the speed of sound. At high altitudes these correspond to speeds of about 1300 and 1650 mph. During the past year the technical and semitechnical press have devoted much space to faster-than-sound tactical fighters.

Today the turbojet designer's basic objective, in simplest terms, is to produce a tremendous amount of thrust in a small lightweight engine, with efficiency high enough or fuel consumption low enough to provide the required range capabilities. Power plants must have improved thrust per pound of engine weight and per unit of frontal area—a requirement that cannot be satisfied merely by building turbojet engines of increasing frame size.

For geometrically similar jet engines, the air-flow capacity and thrust vary with the flow areas and thus with the square of the scale dimension. The weight of the engine varies with the volume and thus with the cube of the dimension. For example, if every dimension of a jet engine is doubled, the thrust increases by a factor of four, weight by a factor of eight. The larger jet engine will therefore weigh twice as much per pound of thrust produced as the smaller jet engine whose every dimension is one half of the larger engine.

However, some constructions of relatively less weight can be used in the larger jet engines. And certain components, such as the ignition system, have a fixed weight regardless of engine size. These factors indicate that the specific weight of the larger engine does not increase quite as rapidly as in the theoretical example. But the main practical limitation of jet-engine size still

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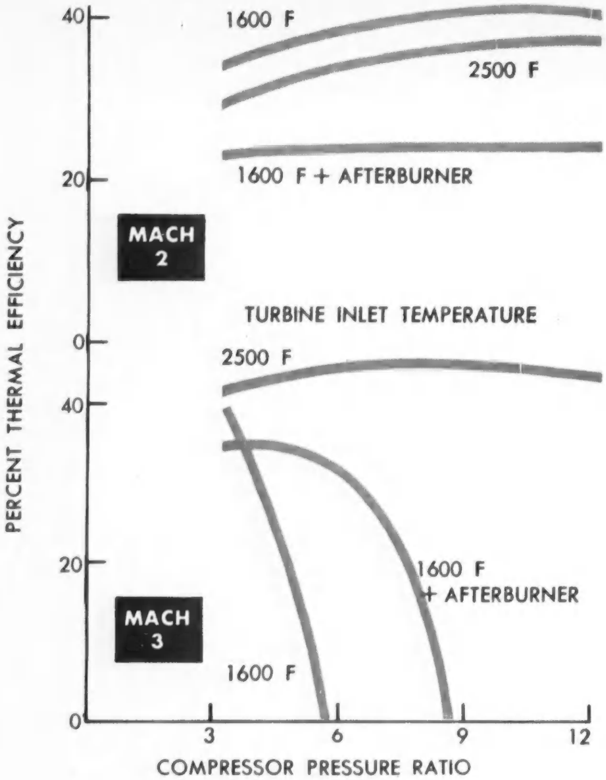
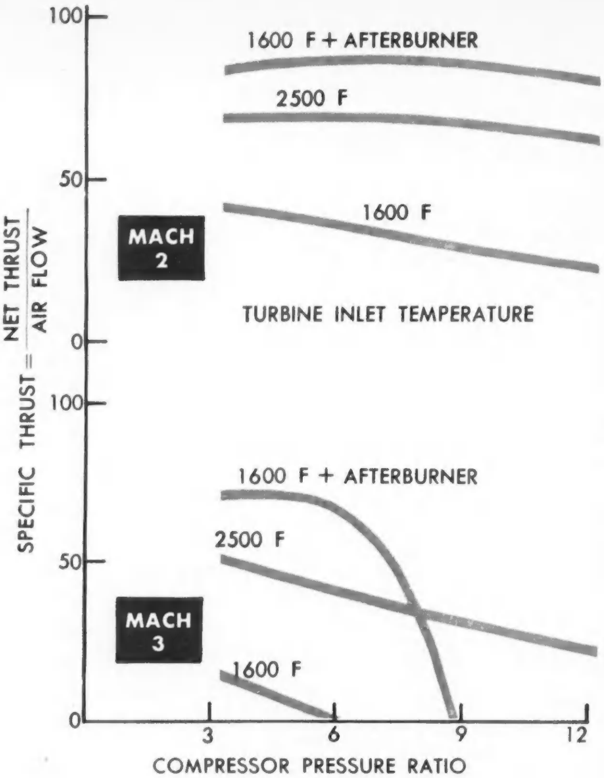


THERMAL EFFICIENCY VS COMPRESSOR PRESSURE RATIO—Mach 2 curves undergo drastic changes when speeds reach Mach 3.



SPECIFIC THRUST VS COMPRESSOR PRESSURE RATIO—At Mach 3, engines need low pressure ratio, high combustion temperatures.

remains the tendency for the engine weight to increase much more rapidly than the thrust capacity. These elements often allow airframe manufacturers to obtain for less weight the thrust power required by using a number of smaller jet engines rather than a few large ones.

Heat Barrier

The limitation just now is not power but the thermal barrier resulting from high flight speeds. For example, the official world record is approximately 750 mph. The ram temperature rise corresponding to this speed is 100 F—welcome heat for Arctic or high-altitude flight where it can contribute toward solving the cabin-heating problem. However, for summer and tropical flight this temperature rise requires the use of refrigeration equipment to cool the cabin and cockpit air.

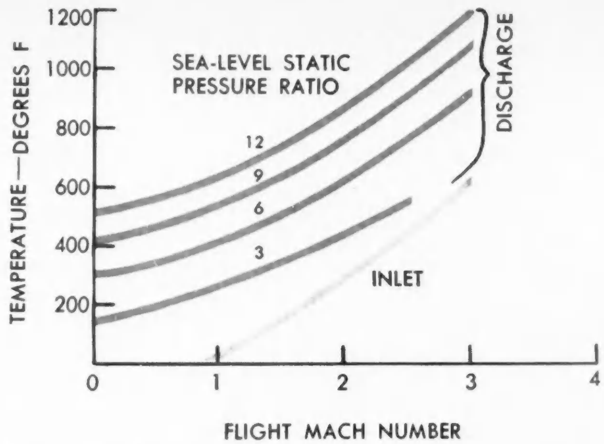
The ram temperature rise varies with the square of flight speed. For example, at double the present world speed record, the ram temperature rise would be 400 F. Because mechanical strength and material properties decrease substantially at higher temperatures, ram heating at supersonic speed is vitally important in gas-turbine design where so much of the material is already at high temperatures.

Turbojet engines now in production were designed for flights in the subsonic and low supersonic speed range. However, structural modifications have made these engines into satisfactory power plants for aircraft operating up to speeds between Mach 1 and 2. Flight speeds of Mach 2 and higher impose exacting and stringent design requirements on both aircraft and power plant. Let's discuss a few of the desirable features and important problems involved in turbojet engines designed to operate a substantial part of their missions at such speeds.

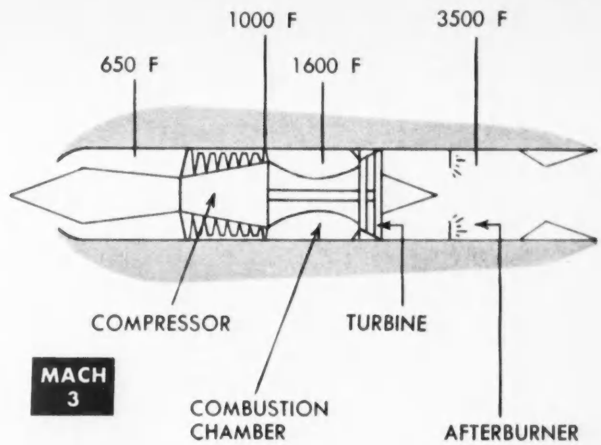
Thermal Efficiency

In view of the comments about a jet engine's great thirst for fuel, you might get the impression that the jet engine is always a relatively inefficient power plant. True, at low flight speeds the jet engine tends to be relatively inefficient compared with propellered reciprocating engines. However, at high subsonic and especially at supersonic speeds, the jet's propulsive efficiency improves substantially so that the over-all thermal efficiency of the jet engine is good. In fact, at supersonic speed range the turbojet has thermal efficiency comparable with the maximum obtained from diesel engines or central-station steam-power systems. Some of the best steam-power stations today achieve over-all thermal efficiencies of 38 percent. Because the amount of power required by the airplane flying at supersonic speeds is high, the rate of fuel consumption is also high. For example, a 200,000-pound bomber flying at Mach 2 requires a 5-inch-diameter fuel line to supply its total power-plant requirement.

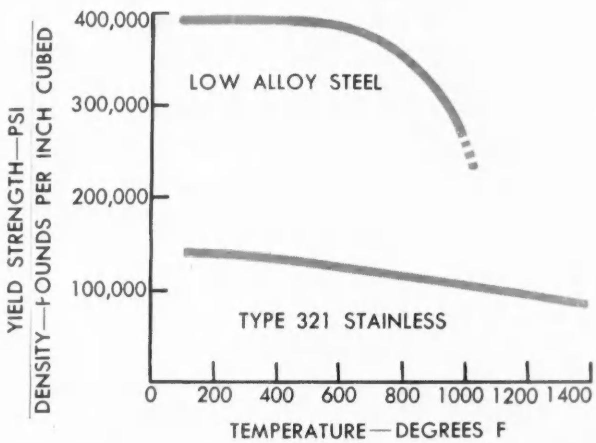
The illustration (left) shows the turbojet engine's thermal efficiency at Mach 2 for various compressor pressure ratios and turbine inlet temperatures. Thermal efficiency here denotes the ratio of the energy output for overcoming the airplane drag divided by the thermal energy input of the fuel used. Thermal efficiencies are relatively high, and the curves quite flat, suggesting that moderate pressure ratios and high combustion temperatures will probably give the most practical engine.



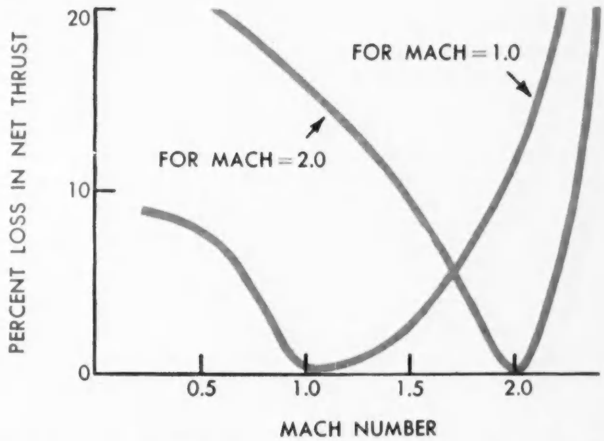
TEMPERATURE LEVEL throughout the compressor is increased by energy put into inlet air as flight speed increases.



HIGH INTERNAL JET TEMPERATURES are almost as troublesome as high surface temperatures when aircraft travel at supersonic speeds.



ALL-STEEL CONSTRUCTION either of low-alloy or stainless steel is required for high compressor discharge temperature.



EFFICIENT RAM RECOVERY over a wide range of Mach numbers presents a problem solved by engines with variable inlet areas.

The Mach 2 curves change drastically when Mach 3 flight speed is required. The high-temperature engine (2500 F) or the engine with afterburner will give thermal efficiencies of from 35 to over 40 percent with compressor ratios as low as 3 or 4. Incidentally, these pressure ratios refer to the actual pressure ratios at specific flight speeds.

Substantial gains in the thrust can be made in turbojets by increasing both the airflow through the engine and turbine-inlet gas temperature. At Mach 2, specific thrust—thrust per pound of airflow—must definitely be high to keep the engine size and weight to a minimum. The illustration (opposite page, right) shows the values of specific thrust that can be obtained at Mach 2. You can see that either high turbine inlet temperatures or exhaust reheat (afterburner) with lower turbine inlet temperatures must be used.

With specific thrust at Mach 3, you will note the substantial change in the curves from those for Mach 2. The turbojet with afterburner has high specific thrust but somewhat lower efficiency than the engine with high inlet temperature without an afterburner. Hence the optimum high-Mach-number engine must have a moderately low pressure ratio and a high combustion temperature either ahead of the turbine or in the afterburner.

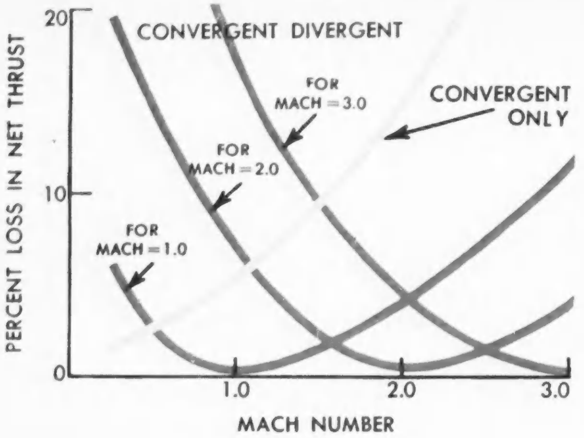
High-temperature Problem

Temperature presents another inherent problem in supersonic engine design. The energy put into the inlet air increases the temperature level at the compressor inlet and throughout the compressor as flight speed increases (illustration, top, left). Numbers on the curves are the compressor pressure ratios when the inlet conditions correspond to standard sea-level static atmosphere. (Calculations assume constancy of the actual engine speed, turbine inlet temperature, and the turbine diaphragm flow area. The exact shape of the curves varies with engine design.)

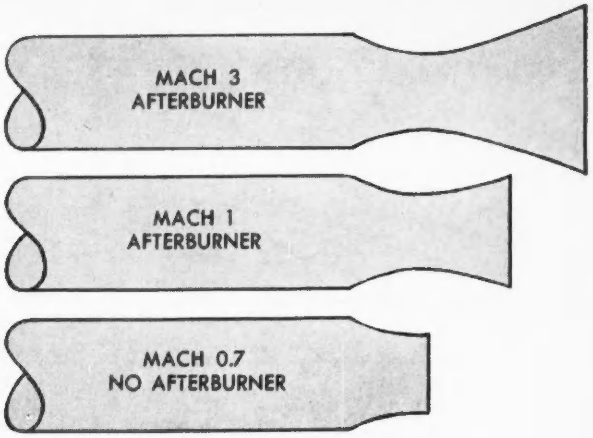
The temperature problem is a major one. Although much has been said about the problems of aircraft skin temperature at higher supersonic speeds, the troubles of high temperatures in the engine are none the less important. The expected Mach 3 temperatures at different areas of the engine are shown in the illustration (top, right). Realizing that the melting point of lead is 621 F may help you visualize their significance.

Thus it presently does not seem feasible to refrigerate enough cooling air to surround the engine with a cool atmosphere.

These high temperatures at higher supersonic speeds cause an increased



EXHAUST NOZZLES must be made convergent-divergent to allow for the high expansion pressure ratio attained at high flight speed.



ESSENTIAL CHANGES are needed in the physical shape of nozzle structure to obtain maximum efficiency under various conditions.

fire hazard from fuel and lube oil. For example, the temperature of the high pressure end of the compressor casing is higher than the ignition points of most hydrocarbon fuels and lubricants. The engine fire wall must now become a duct to bring the fuel and lube lines to the engine. Hydraulic mechanisms may not be feasible unless cooled. This could lead to the development of more pneumatic systems. Electric equipment will need further special attention. It may be desirable to remove the accessories from the vicinity of the engine and locate them in a separate insulated and cooled accessory compartment. In addition to the turbine end, all the main shaft bearings become "hot-end" bearings. Refrigeration, or cooling, of the lube oil will be required.

The heat absorbed by the lube oil is in the order of 10 Btu per hour per pound of thrust. For example, an engine having a sea-level static-dry, or unaugmented, rating of 15,000 pounds thrust will reject to the oil system about 150,000 Btu per hour—approximately the amount needed to heat a six-room house on a zero-degree day. If refrigeration subsequently cools the oil, the equivalent refrigeration capacity reaches more than 10 tons. Development of higher temperature lube oils will ease the bearing and cooling problems to some extent.

Higher temperatures at supersonic speed in turn affect pressure ratio. Because of higher inlet temperatures, maximum ratios diminish as speed increases. Thus for a pressure ratio of 3 or 4 at higher supersonic speeds, the engine must be designed for a sea-level pressure ratio of approximately 9.

Internal gas pressure, highest during high-speed flight, causes a circumferential stress—the most severe stress in compressor wall casings.

The high compressor discharge temperature requires all-steel construction. The strength of the low-alloy steel decreases rapidly at temperatures approaching 1000 F (illustration, lower left, page 9). The 321 stainless steel can be applied to handle the higher temperature, but its ratio of yield strength to density is much lower than for the high-strength low-alloy steel. Weight increases substantially if temperatures are high enough to require extensive use of stainless steels in the compressor casing.

Ram Effect

At high supersonic speeds the compression of air, or ram effect, that occurs at the inlet is often greater than the pressure rise in the engine compressor. If you can take full advantage of this effect, the "ram recovery" is 100 percent. Unfortunately, an inlet that will give you 100 percent ram recovery at high supersonic speeds isn't very efficient at take-off, because fixed-area inlets won't operate efficiently over a wide range of Mach numbers (illustration, lower right, page 9). Engines with variable inlet areas are required to solve this problem.

Just about the same is true for exhaust nozzles (illustrations) where a variable area nozzle is necessary to get maximum efficiency under all flight conditions. Convergent-divergent nozzles are required at high flight speeds to take care of the high expansion pressure ratios.

Poor ram recovery and exhaust nozzle efficiency cause a drastic penalty in engine performance. As an example, consider two airplanes flying at Mach 2.5. In one airplane the ram recovery is 80 percent, and the exhaust nozzle efficiency 100 percent; in the second the ram recovery is only 60 percent and the exhaust nozzle efficiency 96 percent. But because of these lowered efficiencies, the range of the second airplane is cut 25 percent. All these factors pose additional problems to the designer.

Jets Coming into Their Own

The problems of a jet engine designed to fly a substantial part of its mission higher than Mach 2 are accentuated by the high temperature and pressure levels, and satisfactory operation over a wide range of flight speed is required. Successful design demands careful attention to problems of stress and weight, bearing cooling, accessory cooling, and variable geometry inlets for nozzles.

Exhaust nozzle and inlet losses greatly affect the performance of the installed power plant. Wide range flow areas and pressure ratios aggravate the difficult jet-nozzle problem.

Although the turbojet engines have made many important applications in the subsonic speed range, it appears that they are only now coming into their own. For the propulsive efficiency of turbojet engines increases appreciably in the supersonic speed range, and the engine makes a very effective and efficient power plant for these high supersonic speeds. The outstanding characteristic of the turbojet engine is its suitability and adaptability over a very wide range of flight speeds extending far into the supersonic range. Ω

GERMANIUM RECTIFIER CELL rated 2000 watts (*left*) has the same capacity but is only one-fortieth the size of the selenium cell. Author McIntyre—application engineer—joined the Company's Lighting and Rectifier Department in 1947. He is now with the Illuminating Engineering Laboratory, River Works, West Lynn, Mass.

GERMANIUM RECTIFIERS—BIG LOW-COST POWER

By H. N. McINTYRE

For the past few years the electronics industry has engaged in a program to decrease electronic components to the smallest possible size. And among the developments contributing to the success of this program is the tiny germanium transistor.

Controlling minute quantities of current, the remarkable transistor replaces delicate space-consuming vacuum tubes in low-power high-frequency applications, such as the "Dick Tracy" wrist-watch radio you hear so much about. Today it is almost an actuality. Another example is a pocket-size radio transmitter used by public speakers in place of a microphone and its restrictive trailing wire.

Transistor or Rectifier

The properties of germanium that are bringing about this change in the electronics industry are about to revolutionize still another field of engineering—power conversion.

Generally speaking, the function of germanium in a transistor is the same as in a rectifier (further explanation, page 13). However, there is one difference: a third element—functioning like the grid of a vacuum tube—is introduced on the transistor to control the rate of rectification. Aside from this the transistor differs from the rectifier mainly in the order of power magnitudes involved.

The transistor is normally employed at voice frequencies and slightly higher, where current involved is small. (Speech is reproduced with good fidelity within a frequency range of 150 to 7000 cps.) On the other hand, a broad-area germanium rectifier used at power frequencies—60 cps and less—can rectify many thousands of amperes of current.

This increase in power-handling capability is a direct function of the germanium area. Again, in a transistor the amount of germanium is minute, only a dot. But in the broad-area rectifier the rectifying surface of the germanium may range from a few square millimeters to better than a square centimeter.

Mighty Midget

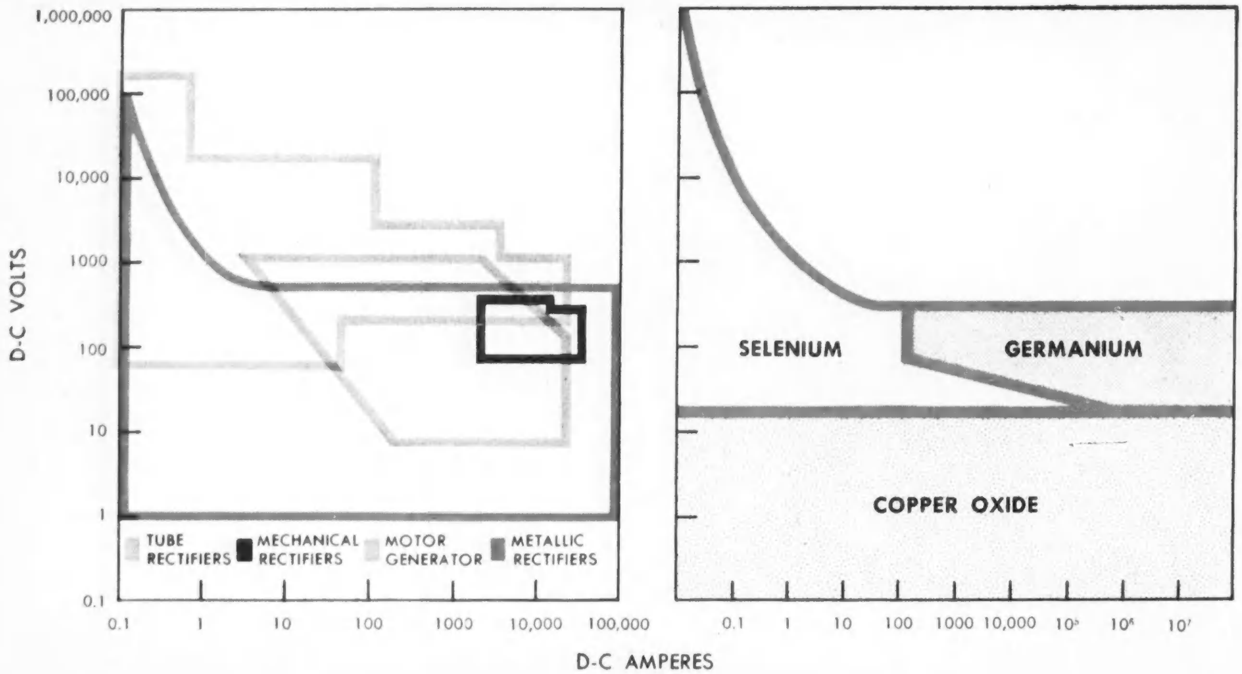
When the germanium cell is properly cooled, its load capacity is remarkable. An air-cooled cell with a rectifying surface about the size of a dime (photos, left and next page) will handle a 2000-watt load continuously. Including heat-radiating fins, it takes up just 8 cubic inches of space and weighs only 12 ounces. Under the same cooling conditions an equivalent-rated selenium rectifier cell occupies about 330 cubic inches and weighs about 3 pounds. As you can see, this is a 4 to 1 advantage in weight and better than a 40 to 1 advantage in size.

Many present devices for supplying large quantities of direct current can be replaced by a germanium rectifier. These include other types of metallic rectifiers employing, for example, selenium or copper oxide as the rectifying element. Also included are mechanical rectifiers, mercury-arc rectifiers, and motor-generator sets. (In those applications where a variable d-c voltage is required, however, motor-generator sets may be the logical choice.)

In fact, direct-current loads at almost any voltage can be supplied with a combination of germanium-rectifier "building blocks" developed by General Electric. These blocks will usually give you greater installation and operating economy in the ranges previously covered by metallic rectifiers and motor-generator sets (illustration, next page).

At extremely low voltages the copper-

APPLICATION OF METALLIC AND OTHER TYPES OF RECTIFIERS



GERMANIUM RECTIFIERS can replace most present types of converters over a wide range of applications (*above*). The chart (*right*) illustrates the most economical voltage and current ranges—on a first cost basis—for each of three metallic rectifiers.

HEART of this 2000-watt rectifier cell is a wafer of germanium the size of a dime. The complete unit, including cooling fins and mounting brackets, weighs only 12 ounces.

oxide rectifier would have a smaller initial cost than its germanium counterpart. Similarly, at extremely high voltages the initial cost of a selenium rectifier would be smaller. Still, a germanium rectifier would probably cost less to operate over a period of time and would provide a greater return on an investment.

One basic building block now in production is an air-blast-cooled germanium rectifier conservatively rated at 25 kw. This unit incorporates two 3-phase bridge circuits to provide continuous low-ripple direct current from a 3-phase power source, plus a blower for cooling and a transformer to step down input voltages.

In its present form this standard unit can be fed from any 208-, 230-, or 460-volt 3-phase source. Depending upon internal connections, the total continuous output would then be either 400 amp at 65 volts d-c, or 200 amp at 130 volts d-c. By connecting the outputs of the 25-kw unit in series or parallel, d-c loads of any practical voltage or current requirement can be handled.

A second germanium-rectifier building block, liquid-cooled instead of air-blast-cooled, has an even greater size and weight advantage over other metallic rectifiers. A standard 120-kw unit, it supplies continuous d-c power at 2000 amp and 65 volts and operates equally well in a corrosive atmosphere. You can overload it to 4000 amp for 30 seconds or to 2500 amp for one hour.

Efficiency Tops

Operating costs of germanium rectifiers are highly attractive to a potential user. For they are not only more efficient than other metallic rectifiers but also more efficient than any rotary converters—with the possible exception of rotating switch-type rectifiers.

The efficiency of a 3-phase germanium rectifier is 98 to 99 percent. Including transformer losses and power required for cooling, the over-all efficiency of the standard 25- and 120-kw units mentioned before is better than 94 percent. By contrast, you seldom obtain more than 85 percent efficiency with a selenium rectifier and, at or below 65 volts d-c, no more than this with motor-generator sets.

Germanium rectifiers are frequently operated at a current density up to 300 amp per square inch of rectifying surface. Yet at this high loading, they have less than one-volt drop in the forward direction. On the other hand, selenium rectifiers have approximately one-volt drop at only 0.160 amp-per-square-inch forward loading. Based on this, a quick calculation will show you that germanium can carry almost 2000 times the current density of selenium with less voltage drop.

As for reverse current, germanium is again particularly good, having a reverse-to-forward resistance ratio in the order of 400,000 to 1.

Unusual Characteristics

The tremendous current density you can utilize as a matter of course with a germanium rectifier is possible only because of low losses within its cells. And it is these low losses that are responsible for germanium's high efficiency. They mean savings of thousands of dollars in copper, cooling equipment, and power costs; they provide additional savings in size and weight of a germanium rectifier.

But so tiny a rectifier can have little thermal capacity. This means that you must rapidly remove the heat generated even though the losses are small. Therefore, to take advantage of germanium's other outstanding features, you must understand another characteristic—low thermal capacity.

This is especially important if you are going to use germanium rectifier cells in electric equipment of special design. For heavy overloads can produce short-time-current densities that will exceed the heat-dissipating capacity of what you might consider an economically practical cooling system. As an example, a short circuit across a rectifier might burn out cells unless it were removed within about five thousandths of a second. Fortunately, current-limiting fuses can be used to clear the fault within a safe margin.

There is another characteristic of a germanium rectifier that needs explaining. During that portion of the cycle when the polarity of the input current has reversed, the rectifier is "blocking" and its resistance is extremely high. Little current then flows through the load so that for practical purposes full transformer voltage is applied directly across the rectifier cell. If the peak inverse voltage—the safe limit to which the cell can be stressed electrically—is exceeded, the cell is damaged. However, this is true of any electronic tube or capacitor, not a condition peculiar to germanium alone.

In practice the established applied voltage ratings of the cells are comfortably lower than their maximum inverse peak voltages. And so, if proper design precautions are observed, you'll have no trouble with this characteristic.

Regenerative loads—those that might tend to act as a generator under certain conditions—can be safely supplied by a germanium rectifier, but again only if you are certain that reverse voltages will never exceed safe ratings. (A rectifier will not transfer the energy supplied by the regenerative load back into the supply line.)

As with all metallic rectifiers, operating temperature of the germanium cell is rather critical. At present, 80 C is the maximum total temperature at which they are operated. Heat exchangers within the equipment insure that this temperature will not be exceeded under normal conditions. Where surrounding temperatures are high, liquid rather than air-blast cooling is recommended because you can control cooling temperatures much easier with a liquid.

Long Lived

The useful life of a metallic rectifier is defined as the length of time required for its forward resistance to increase 75 percent. For example, when operated at the current densities usually employed for power-conversion applications, selenium will normally reach the end of its useful life in from 30,000 to 50,000 full-load hours.

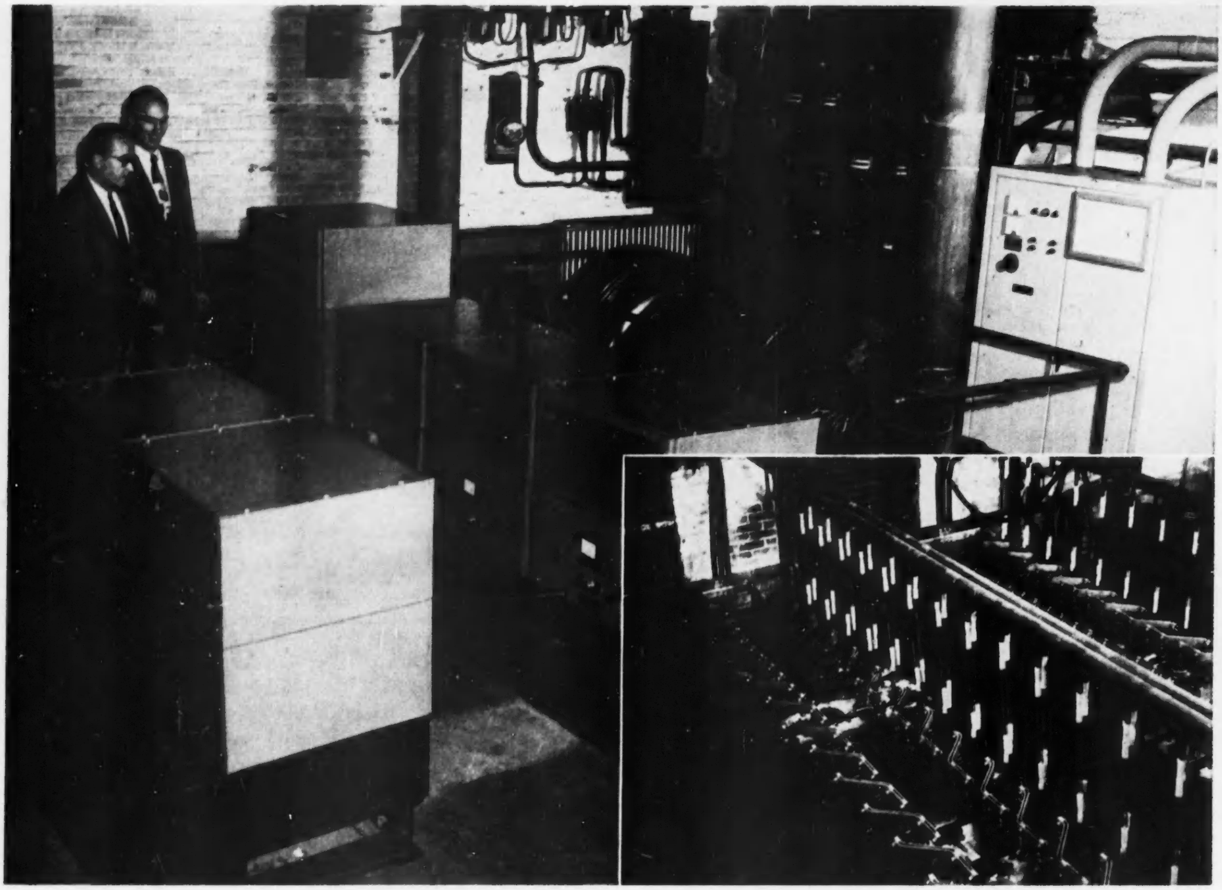
Germanium rectifiers have been on life test in industry and in the laboratory for more than three years with no detectable increase in power losses. In effect, this means that there's no limit to useful life, provided the rectifier's

THE METALLIC RECTIFIER ... HOW IT WORKS

The metallic rectifier is a static device for converting alternating current into direct current. It makes use of a highly unusual property of certain materials called semiconductors, such as selenium, copper oxide, and germanium.

Allowing current to flow in only one direction, semiconductors eliminate the negative, or reverse portion, of an alternating input current. The positive portion of current passing through the rectifying material does, however, maintain its pulsating nature. And to get a d-c output of nearly constant magnitude, the current is passed through a special circuit configuration. The end result: direct current equivalent to that supplied by a motor-generator set.

There is actually no such thing as a perfect rectifying material. That is, you will always have some leakage current in the reverse direction and some voltage drop in the forward direction. But for practical purposes a rectifier is considered efficient if the leakage current and forward voltage are extremely small.



APPLICATION typifying great flexibility of germanium rectifiers is used in hydrogen-oxygen plant. Interchangeable with motor-generator set or incoming power at control panel, six 25-kw rectifiers supply 1200-amp 125-volt d-c power to 80 cells in adjoining room (*inset*).

rating is not exceeded. Nor do you need to adjust anything over a period of time to compensate for changing characteristics.

A rotating machine, such as a motor or generator, will last until it burns up or wears out. Depending on how well you take care of it, it could last indefinitely. The same is true of germanium rectifiers, except that additionally they require little maintenance because they have no rotating parts other than the cooling fan.

Some Applications

Many germanium rectifier equipments are already in operation or about to be installed. These applications give you an indication of the great flexibility of germanium rectifiers.

For example, they are being used as a power supply for a hydrogen-oxygen plant (photos). Here, two groups of three 25-kw units supply 1200 amp at 125 volts for an electrolytic process. Several liquid-cooled power supplies are being installed for this application, the largest rated 16,000 amp, 65 volts, d-c.

The power for an electrolytic tin-reclamation process is being provided by four of these same 25-kw air-cooled units that are connected to supply 800 amp at 125 volts d-c. They will replace motor-generator sets formerly used as the power supply.

In another application two water-cooled germanium rectifiers will serve as a power supply for sintering furnaces. Self-contained within a single enclosure, each unit will provide 6000 amp at 15 volts d-c.

A list of some of the applications for which germanium rectifiers are now being used includes titanium-refining arc furnaces, adjustable-speed motor drives, aircraft-engine starters, and telephone-exchange battery chargers, to name a few.

The Big Question

Are germanium rectifiers ready? This is the question most frequently asked but with the least reason. The answer is an unqualified yes. Their acceptance by industry to date shows this surprisingly well. Their performance characteristics are well-known by engineers. And available to industry is a considerable amount of application information and data.

Today you can purchase economical production-type germanium equipments and get good deliveries. Or you can buy just the germanium rectifier cells in a variety of ratings and use them in equipments of special design. Industry has in fact purchased thousands of these components, ranging in size from tiny convection-cooled dot rectifiers (page 29, July 1952 REVIEW) of ½-amp capacity to the 75-amp blower-cooled cells used in the present 25-kw rectifiers.

And this is just the beginning. As with any new material, there has been an initial period of hesitancy during which potential users of germanium power rectifiers have held off for word of successful installations. The end of this period is rapidly approaching. Ω

CREATIVE ENGINEERING, PLUS MECHANIZATION AND AUTOMATION, ALLOWS A MANUFACTURER TO PRODUCE A BETTER PRODUCT AT LOWER COST

Manufacturing Engineering—What Is It?

By E. R. KOESTER

It's common practice today for successful manufacturers to use trained personnel whose sole job is to translate new product designs into well-defined manufacturing specifications and into tools to build the products. Some call this planning for manufacture. Others call it industrial engineering, while still others have labeled it methods work. In a broader sense, this activity may well be called *manufacturing engineering*, because its sphere is one of specialized engineering—directing creative energies toward the development of methods and machinery that yield the ultimate in manufacturing efficiency with a minimum of human effort.

Manufacturing engineering has gained stature in modern industry since its sphere was broadened to include basic product-design considerations that make for efficient and low-cost manufacture. These considerations are important because from a product-engineering point of view you might develop a masterpiece of engineering. But unless that masterpiece can be converted into an item that can be manufactured and sold at a competitive price, even the best-engineered job may prove valueless.

Basic concepts of manufacture must be conceived in the early product-development stages. The pattern of manufacture is drawn while the functional characteristics are developed. Both are important and related. The objectives of both must be integrated to evolve a well-designed product that can be manufactured at an acceptable cost.

This broad engineering approach is gaining impetus in modern industry, because an economic balance between engineering contribution and manufacturing cost must be resolved in every engineered product.

There are numerous ways to design a product. For example, you can design it to last forever, or you can design it to last for a day. By the same token there are many ways to manufacture a product. You can operate like your early ancestors, or you can tool yourself out of business. Obviously, you must know where the economic balance lies.

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Mr. Koester, who joined General Electric in 1917 as a toolmaker, is now Manager of Manufacturing for the X-Ray Department in Milwaukee.

Economic Balance

More and more you hear about the automatic factory of the future. This is not idle talk. Industry as a whole is rapidly approaching large-volume proportions that will permit investments in machinery and equipment to mechanize and automatize practically all its operations. Striking examples are the steel and paper industries; the automotive industry is fast moving in the same direction.

Such activity, you can be sure, is having a tremendous impact on those industries where only limited mechanization and automation now exist.

But mechanization and automation are not cure-alls, because industries that operate at low volumes will find a definite limit of mechanization and automation they can use. Even so, to aid the lower-volume industries to meet ever-increasing competition, a way must be found to harness the basic principles already utilized in the mass-production industries. At the same time, economic balance must be maintained, otherwise the unwary industrialist could easily mechanize himself out of business. Finding this economic balance is one of the top problems facing manufacturing engineers today.

Some Important Factors . . .

Profitable businesses do not come of themselves but are invariably sparked with enthusiasm, alertness, and creative ingenuity. Success can be attributed in a large measure to these basic operating principles . . .

- Ability to integrate product development and tooling so as to achieve the fullest manufacturing-cost advantage obtainable.
- Ability to direct manpower into work channels that yield the greatest output with the least amount of effort.
- Ability to harness all the available technological resources in materials and machinery at your disposal.

. . . Put to Work

A few simple rules drawn from the experience of successful manufacturers show how these basic principles can be put to work. You'll note that attention is focused not so much on unique and singular contributions but rather on the ability to harness industry's vast and combined resources already available although not fully utilized. For it's senseless to invest time and money in areas where vast expenditures have already been made. Steel and standard hardware are typical. Many others fall in the same category.

Achievement and success, then, result from the ability to co-ordinate manufacturing activity with a view toward seeking full realization of the three broad principles mentioned.

RULE 1—*Make sure that no opportunity is overlooked to incorporate sound manufacturing practices in initial development of the product.* In well-managed industries it is common practice for product engineers and manufacturing engineers to sit side by side in the early stages of product development. Thus the best methods are fully explored by which manufacturing can and will perform the task of building the product. These methods are pre-evaluated on the engineer's drafting board. Because the manufacturing engineer is a specialist in his field, he can give valuable assistance by calling attention to the most up-to-date manufacturing approaches and techniques. Because such an approach will act as a safeguard against costly product designs, it permits changes to be made on paper rather than in metal. It's also good practice to have both the product and manufacturing engineer approve final designs before a product is released from the drafting board.

RULE 2—*Don't try to become a specialist in all fields. Capitalize on investments industry has already made.* A common error often made by manufacturing engineers is exploring mechanization possibilities in well-established industrial fields. An extreme example would be an attempt by a small producer to make his own steel; his output would have to reach tremendous proportions to support any kind of investment. You buy steel from those who specialize in steel simply because they sell it at a price that already contains the advantage of almost complete mechanization. In other words, the small producer already has at his disposal tremendous mechanized resources that can give him the cost advantage of mass producers.

Thus it is important that you fully explore the market for available mass-produced items. Capitalize on investments already made. Don't incur increased burdens in capital expenditures until you are satisfied that mass-produced shelf items are not available. Sometimes only the slightest change in engineering specifications can transform a special part into a "dime-a-dozen" item. There are also times when shelf items can be purchased and retailored at only a slight additional cost to meet special requirements. Loft manufacturers have tested and proved this general approach time and again and have successfully competed in the manufacturing field.

RULE 3—*Never be satisfied with a manufacturing practice just because it works. Consider it obsolete the moment it is put into use.* If you admit that today's practices will become obsolete tomorrow, then in long-range view they are obsolete today. And the best time to look for improvement is just as soon as a new idea has been put to work. If you wait, rapidly expanding industrial advancements will leave you behind and you will lose your position in competitive fields.

This means that you must continually check your performance on the bench, at the machine, and in your vendors' factories to make sure that you keep up with forward thinking. Watch industry's trend toward greater mechanization of standard items. More and more, basic items are being mass-produced by specialists who are willing to invest millions to get set up. This is not surprising because many of the great variety of products manufactured throughout industry have common and basic operating functions with parts that can readily be standardized.

Follow the machine-tool industry. Tremendous strides are being made in this field. In many progressive shops it is not uncommon to replace machinery after less than two years' use—not because of wear but because of obsolescence. And many times such obsolescence is brought about because an alert engineer discovered a better and newer machine that can produce many times the output of the previous machine. Obviously it makes sense to replace such a machine even if it is only two years old.

This general approach is a far cry from the old idea that a machine cannot be replaced until it is worn out. A half-century ago this might have worked, but it doesn't hold today because of the tremendous economic advances throughout the machine-tool industry, where millions are spent yearly in research and development.

Make it a practice to visit machine-tool builders. Have them visit you. Without adding a single man to your work force, you'll automatically triple your contribution. In effect, you're engaging and utilizing the services of men who keep constant vigil on manufacturing trends, men who specialize in the development of newer and better equipment.

RULE 4—*Consider it a challenge to progress wherever hand labor is employed on machines and assembly.* This rule, while limited in scope, does have a fundamental application in every shop. Tremendous waste of effort still exists, even in large-volume manufacturing setups. A striking example is a recent manufacturing appraisal of a leading appliance factory: Less than 30 percent of all factory employees were actually engaged in production work; more than 70 percent were material handlers—carrying work to and from machines.

Over 60 percent of all "man effort" was still geared to machines where labor must present the work. And 30 percent was done without the aid of power tools. Only 4 percent of the machines were fully automatic, and 5 percent semiautomatic.

These facts were gathered in a factory that felt reasonably secure in its competitive position. Yet the hard facts are that some enterprising competitor could put this plant out of business. Conditions like these can be found in any factory and are corrected only by removing wasteful procedures.

You'll find a few "Don'ts" from a manufacturing engineer's notebook on this page.

RULE 5—*Maintain a constant vigil on materials supplied by vendors. Make sure that the vendor knows your requirements and is keeping pace with general industrial advancement.* This is an important rule because in most manufacturing setups more than half of a product's parts are supplied by vendors.

In a real sense the vendor, or material supplier, is your largest factory. Thus it is apparent that the horizon of the manufacturing engineer extends far beyond his own plant. This cannot be overemphasized, particularly when you recognize that generally a vendor's materials are not subjected to as intensive and exacting a scrutiny as are materials processed in your own factories.

A program must therefore be established that will subject purchased material to the same intensive and exacting scrutiny that home-processed material usually undergoes. Here is a simple approach . . .

- Subject all purchased items to an intensive cost analysis equivalent to that applied to home-processed material.
- Make a detailed analysis of all the elements of cost. Search out, develop, and recommend to vendors new materials and modifications in product design that contribute to lower cost.
- Invite the vendor to visit you. Visit him. Become familiar with his facilities and capabilities. Establish personal contacts and associations that will enable you to discuss the details of cost with him. Usually you'll find that the vendor is just as anxious as you are to reduce costs, is willing to assist you in your problem, and is eager to accept any improvements.

RULE 6—*Integrate manufacturing engineering activity by establishing complete unification and co-ordination between all contributing agencies.* This rule is extremely important and focuses attention on the necessity of teamwork. Its significance is felt when it is recognized that no one particularly likes change. Conversely, the manufacturing engineer is sure of only one thing—change. He's always on the lookout for areas where improvement can be made. And he knows that as long as labor performs the task, an opportunity for improvement exists.

Because his delegated authority is limited to his specific sphere, he must develop a team relationship between the various services to achieve the desired result. This can be done only if the manufacturing engineer carefully delineates his program and desired objective.

Organized team activity, irrespective of kind, brings effective results. To let the one hand know what the other is doing is a good rule to follow because it produces teamwork, plus a sense of joint responsibility in common enterprise and with common interests to reach the desired objective.

The End Result

The manufacturing engineer's opportunity may be summed up in two words: creative manufacturing. This means diligent seeking to mechanize, not only for the sake of mechanization but also to build a better product at lower cost. Equally, his creative endeavors must not be sparked for profit alone.

The worker, too, makes his contribution. For him the elimination of tiresome and tedious hand drudgery is sure to give him even greater satisfaction in his daily work. Ω

Some DON'TS . . .

From a Manufacturing Engineer's Notebook

DON'T ask an operator to haul material. His hands are planned for production, not hauling. Use conveyors—bring the work to the man, not the man to the work. Keep the machine busy and you'll gain precious machine hours.

DON'T tool up a part until you are satisfied that the product engineer has given full cognizance to the use of automatic manufacturing methods. Don't give up easily. The product engineer is just as anxious as you to design into a product those characteristics that lend themselves to automatic tooling.

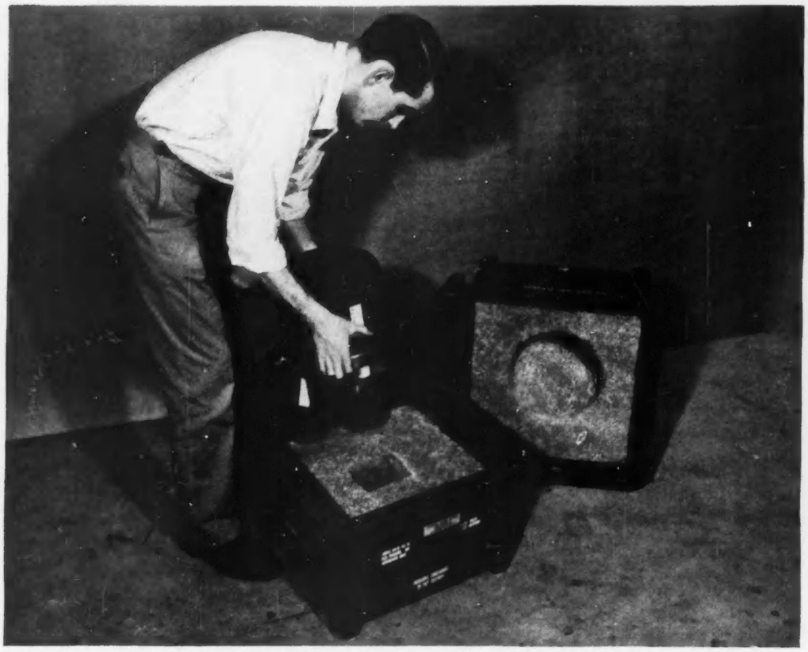
DON'T freeze on the design of special tools and fixtures until you have exhausted every opportunity to incorporate features requiring the least amount of handling time, such as automatic clamping devices, automatic disengaging and ejecting devices, dual-station setups, and any other features that keep the metal cut, welded, and drilled. All of these items will result in greater machine output with a minimum of work-handling time.

DON'T freeze on a factory layout until you are sure that a sound analysis has been made of material flow. Remember this: The shortest distance between two points is a straight line. And the shorter the line, the shorter the work path, and vice versa.

DON'T pile up excessive inventories between machines. Make the manufacturing floor a producing center and not a stock room.

DON'T be satisfied with antiquated material-handling facilities. Study your handling problems at receiving, between machines, at assembly, on the bench, in the stock rooms, at shipping, even in the freight car. Seek advice. Engage the services of material-handling engineers who are experts in their fields. They can guide you in the selection of handling facilities best suited for your job. Watch how material is piled. Among the greatest waste is the improper piling of material in stock areas. Make it a point to palletize your material to permit easy access. The necessity of grubbing around in a pile of material can become your greatest source of handling costs.

DON'T be ashamed or apologetic if the life span of a current manufacturing practice is shortened because of the changing pattern of technological improvement. Rather, consider it an achievement whenever a better way is found to do the job.



MOLDED RUBBERIZED-HAIR DUNNAGE PAD FITS COMPONENT IT PROTECTS. AIR FILLER AND

NEW

Radar component for the Air Force is quickly packaged in an airtight container that is fully reusable. It offers protection against shock, moisture, and fungi during transit or storage.

OLD

Heavier and less sturdy, the old-style wooden crate with cardboard and excelsior inserts was normally scrapped once its contents were removed. Labor and material costs were 20 percent higher.

Reusable Containers:

INSERTS CUSHION UNIT. WHEN CARTON IS SEALED TO FORM A MOISTURE-VAPORPROOF BARRIER, IT IS WRAPPED IN CORRUGATED PAPER.

PRESSURE-RELIEF VALVES ARE PROTECTED BY COVER ON CONTAINER FRONT. BOLTING COMPLETES JOB. NEW WAY IS 80 PERCENT TIMESAVER.

Down-to-Earth Progress in Packaging

(Story continues on page 20)

IN ANOTHER COAT OF WATERPROOF PAPER, CARTON IS FLOATED IN EXCELSIOR, AND ASSEMBLED BOX IS SECURELY NAILED FOR SHIPMENT.

Reusable Containers

(Story begins on page 18)

By R. H. THOMAS

As every engineer knows, the solution to one problem often carries with it the solution to others.

Take the problem of designing a reusable metal container for shipping military electronic equipment—not a glamorous type of engineering achievement but a challenging one nevertheless. When this down-to-earth assignment was completed, the container that evolved was not only reusable but also lighter and cheaper than conventional packaging (photos, pages 18, 19, and opposite). And it was sturdier and less bulky.

Knockabout

It all started when officials of Wright-Patterson Air Force Base, Dayton, Ohio, asked G-E engineers to design a container that could be used to ship, reship, and store radar-set components throughout their active life. They sought a package that would be fully reusable—one that would meet existing requirements of sturdiness, airtightness, and resistance to fungi and moisture.

Under conditions then in existence a radar set reshipped by the Air Force was likely to be damaged in transit. For the old-style package—a wooden crate with cardboard and excelsior inserts—was normally scrapped once its contents were removed. Thus an antenna sent out for a part replacement might be severely knocked about en route to a maintenance depot, thereby becoming a candidate for major repairs.

What's more, the old-style package at its best was heavy, unwieldy, unduly bulky for storage purposes, and unreliable protection against shock, moisture, and fungi.

What Shape?

The initial problem was deciding on the proper shape for the container. Because a cylindrical airtight steel can was readily available at that time, it was tried first. Its cover was held in place by a recessed closure ring fastened with a single bolt.

Under preliminary testing the cylindrical container proved to be unsatisfactory. For it suffered damage when subjected to the required drop tests. The closure ring would flatten out, making it difficult to open the cover. Or the closure ring would rupture and release the cover. Either way the airtight seal was lost.

The round container was objectionable for still another reason. In comparison with a square container of equal cubage, a high percentage of shipping space was wasted.

Because of these and other drawbacks, we concluded that a square container with a center closure would be preferable to the cylindrical type. And so 10 basic sizes were planned to accommodate different kinds and shapes of electronic equipment. Each was to be made in two sections, a base and cover, with closure edges flared to accommodate bolts, washers, and nuts. (Snap fasteners could eventually be used.) To make the container airtight, its two sections would close on a specially fitted rubber gasket that would satisfy standards of elasticity, compressibility, and reaction to temperature extremes.

Snug Fit

Another major problem was a packaging material—dunnage—to prevent damaging in transit: What should we use inside the container to hold the packaged unit in place and to cushion it against shock? Wood, cardboard, excelsior, and paper compounds were ruled out by the Air Force because they tend to absorb moisture. Unless artificially dehydrated before packing, they might lead to rust or mildew.

Three practical possibilities were left: synthetic cushioning, foam rubber, and rubberized animal hair. We eliminated synthetic substances from consideration—at any rate for the present—because they are not past the development stage for cushioning applications. Rubberized animal hair was eventually chosen in preference to foam rubber because it's 1) less affected by extreme variations in temperature, 2) lighter in weight, 3) cheaper, and 4) its surface is less likely to be ruptured by continual vibration.

Rubberized hair could be tailored to fit the package and its contents by either of two methods: molding or die cutting. Experiments showed us that molding is more suitable. In most instances as few as two dunnage pads—one inside the cover, the other in the base—would suffice. And antennas, modulators, radar sets, and other components could be snugly fitted by carefully designing recesses in the pads.

In practice, dunnage pads are especially designed for each new unit to be shipped. Their contours are formed in such a way that the force of any subsequent shock is evenly distributed. The density of the rubberized hair in the pad depends on the weight and shape of the component it protects. Generally speaking, the heavier the component the denser the dunnage.

New Twist

At first we planned to fabricate the containers by drawing them into shape with dies. But it soon became clear that this process would entail tooling costs in excess of $200,000—too much money.

We finally settled on a welded construction that produced an airtight container at a surprisingly low cost. It is made of 14-gage steel (0.0747 inch) reinforced with 12-gage steel (0.1046 inch) at the corners.

On reusable containers that weigh less than 200 pounds when packed, steel drop handles are attached to the base section for easy lifting. For the larger sizes, legs are extended four inches from the base to accommodate lift trucks.

A feature worth special mention is the control of both humidity and air pressure inside the new container. Mounted under a protective cover on the front of the base is an air-filler valve and an air-pressure relief valve. When the unit is stored under humid tropical conditions, dehydrated air can be passed through the air-filler valve. This way fungi and moisture hazards are minimized. When the container encounters low-pressure atmospheric conditions, the air-pressure relief valve

SMALLER AND LIGHTER reusable metal containers were designed by the author who came to GE in 1952. Mr. Thomas, packaging engineer, is a member of the Light Military Electronic Equipment Department, Electronics Division, French Road, Utica, NY.

automatically equalizes inside-to-outside pressures. (Its main use is in air transport.)

Proof of Pudding

There's no question that reusable containers are durable, adaptable, and compact. But how much better are they than the package they replace?

For one thing, the material and man-hour outlays formerly needed for packaging equipment are considerably lessened. For another, both the weight and cubage of packaged equipment are diminished to a great degree. As an example, the old-style package containing a certain radar antenna weighed 389 pounds; the same antenna in the new style container weighs only 255 pounds. In comparison with the 43.8 cubic feet occupied by the old package, the new container takes up only 20 cubic feet. Finally, where we once needed five hours to pack this same antenna for shipment, we now need only one hour.

Containers weighing less than 200 pounds when full are subjected to a free-fall drop test—that is, they are dropped 30 inches onto a steel or concrete surface. The tests are repeated for all corners. Containers weighing more than 200 pounds fully packed undergo a cornerwise drop test. Here one corner is placed on a 12-inch block, the other corner on the same side on a 5-inch block. Then the opposite side is raised 36 inches and allowed to fall freely to a steel or concrete surface.

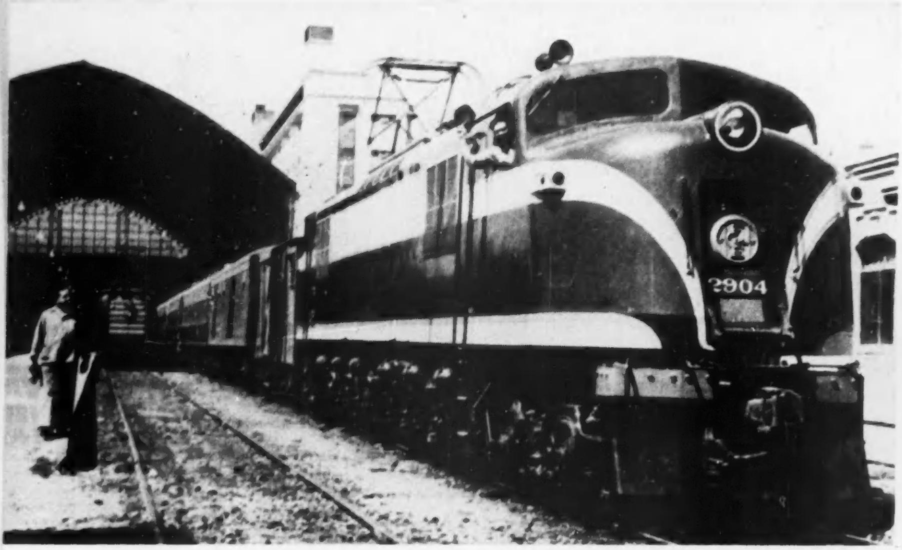
We also put the containers through a submersion test to check their ability to retain a given air pressure. First, the air-pressure relief valve is used to establish an internal pressure of 5 psi. Then the sealed container is submerged in water. If bubbles disclose any air leakage, the container is not acceptable.

Logistics

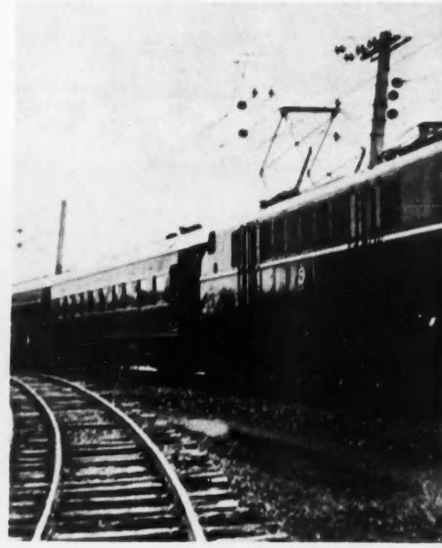
The excellent performance of the new containers has satisfied the military packaging experts: they consider the units ideal for their purposes. In fact, they are now drawing up a new packaging specification based directly on the plans of the container units described here.

From a strictly economic viewpoint, the containers are mutually beneficial to both the military and General Electric. For they unquestionably afford better protection to radar sets and other electronic equipment.

But best of all, from the logistical standpoint the new containers are fully reusable. They can be employed for repeated transport of radar components. They afford better protection to spare components in storage and in transit. And they are reliable safeguards against moisture, fungi, and shock. Ω



CHILE *The Golden Serpent*, through train between Valparaiso and Santiago, is hauled by one of the Chilean State Railway's newest electric locomotives.



BRAZIL Electric locomotives handle much traffic on the Paulista

Electrification Trends

Review STAFF REPORT

Standardization may be a byword in U.S. industry, but it's interesting to note that four South American railroads —with varying track gages and service conditions—have attained a degree of standardization of their electric locomotives that hasn't been approached in North America. This standardization is represented by orders placed since 1938 with various North American manufacturers for 108 3000-volt d-c locomotives.

Why Electrify?

The underlying reason for the electrification of South American railroads is the fuel problem: Cost of imported coal is extremely high, and native coal is often scarce, of poor quality, or relatively inaccessible. On the other hand, water power is abundant and easily accessible in many parts of the continent. South Americans learned from World Wars I and II that their sources of power supply must be immune to naval blockade. Where water power exists within economic distance from a rail or industrial load center, electrification offers freedom from worry about imported fuels.

Another benefit—probably as important from the operating standpoint as the application of electric traction itself—is the use of regenerative braking on the majority of these locomotives. Its primary advantage is that the locomotive controls train speed on a downgrade without using the train brakes. Therefore the train braking system—compressed air or vacuum—is always fully charged, the brake shoes and wheels are cool, the entire system is ready for any kind of a brake application the engineer may make. These factors result in maximum safety, smoothness, and economy in train operation.

Standardization

Significantly, all the locomotives under consideration are of the 3000-volt d-c straight-electric type—a system that seems well-established as the standard for electrification in South America. The earliest application was on the Paulista Railway in Brazil, followed by the Chilean State System, the Chilean Transandine, the Central of Brazil Railway, the Sorocabana Railway, and the Santos Jundiahy lines.

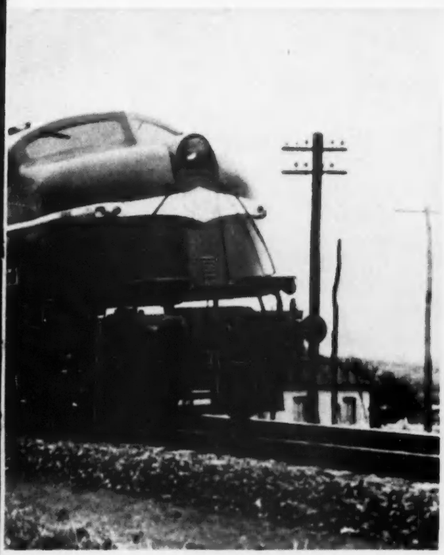
In addition, the same wheel arrangement is prevalent in the road locomotives for 63- and 66-inch gages (Table, page 24). This running gear has evidently proved satisfactory for the type of track and train speeds encountered on the mainlines of Latin-American railroads.

As evidence of further standardization, a number of locomotives, although built by competing manufacturers, have the same motor. That is, the complete motors are interchangeable and will operate in the same locomotive and share the load within acceptable limits. Moreover, by arrangement among the manufacturers, auxiliary motor-generator sets on a number of these locomotives were also made interchangeable.

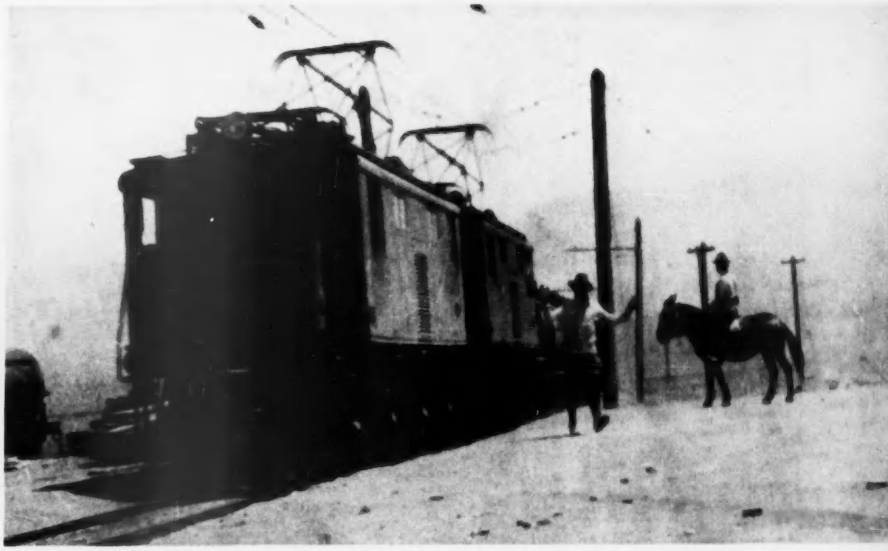
To predict the probable trends of electrification in several Latin American countries, we must first have some background on each local situation.

Argentina

The lack of water power near the centers of population and the scarcity of good native fuel have prevented extensive railroad electrifications in Ar-



Railway's wide-gage mainlines. Wood is still a major fuel, especially on the meter gage.



CHILE Some industrial lines in northern Chile, like the Anglo-Chilean Consolidated Nitrate Corporation's, are electrified for all or part of their length.

in Latin America

gentina. Because the country has some oil, the State Railways have embarked on an extensive program of dieselization. The Ministry of Transport has said that the future lies in electrification and diesel power. Apparently the Buenos Aires suburban service presents the most urgent problem, and electrification is regarded as the ultimate solution. At present the General Urquiza, General Mitre, and General Sarmiento Railroads are operating electric suburban services. Recently the General Urquiza Railroad acquired 78 new cars comparable in size and power to those now operating in the Chicago subway.

Bolivia

Although a terminal electrification forms the Guaqui-La Paz Railway's entry into the city of La Paz, no extensive electrifications are planned for the immediate future. However, Bolivian oil resources may in time contribute fuel for diesel-electric locomotives. A treaty with Brazil provides for joint exploitation of these reserves—an exploitation that may be realized in connection with the meter-gage transcontinental railroad now being built west of Santos, Brazil, its Atlantic terminus. Construction has already proceeded more than 300 miles into Bolivia. Eventually the line may extend to Cochabamba, giving this isolated region access to both Pacific and Atlantic ports.

Brazil

Coal, high in ash and iron content and low in heat units, is available in the State of Santa Catarina. However, because it can be successfully burned only when mixed with imported coals selling as high as $25 per ton, the Brazilian railroad man turns to diesel- and straight-electric locomotives for the solution of his motive-power problem. In steam operation, coal costing $25 per ton and delivering 10,500 to 11,000 Btu per pound must be burned in locomotives with an over-all thermal efficiency of about 5 percent.

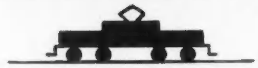
On the other hand, in diesel-electric locomotives, oil costing about the same as coal and delivering 18,500 Btu per pound is burned with an over-all thermal efficiency of about 24 percent. This combination results in situations that are spectacular, sometimes even fantastic: the ratio of Btu's converted into useful work is 8 to 1 in favor of the diesel-electric! In one interesting application the use of diesel-electric locomotives on the Central of Brazil Railway justified itself in something like 180 days, solely on the basis of savings in fuel costs. But because Brazil has no known oil deposits of any great size, all the diesel fuel must be imported—usually by tanker from Venezuela.

Although wood is still a locomotive fuel in Brazil, its use is diminishing because adequate supplies are increasingly difficult to obtain. As the treeless belt on either side of the railroad widens, a point is reached where no more local wood is available. In the parts of Brazil where the forests have not been leveled, however, wood is still the principal locomotive fuel.

About 30 years ago the Paulista Railroad turned to the energy of falling water for its propulsion power. The initial electrification involved 28 route miles of track and required 16 locomotives. Today the line uses 80 locomotives—all 3000 volts d-c—on its 308 electrified track miles.

The Paulista uses two principal gages of track—63 and 39⅜ inches (meter

ELECTRIC LOCOMOTIVES OF NORTH AMERICAN MANUFACTURE SHIPPED TO LATIN AMERICAN COUNTRIES SINCE 1938

Railroad	Number and Types of Locomotives	Continuous Horsepower	Weight (Tons)	Track Gage (Inches)	Wheel Arrangement
Central of Brazil	**15 Road**	**4050**	**182**	**63**	
Paulista	**22 Road**	**4050**	**182**	**63**	
Paulista	**5 Road**	**5110**	**273**	**63**	
Paulista	**8 Switcher**	**510**	**78**	**63**	
Sorocabana	**46 Road**	**1980**	**145**	**39⅜**	
Chilean State	**4 Road**	**4000**	**230**	**66**	
Chilean State	**8 Road-switcher**	**1320**	**77**	**66**	

gage). Although a large percentage of the wide-gage lines are already electrified, the ever-extending outlying lines will probably be developed by wood-burning steam locomotives on the meter gage. Then, when traffic reaches justifiable proportions, the gage will be widened to 63 inches, with provision for future 3000-volt d-c wire installation. And power for future extensions will also come from water.

The largest and most important railroad, the Central of Brazil, has operated a steadily expanding electric suburban service out of Rio de Janeiro since 1937. By 1950 it had 110 miles of track electrified and the company reported approximately 190,000,000 passengers annually. Early last year President Vargas approved recommendations by the Brazil-United States Commission for improving this service. To be completed in five years, this project includes the addition of 100 new multiple-unit electric trains and improvements to the roadbed and transmission system. The little remaining Rio suburban service not now electrified will soon be converted.

The Central of Brazil constructed the first 3000-volt d-c locomotive to be built in South America, followed by five more, all for light service. Subsequently, 15 large locomotives of North American manufacture were purchased for mainline passenger and freight service.

This railroad recently electrified, also at 3000 volts d-c, its Sao Paulo suburban lines for 11 miles, which means that the terminal areas at both ends of the Rio-Sao Paulo mainline are now electrified. Realignment and other improvements reduced the running time between these two cities by two hours. Two trains requiring about 10 hours for the 310-mile run are now operated daily. A future step may be complete electrification of this line.

At the same time, the Central Railway has pursued an aggressive dieselization program. The 120 new diesel-electric locomotives acquired during 1952 will enable it to eliminate a large share of steam traction throughout its entire system.

In 1946 the Santos Jundiahy Railway took over operations from its predecessor, the British-owned Sao Paulo Railway Company. Although only 86 miles long, it carries considerable traffic. Its mainline joins the port of Santos with Sao Paulo (a city as large as Philadelphia) and connects with the Paulista Railway. Electrification at 3000 volts d-c was undertaken; by the end of 1952, 54 route miles were completed, permitting through electric operation between Sao Paulo and Campinas. Material for this electrification was furnished from England, and power is obtained from the 88-kv transmission lines of the Sao Paulo Light and Power Company. Because the company's 15 3000-hp locomotives are equipped with regenerative braking, all substations have banks of loading resistors that cut in automatically to absorb excess power returned to the line. Three 3-unit passenger trains of lightweight construction were recently placed in service, each consisting of two driving-trailer cars and a central motor car.

The Sorocabana Railroad, operated by the State of Sao Paulo, is a meter-gage system with 2131 miles of track. In 1944 it inaugurated an electrification of 87 miles of double track from Sao Paulo to Santo Antonio. Twenty 145-ton 2000-hp locomotives were furnished for the electrification of this meter-gage railroad that can operate locomotives with an axle loading of 40,000 pounds.

Shortly after the initial electrification, railroad officials announced plans to eventually extend it to the extreme western terminus at Presidente Epitacio. The first of four steps has been completed—carrying electric operation about 280 miles from Sao Paulo. Twenty-six more locomotives were ordered, all duplicates of the original 20. North American manufacturers also supplied the substation equipment and overhead-line material.

Several meter-gage railway networks in other Brazilian states have electrification projects either in progress or planned for the immediate future. These are all at 3000 volts d-c and involve a total of some 400 miles of line. Twenty-four 1070-hp locomotives are being imported from England; 10 more have been built by IRFA (Industrias Reunidas de Ferro e Aco), a Brazilian organization now in full operation building cars and locomotives.

Serious consideration is being given to the development of a standard meter-gage 3000-volt d-c 4-motor all-purpose locomotive having an axle load from 26,000 to 29,000 pounds and equipped for regenerative braking. Greater power demands would be met by multiple operation of two or three units. Such a locomotive could be used on both level and rolling profiles as well as in the mountain districts. Thus in a conservative manner the Brazilians are pointing the way to possible standardization. Such a development would greatly help to bring about further electrifications.

Dieselization has made good progress on the Brazilian railroads. Locomotives already in service demonstrate the economy of using costly imported fuel oil in a high-efficiency diesel engine as compared with burning wood in the firebox of a low-efficiency steam locomotive. However, the contrast between fuel oil and hydroelectric power costs may change the picture in favor of straight electrification.

Chile

In 1924 the Chilean State Railways—a government organization—electrified the route between the Pacific port of Valparaiso and the capital city of Santiago, a distance of about 116 miles generally known as Zone 1. The 3000-volt d-c system was used in this installation that covered 233 miles of 66-inch gage track; 62 locomotives were purchased for the initial electrification.

Part of the reorganization and modernization plan adopted in 1952 is to extend the electrification as far as Chillan, 250 miles south of Santiago. The 73-mile branch to Cartagena will also be electrified, and the Santiago-Valparaiso line will receive three new electric motor cars and nine trail cars.

Transandine Railway is another interesting meter-gage electrification that crosses the Andes near the Chile-Argentina international boundary at a 10,471-foot altitude. Severe grades and curves exist throughout almost the entire 155 miles of line. In the main ascent on both the east and west sides of the summit, the Abt rack system is used on the steepest grades. The maximum grade is eight percent on the Chilean side.

About 1927, the line on the Chilean side was electrified at 3000 volts d-c from its junction with the Chilean State Railways at Juncal to the summit. The motive power consists of three combined adhesion-and-rack locomotives of Swiss manufacture, weighing approximately 95 tons and equipped for regenerative braking. The 1952 modernization program included the purchase of two additional locomotives and mobile substations.

The Tocopilla-El Toco Railroad, owned by the Anglo-Chilean Consolidated Nitrate Corporation, is a 42-inch-gage line that carries both regular freight and passenger traffic. Of its 194 miles of track, 24 are electrified at 1500 volts d-c using overhead trolley wire. Seven 60-ton locomotives provide the motive power.

In addition to freight and passenger lines, a number of industrial and mining railroads in Chile are also electrified. One important example is the Cruz Grande el Tofo Railroad operated by the Bethlehem Chile Iron Mines Company for hauling ore from the mines to tidewater. Consisting of 16 miles of standard-gage track electrified at 2400 volts d-c, all equipment is of North American manufacture. Three 110-ton freight locomotives—equipped for regenerative braking—and seven 60-ton switchers furnish the motive power.

Also, the Chile Exploration Company operates approximately 104 miles of standard-gage line, nearly all electrified at 650 volts d-c and utilizing both overhead-trolley and third-rail contact systems. Four of the locomotives are of European manufacture and weigh 87 tons each; the remaining 21 locomotives are from North America and range in weight from 70 to 83 tons.

Because of ample water power for hydroelectric developments, the future of electrification in Chile is promising.

Colombia

Although water power is available in this rugged country, it has not shown any activity in the electrification of its railroads. Venezuelan oil fields a short distance east of the port of Barranquilla, plus Colombia's own oil and coal reserves, make the capital expense involved in electrification economically unjustifiable.

For the past 10 or 11 years the Colombian National Railways has increasingly used diesel-electric rail cars in passenger service, and currently diesel-electric locomotives are being introduced. In some runs the change of elevation is approximately 9000 feet.

Venezuela

As is widely known, Venezuela is South America's greatest oil-producing country—resulting in the operation of Venezuelan railroads by oil-burning steam locomotives. Logically the next step was the application of diesel-electric locomotives, coupled with the development of improved motor transport on the republic's 600 miles of highway.

The only electrification is the 23-mile La Guaira and Caracas Railroad between the capital and its seaport. Motor coaches handle passenger traffic, but freight is still hauled by steam locomotives. No electric-railway progress can be expected as long as Venezuela remains among the major oil-producing countries of the world.

The Orinoco Mining Company in developing the Cerro Bolivar iron-ore deposits has built a standard-gage railroad 95 miles long utilizing diesel-electric locomotives.

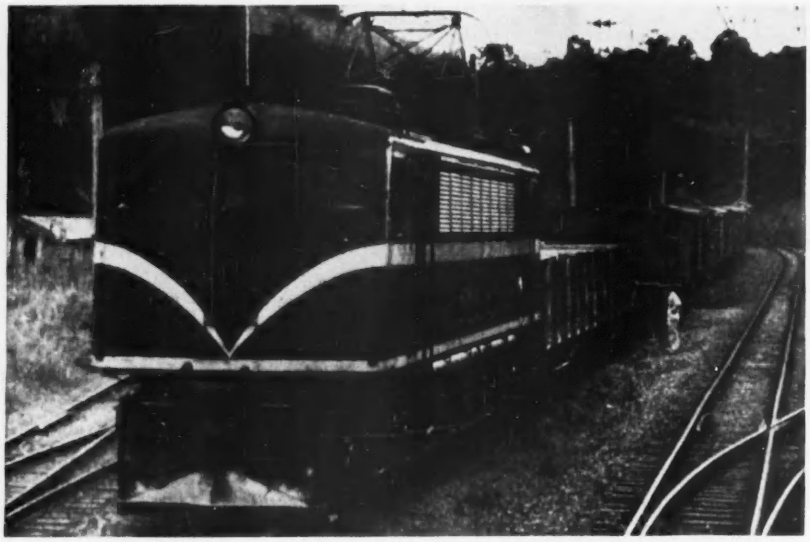
Little can be said about railroad electrification in the remaining South American countries.

Central America

With the exception of Costa Rica's Pacific Electric Railway, no extensive electrifications exist in any of the seven Central American countries. A single-phase 20-cycle 15,000-volt overhead-trolley electrification, the Costa Rican equipment was built by European manufacturers. The line is 42-inch gage and extends 81 miles from Puntarenas on the Pacific coast to the capital, San Jose, where it connects with the steam-operated Northern Railway that reaches the Atlantic Ocean at Port Limon.

The availability of Mexican, Venezuelan, and Californian oil, as well as relatively light traffic, indicates that the

LOCAL PASSENGER SERVICE on electrified railroads in the countries of Brazil and Chile is often handled by multiple-unit trains made up of one motor car and two trail cars.



ELECTRIC LOCOMOTIVES on the meter-gage Sorocabana Railroad, operated by the State of Sao Paulo in Brazil, have more than doubled the capacity of the line over steam operation.

diesel-electric locomotive is more economically feasible than any extensive electrification in the foreseeable future.

Mexico

The electrification of the Mexican Railway's mainline between Vera Cruz and Mexico City is outstanding. The first section to be electrified, the Maltrata Incline, comprised the heaviest grades encountered on the entire mainline—grades as high as 4.7 percent with spots exceeding 5 percent. Installed in 1925, this section was subsequently extended to 64 route miles.

This installation uses 3000 volts d-c with the overhead catenary system. Ten locomotives were initially placed in service, and two more were added in 1928. Equipped for regenerative braking, the locomotives are 6-axle 2500-hp units weighing 150 tons. All equipment is of North American manufacture.

The economies of electric operation over this difficult profile are evident . . .

- Faster schedules than were possible under steam operation are maintained in both directions.
- On the downhill runs the regenerative braking eliminates the stops formerly necessary to allow the brake shoes and wheels to cool.
- Better controlled train speed permits faster schedules with increased safety.

And the Future?

An analysis of existing installations and conditions in the various Latin American countries points toward several significant conclusions.

Trends toward standardization on 3000 volts d-c for railroad electrification are noticeable. For the most part, the power is generated by hydroelectric stations. This pattern seems well-suited to existing conditions in both natural resources and railroad-operating characteristics.

The multiplicity of track gages apparently has not offered too much of a handicap to the development of a fundamentally uniform electrification pattern. The reason is probably that the horsepower of a given type of locomotive varies somewhat uniformly with the track gage and locomotive weight. Therefore, within limits one locomotive design may easily be made applicable to various gages and operating requirements.

The diesel-electric locomotive has a justifiable place in the Latin American motive-power picture along with the straight-electric locomotive. Depending on the local fuel situation, the diesel will play a more or less important part. It forms an economical tool supplementing mainline electrification both by its use in switching service and on feeder lines. In some instances the diesel-electric can be expected to appear in appreciable numbers in mainline service.

Steam locomotives burning oil, coal, or wood still form the backbone of the motive power on Latin American railroads, and they will continue to exist as long as they are economically justifiable.

The positions these three competing forms of motive power occupy in the railroad picture will not remain stationary; instead they will fluctuate with variations in the cost and availability of different forms of locomotive fuel and electric power. Electrification for the sake of electrification, dieselization for its own sake, or adherence to steam power as a matter of tradition should not be allowed to cloud, or confuse, the main issue. The goal of all railroad operators is continued reduction in operating costs, better operating schedules, and increased safety to passengers and operating personnel. The choice of motive power for any particular application should certainly be determined by an unbiased consideration of its suitability as measured by these criteria. Ω

EVERYWHERE YOU TURN, SILICONES

By J. S. HURLEY, JR.

SAMPLING of products that vie for the consumer's dollar all contain silicone. Easier and faster to rub out, silicone waxes and polishes have a high depth of gloss that is long-lived.

If your car has a fluid transmission, chances are that silicone rubber gaskets seal the system. Silicone-rubber boots prevent your spark plugs from fouling in damp or rainy weather. When you polish the car, silicone fluids make the job easier. The silicones in your wife's hand cream give it water repellency, protecting her skin from water-borne irritants.

In fact, silicones are with you everywhere you turn (photo). If you are not directly involved in the silicone field, perhaps this abundance and variety of uses is a bit confusing. You would be justified in asking: What is a silicone? where is it used? and why?

New Kind of Chemistry

Silicones owe their present position in the chemical market to the electrical industry. The continuous search for a better insulating material led the General Electric Research Laboratory to investigate the original work of Professor F. S. Kipping, an English chemist.

Kipping's investigations were expanded in this country, and a resinous material was developed. For operation at high temperatures, engineers could use this new resin to bond, impregnate, and impart electric strength to glass insulating cloth and tape, asbestos, and mica products. (This was particularly important to the United States Navy during World War II.) Out of this research came not only insulating resins but also a whole line of new products. These included dielectric fluids, synthetic rubbers, mold-release materials, ingredients for waxes and polishes, coating materials, adhesives, antifoam materials, water repellents, and organosilicone chemicals for process industries and the manufacturers of silicone specialties.

It may not mean much to you, but one chemical dictionary describes a silicone as "A polymeric compound containing Si-0-Si-0 groups; available as oil, grease, or resin of unique stability to heat and chemicals; used in high-temperature electric insulations."

For our purposes it's sufficient to say that silicones are derived from sand and contain a skeleton of alternate silicone and oxygen atoms, with organic groups—that is, compounds of carbon—attached to the silicone atoms. Silicones obtain some of their characteristic properties from sand: namely, their resistance to heat and chemicals and their disinclination to react with other elements. On the other hand, the organic portion of a silicone gives it the flexibility needed to develop different products.

Thus you have a basic material with properties resembling those of organic products but also possessing a whole new set of properties for industry to utilize.

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A pioneer in the development of markets and applications for silicone products, Mr. Hurley joined General Electric in 1937. He is currently Supervisor, Electrical Industry Sales, Chemical Division, Waterford, NY. Active in various technical societies, he is chairman of the ASTM section on silicone varnishes.

Fluids

One of the purest chemical products manufactured today, silicone oil is a clear, colorless fluid characterized by an extremely small change in viscosity with temperature variation. Chemically inert, it resists shear breakdown, has low surface tension, good dielectric properties, and good resistance to oxidation.

Some silicone oils have pour points as low as −120 F (photo, left, next page). On the high side, these oils will operate almost indefinitely at 300 F. At 400 F in air the oil loses weight, increases in viscosity, and finally forms a gel. If you exclude the air such as in a closed system, or if an inert atmosphere such as nitrogen or carbon dioxide is used, silicone fluid will operate at temperatures up to 500 F with small change in its original properties. As an example, a silicone fluid was heated for 1400 hours at 492 F in a sealed system in the presence of nitrogen. Essentially no change occurred in its original viscosity.

The flash point of silicone fluid is approximately 600 F, and it ignites at approximately 815 F. The fluid burns only with difficulty, however, and will extinguish itself if the source of heat is removed.

Many applications of silicone fluid are successful because one or more of

SILICONE FLUID pours at −100 F (*right*) while standard petroleum fluid freezes over.

WATER rolls off textile materials treated with water-repellent silicone fluids.

TISSUES treated with silicone, an early application, keep eyeglasses sparkling clean.

their basic properties are utilized. For simplicity, the Table shows major applications of silicone fluids and the principal properties that make them successful. As an example, take the use of silicone fluid in torsional vibration dampers. It is successful because its viscosity remains essentially constant under conditions of high shear, because it does not change viscosity with increase in temperature, and because it is stable and inert to metals.

You may be surprised to learn that silicone fluids are much more compressible than petroleum oils and most other organic liquids. This property made it possible to develop a new type of liquid, or hydraulic, spring that is expected to find extensive usage in the aircraft, automotive, and machine-tool industries. Already, liquid springs have replaced ordinary coil springs in some punch-press operations.

But one application more than any other has made silicone a household word—its use as an active ingredient in polishes for automobiles, furniture, shoes, and other articles. Here the principal advantage of the silicone is that it provides an easier rub-out, because it is incompatible with and lubricates the waxes contained in polishes. In addition, it produces a finish having a better depth of gloss and a longer life than conventional polishes. A large number of liquid polishes and waxes on the market today contain silicone in varying amounts. And an increasing number of paste polishes are being produced with silicones. You can expect to hear much more about it in the future.

Silicone fluid applied to the molds used to form products in the rubber industry has been standardized, making possible the production of more uniform and cleaner products. Additionally, it reduces down-time formerly required for cleaning molds between operations. In the shell-molding process (page 38, July 1953 REVIEW), a relatively new technique of casting metals, silicone fluid plays a major part: it provides a clean, sure, and economical release of the cured sand-phenolic shell from the metal pattern. This process has been gaining popularity in the metal-working industries as a means for making a wide variety of parts by a precision-casting method.

On the surface, silicone fluids appear to be ideal materials for lubricating applications, especially because of their good thermal properties. Yet the standard fluids produced today are suitable only for lubrication under specialized conditions. This is primarily so because their chemical inertness prevents the formation of boundary lubricating films as with other lubricants. However, as a result of work now undergoing evaluation, the real solution to the use of silicones as lubricating materials is near. True lubricating silicone fluids with excellent load-carrying capacity, plus resistance to both high and low temperatures, will evolve. These new fluids will offer solutions to lubricating problems for which until now there has been no suitable material.

In the last few years interest in silicone fluids used as insulating fluids has increased. And so, much time and effort has been spent determining their dielectric properties.

The dielectric strength of a dried silicone fluid of a viscosity most frequently used for electrical applications is 35 to 40 kv measured in a standard test cell. These values are in the range normally expected for a good petroleum dielectric oil. Silicone fluid capably withstands high voltages of short duration, and under tests they have shown an impulse strength of 285 kv. Under the same tests the best grade of transformer-type mineral oil would break down at about 85 to 90 kv.

Silicone fluids are used as liquid dielectrics for pulse transformers, specialty transformers, capacitors, and radar and television equipment. Here their electrical properties and ability to operate at temperature extremes are the important characteristics. But in some applications their general chemical inertness is the most essential property. In a polyethylene-insulated capacitor, for example, fluids have a less harmful effect on the polyethylene than does a petroleum oil, even though the temperatures involved are not high enough to exclude the petroleum fluid from consideration. Silicone dielectric fluids are specified for certain military electronic equipment where uniform operation must be maintained under adverse conditions.

One of the more interesting new fields for silicone fluids is in cosmetics and pharmaceutical products. You can now get hand creams with a silicone base having all of the advantages of other protective creams, plus water

STATOR life is extended six-fold after application of special silicone water repellent.

SILICONE FLUIDS—APPLICATIONS AND PROPERTIES

Products	Surface Activity	High Viscosity Index	Low Surface Tension	High Temperature Resistance	Low Pour Point	Resists Shear Breakdown	Compressibility	Inert Chemically	Electrical Properties	Water Repellent	Nonvolatile	Low Toxicity
Wax and Polish	—		—					—		—		
Antifoam	—		—					—				
Mold release	—	—	—	—				—			—	
Dielectric fluids				—	—			—	—	—	—	
Additives for paints	—							—				
Adhesive paper	—		—					—		—	—	
Cosmetics	—		—					—		—		—
Pharmaceuticals	—		—					—		—		—
Viscous Dampers		—		—	—	—					—	
Fluid Springs		—		—	—		—				—	

repellency and its subsequent protection. For the same reason, ointment bases containing silicone provide more effective use of medication over a longer period. An alcohol-soluble silicone fluid, specifically for cosmetic use, offers an opportunity for the development of clear cosmetic solutions as a change from creams, emulsions, and ointments. (Formerly, silicones were not soluble in the common types of alcohol.)

Other possibilities are being considered for silicone fluids—lipstick base, lip pomade, hair lotions and dressings, cold cream, and baby lotions. Suntan formulations with silicone fluid added give you longer and better protection, because the loss of sun-screening agents is reduced when your skin comes in contact with water.

Silicone fluids compounded with silica-type fillers are used in the processing industries to keep agitated liquids from foaming. Only a small amount—in the order of parts per million—is needed to do a job. Similar materials may be used as dielectric compounds when formulated into a grease-like material.

Today you can buy fabrics containing silicones as the water-repellent agent (photo, center, opposite page). Used in combination with crease-resistant finishes, silicones also produce a more durable finish than formerly possible. Coming along too is a treatment for leather goods that affords greater protection against water than any known existing finish.

Treating paper to keep it from sticking to materials is another application of silicone fluids. In one instance, silicone-treated paper is used as a separator sheet for sticky materials, such as uncured rubber and gum. A silicone-treated glassine paper is employed as an interleaving sheet for pressure-sensitive cellophane used as a cheese wrap.

Another type of treated paper separates electrical and other adhesive tapes. You might think this application of minor importance but consider this: For some time manufacturers have had better adhesives on their shelves, but they could not use them on tapes because the interleaving paper would stick. Now they can not only use the stronger adhesives but also push for even better ones.

By reducing breakage and rejects, silicone fluids are helping in the manufacture of glass products. To accomplish this, a fine spray of silicone emulsion is applied to the glass surface in the final stages of manufacture. The treated bottles or lamps—whose surfaces are in effect lubricated—will not scratch when rubbed against one another, allowing more freedom of handling during inspection and packaging. Additionally, the reduced scratching maintains the strength of the glass so that breakage will be lessened during filling and transporting of the finished product. Bottle breakage on the filling lines alone has been reduced by a factor of about 100 in some test runs.

One final application of silicones worth pointing out—one that most people are familiar with by this time—is silicone lens tissue. An occasional wipe with these tissues cleans eyeglasses, keeping the lenses sparkling and free of dust (photo, right, opposite page).

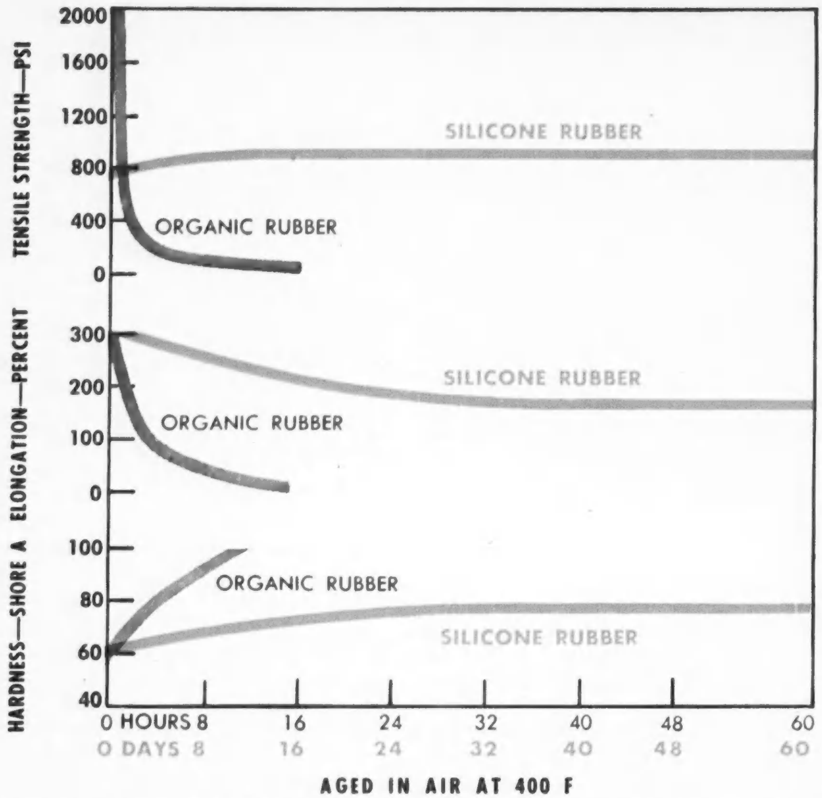
Rubber

The United States Navy sparked the development of another silicone product—rubber as a primary insulation for wire and cable. For more reliable operation of their equipment on shipboard, they needed material that would operate even if a fire broke out in the immediate vicinity of the cable. When silicone rubber burns, it doesn't leave a conducting carbonaceous ash (carbon is a conductor) but continues to maintain an insulating system. Thus the electric equipment will usually operate until suitable repairs can be made. With ordinary cable the insulation would of course burn out, the wires would short, and the electric equipment it served would not function (photos, top, page 31).

Ten years ago the first patent application for silicone rubber was applied for. Let's take a closer look now at today's silicone rubber—certainly one of the most interesting of the silicone products for applications in the electrical field. Elastomeric materials are not new in the electrical industry, but in silicone rubber you have—in one product—a material possessing and maintaining excellent electrical properties even at high temperatures, plus resistance to unusually high and low temperatures (photo, upper left, page 31).

The silicone-rubber compound used for electric insulation is a simple formula compared with an organic formulation like butyl rubber, for example.

Essentially, silicone rubber is composed of only a silicone gum and a filler, plus a catalyst. None of its properties changes because there is no



PHYSICAL PROPERTIES of silicone rubber remain stable at elevated temperatures. Note that the abscissa for organic rubber is in hours, silicone rubber in days.

loss of the plasticizer or a change in one of the ingredients as with other synthetic rubbers. The silicone gum is an extremely viscous, colorless, almost clear material. Like organic rubbers, it is reinforced by incorporating inorganic fillers such as silica, calcium carbonate, lithopone, titanium dioxide, iron oxide, and many others. Depending to some extent on the type of reinforcing filler you employ, a wide variety of colors can be produced for identification purposes or to fit in with a color scheme.

Silicone rubber has many of the properties of ordinary elastomers, but in addition it possesses the remarkable resistance to high and low temperatures that characterizes all silicone materials. Some rubbers produced today remain flexible as low as −120 F and are still operable at temperatures as high as 550 F.

Originally, engineers and chemists were confronted with many problems in silicone rubber manufacture and fabrication. Recent developments, however, have reduced and standardized the technology of silicones so that these compounds are now made and fabricated on conventional equipment used throughout the rubber industry.

At ordinary temperatures, the tensile strength, elongation, and abrasion resistance of silicone rubber is not as great as that of other synthetic rubber compounds. But the properties of silicone rubber are maintained when exposed to elevated temperatures, whereas those of organic rubber change rapidly in high temperatures, resulting in early failure (illustration).

Electrically, the power factor, dielectric constant, and insulation resistance of typical silicone rubber compounds are in approximately the same range as those of organic rubbers. And by a proper choice of fillers, many variations in these properties are obtained.

From continued compounding studies you can expect new knowledge allowing chemists to effectively tailor the dielectric properties of a compound to a given application. In a limited way GE is doing that right now with a special compound (SE-965) recently developed for extrusion of cable insulation. Simple to process on wire manufacturers' standard vulcanizing machines, it possesses low moisture-absorption characteristics, good dielectric strength, and high insulation resistance.

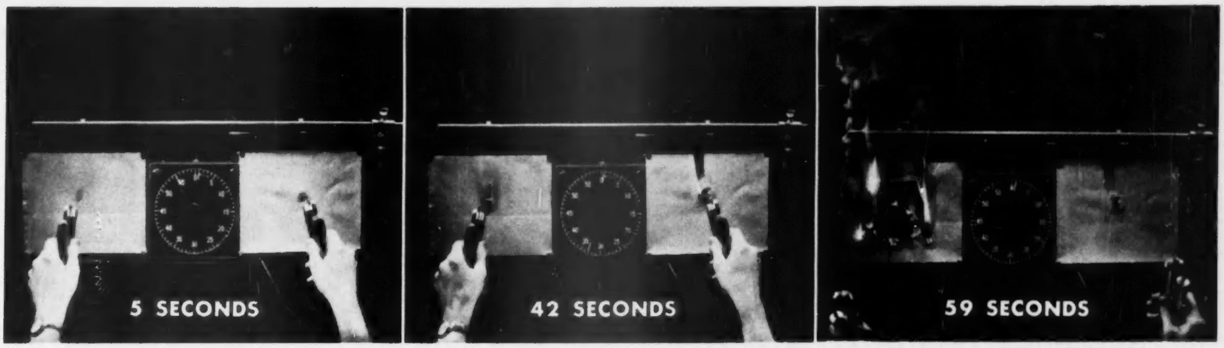
Another compound (SE-100) introduced in 1953 indicates the marked improvement in electrical properties accomplished by compounding. This product changed our entire thinking concerning silicone rubber compounds. When coated on glass cloth (photo, lower left, next page), it shows dielectric-strength values as high as 1400 volts per mil—a value approaching that of a silicone resin or other general insulating resins. What's more, it maintains these properties even when aged at high temperatures. Exposed to 96 percent humidity for 96 hours, it still maintains a dielectric strength of 1000 volts per mil. The new product, putty-like and white in appearance, is designed especially as a coating material for glass cloth and sleeving as well as organic insulating products used in the electrical industry.

A third compound also possessing unique properties (SE-550) is capable of operating at temperatures as low as −120 F. Here, in one compound, is a product that operates over the widest range of temperatures—wider than any of today's nonsilicone elastomers. It is of particular importance, incidentally, to the aircraft industry where its low-temperature property can be utilized to advantage. At the high elevations and low temperatures of modern flight, SE-550 is well suited to such uses as gaskets and seals.

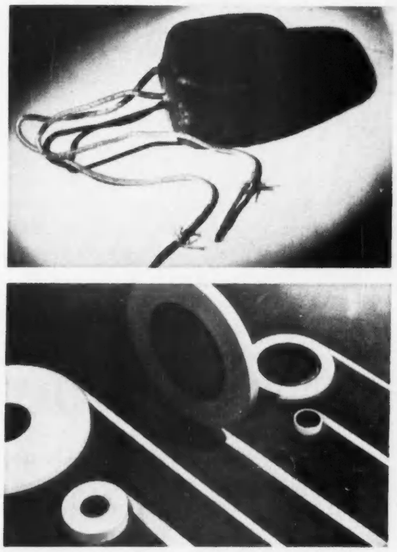
These are but a few of the unique silicone rubber compounds developed up to now. For silicone rubber, with its many modifications, is one of the most promising materials in the entire silicone field. Where the price of silicone rubber is a barrier, it can frequently be overcome by carefully considering the application and then designing to take advantage of its properties.

One of the first and still one of the most extensive applications of silicone rubber is as a bushing for liquid-filled capacitors—an outstanding example of the benefits obtained by designing around silicone's properties. In this instance an engineer utilized the low compression-set properties and chemical resistance of the silicone rubber. Not only was the design successful, but also a cost saving was realized over former bushing materials.

This same material solved a problem on the hermetically sealed motor-drive units of major home appliances such as washing machines. Silicone rubber now insulates the terminal connections and maintains the hermetic seal where the



HOT FLAMES of identical alcohol torches are applied to conventional silicone rubber and special flame-retardant silicone rubber. Samples begin to char (*left*), then flame (*center*). Flame-retardant sample extinguishes self while conventional rubber continues burning (*right*).



SILICONE leads (*upper*) and tape (*lower*) are electrically stable at high temperatures.

NIPPLE made of heat-resistant silicone rubber won't clog and has no rubbery taste.

PHARMACEUTICAL enclosures, or stoppers, of silicone rubber don't contaminate drugs.

connections leave the unit. This same technique is used on terminals of electronic instruments.

Silicone rubber's ability to withstand temperature extremes isn't the only reason for its success. In some food industries where the produce could be contaminated by rubber, conveyor belts are made of silicone rubber to keep food products from sticking to them. At the same time, if the belt must pass through an oven to bake the food, it will take this too.

A new silicone-rubber baby-bottle nipple (photo) supposedly tastes better than natural rubber. The nipple has no rubbery taste because it doesn't contain plasticizers or other compounding agents. Food just doesn't stick to silicone rubber so it seldom clogs. And it can withstand the high temperatures of sterilization for long periods of time without deteriorating. Nipples of this type have been tested by a group of families for more than a year and, by the way, you can now buy them in many local drug stores.

Silicone-rubber closures for pharmaceutical bottles (photo, right) are also showing up on your druggist's shelves in increasing quantities. The chemically inert quality of silicone rubber prevents contamination of the medicinal ingredients—the reason for their popularity.

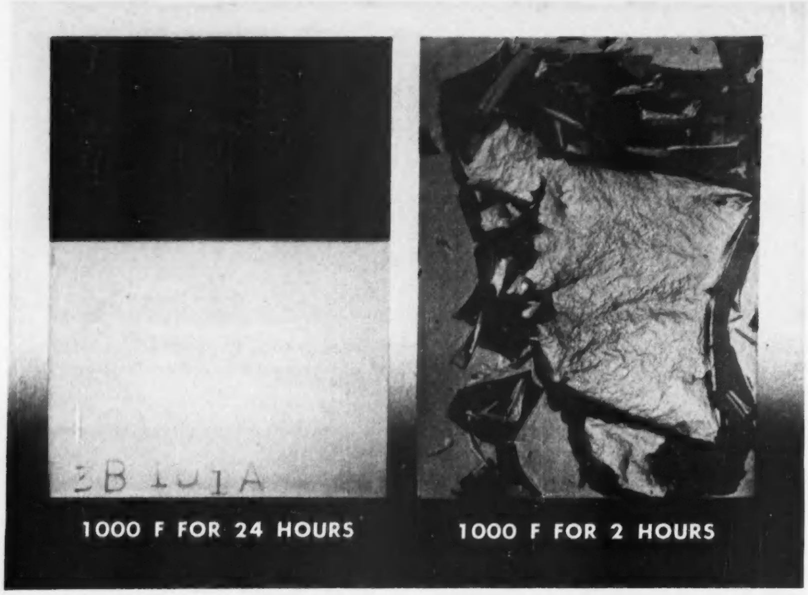
And so you can see why silicone rubber is finding its way into almost every industry. Certainly the aircraft industry consumes large quantities of silicone rubber, and the automotive industry is stepping up its usage, too. In the electrical industry, grommets, spark-plug boots, ring gaskets, seals, ignition and hook-up wire, refrigerator defroster wire, and motor lead wire are just a few of the applications where silicone rubber is finding its place.

Silicone rubber isn't a specialty item any longer. A standard material in a variety of forms, it is making its way into new applications every day.

Resins

We have considered two highly important lines in the silicone industry: silicone fluids and silicone rubber. Now let's look at the silicone resins—the product that really started this industry rolling.

But, first, what are resins? Specifically, synthetic resins? Generally speaking, they are man-made materials resembling natural resins—such as the pitch from certain trees—in appearance and properties. Available either as liquids or solids, they are materials that



PROTECTIVE COATING formulated with silicone resin and applied to a steel panel (*left*) is unaffected by exposure to high temperature, while conventional coating cracks and peels.

plastics are made from. Additionally, and perhaps less widely known, they are used as film-forming substances in varnishes and protective finishes and as adhesives, cement, and impregnating fluids, among other things.

Silicone resins in the early days possessed little else but heat resistance to make them attractive except where absolutely no other resin could do the job. We lived with this situation knowing that chemists and engineers would eventually overcome the inherent weaknesses of silicone, providing new materials to do the things we anticipated in earlier silicones.

Our faith in the future was justified. For today knowledge and understanding of silicone chemistry have increased many fold. We now have silicone resins that look and behave like the resinous materials the industry has been used to handling.

One development, SR-32, is a good example of such a material. It combines excellent dielectric properties with superior heat life, flexibility, and easy handling. When applied to glass cloth, it forms a sheet insulation or it can be slit into tape for cable insulation. It provides a heat-resistant bonding agent for the manufacture of various insulating components, such as glass-backed mica tape, other flexible and composite mica products, and glass sleeving. Samples of glass cloth coated with this resin—one of the best with respect to heat aging—after aging 30 days at 525 F still had a dielectric strength of 2000 volts per mil.

While outstanding in its heat resistance, SR-32's flexibility and dielectric properties are short on the low temperature side, particularly for applications below 0 F. To offset this, another resin—SR-17—was developed and introduced for use over a broader range of temperatures. Properly cured SR-17 coated cloth can be bent over a one-eighth-inch-diameter mandrel at temperatures as low as −30 C without any significant change in the dielectric strength.

In many electrical applications, whether silicone or not, one of the most important parts in the over-all insulating system is the varnish used to impart life and dependability to equipment. But silicone-resin varnishes offer greater dependability in this respect because of their greater thermal resistance, ability to maintain electrical properties under severe conditions, chemical resistance, and resistance to oxidation.

One resinous water-repellent coating recently introduced provides longer life for electric equipment operating under such adverse conditions as moisture or salt spray.

Although the principal use of silicone resins is for electrical applications, equally important is its use as a vehicle for paints and finishes. Protective and decorative coatings formulated with silicone resin provide a product that has outstanding resistance to heat, weather, and chemicals. Panels coated with these formulations have been exposed to 500 F for 1000 hours with no signs of cracking or other indications of failure (photo). Silicone protective finishes are suitable for hot exhaust stacks, furnaces and boilers; space heaters and chemical-plant equipment; outdoor metal signs and siding; and high-temperature motors.

In the field of building construction, silicone resins impart a high degree of water repellency to a variety of above-grade masonry materials. Products containing these silicones are on the market now under a variety of trade names.

The present resins are a definite improvement over early silicone resins, but much still needs to be done. Accordingly, the technology of silicone resins has advanced to a much higher level. This is sure to result in silicone resins of far better physical properties.

We cease to be surprised as new applications of silicones are developed that once were considered an impossibility. Look around you—either at home or in the office—and you'll find that silicones have taken a place in your life. They put a better polish on your furniture, take the wobble out of that expensive table, and make it easier for you to polish your car. The capacitors in your fluorescent lights may have silicone rubber gaskets. The fluorescent tube itself may be silicone-treated to be sure that it performs properly under conditions of high humidity. Your refrigerator may be defrosted by a silicone-insulated resistance wire. Your basement may be drier because of the silicone additive in the cement paint. The paint on your woodwork may be more durable and retain its color better because of the silicone fluid added by the manufacturer. The list is almost endless.

The silicone story is an example of how the chemist, starting with sand, has improved on nature by modifying the sand to form a wide variety of products. These products make your life easier and better. And all in all, you can look to silicones to provide even greater benefits in the next few years. Ω

ANNUAL INDEX . . .

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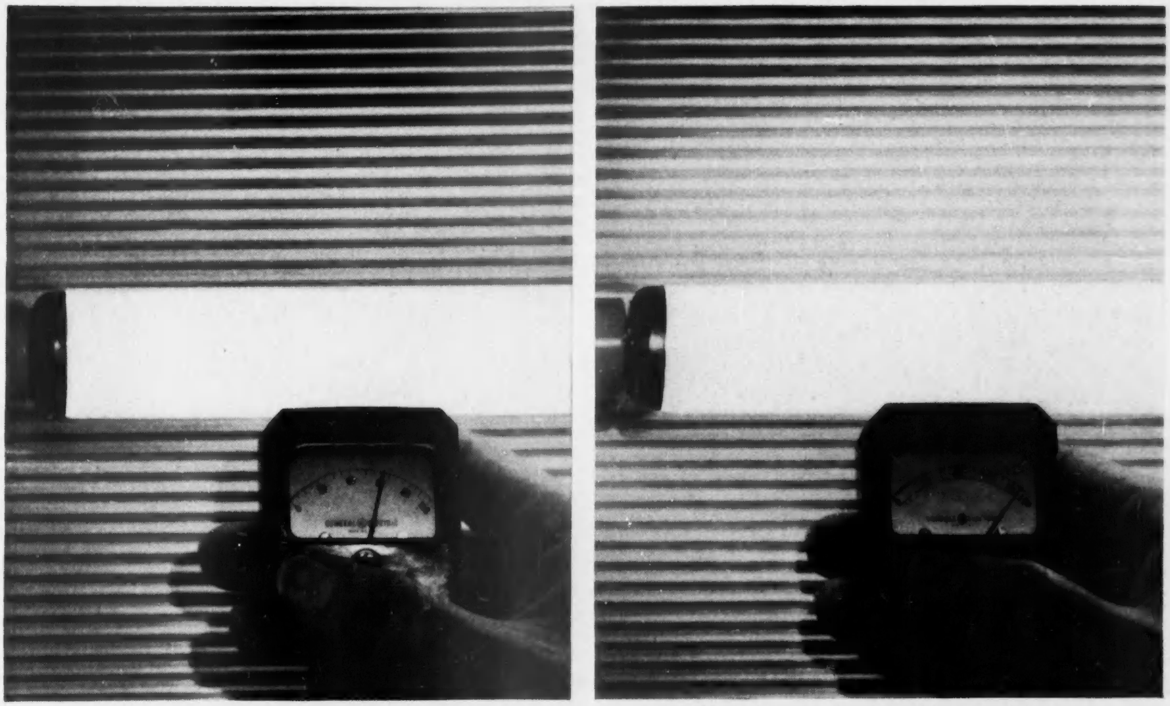


Regular slimline, left, gives 620 units of light. New High Output Rapid Start lamp, right, gives 840 units of light.

NEW GENERAL ELECTRIC FLUORESCENT LAMP GIVES 1/3 MORE LIGHT THAN ANY PREVIOUS FLUORESCENT

LIGHTS ALMOST INSTANTLY—General Electric announces the most important advance in fluorescent lighting in 10 years: the new High Output Rapid Start fluorescent lamp. The 96-inch High Output lamp gives 36% more light than the most powerful G-E fluorescent lamp previously available.

For new installations, General Electric High Output lamps offer this ⅓ bonus of light without increasing the number of fixtures or maintenance costs.

This big increase in light, with no increase in lamp size, has been achieved through a special cathode developed by General Electric which permits a boost in lamp wattage to 100. Because the cathode is of the famous General Electric triple coil design, these Rapid Start lamps light up almost instantly. General Electric High Output lamps have a rated life of 7,500 hours, the same as all General Electric general lighting fluorescent lamps.

A new G-E base and socket design protects the lamp contacts by recessing them. A simple push-pull sets the lamp in its fixtures.

HAS VARIETY OF USES

The new General Electric High Output fluorescent lamp is especially suited for use in areas with high ceilings, in factories, warehouses, offices and stores. Also in store windows, showcases and other places where you want higher lighting levels in keeping with the modern trend. New fixtures designed for the G-E High Output lamp will soon be available from a number of lighting fixture manufacturers.

For information, write to Lamp Division, General Electric Company, Dept. 166-GE-11, Nela Park, Cleveland 12, O.

Progress Is Our Most Important Product

GENERAL ELECTRIC

G.E. announces new d-c brake

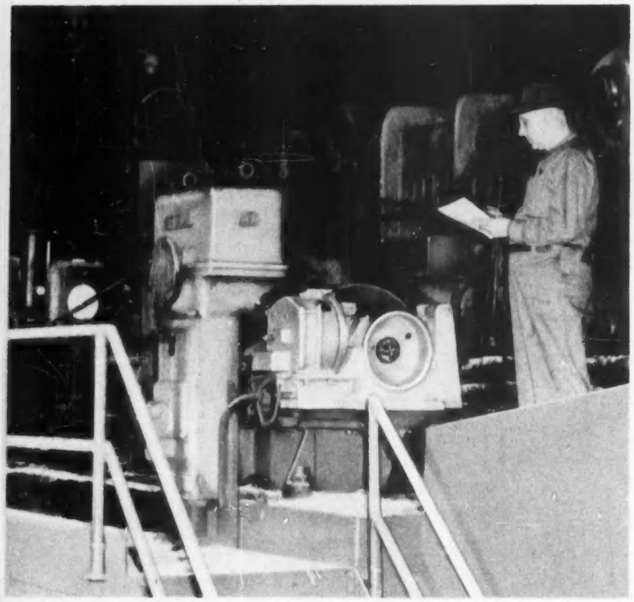
ONE ADJUSTMENT FOR BRAKE LINING WEAR CUTS MAINTENANCE TIME

USING AISE DIMENSIONS, General Electric's new d-c brake is designed to simplify and speed brake maintenance. *One* easy adjustment compensates for lining wear on *both* brake shoes. Even when there is unequal wear on the linings, a self-centering fulcrum automatically compensates both shoes when you make the single adjustment.

Power connection, torque setting and shoe adjustment are all made at one end of the brake with only a wrench. No need to keep both ends clear for servicing—permits mounting in comparatively inaccessible locations.

Save time, too, in replacing worn linings. Simply remove two bolts, slide the old lining out. You can remove coils without the necessity of disassembling the entire magnet structure.

FOR MORE INFORMATION, write for the new descriptive bulletin, GEA-6214, or contact your nearest G-E Apparatus representative. Section 780-6, General Electric Company, Schenectady 5, N. Y.



FIELD-TESTED—Assistant Maintenance Foreman at Jones & Laughlin Steel Corp. makes check on new brake during on-the-job tests. Brake was also thoroughly lab-tested by G.E.

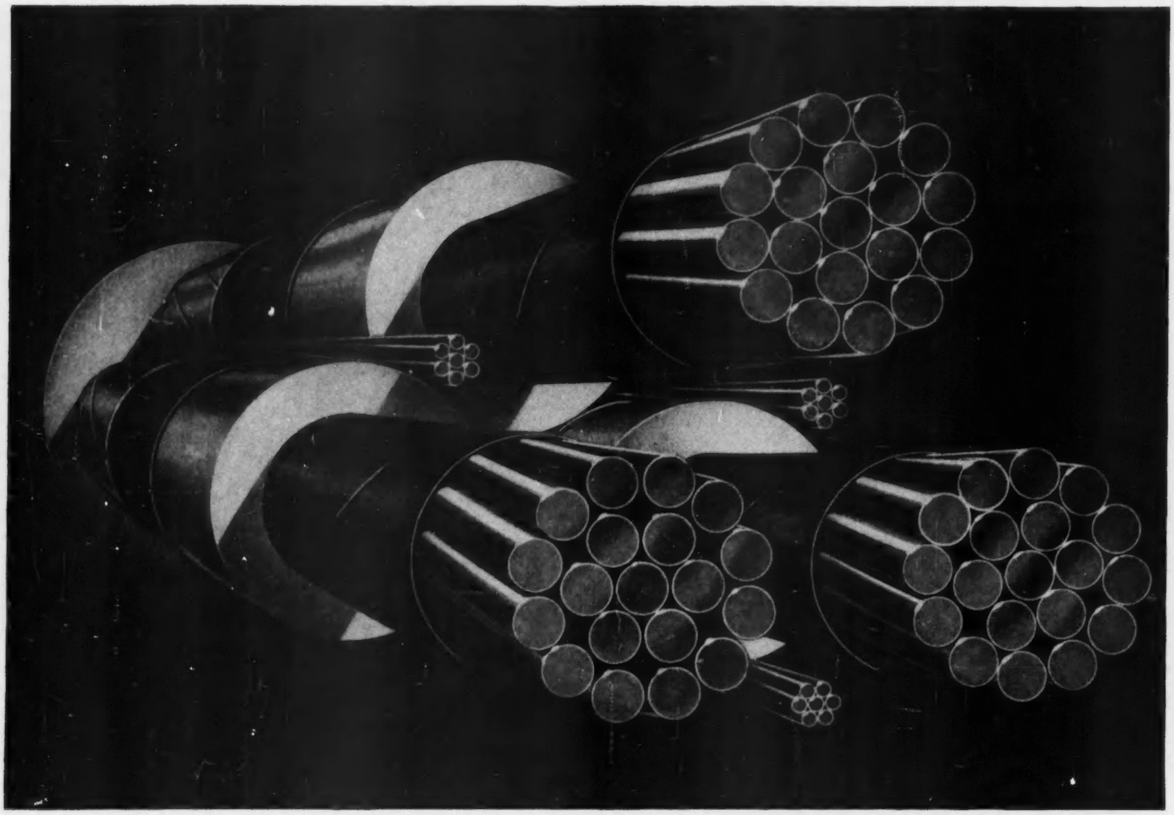
ARMATURE GAP INDICATOR—this easily visible indicator shows when to make adjustment for lining wear.

MANUAL RELEASE—this convenient mechanism provides a positive method of manually releasing the brake.

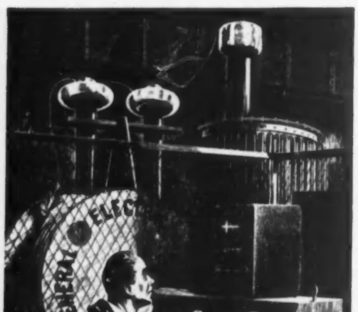
STRONGBOX MAGNET COIL—seals out dust, moisture, oil. Windings protected from mechanical damage.

TERMINAL STUD CONNECTIONS—speeds wiring—protects magnet leads from strain. Easily accessible.

SINGLE-POINT ADJUSTMENT — one simple adjustment for lining wear speeds maintenance. Only a wrench is needed to adjust magnet gap. Equal shoe clearance is obtained automatically. No trial-and-error adjustment—brake is designed to be self-centering.



What goes into G-E Super Coronol Cable?



IONIZATION TEST. Research, development engineering, and testing are among the most important ingredients that go into G-E Super Coronol cable.

What makes Super Coronol* cable resist heat? What makes it resist acids, ozone, and most other destructive factors that shorten cable life? What makes it possible to increase the rating of the cable to 85 C copper temperature, up to 15,000 volts, the highest rating ever announced for a high-voltage rubber-type cable? In short, what makes it a superior high-voltage power cable for transmission, for aerial or underground distribution systems, and for station, apparatus, and mine power circuits?

The right materials are part of the answer, of course, but even more basic are the research, development engineering, and testing that G.E. devotes to all phases of cable construction. Super Coronol cable has been tested in man-made tropical and arctic temperatures and violent electrical storms—to give you a cable that will withstand the ravages of pole-top weather. It has been subjected to a century of test-life in a few years by means of an accelerated aging process—to give you a cable with an 85 C rating. It has been surge-tested, ionization-tested, abrasion-tested, and power-factor tested—to give you a cable that stays in service and minimizes power losses.

When you specify G-E Super Coronol cable, or any G-E cable, you can be sure the product will be the best cable that the research, knowledge, and equipment of the entire General Electric Company can produce. Section W133-1137, Construction Materials Division, General Electric Company, Bridgeport 2, Connecticut.

*Registered Trade-mark General Electric Company

Progress Is Our Most Important Product

GENERAL ELECTRIC

MALFUNCTION OF ELECTRONIC GEAR NO LONGER HAMPERS SCHEDULED FLIGHTS SINCE AIRLINES AND INDUSTRY TEAMED UP TO PRODUCE . . .

Reliable Electron Tubes

By ROBERT E. MOE

Sometime ago it became apparent that the performance and reliability of electronic equipment in commercial airliners (photo) had to be improved. The problem centered around the electron tube itself.

As far back as 1948, Aeronautical Radio, Inc., a nonprofit agency organized by the airlines to study the problem, decided to do something about it. They realized that to maintain electronic equipment employed for navigation, communication, and instrumentation on the same basis as calling in a serviceman to replace a defective tube would be impossible—especially if the aircraft were in flight.

Radical Concept

Before this time, electron tubes were regarded as cheap, expendable items that could be replaced like incandescent lamps when they wore out. But after a little calculation, Aeronautical Radio's engineers came up with this proposition: If the tubes could be made to withstand 1000 hours of severe operating conditions encountered in flight, the lowered maintenance costs would practically let them throw away an entire equipment and install a new system at the end of that period. Or, putting it another way, they could afford to pay 10 times as much initially for electron tubes if the latter remained relatively trouble-free between regular maintenance periods.

This startling new concept called for a real revolution in the thinking of both equipment designers and electron-tube manufacturers. In fact, this philosophy corresponded exactly with the requirements of military aviation. Their planes each carried several hundred electron tubes; the failure of any one of them could mean lives lost or the inability to carry out a mission.

Starting Point

Like any other curative process, the objectives of this ambitious program were preceded by a detailed diagnosis of the electron tube. It involved careful scrutiny and analysis of tubes returned as defective by the airlines in an effort to

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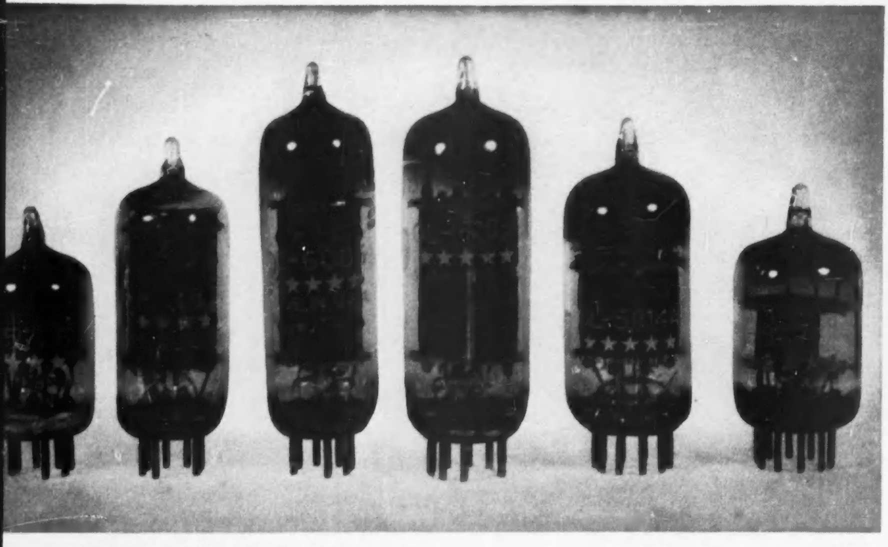
Mr. Moe, who has been with General Electric for 20 years, is Manager of Engineering in the Receiving Tube Sub-Department of the Electronics Division, Owensboro, Ky.



RUGGED FIVE-STAR TUBES, shown in actual size, have raised the life expectancy of airborne electronic equipment to remarkable proportions—50 to 1 in some instances.

locate the major cause of failure. The primary symptom, it developed, was one that you might expect—filament burnout. This was caused by 1) the fine tungsten wire used for the filament, 2) wide variation in the output voltage of aircraft generators, and 3) frequent off-on cycling of the equipment during "push-to-talk" operation.

Havoc played by in-flight vibration and shock with the weak, closely spaced tube elements also contributed to failure. High ambient temperatures in closely packed equipment also caused rapid deterioration of electrical characteristics. A third factor—cracks in glass—occurred as a result of both the mechanical and thermal stresses.

Thus it became obvious that there were two sides to the problem: electrical and mechanical. To alleviate some of the worst conditions contributing to it, Aeronautical Radio began work with equipment designers.

Line of Attack

General Electric's part in this work was to develop and manufacture electron tubes that would cope with difficult conditions of flight. And so, at our Receiving Tube headquarters at Owensboro, Ky., we began what would ultimately be called the "Five-Star" program of producing a new line of rugged and reliable electron tubes (photo).

To start with, we had to develop new electron-tube designs with a filament structure strong enough to withstand overvoltage and off-on cycling. Needed also were new, more rigid structures for electrodes and their supporting members so that they could resist continuous shock and vibration. Special attention had to be given the design and tolerances of the glass bulb and stem and the strain pattern of the glass after sealing and exhaust.

Production of these tubes meant special attention at every step of fabrication, processing, and assembly of their components. For example, we installed binocular microscopes (photo, top, opposite page) in factory production to examine individual parts, and subassemblies and optical comparators (photo, lower, opposite page) to check grids for dimensions and bent turns. Even a separate factory area was utilized with only the older, more experienced personnel employed in production. Piecework rates were replaced by slightly higher hourly pay scales, removing the incentive for personnel to slight any operations in order to increase the number of units produced. As a final step, we instituted new test limits and quality-control levels at much tighter values to assure that the product was receiving all possible care and attention in every stage.

Sudden Death

Another new concept in electron-tube manufacture was introduced—a 48-hour preaging, or stabilization, period at the factory. This we found particularly essential to reliability, especially in reducing the unpredictable type of inoperative, or "sudden-death," failures.

Briefly, the procedure involves aging all tubes for 48 hours under full-load conditions after their initial test. For it's during this time that most of the remaining weaknesses show up. Thus the small but annoying percentage of the tubes is eliminated that would surely cause trouble during the first few hours of equipment operation. Experience backed by many thousands of tube-hours of additional life-testing has shown us that, after this initial aging period, failures are reduced to a remarkably low level. Any remaining defects usually result from gradual deterioration that an adequate maintenance program can detect.

Proof of the effect of 48-hour aging is the increase of the tubes' survival rating. Expressed in percentage of total expected tube-hours of operation over a 500-hour period, the survival rating has been raised from 80 percent—the industry and military standard for Joint Army-Navy (JAN) specifications during World War II—to a present lot average of 97½ percent. Although the administration of this plan allows the survival rating of a single lot of tubes—represented by a standard life-test sample—to be as low as 95 percent, the average for all lots over one month must be 97½ percent or better.

The results of this co-operative program with commercial airlines have been remarkable. Life expectancy of electronic equipment in typical airline operation has improved at least 4 to 1, often 50 to 1. Maintenance costs have been so drastically lowered that even with the increased initial cost of these new tubes the airlines reported an annual saving of $250,000 the first year. And this figure doesn't include the reduction in down time with its consequent unavailability of aircraft for scheduled flights. If you were to ask any commercial airline pilot today, he would tell you that he no longer pays attention to his radio equipment; he never has any trouble with it.

Ordinary Radio or TV

Perhaps you wonder whether these new tubes can be used for ordinary radio or TV applications. Generally no, although many of the tubes are patterned after types used in popular radio or TV service.

Certain slight differences in some characteristics result from the redesigned physical structure. Additionally, the new tubes still cost three to four times those of the popular mass-produced tubes presently used in your home TV receiver. This situation exists despite the tremendous upswing in production and the many improvements in techniques formulated after an intensive study of all factors affecting tube reliability. The extra cost is, of course, a direct consequence of all our detailed efforts to make these tubes as reliable as humanly possible. This last phrase is used advisedly, because a large portion of the assembly is still done by human operators; consequently, there is a small but definite chance for variations and errors.

Removing the human variable from the equation will in all probability occur when tubes can be designed that are more susceptible to automatic manufacture.

Other Fields

What other uses are there for these tubes? Many applications are found wherever superior reliability is the primary consideration. For instance, the new tubes are used in police and mobile communications equipment, in digital computers that employ many thousands of tubes in each installation, and in guided missiles. They are also utilized for control functions in atomic-energy installations where any slip might mean disaster, as well as in semiautomatic unattended industrial-control applications.

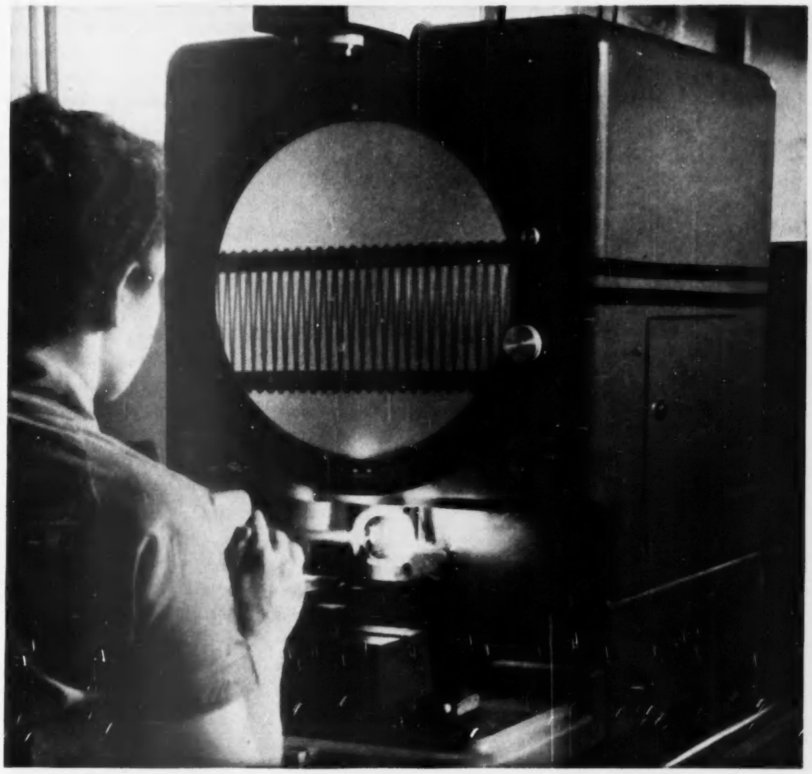
Another more far-reaching program has been going on in the military electronics field, again under the supervision of Aeronautical Radio, Inc., by special contract with the government. Here also results with the new tubes show quite a startling improvement over the old.

Not the End of the Road

Today nearly all the new types are on the "preferred list" used by designers of military electronic gear. This is by no means the end of the road, and we are constantly seeking to reduce the failures that do crop up despite our efforts. Still, it's evident that the investment in these new designs, plus their special production and testing techniques, have certainly been worthwhile.

The airlines, our original customers, now use only a relatively small number of the reliable tubes compared with the total number produced. We suspect that one possible reason is that many of the original tubes are still operating and have not needed to be replaced. Ω

BINOCULAR-MICROSCOPE TEST SHOWS UNUSUAL QUALITY STANDARDS OF MANUFACTURE.



OPTICAL COMPARATOR HELPS DETECT ANY DEVIATION FROM MANUFACTURING TOLERANCES.

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

By ARTHUR B. BRONWELL

Man's limits of knowledge have always been just beyond his reach. The ancient Greek philosophers, seeking systematic orderliness and unity in all things, knew this. Newton, Laplace, Faraday, Maxwell, and other illustrious philosophers and scientists of the 17th and 18th centuries realized above all else their inability to penetrate to the limits of knowledge. Their intellectual achievements, as well as those of more recent engineers and scientists such as Edison, Steinmetz, Einstein, and Armstrong, have opened doors to vast labyrinths of knowledge. Each new fundamental concept or basic discovery reveals further spheres of enlightenment. This ceaseless revelation of fundamental concepts, mathematical methods, and fresh viewpoints has resulted in a continuous evolution of engineering education and practice.

Experience repeatedly shows that new fundamental ideas, no matter how difficult they may appear in one generation, can be simplified and distilled for teaching. The hidden concepts embodied in Newton's calculus, Maxwell's electromagnetic theory, Steinmetz's alternating-current theory, and Einstein's relativity were understood by only a few mathematicians and physicists of that day. Significant new foundations in today's engineering practice, these principles are regarded as everyday subjects grasped readily by undergraduate engineering students.

Origin of ASEE

This spirit that great potentialities could be unfolded by the progress of knowledge pervaded the World's Columbian Exposition. On July 31, 1893, the World Congress of Engineers convened under the chairmanship of Octave Chanute, an engineer who became distinguished by his contributions in aviation. After the opening session, subdivisions representing various fields of engineering assembled. The papers presented concerned such themes as mathematics necessary for an engineer, tendencies in engineering education, shop and laboratory equipment, and graphical methods.

Five days later, Professor C. Frank Allen announced to the Congress the decision to found the Society for the Promotion of Engineering Education. This group was to exert a powerful and constructive influence in shaping the future of engineering education in an era of rapidly advancing science and technology, becoming the national forum for leading engineering educators and industrialists. Every conceivable phase of engineering education and its service to the engineering profession has been subjected to critical and constructive analysis through the medium of the Society's meetings, publications, and activities of its Councils, Divisions, Committees, Sections, and Branches. Out of this activity clearly defined concepts have emerged, stimulating a reformation that has given leadership in engineering education to this country.

At the turn of the century, engineering education was suffering growing pains, and obstreperous minorities were forming to revolt against the rigors of inflexibility and orthodoxism, eager to achieve professional distinction. This splitting had started long before the Exposition: first, civil engineers and mining engineers; then mechanical engineers; then the electricals. Around 1900, chemical engineers fought valiantly to form their own engineering curriculum. Beginning a quarter century ago more groups developed in rapid succession: electronics as a major branch of electrical engineering, metallurgy, theoretical mechanics, engineering physics, nuclear engineering, and geophysical engineering, plus many others. Despite educators' efforts to maintain unity in the engineering curricula, specializations and subsequent divisions evolved. Soon it became evident that the vigorous youthful fields unfolded new concepts and analytical methods that transformed traditional fields of knowledge. As a result, engineering education today no more resembles that during World War I than the modern Cadillac resembles the one-horse shay.

In 1896, Professor Mansfield Merriman of Lehigh University, speaking as President of the Society, laid down the keynote of what was destined to become the course of engineering education in the next 40 years. He emphasized that the aim of all education, engineering in particular, should make the student conscious of his mental power, applying it with scientific accuracy to secure economy of construction. He believed that fundamental principles were more important than the details of a trade, that exercises and designs should be so arranged that the student will think for himself rather than copy from the best engineers. And he further thought that the fundamental subjects should be given a wider scope, while languages and the humanities should be so taught as to furnish the broad, general culture needed by every educated man.

The Society proudly claimed 266 members at the turn of the century. There were 2667 total students enrolled in 89 colleges that offered engineering degrees. Today approximately 150 colleges present accredited curricula to 150,500 undergraduate engineering students. Society membership has grown to 7095 individual members (illustration, page 42).

During the golden era of inventions from 1890 to 1914, engineering educators looked to the future, demanding a program of education based on a thorough background of knowledge in physics, chemistry, and mathematics. Also, the Society sponsored a conference on scientific management and efficiency in college administration, inviting such eminent authorities in the management field as Gilbreth, Gantt, and Rautenstrauch.

Professor of electrical engineering at Northwestern University, Evanston, Ill., Mr. Bronwell has served as Secretary to ASEE for the past seven years.

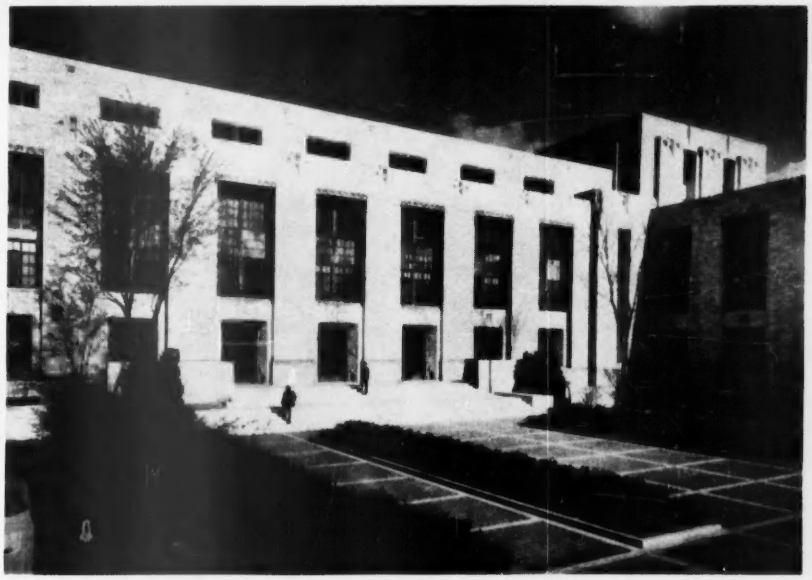
Study of Engineering Education

Initially patterned after half a dozen leading schools, engineering education was now expanding in all directions. A need for an extended investigation of its goals soon became evident. So, with a grant from the Carnegie Foundation for the Advancement of Teaching, the Society entrusted to Dr. Charles R. Mann the task of making a study of engineering education problems. The Mann Report descended on the colleges in 1918 when educators were preoccupied with both the requirements of war training programs and the disorders resulting from the influx of returning veterans. Meanwhile industry and the engineering profession were becoming increasingly critical about both the direction and progress of engineering education. They recognized a serious need for a more thorough study of the philosophy of engineering education and its responsibility to the engineering profession, industry, and the individual student's development.

So from 1923-29, a second and more comprehensive investigation was begun under the direction of Dr. W. E. Wickenden. The study was initially financed by the Carnegie Foundation for the Advancement of Teaching and subsequently by 26 foundations, engineering societies, corporations, and individuals. The report included a detailed and comprehensive analysis of engineering curricula and courses in engineering colleges throughout the country. It also reported on related matters: What kinds of companies employ engineers? how many advance into managerial positions? what do engineers do? what causes success and failure? what are the research responsibilities of engineering colleges? what are the supplementary activities of engineering colleges? what are the costs of engineering education? what is the current status of faculty salaries? and what are the qualifications of teachers? After completion of numerous studies in the United States, the investigators toured Europe to compare educational systems.

Among the many significant recommendations emerging from this study are the beginnings of emphasis on a balanced educational program instead of a purely technological education. The report states. . .

"The Board recognizes the need to develop, broaden, and enrich engineering education in view of the constantly enlarging responsibilities in society and the increasing exactions of professional practice. . . . It is desirable to give a more generous place to distinctly humanistic studies in the curriculum and to give these studies a form and content which will enrich the student's conception of engineering and its place in our social economy; that it is desirable to give the student a more connected and better grounding in engineering principles; that a greater effort should be made to develop the student's capacity for self-directed work; and that these ends should be gained wherever need be at the expense of unrelated studies on the one hand and of detailed technical training on the other."



TECHNOLOGICAL INSTITUTE AT NORTHWESTERN UNIVERSITY HOUSES SOCIETY'S OFFICES.

The report considered at length the advantages and disadvantages of the five-year program, as well as a pre-engineering program similar to the educational systems of the medical and legal professions. It strongly emphasized the need for increased concentration on the fundamentals of mathematics, physics, and chemistry.

Dr. Wickenden and Dr. H. P. Hammond in a collateral study on Technical Institutes urged the development of a technician level of education in this country to train foremen and subprofessional men for industry. Out of this recommendation grew the technical institute movement, which is rapidly spreading over the country's industrialized states and supplying a vital missing element in technological education.

Titled the "Report of the Investigation of Engineering Education," this over-all study dealt in the innumerable facets of engineering education and served to light the pathway of progress for the next 20 years. It gave direction, unity, and purpose to previously existing confusion that came with expansion.

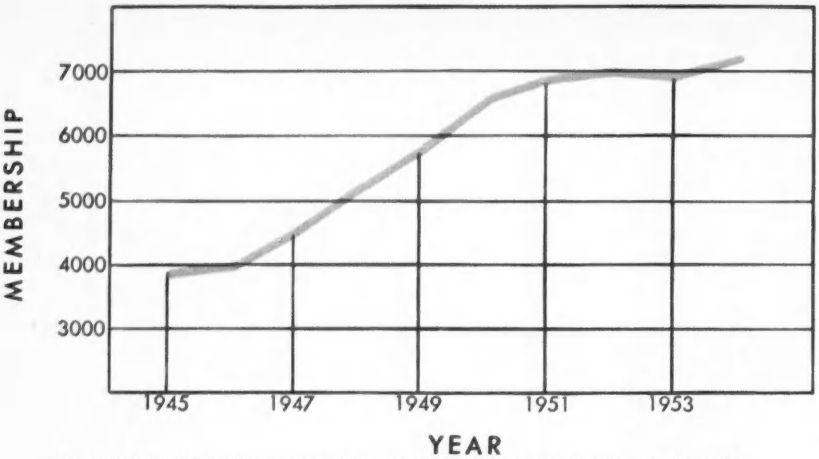
Subsequent Studies

In 1940 and again in 1944 the Society undertook two subsequent studies titled "Report on Aims and Scope of Engineering Curricula" and "Report of the Committee on Engineering Education after the War." These two brief studies clarified the goals of engineering education and the humanistic-social portion of the engineering curricula (Table, page 43).

Reorganization

In 1946 the Society was reorganized under the name of the American Society for Engineering Education (ASEE). Formed in the reorganization were two subsidiary organizations—The Engineering College Research Council (ECRC) and The Engineering College Administrative Council (ECAC). The first has studied numerous policy matters relating to the organization and administration of research, including the relationships between industry, colleges, and government. Published every other year, its Directory of Current Research lists all research in progress in engineering colleges throughout the country.

The ECAC has provided a forum for the discussion of the innumerable administrative problems of engineering colleges. These involve the relationships



ENGINEERING EDUCATORS AND INDUSTRIALISTS COMPRISE ASEE'S MEMBERSHIP.

between colleges and government, the improvement of secondary-school education, the supply and demand of engineers, and scholarship and fellowship programs. Once each year at a closed meeting of this Council, the deans discuss the most perplexing problems of college administration.

Evaluation of Engineering Education

In May, 1952, President S. C. Hollister proposed that a new study of engineering education be undertaken to "determine the pattern or patterns that engineering education should take to keep pace with the rapid developments in science and technology, and to educate men who will be competent to serve the needs of and provide leadership for the engineering profession over the next quarter century." A group of eminent engineering educators—the Committee on Evaluation of Engineering Education—discussed this problem from every conceivable angle in a two-day meeting at Dartmouth College, at which time Dean L. E. Grinter was appointed chairman. This study was financed by contributions from the Engineering Foundation, the constituent engineering societies of Engineers' Council for Professional Development (ECPD), and the General Electric Company. At the outset it became clear that the study could not hope to achieve its desired goals unless the country's engineering educators actively participated. For the failure to provide adequate means of implementing the recommendations of previous reports stood out as a glaring deficiency that somehow must be remedied. By sharing a vigorous forward-looking exchange of ideas, the educators could carry inspiration and stimulation back to their campuses. Accordingly, all engineering colleges in the country were invited to participate in this project by appointing their own investigating committees. Their reports were carefully reviewed by the Society's central committee.

The Committee's report stresses the importance of the selection and development of the engineering faculty. It states that the quality of teaching and the professional competence of the teacher are the most important aspects of engineering education. Enlarging on this theme, the report includes specific recommendations regarding the qualifications and evaluation of teachers and the methods of training teachers to develop professional competence, judgment, and teaching ability. Further, it suggests how engineering colleges can achieve an environment that encourages intellectual growth and student motivation.

In dealing with curricular content, the report states: "This translation of new scientific developments into engineering practice will be facilitated by emphasizing unity in scientific subject matter. For example, there is a great deal of similarity both in conceptional understanding and in analytical methods among the generalizations of heat flow, mechanics of fluids, electromagnetic fields, and vibration theory. When a student understands these generalizations, he has gained a concept of systematic orderliness of many fields of science and engineering that enables him to approach the solution of problems in widely diverse fields using the same analytical methods."

The report discusses at considerable length the curricular goals and the emphasis to be placed on the underlying mathematics, physics, chemistry, and the engineering sciences to keep engineering education abreast of the needs of the profession. In particular, it focuses attention on the broad field of solid-state physics that embodies the scientific foundations underlying the electrical, magnetic, thermal, mechanical, and metallurgical behavior of materials. It also emphasizes the fundamental importance of nuclear physics and the engineering potentialities that will develop out of these new concepts.

Stressed also is the importance of teaching the *science* rather than the *practice* of engineering, because the science embodies unchanging fundamental concepts, whereas the practice of engineering is subject to rapid obsolescence.

Recently the ASEE received a grant of $30,000 from the Carnegie Corporation to conduct a comprehensive study of the humanities and social sciences in the engineering curricula. The need to strengthen this area has been recognized; however, few schools have attempted fresh and imaginative approaches. Therefore, it seems timely to analyze those programs that show the greatest promise of stimulating the student's interest and imagination and of developing his competence. This area of education provides cultural breadth, giving the student the essential counterbalance that improves his chances of attaining a managerial position.

Other Activities

Because of its growing importance, graduate study will be brought into sharp focus in a comprehensive investigation during the next two years. The study on evaluation of engineering education, the humanistic-social study, and graduate study will comprise a thorough-going investigation into all of the essential phases of engineering education.

The slow evolutionary process of getting new concepts into the engineering curricula often distresses the scientist and the engineer—impatient with the seemingly endless delay in bringing engineering education abreast of the frontiers of knowledge. But fundamental concepts never make themselves known in sharply delineated form. The educator assimilates new concepts into his pattern of teaching so that the student will see a unity and a logical orderliness in the whole. Not an easy process, it may involve a substan-

GOALS OF TECHNICAL STUDIES . . .

Mastery of the fundamental scientific principles and a command of basic knowledge underlying the branch of engineering that the student is pursuing by . . .

> Grasping the meaning, evolution, and limitations of physical and mathematical laws.
>
> Knowing materials, machines, and structures.

Thorough understanding of the engineering method, and elementary competence in its application by . . .

> Comprehending the interacting elements in situations that are to be analyzed.
>
> Thinking straight in applying fundamental principles to new problems.
>
> Developing a foundation for engineering judgment.
>
> Being resourceful and using originality in devising means to an end.
>
> Understanding the element of cost in engineering and the ability to deal with this factor just as completely as with technological factors.

Ability to select the significant results of an engineering study and to present them clearly and concisely by verbal and graphic means.

Stimulation of a continuing interest in further professional development.

. . . AND HUMANISTIC-SOCIAL STUDIES

Understanding of the evolution of our social organization and the influence of science and engineering on its development.

Ability to recognize and make a critical analysis of a problem involving social and economic elements, read with discrimination and purpose, and arrive at an intelligent opinion.

Ability to organize thoughts logically and to express them lucidly and convincingly in oral and written English.

Acquaintance with some of the great masterpieces of literature and understanding of their influence on civilization.

Development of moral, ethical, and social concepts essential to a satisfying personal philosophy, to a career consistent with the public welfare, and to a sound professional attitude.

Attainment of an interest and pleasure in these pursuits and thus of an inspiration to continued study.

tial amount of trial and error. Currently experimenting with ways of accelerating this evolutionary process, the Society is conducting summer institutes in specific areas that show substantial promise of improvement. Leading educators and research scientists combine their knowledge of the principle problems of education to clarify the fundamentals and develop logical, orderly patterns of teaching. The two summer institutes held this year—one in solid-state physics and the other in nuclear science—affirm the effectiveness of this new technique. To achieve widespread distribution of the ideas, conference papers will be published; it is hoped that some of the young and energetic teachers attending the conference will be inspired to write textbooks.

ASEE-sponsored summer schools have raised the educational sights and increased the professional competence of engineering teachers. In the early days, the Society sponsored one summer school each year; last year it sponsored six, with about 450 teachers attending.

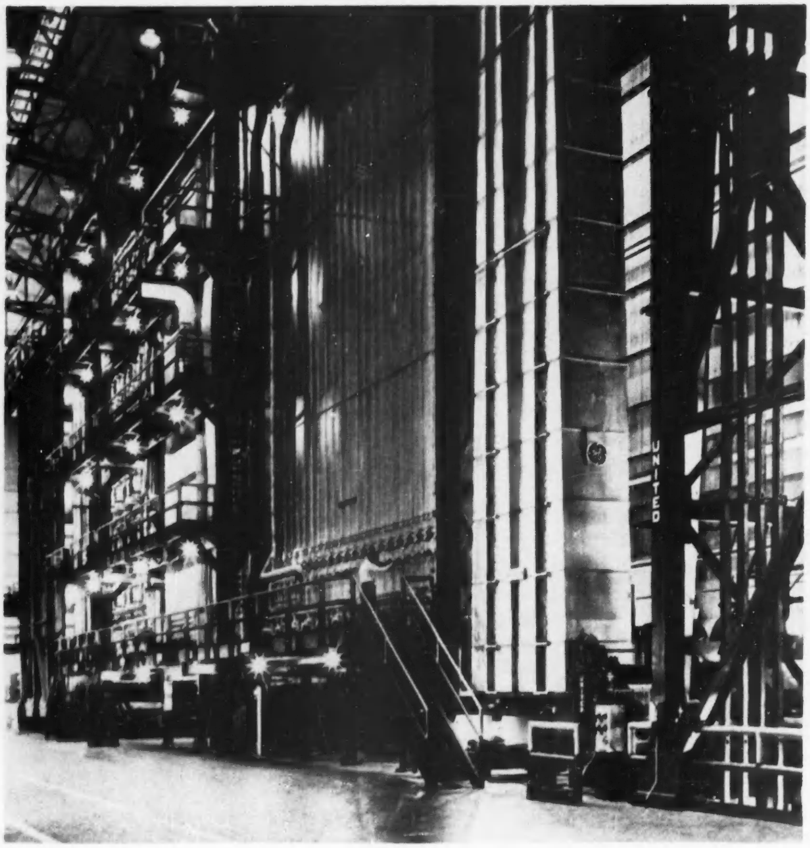
Together with about 1000 faculty members in colleges throughout the country, the Society two years ago completed an intensive investigation titled "Improvement of Teaching." More than 10,000 copies of this report have been supplied to engineering colleges for distribution to faculty members.

Another venture destined to be an ASEE milestone is the development of a vigorous Young Engineering Teachers movement (YET). Springing up in engineering colleges and in the sections of the Society throughout the country, this popular new development will help young faculty members broaden and enrich their outlook on engineering education. And it will bring to the Society more of that element of vigorous unorthodox thinking that is characteristic of young people and so vital to progress.

Drawing general conclusions as to the contributions of a Society such as ASEE is difficult. Although the major projects are always the focal point of attention, they constitute only a small portion of its total contribution to engineering education. Probably the Society's greatest contribution has been its functioning as a national forum, bringing together the viewpoints and efforts of leading educators to define the major issues and achieve a logical, orderly solution to engineering education problems. ASEE has been a tribute to the ideal that visionary educators can guide and direct the course of engineering education, and thereby influence the progress of engineering in its service to mankind. Ω

Modernizing with Protective Atmospheres

By A. G. HOTCHKISS and H. M. WEBBER



SIZE of protective-atmosphere furnaces seems to be unlimited, as indicated by this tower-type furnace that can bright-anneal steel tin-plate strip at the rate of 30 tons per hour.

New life came to a manufacturer of stamped nameplates, refrigerator hardware, and emblems after he installed a bright-annealing furnace with protective atmosphere. Prior to this he had to anneal the parts between stamping operations, causing the surfaces to oxidize so badly that acid pickling was necessary to remove the scale before restriking them. This wasted metal—and pickling was a messy and costly process. Now the atmosphere gas in the heating and cooling chambers protects the parts and thereby eliminates the oxidation and resultant scale. Pickling became unnecessary, metal was saved, and costs were reduced.

In another instance an electric-refrigerator manufacturer needed to fabricate various subassemblies such as evaporators, fin condensers, mufflers, and floats. Ordinary brazing and welding operations oxidized the parts and sometimes left flux deposits, again requiring pickling and subsequent rinsing. It was impossible to know when all loose particles had been removed that might otherwise clog strainers or cause wear and noise in mechanisms; also, inadequate rinsing could result in corrosion. The hazards and cost of pickling are avoided by furnace brazing the steel parts with copper in protective atmospheres, providing clean, dry surfaces inside and outside the assemblies. This way, numerous joints can be brazed simultaneously in each assembly, greatly improving the uniformity of quality, minimizing rework, and further reducing costs.

These typical uses of protective atmospheres have been followed by thousands of others—not only for bright annealing and brazing but also for various other heat-treating and general industrial processes. A few furnace-heating processes, such as porcelain enameling, require oxidizing, or air, atmospheres: also, air atmospheres are adequate for certain metals, such as aluminum in some forms, for which protective atmospheres offer no advantages. However, by doing jobs more efficiently, numerous operations have been modernized. Then too, basic manufacturing procedures have sometimes been completely renovated by instituting new processes made possible only by using protective atmospheres.

You may ask: What is a protective atmosphere? what are its functions? what gases are used? what processes are the atmospheres suitable for? what metals do they apply to? what are their advantages?

Protective Atmosphere—What Is It?

A protective atmosphere is a gas or mixture of gases, supplied from an external source, that blankets the work being treated. In furnace applications it fills the heating chamber, and the cooling chamber if there is one. Electric heating units inside the furnace are commonly blanketed, too, and they radiate their heat directly to the work; but sometimes the work and atmosphere are within a retort, surrounded by the furnace and its heating units. In gas-heated furnaces the protective atmosphere surrounding the work is usually separated from the heat source by means of a retort with the flames outside or by radiant tubes in which the combustion takes place.

A protective atmosphere prevents,

TYPICAL PROTECTIVE ATMOSPHERES AND THEIR APPLICATIONS

Applications	Materials and Processing	Temperatures (Degrees F)	Typical Protective Atmospheres
Bright annealing	Low-carbon steels	1200–1350	Rich exothermic gas
	High-carbon steels	1200–1450	Purified exothermic gas
	Stainless steels	1800–2100	Dissociated ammonia
	Copper	500–1200	Lean exothermic gas
	Silicon iron	1450–2000	Hydrogen
Bright hardening	High-carbon or carburized steels	1400–1750	Endothermic or purified exothermic gas
Copper brazing	Low-carbon steels	2050	Rich exothermic gas
	High-carbon steels	2050	Endothermic or purified exothermic gas
	Stainless steels	2050	Dissociated ammonia
Silver-alloy brazing	Copper or brass	1300–1600	Lean exothermic gas
Sintering	High-carbon ferrous metals	1800–2100	Endothermic or purified exothermic gas
	Copper-tin-graphite mixtures	1400–1600	Rich exothermic gas
Oxide prevention in storage and cooking Fire and explosion prevention	Paints and varnishes Synthetic resins		Lean exothermic gas

minimizes, or controls changes on work surfaces being treated. This eliminates or minimizes oxides or prevents loss of carbon, called *decarburization*, on surfaces of steel parts. The parts will have hard wear-resisting surfaces when heat-treated and will have maximum physical properties if decarburization is prevented.

Sometimes oxides on metals are reduced deliberately in protective atmospheres. Depending on the reaction desired, constituents such as carbon or nitrogen are added to the surfaces of steel parts by carburizing, carbon restoration, nitriding, or carbonitriding in protective atmospheres.

What Gases Are Used?

Numerous gases or gas mixtures are used for protective atmospheres. Of the individual gases, hydrogen and nitrogen are the most common and are ordinarily purchased in steel bottles. Mixed gases, less costly and more commonly utilized, are prepared where used.

Dissociated ammonia is made by cracking anhydrous ammonia vapor under heat into its constituents, hydrogen and nitrogen. Exothermic gas is produced by burning with air a hydrocarbon fuel gas, such as coke-oven, natural, propane, or butane gas. The resulting mixture contains mostly nitrogen, but it is also rich or lean in hydrogen and contains carbon monoxide, carbon dioxide, and water vapor. The amount of each, except the water vapor, depends on the proportions of input air and fuel gas. To avoid decarburization, the mixture is purified of carbon dioxide and water vapor.

Endothermic gas—a similar mixture but of a more active nature—is formed by reacting hydrocarbon fuel gas mixed with a small amount of air over a catalyst that is maintained at high temperature by a separate heat source.

Some of the common uses of protective atmospheres in an endless and constantly expanding list are itemized in the Table. Although surfaces are sometimes slightly discolored during these treatments, they are clean and scale-free, and in many applications their brightness is retained. Certain atmospheres prevent surface decarburization.

Typical atmosphere gases used are also listed in the Table, but suitable alternatives are usually available.

Materials treated in protective atmospheres (Table) are in wide variety: an assortment of carbon and alloy steels, nonferrous metals, paints and varnishes, and others.

What Are Their Advantages?

Advantages of using protective atmospheres depend on various circumstances. Some offer lower cost, better quality, reduced number of operations, and shorter manufacturing cycles. Pickling, grinding, machining, or sand blasting for removal of scale or decarburized surface skins are often eliminated or minimized. Further, new fabricating methods utilizing protective atmospheres can be adapted to advantage. For example, parts machined from castings, forgings, and bar stock are redesigned and fabricated by using inexpensive stampings, screw-machine parts, pieces of tubing, or pressed metal powders, bonding them by furnace brazing or sintering operations.

Bright Annealing—Bright stamped parts such as nameplates are commonly treated in a mesh-belt conveyor-type furnace (photo, top, next page) with heating and cooling chambers attached and with protective atmosphere maintained throughout. Parts are laid on the wire-mesh belt and carried through the furnace automatically and continuously. Similarly arranged are roller-hearth conveyor-type furnaces for high-scale production, such as annealing steel cartridge cases. This furnace is often equipped with return conveyor and transfer tables for complete automatic handling and return of trays (photo, center, next page). Box-type furnaces are universally employed for manually pushing tray loads of work through heating and cooling chambers in small-scale production. Protective atmospheres are used in other batch-type furnaces also, such as the bell-, elevator-, and pit-type furnaces; the selection depends on the nature of the product, the best method

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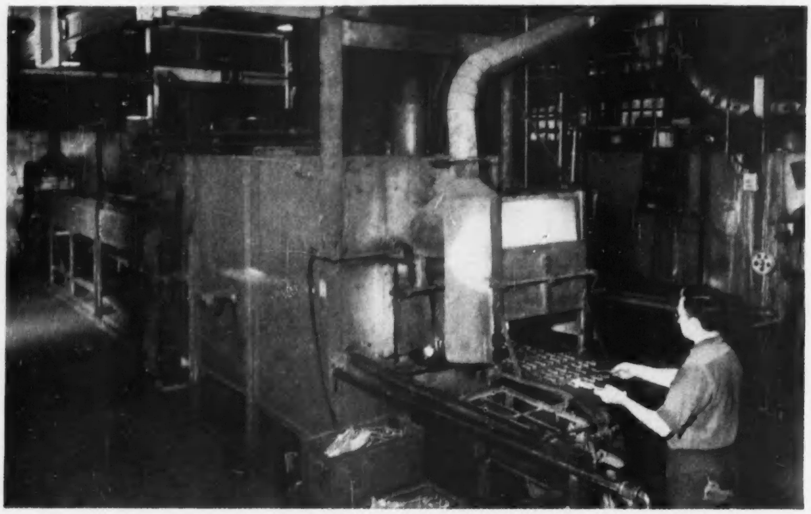
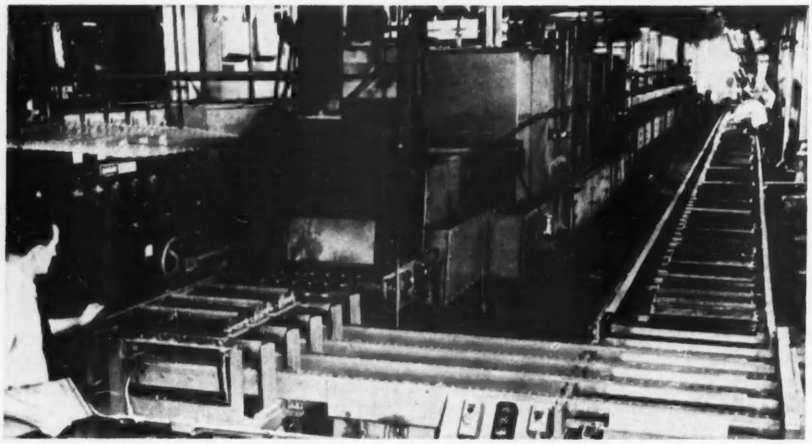
Both authors are with GE's Industrial Heating Department, Schenectady. Mr. Webber, application engineer, Marketing Section, joined the Company in 1926. Mr. Hotchkiss—Manager of Furnaces and Associated Equipment Engineering—has been with GE for 28 years. They are co-authors of the book, Protective Atmospheres *(Wiley, 1953).*



MESH-BELT CONVEYOR FURNACE, with heating and cooling chambers attached and protective atmosphere maintained throughout, treats bright stamped parts such as nameplates.



ROLLER-HEARTH CONVEYOR FURNACE for high-scale production, such as annealing steel cartridge cases, is equipped with return conveyor and transfer tables for automatic handling.

ROTARY-HEARTH FURNACE gives continuous heating of parts and offers such advantages as uniform hardness, freedom from scaling and decarburization, minimum labor, and low cost.

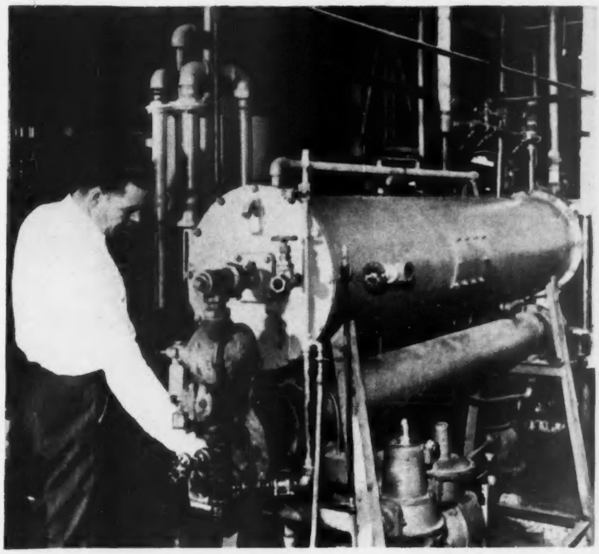
of handling it, and the treatment required.

There seems to be no limit to the size of protective-atmosphere furnaces, as indicated by a huge tower-type furnace for bright-annealing steel tin-plate strip (photo, page 44). This furnace can anneal 30 tons per hour of strip averaging 0.010 inch thick by 30 inches wide at a speed of 1000 fpm. The protective atmosphere is purified, fairly lean exothermic gas. It gives better surface qualities on the strip than previously obtained with refrigerated rich exothermic gas in batch furnaces. Having low concentrations of flammable constituents, this gas is also relatively inert from the safety standpoint. Slight stretching of the strip in the heating chamber improves the flatness, and the continuous method improves the uniformity of annealing—an advantage in making all kinds of cans.

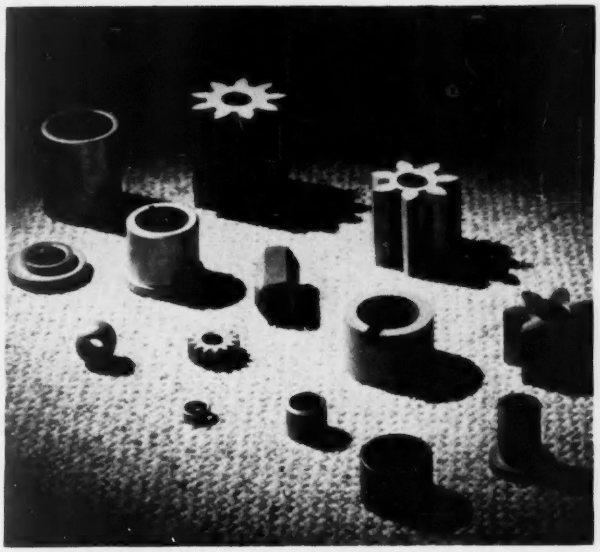
HARDENING—Heat-treating operations on medium- and high-carbon steels of the straight-carbon or alloy types require protective atmospheres best suited for the job. Atmospheres are generally selected that will neither oxidize nor decarburize, such as purified exothermic gas or endothermic gas (Table). Box-type furnaces are utilized for tools and dies or small lots of gears, but continuous furnaces are employed for higher production parts. Roller-hearth type furnaces are utilized for automatically heat-treating miscellaneous machined parts, such as splined shafts and pinions; plate-belt conveyor-type furnaces are employed for such work as stamped springs and levers, alloy-steel cap screws, and miscellaneous gears and pinions.

The rotary-hearth-type furnace, (photo, lower) provides continuous heating of parts; here the cutlery is manually charged and discharged, then quenched in oil. Because decarburization cannot be tolerated, the parts are treated in a nondecarburizing protective atmosphere of purified, rich exothermic gas. Advantages of heat-treating the blades in a rotary-hearth furnace include: uniform hardness due to the good control of temperature; freedom from scaling and decarburization, eliminating excessive grinding and polishing; minimum labor because one operator charges and discharges the work by hand with the rotating hearth; and low over-all cost.

FURNACE BRAZING—Small quantities of subassemblies are commonly furnace brazed in box- or mesh-belt conveyor-type furnaces. Large quantities, as for refrigerator and automotive production



EXOTHERMIC-GAS PRODUCER—the most common atmosphere-gas generator—burns inexpensive hydrocarbon fuel gases mixed with air.



SINTERED POWDER-METAL PARTS usually show cost savings of 50 or 60 percent over gears cut from castings or bar stock.

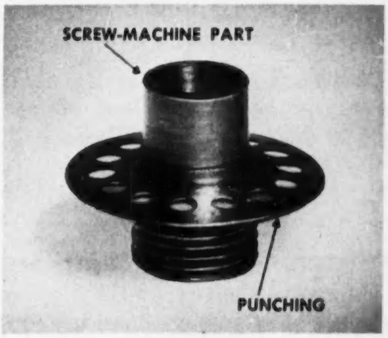
are brazed in roller-hearth conveyor furnaces. The cost of the steel breather assembly for fuel injection pumps (photo, lower, right) was reduced 70 percent by converting the manufacturing method to furnace brazing in rich exothermic protective atmospheres. Originally machined from bar stock involving considerable waste of material and expensive machining operations, the assembly is now made from an inexpensive punching and a screw-machine part and is copper brazed.

The bright brazing of stainless steels and other high-chromium alloys in highly purified protective atmospheres is another successful production method. A typical example is an assembly consisting of a machined block having numerous annular ducts and radial holes. Prior to assembly, tiny holes are drilled in the annular rings that cover the ducts. These rings must be bonded tightly and strongly to the body of the assembly, keeping duct interiors completely free from any particles of oxides or flux that might plug the holes if loosened. And with so many joints to be brazed in one assembly plus this cleanliness requirement, bright furnace brazing obviously is the right way to do the job. Accordingly, the product was developed to be made by this method with highly successful results. In a protective atmosphere of pure dry hydrogen or dissociated ammonia the assembly is brazed in a metal retort in a bell-type furnace. Copper is the brazing metal used.

SINTERING—In powder metallurgy, metal parts are formed from fine metal powders that are compressed in dies between punches under great pressure. The briquettes thus formed are passed through protective atmosphere furnaces, sometimes at temperatures below the melting point of any of the constituents and other times higher than the melting point of one of them. The particles grow together by surface diffusion. The resulting parts are strong and frequently have various advantages over similar parts machined from forgings, castings, or bar stock.

Sintered powder-metal parts such as gears (photo, top, right) usually show cost savings in the order of 50 or 60 percent over gears cut from castings or bar stock. Superior gears are produced because the teeth are more accurately shaped and have better finish. Greater efficiency and quietness of operation are common advantages. Sintered gears are used for electric appliances—wringer-type washers, automatic washers, and fans—and for automotive pumps. Bearings, cams, and lock parts also are often made by powder metallurgy, with accurate dimensions and close tolerances at low cost, usually without any machining operations. Such parts sometimes have an added advantage: many of them have 20 to 30 percent porosity and can be dipped in lubricating oils after sintering to make them self-lubricating in service.

The exothermic-gas producer—the most common atmosphere-gas generator

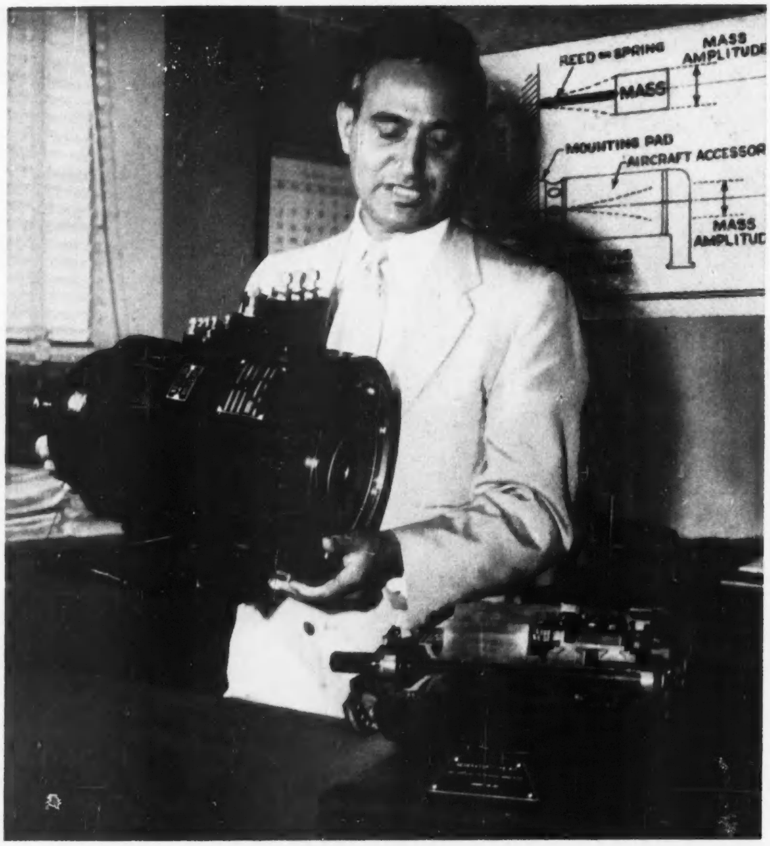


CONTROLLED ATMOSPHERE allows use of cheaper material in breather assembly.

—burns hydrocarbon fuel gases mixed with air (photo, left). The output gaseous mixture can be varied; one type is flammable and is reducing to iron and copper at elevated temperatures, whereas another type is nonflammable. These gases are quite inexpensive—one reason why they are so widely used.

In Summation

At the turn of the century, protective atmospheres were used on a small scale. Only within the last 25 years has most of the progress in their commercial utilization been made. Protective atmospheres contribute definite benefits to many products and processes, both in the mills and in the fabricating plants. Consequently, to capitalize on these advantages a substantial portion of the furnaces built today are equipped with protective atmospheres. Ω



"A-c machines are extremely light. We can get 40 kw out of one model that weighs only 80 pounds."

Aircraft-Generator Engineer Kalikow Says . . .

Nothing Is Really Ever Finally Solved

Shortly before America's entry into World War II, military planes were equipped with d-c generators having at most a power output of 600 watts. Faced with this intolerable situation, the U.S. Navy called on the electrical industry for help. The result was the first true aircraft generator ever built. It had a power output of 5000 watts, within approximately the same weight limits as the old machines. Astonished as the Navy was, this marked only the beginning. For through unceasing development, a-c aircraft generators are produced today that weigh only 80 pounds and have power outputs of 40,000 watts.

For the story of this remarkable engineering feat, we called on Irving Kalikow, Manager, Aircraft Generator Engineering Subsection of GE's Synchronous and Specialty Motor and Generator Department, River Works, West Lynn, Mass. A frequent contributor to popular magazines as well as the technical and trade publications, Kalikow has been described as an engineer who is without doubt the most qualified person in the industry to speak on the subject of aircraft generators.

We found that to Irving Kalikow engineering is a mixture of romance and adventure. Speaking of the hectic days when the electrical industry was suddenly caught up in the war effort, he comments, "We knew practically nothing about the aircraft business, and most of the problems were new combinations of electrical, mechanical, and environmental difficulties. But under the stress of urgency, we learned fast." And of the era of supersonic flight—where the air blast that cools a generator is hot enough to boil water—Kalikow says enthusiastically, "Maybe the best is yet to come."

—Editors

REVIEW: Mr. Kalikow, we understand that there are quite a few unusual engineering problems associated with aircraft generators. Would you describe a few for us?

KALIKOW: Well, aircraft generators are vastly different from industrial motors and generators—although their problems differ mostly in degree. That is, they have many of the same design and application troubles, only more so.

REVIEW: What is the underlying problem, Mr. Kalikow?

KALIKOW: As in all aircraft equipment, the prime consideration is to get the most output—with reliability, of course—for the least weight and space. These size and weight restrictions, coupled with really tough environmental and operating conditions, call for design solutions quite radical compared with conventional equipment.

REVIEW: Isn't aircraft-generator engineering a relatively new art?

KALIKOW: Relatively, yes. It all began back in 1940 or so, shortly before the start of World War II, when the Navy aroused our interest. They wanted more power for their new aircraft. All they had then was a 12-volt generator putting out some 40 amp and weighing about 40 pounds. It had an output of 600 watts.

REVIEW: That isn't much power by today's standards.

KALIKOW: About enough to run your electric sandwich grill. Anyhow, we turned the problem over to our chief consulting engineer, S. R. Bergman—a protege of Steinmetz. Bergman learned a lot from him. He was nearly always successful in thinking up new and screwy designs—that worked. But this time he really came up with something that astonished the Navy. His machine, the first true aircraft generator ever built, put out 30 volts and 170 amp—5000 watts! It weighed only 45 pounds. The Navy was so impressed that they immediately gave us several more contracts to build other types of aircraft generators.

REVIEW: That's quite an increase, from 600 to 5000 watts within the same weight limit. What was the trick?

KALIKOW: Bergman employed three new fundamentals that we still use today to reduce weight—higher voltages, speeds,

"The first generators were equipped with magnesium mounting flanges—for lightest weight—and they held together all of 10 minutes."

and temperatures for all components. He was the first to use glass-insulated wire coverings and glass insulation throughout the machine. One of the amusing stories I remember about Bergman is how he got hold of the glass insulation. He took glass fibers—that's all they had to work with in those days—to a shoelace manufacturer who wove the fibers into laces. Then he cut them up and wrapped each wire.

REVIEW: Did he use gear step-ups to get higher speed for his generator?

KALIKOW: At first he did, but his idea of higher speed posed a problem. The aircraft engine only put out about 2000 rpm at the mounting pad—the flange that mounted the generator to the engine—and Bergman wanted 6000 rpm. After a terrific struggle with the engine builders, this high speed was agreed on, and it eventually became the standard for the aircraft industry. Incidentally, the 30 volts of his first machine also became the d-c standard, and to this day it is unchanged. This is a remarkable tribute to Bergman's genius. He built better than he knew—for shortly after, in late 1944, he died.

REVIEW: That would be well into World War II.

KALIKOW: Yes. Those were hectic days. We went all out to design and build electric-generator equipment for our bombers and fighters. Using the Bergman designs as a starting point, we turned out in rapid succession—200-, 300-, and 350-amp d-c generators, and a combination 200-amp d-c, 1.2-kv a-c generator. Because these were basically new designs, the Air Force and Navy wrote their specifications around them. As a result, our generators were picked for large-scale production throughout the war effort.

REVIEW: Was General Electric the sole builder of these machines?

KALIKOW: No. We licensed Ford and Autolite to produce our 200-amp low-speed-range and 200-amp wide-speed-range generators for the B24 *Liberator* and B17 *Flying Fortress* bombers.

REVIEW: Mr. Kalikow, can you tell us of some of the operational problems you encountered in developing these generators?

KALIKOW: All right, let's just take the simple problem of the mounting flange. The generators are mounted directly on the rear accessory case of the aircraft engine by means of three-eighth-inch studs. Well, the first generators were equipped with magnesium flanges—for lightest weight—and they held together for all of 10 minutes. After the flight, we found the generator at the bottom of the engine nacelle, with its flange and shaft broken.

REVIEW: That must have been a sorry spectacle. Did you try another material? Or did you change the design?

KALIKOW: Both. We reasoned that the shock of take-off or starting caused the failure. So we changed the design to aluminum. And we made sure that the

"At about 25,000 feet, ordinary carbon brushes disintegrate or disappear in a cloud of dust. They don't just wear out, they dust out . . . ."

generator withstood the shock of a five-ton hammer blow before we installed it on the aircraft engine. This time it lasted all of 20 minutes.

With this second failure, we stopped theorizing and really got down to business. We sent down a team of vibration experts, and they came back with the facts. The answer was reasonably simple—we were tuned in to one of the vibration frequencies of the reciprocating engine. The generator at its natural frequency was vibrating like a reed or tuning fork, excited by one of the many components of the engine's vibration.

This engine vibration can really be terrific. You've experienced some of its effects when riding on airliners, I'm sure. You can actually feel the whole plane vibrating, especially at take-off when the engines are running at full power. Imagine what it must be, then, right on the aircraft engines where our generators are mounted. We've measured up to one-eighth-inch of actual displacement at vibrations of 200 cps at the generator's mounting face. And that corresponds to over 100 g's of accelerating force. Now if a peak of this vibration happens to coincide with the natural frequency of the generator mounted on the engine, why naturally, the flange will break off in short order.

REVIEW: Couldn't you de-tune the generator so that its natural frequency would not coincide with the engine vibration?

KALIKOW: That's just exactly what we did. We changed the generator's natural

"We are going through now what the electric utilities went through 50 years ago when they changed from direct to alternating current."

frequency by stiffening the flange mounting. We made the flange of forged steel, and after several experimental design changes, we eliminated the mounting flange as a source of trouble on reciprocating engines.

REVIEW: You say you ended the mounting flange as a source of trouble. That seems to imply other difficulties.

KALIKOW: We had, and still have, a formidable torsional vibration problem with these same reciprocating engines. You see, where so much engine power—1500 to 3500 hp—is generated by explosive means within the relatively small confines of an aircraft engine, the whole thing weaves, twists, and shudders under the impact of perhaps 28 man-sized pistons whirling around at up to 3000 rpm. Every second time around, each piston receives its power stroke. And primarily this uneven power impact causes the torsional vibration difficulties.

REVIEW: Will you explain that in a little more detail?

KALIKOW: You see, the generator driveshaft doesn't get rotated smoothly. In other words, its speed varies while it is turning, and that really causes a peck of trouble. Our very first generators had solid shafts. They proved to be disastrous. The punchings got shaken loose, the commutator broke away from the armature shaft, and finally the engine-engaging spline broke off entirely. In effect, all the torsional vibration coming from the main engine was transmitted—and magnified by the step-up gear—into the armature.

REVIEW: What kind of a shaft did you devise to overcome this?

KALIKOW: In effect, we came up with two shafts—one within the other and connected at their outboard end. The inner shaft, connected to the aircraft engine, was made thin and flexible to absorb the torsional vibrations. The solid outer shaft held all the components of the armature structure, giving us a flexible drive with no increase in space or weight.

REVIEW: Did this inner shaft solve all your torsional problems?

KALIKOW: Actually it was only the beginning. It seems as though in aircraft nothing is really ever finally solved. But in this business, problems other than torsional vibration confront us that are equally fascinating.

REVIEW: We understand that the wear and tear on armature brushes gave you considerable trouble.

KALIKOW: Early in the game, brush trouble came to perch on our doorstep. It has never been gone for long either. Mostly it was—and still is—caused by the need to operate the generators at high altitudes. There are other aggravating conditions, too. High speeds, high temperatures, and many electrical problems such as sparking, arise because these generators must be kept small yet still be able to operate over extended speed ranges at extremely high outputs.

REVIEW: How does altitude affect the armature brushes?

KALIKOW: Before I go into that, let me tell you something about the size and outputs of these generators. Today we are getting 400 amp at 30 volts—12 kw—out of generators that weigh only about 50 pounds. This is over twice the output with but little more weight than Bergman's first machine, which, as I pointed out, was once considered fantastic. Now the interesting thing about it all is that the size of the commutator has remained the same—namely, 2⅝ inches in diameter and about 2½ inches long. I'm sure you'll agree that 400 amp is a tremendous current to draw out of such a small commutator.

Let's leave the problems of commutation at high speeds—those up to 8000 rpm, of keeping the commutator round despite the terrific centrifugal forces, and of brush stability, with the obvious comment that all of these problems are in themselves extremely serious and give rise to tremendous brush problems. More important than these is what happens at high altitude.

You see, at about 25,000 feet, ordinary carbon brushes disintegrate or disappear in a cloud of dust. They don't just wear out, they "dust out" in a matter of minutes. This phenomenon was reported early in World War II. In fact, it coincided with the advent of the supercharger that enabled our aircraft to attain high altitudes. Strangely enough, the British, who'd been flying generators for several years before us, had never heard of this dusting trouble.

REVIEW: What was the answer to that riddle?

KALIKOW: The British never flew very high. They didn't have the planes or the type of mission that called for high altitudes.

But to get on with the story, we and others in the electrical industry built elaborate altitude chambers capable of simulating actual operating conditions in order to really study the problem. And as a result of this concentrated effort, brushes were made available that were more or less adequate. The dusting problem was for the time being overcome by providing special impregnants within the brush. By a process rather imperfectly understood, they provided a film on the commutator that allegedly cured the trouble. While these film-producing brushes did a rather good job, the addition of foreign matter to the already overburdened brush made its commutating job even harder. As a result, we spend a major part of our efforts finding exactly the right kind of impregnant and how much of it to use for each rating and design of the generator. This study, incidentally, is still going on within the entire industry.

REVIEW: Sounds like a really tough problem. Do you know what causes the brushes to disintegrate at high altitudes?

KALIKOW: Our research laboratory spent several years investigating this dusting problem basically, only to learn that it was not an altitude problem at all.

Rather it was a lack of sufficient water vapor in the air because of the extremely low temperatures associated with high altitudes.

You see, carbon—or graphite material—owes its slipperiness at sea level to an adsorbed film of water vapor on its surface. Under the action of commutation, this water is evaporated and it must constantly be replenished from the surrounding atmosphere. At a critical altitude—or rather, at a critical low temperature—there just isn't enough water vapor present in the atmosphere to maintain these slippery water molecules on the carbon. Lacking this slipperiness, the carbon surface behaves like sandpaper and the whole brush grinds itself to pieces against the commutator.

REVIEW: What do you do about cooling these generators up in the air? Use a fan?

KALIKOW: No, fan cooling isn't adequate. We blast-cool them mostly. That is to say, we use the ram air pressure generated by the forward motion of the airplane to force large quantities of air through the machine. There's generally a scoop in the leading edge of the wing structure, or right behind the propeller, that picks up the air. This is conducted through a three- or four-inch-diameter tube back to the generator. Incidentally, the air pressures in flight vary considerably.

REVIEW: It all sounds like a complicated business to us.

KALIKOW: It is. The several design considerations I've touched on are in reality exceedingly complex. And there are many more—for example, the entire area of design and development of high-temperature insulation. Then too, there is the story of our bearing problems at high speed and at high vibration, plus of course the highly interesting story of our advances in the electrical and magnetic designs themselves. And I've completely omitted mention of the entire electric-system problem—how the generator is tied in with the whole functioning of the aircraft.

REVIEW: What is the over-all picture in the aircraft industry today, Mr. Kalikow?

KALIKOW: We have done rather well, I think. For instance, here at General Electric we have some 31 generator models—on the shelf, practically—for the aircraft designer to choose from. These include 15 models of d-c machines that put out 200 to 400 amp at 30 volts, and four models of starter generators used on jet engines that put out approximately 400 amp d-c after starting.

"At the extreme high altitudes of new aircraft we can't get enough ram air pressure—the air is too thin—to cool the generators."

We have 12 models of a-c generators, the newest addition to our line, and we are modestly proud of them. They range in output from 15 to 120 kw, 400 cps at either 120 or 208 volts.

These a-c machines are extremely light, too. For example, we can get 40 kw out of one model that weighs only about 80 pounds. This is considerably better than the d-c types where our best effort to date has been 12 kw for about 50 pounds.

REVIEW: Is this better output-to-weight ratio the reason the aircraft industry is experiencing a rapid swing-over to a-c generators?

KALIKOW: Only one of the reasons. We are going through now what the electric utilities went through 50 years ago when they were forced to change their distribution systems from direct to alternating current. What with the increased need for electric power in the airplane and the continuing trend to larger aircraft, you'll soon see the time when most of the new installations will be alternating current.

REVIEW: Do you consider this the most significant change taking place in the industry today, Mr. Kalikow?

KALIKOW: No. Right now we are entering into a fantastic new era of high temperature. For today's jet aircraft flying at supersonic speeds have raised the blast-cooling air pressure to several hundred inches of water. This is caused by the aircraft flying at such high speed that the air impinging on it is greatly compressed. And in turn this raises the air-blast temperature as well as the aircraft's skin temperature to amazing values.

For example, cooling air at 248 F is now a specification requirement for all new military aircraft. I'm sure you appreciate that 248 F is more than hot enough to boil water at sea level—and this air temperature is used to cool the generators. Impossible as this may seem to you, we are doing it. We now have d-c and a-c machines designed and built, undergoing qualification tests.

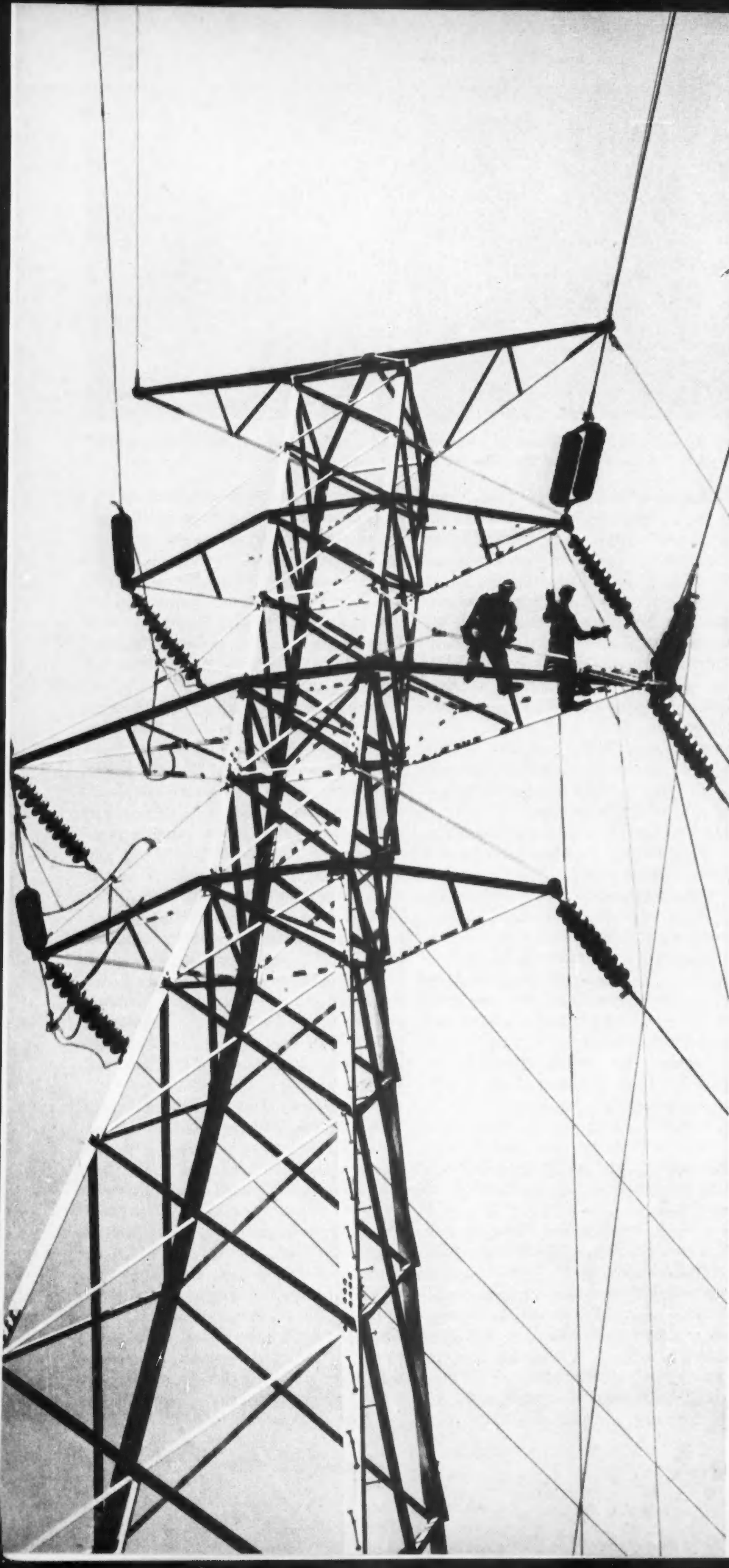
REVIEW: This is truly remarkable. It's certainly proof that everything in engineering—and elsewhere—is relative.

KALIKOW: But even this is not the end of the high-temperature story. Now they tell us that 248 F isn't high enough, and they're talking of 284 F. Well, we hesitate a bit but perhaps we can meet their 284 F requirement with air cooling. Then we find that at the extreme high altitudes of new aircraft we can't get enough ram air pressure—the air is too thin—to cool the generators. So now we're going to switch over to oil-cooled, or environment-free, generators as we call them. In this instance, more or less cool oil—still at a whopping 248 F—is circulated through the generator to absorb heat losses, and then the coolant gives up its heat to the fuel or a refrigerating system or some other heat sink in the aircraft.

So you see, our aircraft generator developments are now embarked on a new era of oil seals, plumbing, and extremely high temperatures. This environment-free type of generator will bring up a host of new problems that I'm sure will challenge and interest engineers.

REVIEW: What do you think Bergman would say if he could see what happened to his generators in only 10 years?

KALIKOW: I'd like to know the answer to that myself. It's true we've kept pace with the aircraft industry during its period of greatest growth. But maybe the best is yet to come! Ω



Except that atmospheric air is a good insulator, electricity would probably be unknown to us. Or at best it would be only a laboratory curiosity of little or no practical value.

We are fortunate that many other natural materials also possess the insulating properties of air to a greater or lesser degree. Because without them it would be impossible to direct current along a given path, and none of our electric machines, systems, or devices could operate. Yet despite this, some engineers commonly overlook the fact that insulation—and insulators—are a major part of an electric system. What other element could be more important?

Of the many different kinds of insulators, the type we will talk about here is the porcelain insulator. It is this one

THE PORCELAIN

that you see everywhere supporting buses and conductors (photo) on outdoor distribution and transmission circuits. (For a discussion of liquid insulators, see "Liquid Dielectrics," page 23, May 1954 REVIEW.)

Lone Telegrapher

Sixty years ago the development of electric power was in danger of being stifled. Large blocks of power at normal distribution voltages couldn't be practically and economically transmitted over what engineers then considered long distances. Too much copper was required to minimize the voltage drop, and the only alternative was to resort to higher transmission voltages. But good transmission-line insulators for the higher voltages were lacking.

At about this same time a Morse telegrapher in upstate New York was constantly annoyed by the failure of his telegraph circuit. He traced the trouble to telegraph-line insulators. The material used was porous, and in wet weather it absorbed water and permitted current to leak through the insulator to ground via the wooden telegraph pole. He began a search for a better material.

INSULATOR—SILENT PARTNER IN POWER TRANSMISSION

By H. A. FREY

The telegrapher, Fred M. Locke, succeeded in the search. He developed a wet-process method of making porcelain transmission-line insulators. The material—now known as electrical porcelain—is nonporous and maintains high dielectric strength even after long exposure to moisture. Not only were the insulators excellent for communication circuits but also admirably suited for power transmission at high voltages. For the latter application they were quickly adapted. Thus in 1893 the telegrapher established the Locke Insulator Company at Fisher's Creek, NY, for the manufacture of wet-process electrical porcelain insulators. (Years later, in 1920, the company became affiliated with, and in 1951 a department of, General Electric.)

Long Suffering

Since the days of pioneers like Locke, the electrical porcelain insulator has undergone extensive development in material, design, and processing (photo, next page). Today its prime purpose is to provide mechanical support for conductors at high voltages.

Service requirements for such insulators are severe. Unsupervised and unattended, they must withstand exposure to the elements for many years without loss of mechanical strength or deterioration of their insulating properties. They are subjected to long exposure to the sun and, in many locations, to a variety of atmospheric contaminants—acids, alkalies, and salts, for example. Without absorbing moisture, they are expected to withstand rain, fog, and high humidity, as well as temperatures as low as −50 F. Cold rain and hail striking sun-heated surfaces are a source of thermal shocks.

On the mechanical side, porcelain insulators are subject to shocks from rough handling during transmission-line construction. Once installed, they are often targets for boys with rocks or .22-caliber rifles.

A transmission line sagging under a heavy coating of ice after a hailstorm is a sight you have probably seen many times.

During the thaw that follows, when the conductor is suddenly relieved of its heavy ice load and snaps upward in oscillation, its supporting insulators are subjected to great mechanical shock loadings. In normal weather, too, insulators are subjected to vibration and shock loading from conductor movements in the wind.

Electrically, insulators undergo the great electric stress of overvoltages caused by lightning or switching surges. And they are expected to withstand the searing heat of leakage currents sparking across their surface as a result of dirt and grime accumulation without burning or even charring.

Electrical Porcelain

The best conductors of electricity are known to be metals, so it may surprise you that the best transmission-line insulators are a combination of metallic oxides.

Chemically speaking, wet-process electrical porcelain insulators are composed of the oxides of silicon and aluminum, plus relatively small percentages of other oxides such as those of potassium and sodium. Used in their actual manufacture are 1) flint, a finely pulverized quartz rock; 2) ball clay, a highly plastic material; 3) kaolin, sometimes called china clay; and 4) feldspar, a finely ground igneous rock with a low melting point, used as the fluxing medium.

These materials, mixed in the proper ratio, are dispersed in water to make a thick fluid commonly called *slip*. Such a dispersion permits the breakdown of agglomerates and the intimate intermixing of individual particles. The liquid dispersion is passed through 100-mesh screens (0.0059-inch opening) to remove undispersed agglomerates and foreign matter and then passed over electromagnets to remove stray bits of iron.

Slip prepared in this way is pumped into filter presses where excess water is removed from the mixture until the moisture content is reduced to about 23 percent.

At this point the slip becomes a plastic clay-like mass having the consistency of putty. It is then put through pug mills (photo, lower, page 55) that disintegrate the clay and extrude the disintegrated fragments to a vacuum chamber for the removal of occluded air. Finally, a solid and continuous cylindrical-shaped mass of clay is extruded from the mill and sliced into short lengths called *pugs*. These are ready for the final forming, glazing, and firing operations.

Most transmission-line insulators are made by pressing the plastic clay pug in molds, although in some instances the parts are formed by casting the liquid slip directly in plaster-of-paris molds.

After forming, machining operations are performed on the molded insulator parts, and they are dried in humidity-controlled dryers. The drying operation itself is highly important, because during the process the piece loses approximately 20 percent of its weight as a result of water evaporation. As you can imagine, substantial volumetric shrinkages occur. If the parts aren't uniformly dried, differential shrinkage results in cracks or strains that render the final product useless or of poor quality.

A glaze is applied to the insulator either by dipping or spraying after the drying operation is complete. The glaze is a ceramic composition not unlike the porcelain body. Placed on the silicon-carbide shelves of kiln cars, the insulators are then pushed through tunnel

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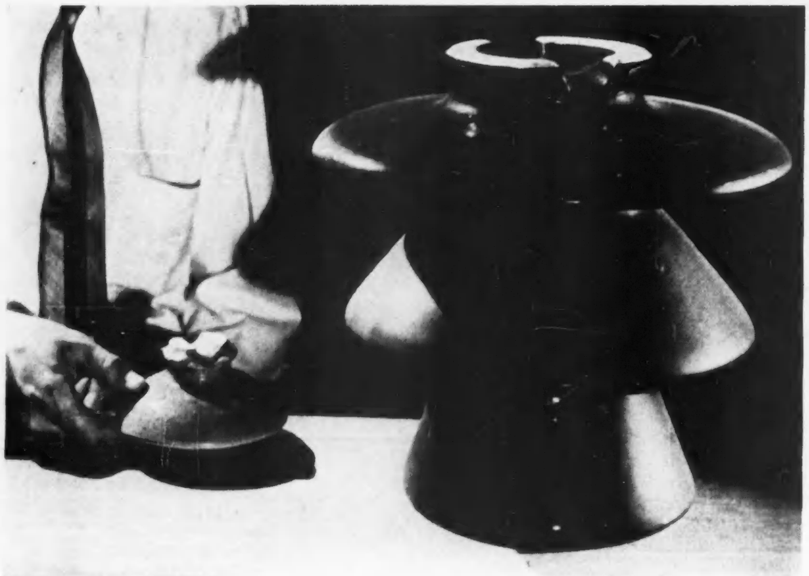
In 1926 Mr. Frey began his career with General Electric. Following a broad experience in design, research, and development, he is now Manager of Engineering, Locke Department, Baltimore, Md. Six years ago he received the Company's Charles A. Coffin Award.



OLD AND NEW: Modern radio-noise-free pin-type insulator of porcelain for high-voltage transmission lines overshadows 1906 design—still usable after 17 years of service.

kilns. As the cars progress through the tunnel, the kiln temperature is slowly raised to 2300 F.

More water is driven off during this heating cycle, organic matter burned out, and the fluxing elements melted to produce the all-important mechanical, chemical, and crystalline changes that result in the formation of good electrical porcelain. As the cars pass through the kiln beyond the firing zone, they are slowly cooled to room temperature.

Many complete insulators require metallic parts for interconnection and for the transmission of mechanical load. These parts are attached to the fired porcelain elements using specially controlled portland cements.

Remarkable Properties

Each insulator must pass a test to insure its mechanical and electrical soundness. Although the exact nature of the test depends on the design of the particular insulator, all must be subjected to a voltage sufficiently high to cause flashover. Some—such as suspension insulators—are put through mechanical strength tests to make sure they will be capable of withstanding their rated working load.

When material and processes are properly controlled, the resulting porcelain is a truly remarkable material. Virtually free of electrical or mechanical deterioration with time, it will not burn, char, or be affected by most atmospheres, acids, and alkalies. And within practical limits, it is apparently free of mechanical fatigue.

The porcelain body itself is nonporous and will not permit infiltration of fluids even under pressures as high as 10,000 psi. It is in this respect, incidentally, that wet-process electrical porcelain differs radically from dry-process porcelain.

When loaded in compression, electrical porcelain has extremely high strength. (Its true compressive strength is unknown, because specimens invariably break in hoop tension or shear when subjected to compression test.) In tension, however, its strength is relatively low—a weakness partially offset by the glazing technique mentioned earlier.

Applied to porcelain insulators, the glaze performs two principal functions: First, it provides a slick surface that dirt doesn't readily adhere to, making cleaning easy either by natural wind and rain—or, in exceptional cases, by manual labor. Second, it actually increases the physical strength of the insulator.

How does the glaze increase strength? If you'll recall, after the glaze is dipped or sprayed onto the insulator, it is fired in the kiln at temperatures up to 2300 F. At these high temperatures, chemical and crystalline changes take place within the porcelain and glaze, both essentially alike in their ceramic composition. However, if after these changes the thermal coefficient of the glaze is lower than that of the porcelain body, then as the porcelain cools from kiln temperatures, it will shrink more than the glaze. But because the two are integrally bonded together, the glaze will be compressed on the porcelain surface. Accordingly, before a tensile surface failure can occur in the insulator, the initial compressive stress in the glaze must be overcome.

If glazes are properly selected, the strength and impact resistance of porcelain can be increased as much as 50 to 100 percent. By the same token, if improper glazes are used—those having a higher thermal coefficient than the porcelain body—the reverse will be true. In fact, temperature changes may cause such glazes to crack and craze in service, resulting in serious reductions in the mechanical properties of the insulators.

Quite recently, research has shown that glaze thickness is also an important factor in controlling impact strength. If the glaze is applied in either too thin or too thick a layer, the best performance isn't realized. In other words, to obtain the maximum strength from the glaze and porcelain combination, you must control glaze thickness within extremely narrow limits. This is accomplished in practice by the use of specially designed automatic glazing machines (photo, top, opposite page), as well as by control of the physical characteristics of the raw glaze.

Flashover Problem

The dielectric strength of electrical porcelain is something in the order of 200 to 250 volts per mil of thickness. Distributing the electric stress to take advantage of this inherent dielectric strength is one of the problems in designing insulators. Even after this is done, there's another problem. While the dielectric strength of one inch of porcelain may be in the order of 200,000 volts, the dielectric strength per inch of long, practical air gaps may be only about 10,000 volts. Thus you must design the insulator not only to utilize its own dielectric properties but also to take advantage of the lesser dielectric properties of the surrounding air.

Electrical balance between these differing dielectric strengths is achieved through physical design (illustration, left, page 56). The dielectric strength through the ceramic material—between the metal cap and pin—of the suspension insulator may be approximately 140,000 volts under normal frequency conditions. So that the electric breakdown won't take place through the air path between the cap and pin, the insulator is designed with a flared skirt to increase this distance. When the porcelain surfaces are clean and dry, the voltage required to break down this air path is about 80,000 volts.

Unfortunately, insulator surfaces will not always be dry and clean in service. And the dirt deposited on the surface almost invariably contains some soluble components. In the presence of moisture, these form conducting electrolytes that can drastically reduce the insulator's flashover voltage. To offset this, corrugations on the underside of the skirt are provided to increase the leakage distance—in effect, increasing the resistance of the path.

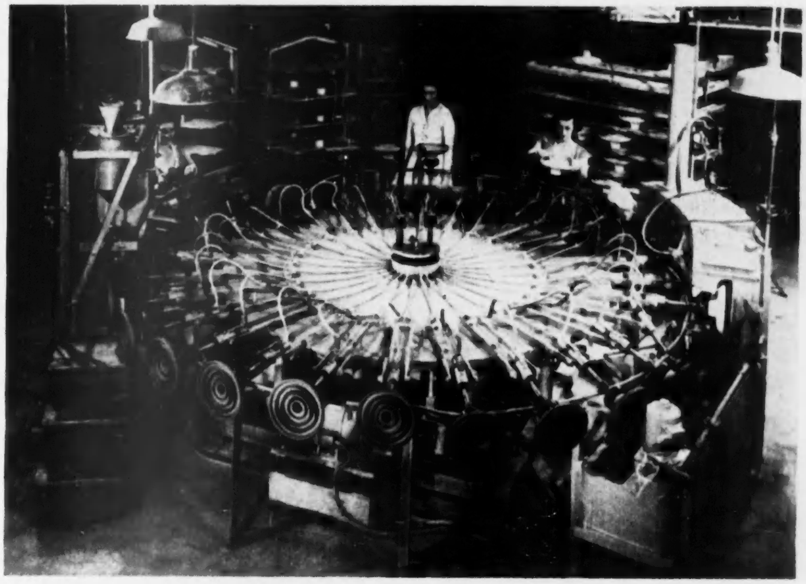
Radio-TV Interference

As you know, thousands of insulators are in use in every community. Radio and television reception could be adversely affected were not these insulators designed to operate at their normal circuit voltages without producing objectionable high-frequency signals. The cause of such interference is usually corona—a partial electric breakdown of the air around the insulator that gives rise to bluish tufts or streamers, a hissing sound, and the smell of ozone.

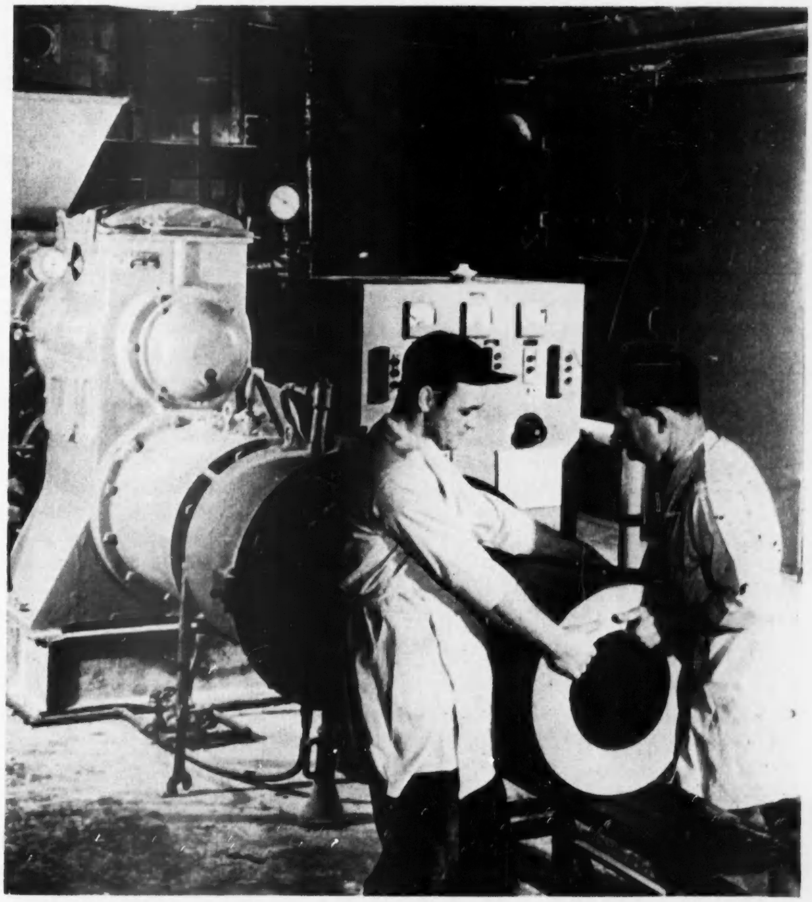
This problem is considerably complicated, because porcelain has a dielectric constant of approximately six while that of air is one. Thus wherever small air gaps are in series with porcelain, there is the hazard of localized breakdown of the air, or corona, with resulting radio interference.

Used in insulator design and manufacture are a variety of means to eliminate such an occurrence. The pole-type insulator (illustration, right, next page) is a typical example. Here a tie wire is employed to hold the conductor in place. Between the porcelain and the tie wire, there's a small air gap. Because of the difference between the dielectric constants of the two materials, corona forms at this point.

To prevent it from forming, special conducting glazes are applied over the head of the insulator as illustrated. These glazes, in effect, short circuit the small air gap and so prevent corona at operating voltages. Resistivity of these conducting glazes is extremely high. While they suppress corona from the area around the tie wires, they do not effectively diminish the surface-leakage resistance between the conductor and ground.

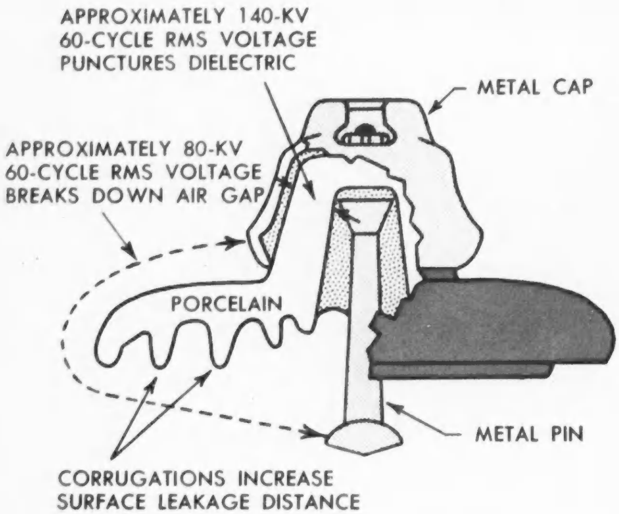


AUTOMATIC GLAZING MACHINE controls glaze thickness and uniformity within extremely narrow limits to obtain maximum strength from the glaze and porcelain combination.



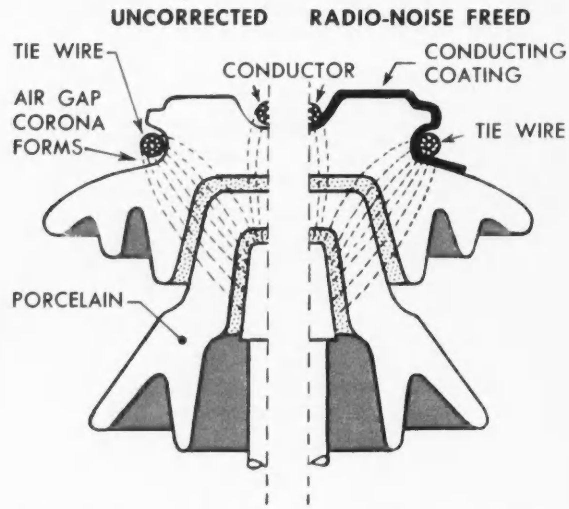
PUG MILL shreds clay, removes metallic contamination and air, then extrudes clay. Weighing up to 600 pounds, the pugs are later shaped into parts of apparatus bushings.

SUSPENSION INSULATOR



ELECTRICAL BALANCE between differing dielectric strengths of porcelain and air is achieved through physical design.

POLE-TYPE INSULATOR



CORONA FORMATION, with resulting radio interference, is eliminated by applying special conducting glazes (*right*) to porcelain.

Such conducting coatings are regularly applied to line insulators to keep radio noise levels under control. Today properly designed insulators have lower radio noise levels than almost any other type of high-voltage electric apparatus.

Tricky Job

One of the most difficult jobs for the engineer designing high-voltage insulators is that of making his design meet specific mechanical strength characteristics. It is particularly difficult because porcelain is almost entirely nonductile. Conventional methods of stress analysis cannot be applied, because fracture occurs at the first point of local stress concentration where the stress exceeds the ultimate strength of the material. Such fractures begin with cracks and grow rapidly to produce total failure. (Minor local stresses in ductile materials—steel, for example—are equalized as the material yields.)

The designing engineer must also bear in mind that while the tensile strength of porcelain is low, its compressive strength is high. As far as possible, he must work out designs to transmit loads in compression. Although porcelain can be safely worked in tension, to withstand equivalent mechanical loads much larger sections of it are needed than when it is worked in compression. This is done in many designs.

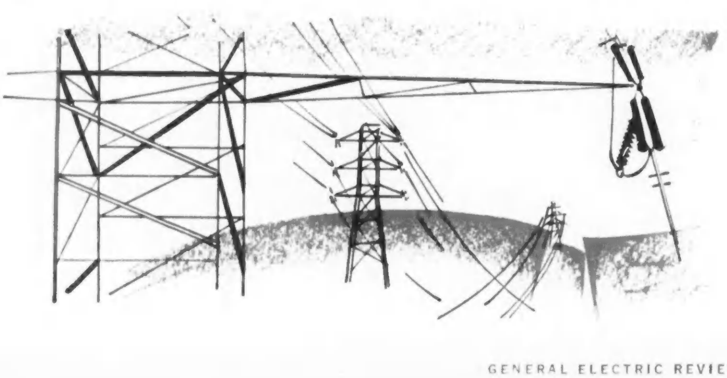
Mechanical terminal parts—the cap and pin of a suspension insulator, for example—must often be applied to transmit mechanical load through the ceramic element. And so, the engineer must be aware of another factor: the difference in thermal expansion between the porcelain and metallic parts.

In practice, the difficulties are overcome through careful design and control during the manufacturing process. Today, insulators are built in which load-carrying sections of the porcelain—no bigger than a man's fist—have mechanical strengths in excess of 25,000 pounds.

Perfection Plus

There's probably no mass-produced product in American industry where uniform high quality is so important as in the transmission-line insulator. The failure of one insulator in service can shut down an entire electric system just as effectively as if all had failed. With thousands of insulators necessary to maintain a single electric system in operation, you can see that for practical purposes the percentage of allowable defectives is nil.

The high-quality standards of porcelain insulators come about only through meticulous design and manufacture. Unrelaxing controls are exerted over every step of their processing—from raw materials to the finished product. Only through the engineer's constantly improving on their design and manufacture are insulators able to keep step with the rising voltages of modern electric power systems. Ω



AMERICA'S LEADERSHIP IN DESIGN AND PRODUCTION OF MACHINES AND TOOLS REQUIRES A STEADY SUPPLY OF MACHINE-DESIGN ENGINEERS

MACHINE-DESIGN ENGINEER—INVENTOR, ANALYST, AND PIONEER

By PROF. L. C. PRICE

For many years the United States has been a leader in invention, design, and production of machines and tools. If we are to maintain leadership in these fields, a steady supply of machine-design engineers is needed. And these engineers must be able to develop new tools and new machines at a cost that will meet increasing competition from abroad.

Engineers who can do these things need creative minds and sound scientific training in engineering analysis at a time when 1) the supply of scientific talent from abroad has been severely curtailed, 2) there's reason to fear that the climate for invention is becoming less favorable than in former years, and 3) design must now be more exact, requiring a more scientific approach with correspondingly better education for the engineer.

Considering these matters in greater detail can help you better understand the problems involved and how their challenge can be met in our engineering schools.

In years past, the United States was fortunate in attracting many machine designers from Central Europe and Scandinavia. Their basic scientific knowledge, combined with the ingenuity of many of our own citizens, produced some wonderful machines. Two world wars a generation apart have largely cut off the supply of such talented immigrants.

Invention in America

Many important inventions have been made in this country. A recent issue of the *World Almanac* lists 250 of what it calls the last century's "great inventions." Of these, 146—58 percent—were made in the United States. I do not know who compiled this list, nor am I forgetting that any American would naturally be more familiar with things that originated in his own country. Still, our share of the world's most important inventions is widely admitted to be far out of proportion to our share of the world's population.

The relative newness of America certainly contributed greatly to bringing this situation about. A venturesome pioneering spirit was bound to be plentiful among people who would settle a new country. And the business of changing the country from wilderness to civilization forced the people to improvise. Greater scarcity was coupled with greater need; availability of only the crudest tools occurred simultaneously with the need for the best ones. Such a situation could hardly fail to make the American people invention-conscious and to place a premium on creative ability.

But the physical forces that fostered this pioneering spirit are much less evident now than they were in the early days of our country's history. Today continental United States stretches from the Atlantic to the Pacific, with railroads, automobiles, and airplanes spanning it daily, literally removing the physical frontier. For individual survival a man no longer needs to depend on his own hands and inventiveness. Would it be strange, therefore, if the average American should be inclined to coast along and reap the benefits of his forefathers' aggressiveness? The need for a pioneering spirit still prevails, but the character of the incentive has changed, and its urgency seems to have lessened.

Design vs Invention

Design and invention are not synonymous, and the qualities that produce them may not exist in the same person. I have heard it said that analysis is a science, creative engineering an art. The analyst takes apart; the inventor creates. Although analysis can be taught in schools, many people believe that creativeness cannot. Indeed it sometimes seems that the more education a man has the less inventive he is. If this is so, it's important that we try to find the reason, remembering that cause and effect are likely to get mixed up. Until now it appears impossible to say whether knowledge crowds out imagination, whether a creative imagination makes its owner impatient of details, or whether the two types are just born that way.

Ironically, many of the really revolutionary inventions were made by people who didn't know enough to realize that it couldn't be done. Let's use the bumblebee to illustrate the point. Its wings are so stubby that aerodynamicists say it can't possibly fly. But the bumblebee doesn't know this, so it flies anyway. As another example, in making plans for the Golden Anniversary of the Wright Brothers' first flight last December 17, someone suggested that a reproduction of the first plane be made and flown at Kitty Hawk, NC. The machine was made and ready to receive the engine when the aeronautical experts decided that they couldn't be certain it would fly, or that it would be safe if it did.

The qualities that a successful designer must have therefore place him somewhere between two extremes: the inventor who creates and the analyst who takes apart, studies in detail, and improves. The more of both these attributes the designer has the better he is. An engineering education, then, must have both tangible and intangible objectives.

Tangibles . . .

Teaching basic engineering sciences is the tangible and, I might say, the easy part of educating design engineers. Still, even this portion of the designer's education grows more difficult, because rapid technological developments require constant increases in both breadth and depth of his scientific knowledge.

For examples of increasing breadth you need only to look around. Before the days of the steam turbine, most engineers used thermodynamics strictly as it treated the expansion of a substance behind the moving piston of a steam engine. A steam turbine, on the other hand, depends on the expansion of steam in a nozzle to convert heat into velocity energy. The velocity is converted into mechanical energy as the expanding steam strikes the blades of a turbine wheel.

The airplane has brought a host of new problems, both structural and aerodynamic. Materials used in quantity today were unknown even as recently as 10 years ago—some of the plastics, for instance. Then too, nuclear energy requires things never before considered practical. An example of this is a pump for liquid-metals having no moving parts whatever (page 24, May 1952 REVIEW). Its electromagnetic operating principle is old, but the application is new. And the list grows daily.

I can best illustrate the need for increasing depth of training by another example—selecting a bolt to lift an object. Without even knowing the weight of the object, almost any novice can pick out a bolt so small that it is sure to break under the load or so strong that it is sure to be safe. If there's to be only one bolt, it will not cost much anyway, and an extra-strong one is entirely satisfactory. But suppose a manufacturer wants to sell a great many bolts in a competitive market. If the bolts are too weak, nobody will buy them. However, a stronger bolt is larger and more expensive; if it is unnecessarily strong, the maker's price cannot meet competition.

So, depending on the size of market and the keenness of competition, the designer must begin to be more exact. He will want to be sure that his bolts have enough margin of safety—but not too much margin. This requires that he must know several things. And the greater the need to conserve material the more exact must his knowledge be. For example, he must know: What is the magnitude of the load? and is it steady or variable? if variable, how severe are the fluctuations? what is the strength of the bolt material under the load conditions? is the material homogeneous? should he make the bolt as cheaply or as lightly as possible?

These and many other questions he will want answered. Their number and difficulty increase with the exactness of the design. To answer them, the designer must either set up a laboratory or find out what has been learned previously about such matters and then adapt this knowledge to his own situation. In other words, he must *design* the bolt. And to make a really good design of a bolt—or any other engineering product—requires a thorough knowledge of the basic engineering sciences plus some other matters not so basic.

In the basic sciences are rooted those things a designer can be taught in

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Since 1948, Professor Price has been Head of the Mechanical Engineering Department at Michigan State College, East Lansing, Mich. Prior to that time, he was in charge of the college's work in machine design. He served as chairman of the Mechanical Engineering Division of ASEE in 1950-51.

being a good designer requires more than sound scientific knowledge."

school—mathematics, physics, chemistry, analytical mechanics, thermodynamics, metallurgy, and properties of materials. This is where graduates of many European universities have often been superior to American engineers.

Until recent years design knowledge in this country was not so complex nor requirements so severe but that many designers could depend on their mechanical intuition to carry them beyond their scientific knowledge. The situation has changed and continues to change rapidly as machines become more complicated and the pressure to save money or material becomes greater. This necessity for greater exactness in design comes just at a time when the supply of scientifically trained men from Europe is drastically reduced. The combination of these two conditions makes it doubly important that we improve our own standards.

Other branches of engineering science not so basic but hardly less important are receiving more attention as the pressure increases for more exact knowledge of mechanical stresses. Typical of these is the subject of experimental stress analysis under the actual conditions of loading. And we also recognize that the fatigue strength of a machine part can often be raised by removing material from its lightly stressed areas rather than adding it at the highly stressed ones, and that the best design is one with uniform distribution of stress. To design with this goal in view requires knowledge of stress distribution so exact that it is beyond mathematical computation in complicated parts. Experimental stress analysis is the only answer.

The increasing demand for higher performance of machines has resulted in much greater operating speeds. This in turn requires that the designer know more about vibration, its effects on materials, and ways of reducing it. These are only a few of the tangible items in the designer's education.

. . . and Intangibles

Now let's turn to the intangibles—by far the most difficult part of an engineering teacher's work.

An engineering education should make clear to the student his own limitations and the limitations of science itself. It should develop his judgment and his resourcefulness so that he can make reasonable assumptions in the absence of knowledge and precedent. His training must also teach him to recognize, coddle, encourage, and nurture whatever creative ability he may possess. Especially must his teacher be constantly on guard lest the teaching of what and how a thing has been done in the past discourage him from original thinking about what can be done and how it might be done.

Perhaps chief among the intangibles is the development of good judgment. This comes with experience. However, its acquisition can be hastened by studies that keep the student constantly reminded of the limitations of both human knowledge and strict mathematical treatment. A good illustration is the wide range of values given to what is generally called the *factor of safety*. To my mind a much better name for it is *factor of ignorance*. For example, a valve spring in an automobile engine goes through a stress cycle of which limits can be predicted quite accurately, and the behavior of the spring material has been thoroughly investigated under such conditions. Hence the ignorance factor is small, perhaps as low as 1.25.

On the other hand, the front wheel suspension of the same car is subjected to unpredictable loads—from slow speed on a smooth street to the punishment of high speed and rough handling on a road full of chuckholes. Obviously the only answer is a high factor of safety with the proportions of the parts determined partly by experimental stress analysis but still based largely on experience. Often the character and severity of the applied loads are the most uncertain things about a design.

Sometimes a student acquires a smug attitude that he expresses by saying, "Theory and practice don't always agree." If that happens, he should be quickly told that the theory is faulty, not the practical result. People who develop theories are human; therefore, any one of them is likely to overlook some things and underestimate the importance of others.

Or a situation may be purposely oversimplified—for instance, a mathematical solution could sometimes be too tedious or even impossible if all known variables were included. Oversimplification may also facilitate the study of the effects of the principal variables. But the student must never be allowed to forget the shortcomings of such treatment or to think that a solution on paper will give him all the answers.

Good machine-design training should aim to develop in the student not only an attitude of humility and inquisitiveness but also a broad outlook and the realization that he is being educated for the long-range view rather than for just a particular job. It should teach him to recognize the difference between acquiring knowledge and skills with tangible, practical, and short-range application—and getting an education in basic principles rather than the more superficial matters that can or should be learned outside. A constant tug-of-war goes on between these two viewpoints.

Development of character is another of the intangibles. A good student of machine design realizes sooner or later that merely being an absorber offers no reward. He will be expected to produce results. And he will find satisfaction in creativeness and a job well done.

Finding and fostering the creative type of mind is greatly emphasized today. Many people think creative ability is inborn and cannot be taught. With so great a necessity, it must be discovered and developed or at least allowed to grow if it cannot be taught. The engineering teacher must always be on the alert to find evidences of it. And while insisting that some things be learned, he must do his utmost to avoid anything that might suppress the spark of originality.

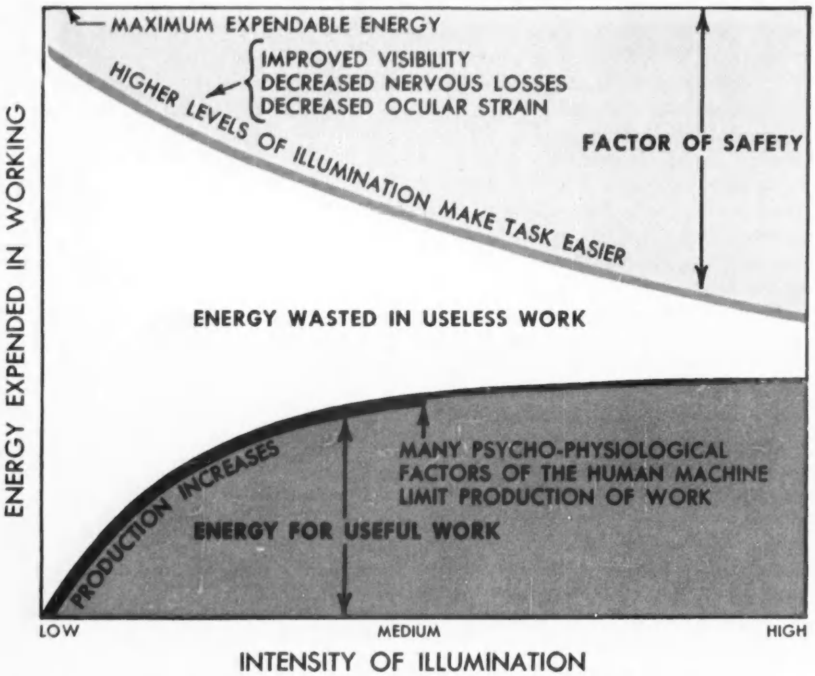
Education Plus

Undergraduate students in mechanical engineering should be encouraged to study design. Also, the curriculum should have enough flexibility so that each student can specialize a little according to his individual preferences. The best seniors should be encouraged to continue their studies in the graduate school, either part or full time.

A good education in the basic sciences provides technical knowledge essential to a designer. At the same time, every effort must be made to find and foster the creative mind and to impress each student with the fact that being a good designer requires even more than sound scientific knowledge.

When he has both knowledge and ability—and the will to use it—he may be a good designer. When he also has a creative and pioneering type of mind, he may become a really great one. Ω

LIGHT AND WORK



LIGHTING AND SEEING CONCEPTS ARE EXPANDING RELATIVE TO WORK AND EXPENDED ENERGY.

Research Paves the Way for Sound Lighting Practice

By DR. SYLVESTER K. GUTH

Our modern world owes its development to research. Product research gives us new things to use; application research tells us how to use them. This applies in light and lighting the same as in other fields of science or engineering. For lighting research provides us with new light sources and lighting techniques.

Forty years ago when committees of the Illuminating Engineering Society were just formulating lighting codes, they realized how little information they had to base their recommendations on. Of course in those days—practically an era of mere footcandles—the lighting specialist had his hands full obtaining even a little light where it would do some good. Even so, he was in a position similar to that of a doctor with plenty of pills in his bag but not knowing the proper doses. So, too, the engineer of that day specified lighting levels according to his ability to provide them.

Science of Seeing

Vision has been studied for several years. Helmholtz and many others have provided us with a wealth of knowledge concerning the eye and the visual sense. But they considered light and lighting only incidentally. Establishing the relationships between light and sight required much new research. And these investigations disclosed that seeing was the area to be studied.

Light and sight are mutually essential partners—one has no value without the other. Thus an entirely new vista opened that included seeing as a dynamic activity of human beings—a science of seeing was born. Human efficiency, comfort, and welfare became important parts of the new and expanded concept.

Perhaps one of the first forward steps in developing this broader concept was made by Luckiesh and Moss. Twenty-five years ago, with some hesitancy, they presented a diagram (illustration) that included with definite knowledge an approximation of the unknown. It interpreted the relationships among lighting, production of work, and the expenditure of human resources. The black line represents the relative energy expended in useful work as determined by many researches. The brown line shows the total energy expended in performing visual work; it represents indirect knowledge and experience rather than definite research results. Thus, for the first time, total human effort and energy were brought into the picture.

It may seem strange to you that this new concept took so long to develop. For everyone has experienced what this illustration shows. For example, if you increase the amount of light on this printed page from a few footcandles to 100 or more, you actually may not read it any faster. But you can read it easier and for longer periods without any appreciable fatigue.

Many researchers joined the ranks of those who were interested in light and vision. Currently scores of colleges and universities all over the world are engaged in such work. And a formidable amount of information has been gathered. No longer an empirical art, the specification of light and lighting is now based on logic and a better understanding of how people need and utilize light for seeing.

Performance

Basically, we are trying to develop conditions that will produce an optimum

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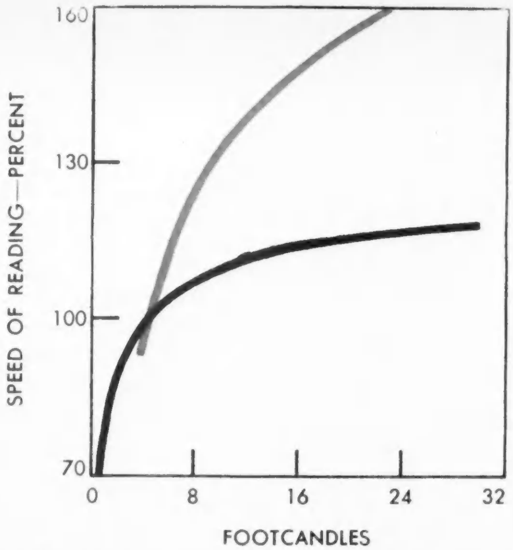


ILLUMINATION increases reading speed of low- (*brown curve*) compared with high-contrast print (*black curve*).

EFFICIENT VISIBILITY REQUIREMENTS

Location	Task	Footcandles for Equal Visibility
School	Fourth-grade reader and workbook	30
	Fifth-grade arithmetic (Pencil on yellow paper)	70
	Place names on maps	150
	Handwriting with white chalk on green chalkboard (20 feet)	175
Office	Typing on white paper	15
	Magazine text	30
	Newspaper text	60
	Handwriting in pencil	60
	Shorthand notes	90
	Bookkeeping	120
	Drafting	120
Industry	Medium-grade assembly and inspection	200
	Metal finishing and surface grinding	500
	Black thread on black cloth	over 1000
	Precision die making	over 1000

rate of performance with maximum ease of performance. Productive work, or rate of performance, is of practical interest. Blackwell, Weston, and many others have studied and are continuing to study this aspect of the problem. Originally, most investigators used such tasks as reading black print on white paper or the discrimination of black objects viewed against white backgrounds. But countless work-world tasks involve lower contrasts and complex configurations. Prescribing footcandle levels was impossible without some knowledge of the visual effectiveness of illumination with these other tasks.

Certain physical characteristics of a task must be considered (illustration). The black curve indicates the increase in the relative speed of reading black type on white paper (high contrast), the brown curve the results with black type on gray paper. These curves have been arbitrarily crossed at 4 footcandles to emphasize the difference in their shapes. The speed of reading the high-contrast material approaches an optimum at about 20 footcandles, but there's no such indication for the low-contrast material. Other tests show that it requires hundreds—even thousands—of footcandles to obtain optimum speed and accuracy for many of our complex work-world tasks.

Visibility Requirements

If detailed performance studies of every work-world task you encounter could be made in the laboratory, we would eventually obtain complete data for specifying light and lighting on this one basis. Unfortunately, this would be an insurmountable job. Some other approach must therefore be developed that possibly can be related in some way to performance.

Not everything you look at is equally visible. Some things you can see better than others. Perhaps you wonder if we can determine how much light you need on various objects to make them equal in visibility? By a relatively simple method of measuring with the Luckiesh-Moss Visibility Meter (pages 26-28, May 1952 REVIEW) we can prescribe footcandle levels.

This instrument is widely used to study the visibility of school, office, and industrial tasks. And a special model is used to evaluate nighttime highway visibility. With the meter, visibility of practically any task can be measured where it is being done and, if desired, by the person doing it. In other words, this tool—actually a small portable laboratory—can be taken directly to the school or factory.

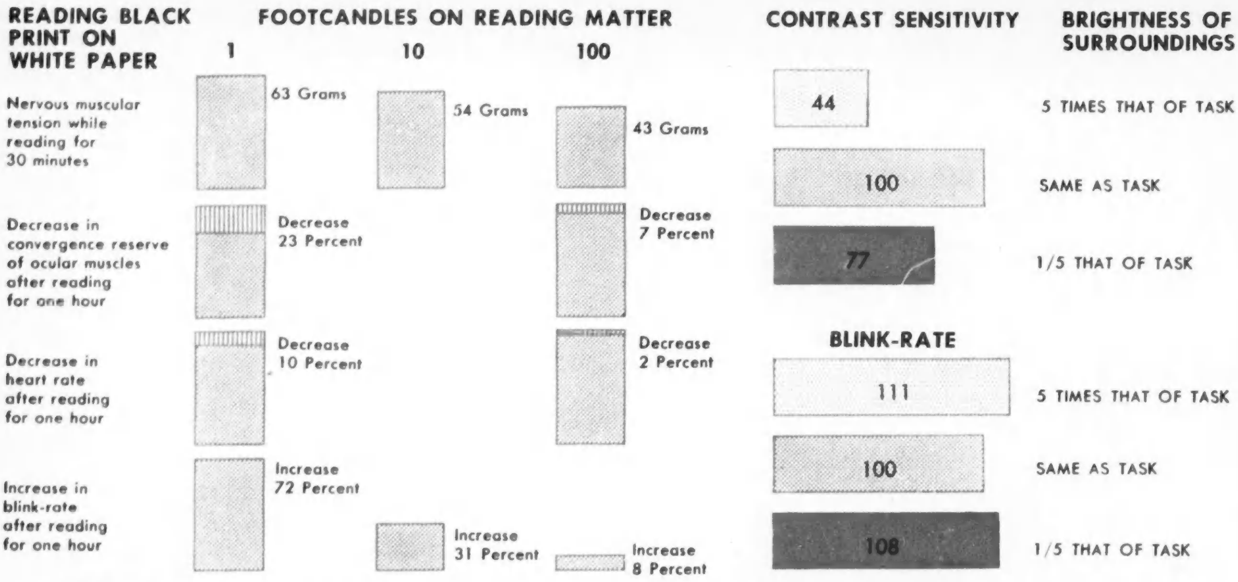
The Table illustrates a few of the results obtained with the L-M visibility meter. It gives the footcandle levels required on a wide variety of visual tasks to raise them to the same visibility level. Some tasks require rather discouragingly high levels of illumination. But the significance of these values is in the relative footcandles. For example, bookkeeping requires six times as much light as reading typing on white paper, and many industrial tasks require still more.

At the moment let's not be concerned with the practicability of attaining these higher footcandle levels. Our interest lies in developing a single standard for lighting practice. It doesn't seem right that light for seeing industrial tasks should be recommended on a different basis than for office tasks just because it may be more difficult to obtain. Visibility does give us a uniform basis for evaluating these different types of tasks, as well as an indication of the amount of light needed.

Ease of Seeing

When the illustration on page 60 was first prepared, the brown line was an approximation; over the years, data have shown this concept to be sound. But no absolute method of measurement has yet been devised. Nevertheless a number of indirect evaluations of the effort expended in seeing have been explored. Some of the results are shown for three levels of illumination (illustration, left, next page). All of these investigations show that with at least up to 100 footcandles you read a well-printed book with greater ease of seeing and less expenditure of human energy.

Because these tests were for a high-contrast task with white pages, they indicate that considerably higher footcandle levels would be necessary for lower-visibility tasks. The footcandle levels for equal visibility shown in the Table indicate the relative amount of light necessary to provide approximately the same ease of seeing. That is, dark low-reflectance tasks can be given a



EXTENSIVE RESEARCH in the ease of seeing indicates that the average person can see with greater ease and less expenditure of energy with at least up to 100 footcandles (*left*). Brightness of the surroundings also contributes to our ability to see more easily.

reasonable visibility level and can be performed with relative ease if higher levels of illumination are provided. Thus footcandle levels and the lighting must be geared to workers' visual needs and to the characteristics of their visual tasks.

Quality of Lighting

Distribution of light on the task and distribution of brightness throughout the visual field can be expressed as the quality of lighting. Part of this involves glare—obvious and exceptionally bright areas. But even less bright and also dark areas are undesirable and produce visual discomfort. During recent years, since higher footcandle levels have become more commonplace, quality of lighting has become one of our most important problems. For people demand a high degree of comfort at all times.

This problem divides into two basic parts. One involves brightness of the surroundings—desks, walls, and floors—and the other, brightnesses of lighting fixtures. Both must be balanced with the brightness of the task and with each other. For the former, the brightness ratios between the task and surroundings should be low (illustration, right). Both the ability to see, as measured by contrast sensitivity, and visual comfort, as indicated by blink rate, are best when the brightness ratios are 1 to 1. Slightly darker surroundings are preferred to brighter ones, but for good seeing conditions the ratios should never be greater than about 3 to 1. Present-day lighting standards benefit by inclusion of these ratios.

The limitations of lighting-fixture brightnesses pose a more formidable problem. Many factors such as the size, number, brightness and location of units, and work brightness must be evaluated. In recent years three groups of investigators in England, Holland, and the United States have studied these factors at length. Considerable work remains to be done, but the accumulated information indicates that we are on the right track. From such research we learn how much to control the brightnesses of fixtures to assure comfort.

The Human Element

We all know that people are different. Their response to any stimulus, whether it be a pin prick or a glare source, varies greatly. Practically all visual research data are presented in terms of averages, meaning merely that the average person will respond in a given manner. Our interest in people should be as individuals so that everyone can be given the opportunity to achieve a given visibility level, performance, ease of seeing, and same degree of comfort.

Unfortunately, most tests involve only a few observers, so it's difficult to determine how individuals would respond or react. However, recently we have obtained significant information on visibility and discomfort with relatively large groups of observers who had so-called normal vision.

For example, on the average, a specific task required 40 footcandles of illumination for a given visibility level. This means that only half of the observers achieved at least this visibility level with 40 footcandles. For some of the group the visibility was extremely low. So that 95 percent of the observers could obtain the desired visibility, more than 100 footcandles were necessary. Certainly we shouldn't be content until practically everyone can have the same ability to see. Let's remember though that many people have slightly subnormal vision. And they, too, require more light for seeing.

Similar results were obtained for brightness and comfort. A brightness at the borderline between comfort and discomfort for the average person may be extremely uncomfortable for others. In fact, to be comfortable for most observers, fixture brightnesses must be reduced to about 40 percent of the value satisfactory for the average person.

These few glimpses of researches in seeing should indicate that we are making great forward strides in providing a sound basis for specifying light and lighting. Much has been accomplished, but more needs to be done. Improved light sources and lighting methods make higher footcandle levels economically possible, but they lay new problems in our laps. Nevertheless, we've come a long way since that day 75 years ago when Edison succeeded in sealing a glowing carbon thread in a bottle. Ω

The Engineer and His Profession's Organization

By T. M. LINVILLE

Engineering as a profession has passed from its phase of private development into that of public development. Long since a profession to its practitioners, it is still in the process of being recognized by the public. The state laws on which public recognition is established are now being improved.

Originally the public could recognize engineers only through eminence—recognition given first by other engineers. But gradually all states and territories have set up boards of engineering examiners to recognize individuals as engineers and require that anyone offering engineering services publicly be examined and licensed. The examining boards, composed of eminent engineers, say in effect, "these individuals are engineers; they belong to the profession." Thus to the public the members of the engineering profession are the lawfully licensed engineers.

Growth of Engineering

As men applied the knowledge of nature's forces and materials to their uses, the engineering profession took root. And it grew as more men expanded that knowledge, taught it, and used it, especially when it concerned applied science.

For these activities, men established the engineering schools. They also formed the technical engineering societies to foster this learning and teaching and to facilitate engineering practice by agreement on codes and standards. A society naturally grew in each branch of engineering and each multiplied through offshoots as the branches enlarged. The engineers—keeping pace with the initiative of free business enterprise and with the teamwork of capital and labor—not only built the engineering profession but also helped build America as we know it today.

Today engineering projects itself into each home, and the health and safety of every citizen is dependent on it. Engineering-conscious citizens have been responsible for the licensing laws of all the states and territories. And on these laws the public profession of engineering is established.

By their licensing laws, some states recognize the specialized branches of engineering — electrical, mechanical, civil, chemical, and others. However, all states recognize only one whole profession—engineering.

Now that the public takes an interest in engineering as a profession, engineers are impelled to unite in a single professional organization to meet the responsibilities such recognition brings. It further interests them to join together to help the public properly recognize their profession and to help protect public health and safety.

The public is organized and represented by municipal, county, state, and federal governments; this suggests that the profession should be organized on the same plan. And because the public recognizes only licensed engineers, it would seem that they should comprise the organization.

The need for this kind of organization creates a problem. Engineers have naturally organized themselves by technological branches, focusing their attention on advancement of technology. The organization of each branch usually has technological subdivisions and geographical districts and sections. Work is done largely by appointed committees in the subdivisions, whereas administration is done jointly by elected representatives from each district and elected representatives from the organization as a whole—a scheme that has worked effectively. It has succeeded because technical organizations deal with engineering science rather than with human relations. These technical societies have neither the organization structure nor the unity that public recognition makes necessary.

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Manager of Research Operation Services Department, Research Laboratory, Schenectady, Mr. Linville came to GE in 1926. He followed the Test Course and the Advanced Engineering Program with a varied experience in power system stability and apparatus engineering. More recently his work has concerned management problems and manpower development. In 1946 he received the Coffin Award. Mr. Linville is a Director of AIEE and President of the New York State Society of Professional Engineers.

The Individual vs Organization

When an organization is intended to regulate human relations, it is important to focus attention on some fundamental principles. Otherwise you may find yourself preaching one philosophy and practicing another. One kind of organization will focus on the individual person, the other on the group of persons—one is organization for freedom, the other for collectivism.

Jefferson said that all men are endowed with certain inalienable rights and that the only legitimate function of government—organization to regulate human affairs—is to safeguard those rights. These rights defined as "life, liberty, and the pursuit of happiness" suggest freedom to live; freedom to think and speak; and freedom to use and develop your interests, talents, and influence to the best of your ability.

A free society or a free profession organizes to restrain those who would trespass or strip freedom from its individuals. A minority of one is still important. Freedom "to" rather than freedom "from" is its essence. And freedom has no meaning except with respect to the individual.

Freedom for the individual and democracy in organization go hand in hand. You may ask about democracy in corporate industry where owners vote shares and employees work by agreement. But here the principles of democracy are not violated. Employer and employee work together by specific agreement. The principles of individual rights and democratic freedoms become vastly important when employees agree on a collective basis—through organization.

The professional engineer works by agreement with his client or employer, and his agreement is an individual one. For as long as he is doing professional work, his responsibility and relationship to his employer is as an individual in close contact.

Thus the place of the professional engineer with respect to labor and management is with management. He is first of all, of course, a professional man belonging to his profession. On the one hand, you may see evidence that some managements have stripped the en-

THE RESPONSIBILITY OF THE ENGINEER TO HIMSELF AND HIS PROFESSION

To his technical engineering society and to his professional engineering society each engineer carries a responsibility. How he develops in his engineering society life determines the strength of the engineering profession. Each engineer should thus . . .

- **Be a member of the engineering society of his engineering branch and participate actively in its operations.**

- **Obtain his legal registration, or license, to practice engineering—a state function and an individual responsibility of each engineer.**

- **Having obtained his legal registration or license, join and participate actively in his state professional society, the majority providing membership in the National Society of Professional Engineers.**

To better prepare himself for effective membership in both his technical and professional engineering societies, each engineering student in college should likewise . . .

- **Join early and participate actively in his Student Branch and continue on into active membership in his engineering society after graduation.**

- **Plan in his senior year to take the initial examinations toward his legal registration, or license, in his state immediately after graduation. Passing these, he becomes eligible for engineer-in-training or junior member status in his state and national professional society. Later he can take his final examination for his license after acquiring sufficient experience, when he then becomes eligible to join his state society in active membership and in affiliation with the national society.**

EDITOR

gineer of his professional responsibilities. On the other hand, you may know of managements who depend on each engineer to stop production at once, partly or completely, if the product is not as intended. And they also depend on the engineers to say how the products will meet the needs of the customer or the market.

When engineers are not making intellectual engineering decisions, they are not doing the work of professional engineers. Good management does not group professionals and nonprofessionals together nor put professionals on nonprofessional work, because they differ so basically. Rather, it encourages engineers to mingle on a professional basis with managers and individual professional workers without distinguishing between them. This can be done by participating in technical societies.

This bit of sketchy philosophy suggests that the purpose of engineering organization in the human and public relations areas is educational. In other words, it is the collection and dissemination of information for the guidance of engineers in their individual acts; the medium for exchange, discussion, and recording of ideas; and the collector, integrator, and communicator of engineer's opinions. In this way the standards of ethics, education, legislation, and public welfare and relations can be improved. Such a purpose can go a long way toward obtaining for all engineers the right to life, liberty, and the pursuit of happiness in their professional work.

Let's assume a single over-all professional society is founded on these principles. Because the functions of the organization are common to all branches of engineering, are focused on the individual's needs, and are closely related to his recognition, freedom, and welfare, membership should appeal to most of the 185,000 licensed engineers in the country. An equal number at least are qualified but not licensed, and the appeal to join the professional ranks by becoming licensed should be strong. Membership would then be large; sheer numbers, as well as relations with the public, would require a decentralized organization paralleling civil government units. Too, the areas of interest would generally expand.

Concept of Organization's Structure

The single over-all professional organization emerging from this discussion is one having the following three fundamental characteristics . . .

- The field of interest and responsibility supporting human and public relations, and advancement of knowledge, teaching, and practice of engineering technology being reserved for the technical society in each special branch.
- An organization of licensed engineers, each having met the public's requirements and having thereby obtained the public's recognition as a member of the engineering profession.
- A decentralized organization of units paralleling those of civil government.

Thus the total organization picture for engineering consists of the technical societies and a large all-inclusive society of licensed engineers. Now, you may ask, "Why can't there be just one society with technical branches, one membership, and one bill for dues?"

In answer to this question, I believe each society should be autonomous. The technology of electrical engineering, for example, can best be developed by electrical engineers acting in such a society with concentration of interest and purpose. The money for developing electrical engineering should come directly from the pockets of individual electrical engineers, with no possibility of diversion for other purposes. Furthermore, functions joined together serve no purpose when they can best be performed separately without a hierarchy over them. This also applies to people who have no common interest and purpose. For example, only electrical engineers have the technology of electrical engineering as their common, foremost interest.

You may say that the technical societies do have interests in common because they have always been impelled to form a council. True, they need to communicate with one another and join forces on technical matters if several societies are simultaneously involved. Moreover, the very absence of recognition of a society to handle human and public

Industry Promotes Study of the Three R's (PART III)

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For free copies of the reprint "Why Read?" send your request to Public Relations Services Division, Dept. 107-2, General Electric Company, Schenectady 5, NY. —EDITORS

The Engineer and His Profession's Organization (*Continued from preceding page*)

relations compels them to unite in a council. And a liaison council will always be needed.

The mistake is substituting a federation of technical societies for the needed all-inclusive professional society. In the first place, the areas of interest of the technical societies are restricted constitutionally, with sharp focus on technology. The council can be no more than its constituent societies. In the second place, the decision of whether to establish the all-inclusive society should be one of individual choice and action. Provide the engineer with the alternatives; then by action rather than words he can choose between them of his own free will.

Developing Present Organization

Engineers now have the independent technical societies that they do or do not choose to join. They have a rapidly developing, independent all-inclusive society of licensed professional engineers that they can join provided they are or become licensed. They also have a federation, or council, of technical societies.

This federation would meet the engineer's needs, it seems to me, provided it established a component (society) charged with the human and public relations responsibilities and provided this component has units paralleling those of civil government and has its own members. This needed organization exists independently with its membership restricted to licensed engineers.

This leads to two ultimate questions: 1) Should the technical and the all-inclusive societies be independent with separate bills for dues? 2) Should the all-inclusive society be restricted to licensed engineers?

My answer to the first question is yes. Independence affords the individual engineer an excellent opportunity to express his wishes. It's the best way, I believe, to determine how much money should be spent in each area and how the work should be done. Each independent society is directly and separately responsive to the engineers' individual interests. I am sure the bill for dues with equal work is no more with separate bills.

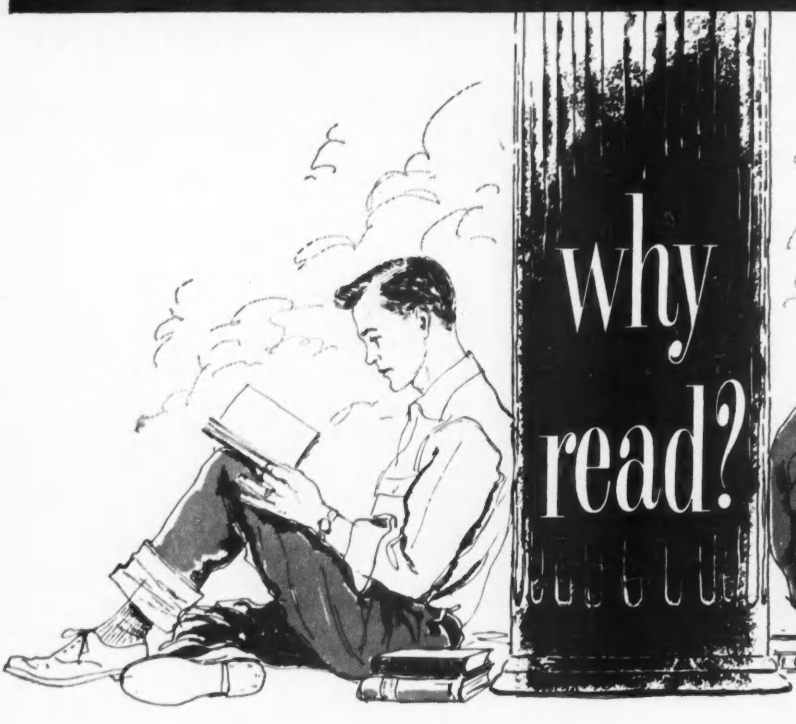
To the second question I also answer yes. Because public relations is the important purpose of the all-inclusive society, it should exclude engineers not recognized by the public—those not licensed.

Hence, I conclude that autonomous, independent technical societies as now exist are needed, that an independent all-inclusive society of licensed engineers is needed, and that a council of the independent societies for communication and co-ordination is also needed.

Fortunately all three of these organizations already exist, although they are not all fully developed. But confusion results because only less than half of the members recognized by the profession itself are presently recognized by the public. This alone explains why many engineers presently want an organization that does not exclude the unlicensed engineer or the nonprofessional affiliates of the technical societies. Nor does the council of technical societies yet recognize the human and public relations areas as a special domain for the existing all-inclusive society of licensed engineers. The latter position is natural because the all-inclusive society of licensed engineers is young, small, and not all-inclusive, and the council has not yet felt willing to leave such a domain to it. But the handling of this domain is the reason for existence of the society of licensed engineers. This situation, I'm sure, explains why the society and the council have not joined forces.

And so confusion exists. But the targets are becoming clearer, and the choices are open for individual engineers to act as they think right. Thus the organization of the profession promises to grow rapidly and soundly by developing the elements already established. Ω

GENERAL ELECTRIC'S ANSWER TO . . .



ONE of our teacher friends wrote us recently. Among other things his letter said, "At our school we have Shakespeare's plays on records. We can't get our boys and girls to read them any more."

That set us to thinking. We had always assumed that everyone liked to read if only for entertainment's sake. We were sure that everyone had to read, simply to learn the things that go to make up our day-to-day lives whether it's how to run a store, or how to put up a TV antenna, or how to make an outdoor fireplace. We had thought that, sooner or later, everyone has to go to the library to look something up.

Study depends on reading

We did a little checking and found, among other things, that Michigan State College thought it necessary to tell each of its freshmen: "Since about 85 per cent of all study activity depends on reading, it is undoubtedly your most important means of learning in college." Apparently, some boys and girls can get as far as college and still not realize the importance of reading.

We tried to imagine what it would be like at General Electric if no one did any reading. We can design a machine to operate by a record-playback that "tells" it what to do, but we don't envision a machine that can read our mail or reports.

We decided this idea wouldn't work very well. But the more we thought about it, the more we realized how important reading is. We put some of our thinking on paper. Here it is.

We read to learn

Everybody reads for learning or entertainment. That's not a startling statement, but it is a basic, enduring truth.

From our experience at General Electric we know how much we depend on reading. In a sense our Company is like a school or college. Working at a job is a continuous process of learning. New things happen every day. New products are developed, new sales fields are opened up, better ways of doing a job are discovered. To us, reading is the most important means of learning.

Scientists in all free parts of the world exchange information because they know that co-operatively they can move along their researches faster. Salesmen need advance information about what design engineers are dreaming up. Financial men read statements about new tax policies so they can forecast their effect on company business. Employee relations men need to know the newest thoughts on benefit plans and retirement age. Plant managers must keep up with their company's policy.

Most of this information is obtained by reading and by digesting what has been read. It's no good to be off base a yard when a printed message is taking the place of oral instruction.

This is reading for learning—not entertainment—but the fact is that many men find themselves so interested in the things they have to read that they forget the whodunit or adventure story they might otherwise have picked up.

"Pull" won't get you by

Industry, to survive today, is quite aware that performance is the criterion of the individual's worth. Never in the history of industry has "marrying the boss' daughter" been of so little personal value as it is now. Or belonging to the right lodge or golf club.

To build a hard-hitting team, industry places responsibility upon key personnel. The men and women of this group are moving constantly toward more exacting (and exciting) positions. These are the people—believe us!—who can read and speak and write concisely, clearly, interestingly. Absorption of knowledge through reading comes first.

A way of self-education

We were talking in the office the other noon about the late A. R. Smith. A few of us remembered him vaguely as a man who wore a black derby and who was one of the world's foremost steam-turbine authorities. Unlike most of his fellow engineers, he had no college education. His "college" was a course of study with a correspondence school. For him, 100 per cent of his study activity depended on reading.

We do not believe that men of narrow learning have the understanding to bring along their successors. In fact, without a grasp of their company's purposes and obligations, they cannot understand its place in the vast pattern of national life. A man's mind is his eyes to see ahead.

Your teacher, we think, will confirm the following belief. Reading is variety itself. No one author, no one magazine's editorial staff has a corner on interpretation or final truth. All ideas are in transition especially in America, and by wide reading you are having the fun of accepting and rejecting and putting two and two together. You experience the luxury of becoming a thinker instead of a yes man. Such were the industrial pioneers 100 years ago who read in one of our most important technical magazines that there wasn't much of a future for electricity, yet who went ahead to establish the electrical age.

Putting yourself "in the know"

Another real dividend paid the reading man is his growing ability to take part in business or social discussion. Although the purpose of reading is not to show off in conversation, the reader is "in the know" and can listen wisely and speak his own piece to advantage. Often the strong, silent man—on the other hand—is a still water not running very deep.

If we want to know, in our spare time, how to bind a book, how to identify evergreen trees, how to mix up and bake a cheesecake, how to build a summer home, we go to the library.

Whether we are technical or business men, we are eager to keep up with published knowledge on many subjects: new alloys for jet engines, legislation on taxes, color television, social security—the list is endless. We are so close to the challenging demands of these years of technical progress and worldly unrest that we must keep our minds in high gear.

The value of sound preparation

Yet we are aware that there are people who can't be communicated to, except through the medium of pictures. If we sound cranky, it's because we ourselves are not immortal; we just want to make doubly sure that every high school boy and girl in America, who will move into our positions, will be mentally prepared to absorb our contributions, build on them, and thereby keep our American system intact.

In the flood of school and college graduates coming to industry for jobs, we are not looking for bookworms. We don't want you to stick up your noses at the tribulations of the Dodgers, "doing-it-yourself," and the other non-reading pursuits that make for a happy, human life; but—what do you know?

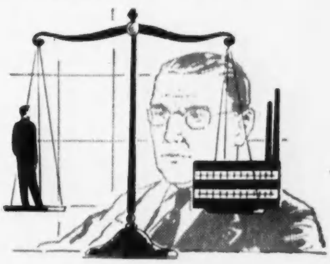
Read things that are worth-while

Do you know your American history? If you know that a communal economic system was established in the early years at both Plymouth Colony and Jamestown, do you know why that system burst at the seams? Was Florida one of the thirteen original colonies? Are you a little ashamed of your brother American when he can't give a TV quizmaster the name of a single member of the President's cabinet? Don't put down the empty look on the victim's face solely as stagefright!

Ignorance is the father of apathy. If you expect to love the children that will be yours tomorrow, you had better heed a statement like this: "In a world that has seen Socialism, in some degree, spread throughout nearly all the major nations, America cannot permit her young people to take their blessings for granted and become indifferent to how those blessings have been made possible. The indifference or apathy that stems from ignorance causes young people to have little if any interest in defending our basic American principles which are under attack."

The leaders of peoples who would destroy us tell the masses to read—the party line. Here, we are free to read even the words, the arguments of our enemies. In fact, in America, the book or pamphlet your local library does not have is still obtainable; your librarian knows how to bring you almost any book cataloged in any library anywhere.

Why are there adults living in these exciting times who are uninformed about things that affect all our lives? Mainly, they do not read.



Why are there still a few young Americans in our schools who do not know the score? Same answer.

Is reading a bitter medicine that you have to get used to? You answer that one. We are prejudiced!

"We are what we read"

Why read? Almost all that is worth knowing is in words. It takes an easy familiarity with reading and a tremendous appetite for recorded knowledge—past and present—to keep in step with these fast-moving times.

Our high school English teacher used to say to us: "We are what we read." Later, an annoyed college instructor said, as we struggled over a long passage: "It's painfully true that the way not to become a fathead is to fatten the mind."

These were hard words, but in them was an elementary truth: If you liken your mind to a container, it is the only one we know of that the more you cram into it the more it can hold.

Your English teacher knows how to make you a better reader. With your co-operation, he will help you develop good reading habits. He will open up some everlastingly long avenues of fun and profit. One day you will be grateful for his help and pleased that you had good-enough sense to consult him. You can solve almost any problem if you know how to read it.