GENERAL ELECTRIC Review

MAY 1955

Dr. H. C. Pollock (left) is holding a 70-Mev synchrotron "doughnut" designed and constructed in the G-E Research Laboratory. He joined General Electric in 1937, after receiving a B.A. from the Univ. of Va. (1933), and a Ph.D. from Oxford Univ. (1937). His research interests at G.E. have included a pioneer separation of U-235, submarine-detection devices, and counter-radar work, as well as studies in radiation physics.

More power to electrons

General Electric's Dr. Pollock combined the principles of two accelerators to produce high-energy electrons

The tools used by physicists to accelerate electrons up to the high energies needed for nuclear research are usually very large and heavy. Some years ago, Dr. Herbert C. Pollock of the General Electric Research Laboratory showed that by combining the actions of betatron and synchrotron, a smaller machine could be made to accelerate electrons. A successful 70-million electron volt synchrotron of this new type — using a magnet weighing 8 tons compared to 135 tons in a 100-Mev betatron — was designed and built by Dr. Pollock and other G-E scientists in 1947.

This was an important link in the chain of increasingly more powerful electron-accelerating machines which are now helping to extend the frontiers of nuclear physics and medicine. Synchrotrons which accelerate electrons up to 300 Mev and more have been constructed recently at Schenectady and elsewhere. Today, physicists are looking ahead to electron energies in excess of a billion electron volts.

Progress Is Our Most Important Product

GENERAL ELECTRIC

MAY 1955 • VOLUME 58 • NUMBER 3

GENERAL ELECTRIC Review

EVERETT S. LEE • EDITOR

PAUL R. HEINMILLER • MANAGING EDITOR

COVER—Clean water, often obtained from remote valleys and distant streams, is harnessed for use in modern urban life and industrial activity by the reliable operation of electric motors and controls. The availability of this essential commodity is but one of the many contributions of electrification in industry as presented on pages 26-31.

CREDITS—Photograph page 8, Paul Berg, Sunday *Pictures*, St. Louis *Post Dispatch*; photographs on pages 10, 11, and 12, U. S. Navy.

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What will you do to put atomic power to work?

In this model of a possible atomic power generating station you see the future of electricity in miniature. It typifies General Electric's farsighted research and planning to harness the atom. And the young men studying it typify the Company's accent on youth to solve problems arising in this new, dynamic field. They are L. O. Sullivan (left), BS, Union '48, operations supervisor, and G. E. Martin, MME, Vanderbilt '50, design and development supervisor at the Radioactive Materials Laboratory in the AEC's Knolls Atomic Power Laboratory, which is operated by the General Electric Company.

Along with other recent college graduates working to tame atomic energy—whether in electrical, mechanical, metallurgical or chemical engineering fields, or in such areas as physics and aeronautical engineering—you will find that you are able to increase your scientific background in an after-college program of technical assignments. In this program as in your career, you select location and field from the broad scope of G-E activities that include atomic power, jet propulsion, electronics, plastics, electrical apparatus and automation components.

Working with experienced engineers, you can make contributions early in your career at G.E. For full data on the G-E opportunity suited to your skills, see your college placement director, or send a summary of your qualifications to General Electric Company, Engineering Personnel Section, Schenectady 5, New York. TR-3

Progress Is Our Most Important Product

GENERAL ELECTRIC

THE ENGINEER—
AND PROFESSIONAL RECOGNITION

The other day we were talking about professional recognition and the engineer, and I told again my baseball story of the great outfielder Andy Pafko, formerly with the Chicago Cubs, later with the Brooklyn Dodgers, and now with the Milwaukee Braves.

It was in June, 1944, at the annual meeting of the American Society for Engineering Education in Cincinnati. Charlie Scott, Chairman of the ECPD Committee on Professional Recognition, had arranged a conference dealing with the responsibility of the engineering teacher for building the engineering profession. A galaxy of great engineering teachers was to take part.

I was going to the conference—but I learned at breakfast that my Chicago Cubs were scheduled to do baseball battle with the Cincinnati Reds that night at Crosley Field. And although I loved conferences on the professional recognition of the engineer, I wanted even more to go to that ball game. I appealed to Charlie, and grand man of understanding that he was, even though I was chairman of ECPD at the time, he said: "Go to the ball game."

So with Professor F. B. Seeley, my friend and wonderful teacher of T. and A. M. at Illinois, and with two other professors, I went to the ball game.

In the third inning, by the grace of God and with some good help from themselves, my Chicago Cubs were leading the Cincinnati Reds 2 to 0, when Ray Mueller came to bat for Cincinnati with a runner on base. He promptly laced out a long high fly ball to the outfield that looked like a sure home run. The crowd leaped up and cheered. My heart sank.

But Andy Pafko, playing center field for the Chicago Cubs, knew only one objective. That was his ball to catch. We saw him turn and run with the crack of the bat; we saw him turn and look back as he ran; we saw him running again; then we saw him leap up and with his arm high in the air he speared the ball.

Instantly the crowd stopped its cheering. You could feel its disappointment. All hopes for a home run were wiped out. But in the next instant, from that great crowd, there again arose a mighty cheer. This time it was for Andy Pafko and his great catch. Today it would be called a Willie Mays' catch.

The applause was spontaneous. And I said to my professor friends: "That's professional recognition. They are *talking* about it down in the Hotel Netherland Plaza, but we are *seeing* it here."

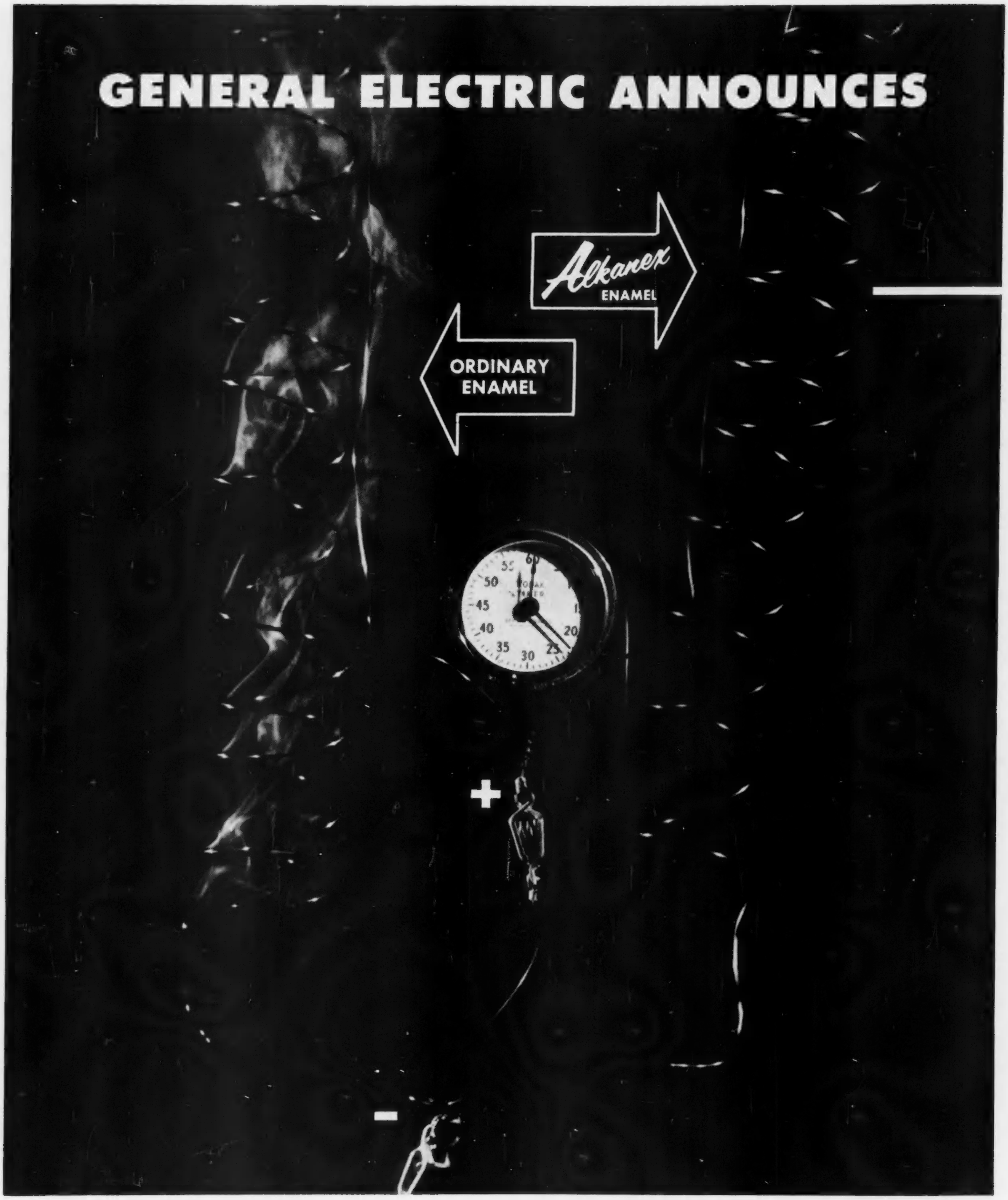
And so it is. The great American public is quick to appreciate ability. And I have found that the public does recognize the engineer in thinking that he can do just about everything there is to be done. But the public sees only the completed product; it does not appreciate the engineer's part in it. It is as if the fans knew only the score of the ball game after it was finished. If the public could intimately see and understand the hits and runs and errors of the engineer as he works to perfect his product—to complete his ball game—its appreciation would be boundless for the wonders he performs.

When I sit in my home looking at the television screen and see the picture that is being brought to me, I often completely forget the picture in my admiration for the wonderful contributions of the scientists, the electronic engineers, and the communication engineers who have made it possible. And when I see the wire leading from the set to the plug in the wall, and visualize beyond it to the great electric generators in the power plant, my admiration knows no bounds for what the power engineers have provided for us.

Truly, we can say with Solomon: "It is the Glory of God to conceal a thing, but to the honor of man to search it out." That is the engineer together with the scientist. That is truly his professional recognition.

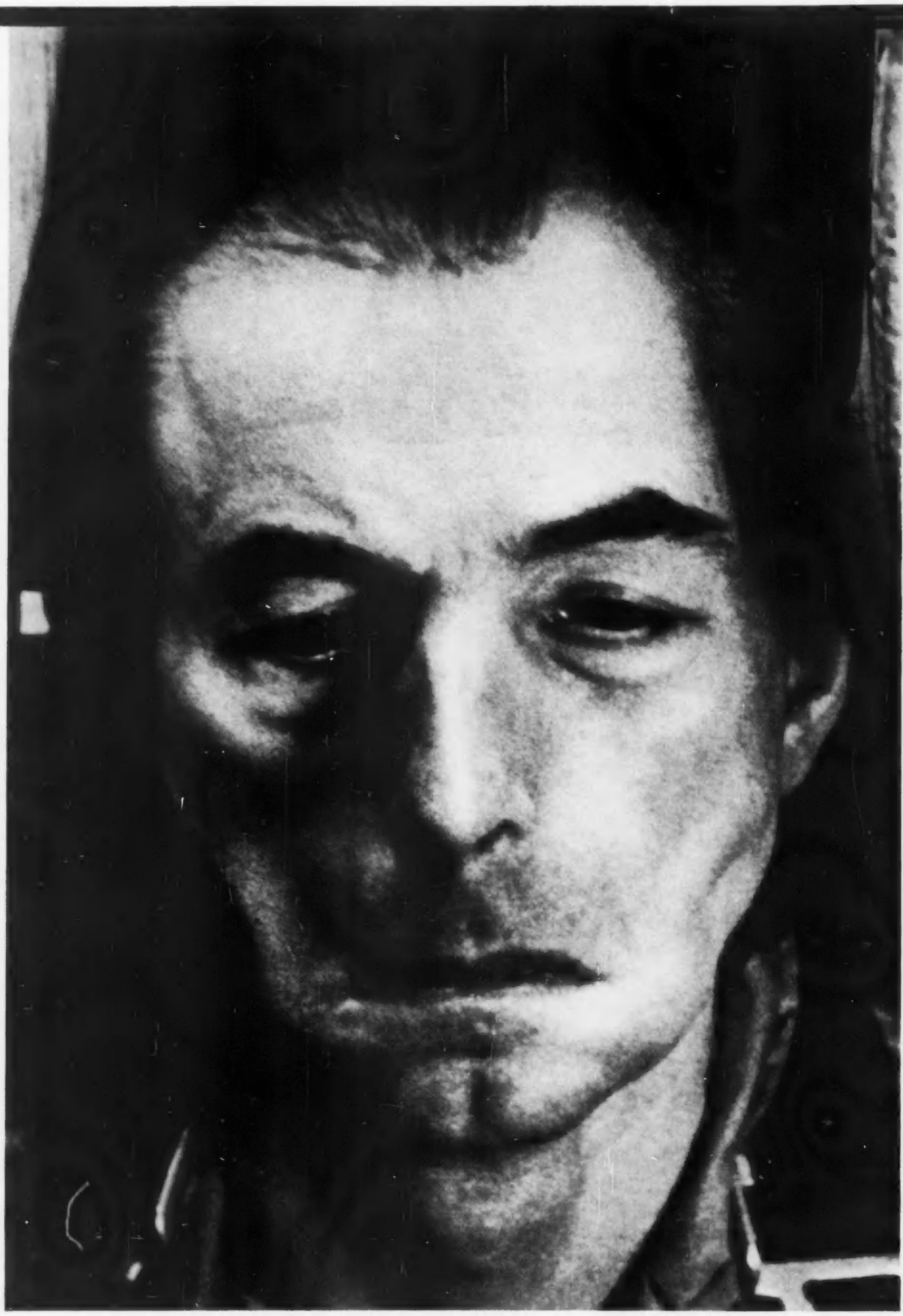
Everett S. Lee

EDITOR



HERE'S A VISUAL DEMONSTRATION OF HEAT RESISTANCE!

In this laboratory test, arranged to demonstrate the heat-resistance of Alkanex enamel compared with conventional enamel, two coils of magnet wire were simultaneously grounded in a dead "short circuit," producing temperatures on the surface of the wire considerably *in excess of 250 C.* In less than 20 seconds the coil on the left, coated with conventional enamel, began to smoke and in approximately 45 seconds the enamel coating had disintegrated. At that point the coil of wire on the right, coated with Alkanex enamel, had barely begun to smoke even though the wire temperature greatly exceeded the normal limits for Alkanex enamel.



Riding the Navy's human centrifuge, aeromedical scientist momentarily undergoes a positive accelerative force of 10 Gs. His blood—slammed down into his lower extremities—is almost as dense as molten lead. Another quarter second and he would be unconscious.

The Invisible Force

Review STAFF REPORT

Ten years hence, military planners predict, combat aircraft will operate at 2000 mph through such high altitudes that nearly all the earth's atmosphere will lie below. Despite the serious stability and control problems plaguing supersonic aircraft today, we've little reason to doubt this prophecy. Man always has conquered his technological barriers—and probably always will.

If there is one thing we've learned from a half century of powered flight, it is that the greatest obstacle to faster and higher flying is not technology or our lack of it but rather human frailty. Alongside the aircraft designer a new kind of specialist has sprung into prominence—the aeromedical scientist. His problems, because they are in the human area, take on a completely different color.

He deals with a system that for practical purposes has no design constants governing its action. It can adapt itself to an astonishingly wide range of stresses and still border on physiological competence. A human, for example, can go without water and sleep for two to three days and without food for 10 to 20 days. Only last year, in fact, he survived without artificial oxygen supply on the summit of Mt. Godwin Austen in Kashmir—a height of 28,250 feet. But these feats, however impressive, are not relevant to conditions inside the cockpit of an advanced aircraft. For there it isn't a question of survival, but more a matter of how quickly a pilot can think and act under severe, sometimes painful, physical stresses.

Of all the human problems inside the cockpit—heat, cold, instrument complexity, noise, and vibration, to name a few—one stands out as perhaps the most problematical. Airmen who have experienced its effects when they try to escape from spinning aircraft describe it as an invisible force so pinning down their bodies that they are practically immobilized. Pulling out of dives, pilots are plunked into their seats, and while with great determination they can still move their arms and legs, they cannot see. They just sit there fighting the force with "pilot strain"—sucking in a deep breath and putting pressure on the abdominal region.

Any accelerating or decelerating mass experiences this invisible force. Engineers measure it in Gs, the force exerted on a body in multiples of the body's weight. A 200-pound pilot, for instance, weighs 800 pounds under an accelerative force of 4 Gs. At 7½ Gs his blood weighs as much as molten iron.

The direction of G is always specified. A pilot swooping out of a dive is subjected to a force from head to feet arbitrarily termed positive-G. It drains blood from his head and causes him to black out. Executing an outside loop, he experiences just the opposite: a force from feet to head called negative-G. Highly dangerous, it slams blood into his brain where it can damage delicate tissues.

Pilots have been hampered by accelerative forces ever since the Wright Brothers—who, incidentally, did their flying in the prone position—first took to the air. The problem is intensified in high-speed aircraft. Consider the simple maneuver of making a standard three-degree-per-second turn, alloting the pilot a full minute to reverse his heading. At 500 mph, positive-G stress on the pilot and plane is 1.56; at 1000 mph, it is 2.48; at 2000 mph, 4.8. High-speed escape from aircraft introduces new problems more complicated than positive-G alone. Anti-G suits help, but they are only an expedient, giving the pilot little more protection today than they did 10 years ago.

The human centrifuge is the tool that aeromedical scientists use to study effects of G. With this machine a test subject is whirled around in a free-swinging car at the end of a long arm. Far and away the newest, largest, and most versatile human centrifuge in this country is operated at the Naval Air Development Center (NADC) in Johnsville, Pa. Going older centrifuges one better, it carries the test subject in an instrumented gondola that can be rotated and tilted during the run. In addition, its arm is long enough—50 feet—to support three auxiliary free-swinging cars positioned at different radii. Less than two years ago when operations began, it was pictured and described in many technical magazines and publications. But since then, comparatively little has been said.

Recently I drove to Johnsville to see for myself what this impressive machine was accomplishing. The United States Naval Air Development Center, located 20 miles northeast of Philadelphia as the crow flies and about half that distance from historic Washington's Crossing, Pa., is a giant of the Navy's research and development program. It is like a fenced-in city. When I pulled inside its gates, two marine sentries mechanically directed me to the visitor's reception office. There, after describing my motives, I was issued a badge and referred to the public-relations officer, Lt. James R. Williford, in the Administration Building some distance away.

Williford is a tall, broad, friendly Southerner. A naval aviator, he wore the Navy winter green uniform with gold wings pinned above his breast pocket. He said that the work at NADC is rarely publicized. If they find some new method for doing something, they don't always tell the world about it because they'd lose their advantage.

When I asked him how big a place NADC is, he rubbed his hands together with relish and spurted, "In area, 751.15 acres. We employ about 2300 people, both military and civilian. There's over a million square feet of floor space here. We maintain seven laboratories and an air station big enough to handle our largest planes." The human centrifuge is housed in the Aviation Medical Acceleration Laboratory and the man for me to see there was the Director, Captain Shepler, he said, reaching for his cap.

On the long trek to the Laboratory—or AMAL as Williford called it—we passed through what appeared to be a huge hangar. As far as I could see, planes stood in a highly innocuous state of disassembly. The Navy had taken the building over from a large aircraft manufacturer during the war to modify aircraft and develop guided missiles, Williford told me. In 1949, when many of the Navy's other activities were moved to Johnsville, personnel, equipment, and more buildings were added, and the operation formally became known as NADC.

Once we were outside the hangar, the Acceleration Laboratory loomed into view. It holds the distinction of being the Center's most modern building. And that it is. Built of concrete and steel, it is a cylindrical flat-topped structure, with a private powerhouse about a hundred feet to the rear. Up its handsome entranceway we stepped through swinging glass doors into the foyer. Exhibited on a table to the left in a plastics case was a working model of a supine aircraft seat and pilot.

Williford led me into and around a circular corridor with offices on either side of a highly polished asphalt-tile floor. Signs on the open doors bore such names as Biochemistry, Physiology, and Pathology. Inside, white-coated men and female technicians bustled about.

When we arrived at the Director's office, Williford removed his hat, formally introduced me, explained my business, and left. The director is a tranquil, bespectacled man in his late 40's. He wore a white laboratory coat over his regulation blue trousers, white shirt, and black tie. Hanging over a chair in a corner of the large office was his Navy dress jacket with four gold stripes encircling the sleeves. Offering me a chair, he sat down behind a large, handsomely grained desk, its surface cluttered with papers, reports, books, and other paraphernalia. Engraved on a brass nameplate was Captain H. G. Shepler (MC), USN. He had an appointment coming up shortly, he informed me, though he'd gladly cancel it. Either way would be satisfactory to him. But since they were presently running a test—the last of the day—perhaps I'd rather have a look at the centrifuge in action. I agreed and Shepler pushed a buzzer. Shortly, a big fellow with black brows strode in. The director introduced him as their Chief Engineer, Howard Hunter.

"We'll have to hurry," Hunter urged amiably as he ushered me out of the office. "They're stopping the test now." As we arrived at the large circular chamber housing the centrifuge, a Navy corpsman helped the test subject out of a free-swinging car. Nearby stood another man in a white laboratory coat. This was Dr. Richard Lawton, Hunter said, the supervising physician. Their test subject for the morning was a psychologist, Flannagan Gray, Lawton informed me. "This is the last of a series of runs to determine how his G tolerance varies with time. After about the seventh or eighth run his tolerance goes up." They have to exercise a certain amount of caution, he went on. Usually they give the test subject some preliminary type of run and work him up slowly to the danger point.

A dark-complexioned man of medium height came toward us and Hunter introduced him as Anthony Greco, Chief of Operations and Facilities. Greco, an extremely affable electrical engineer with a classic Greek profile, said smilingly, "Everything seems to have a definite G tolerance. Even flashbulbs—you get only two out of four flashes." With the centrifuge, he related, they'd evaluated ejection seats and other devices—although their work was primarily medical in nature. A pilot had to be able to operate his equipment under accelerative forces. If a control was too far away they recommended that it be placed closer. "We put the same thing in the gondola that is in the cockpit of an aircraft," Lawton interjected. "Then we run the centrifuge and ask the pilot to operate his equipment. We also evaluate his ability to move with his flight gear on—they're not like street clothes, you know."

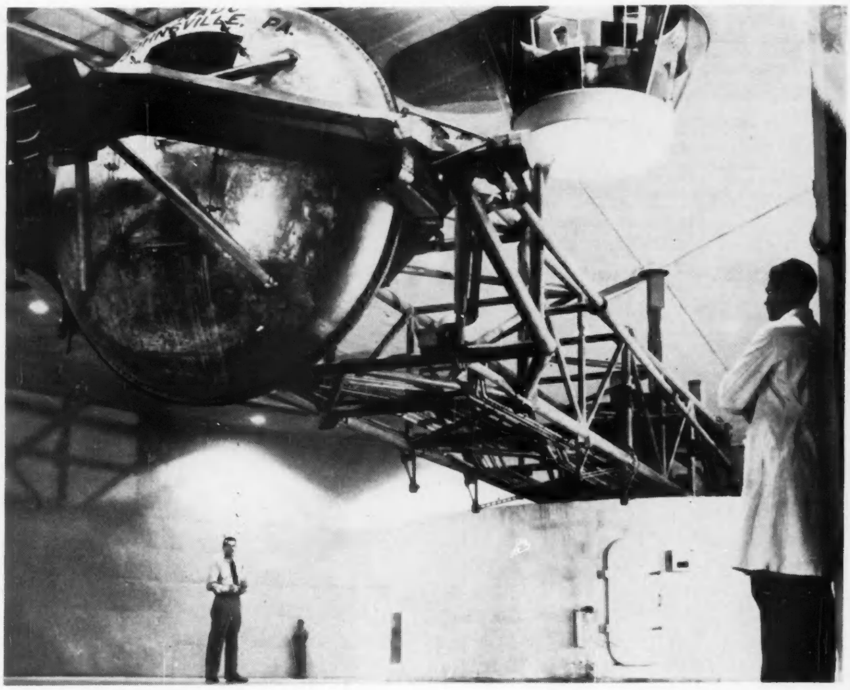
For such tests, he explained, they set up movie cameras in the gondola and then study the film. Greco invited me to have a look inside the gondola. I followed him out of the chamber, up an iron stairway, and into a large room called the control platform. Adjacent to an observation window that looked out on the centrifuge was an open doorway with a retractable platform leading to the gondola.

The gondola seems large on the inside, although its actual diameter is only 11 feet and its width at the center, 6 feet. Temporarily installed at one end was an ejection seat surrounded by an assortment of levers and switches for the test subject to operate. With a handgrip above the seat, he could yank a protective windscreen down in front of his face to simulate ejecting himself from an aircraft. Studies with the ejection seat, Greco related, showed that the pilot was burdened with so much flight gear that he couldn't function easily. Facing the ejection seat at the other end of the gondola was a large panel with three signal lights—red, amber, and green—equally spaced across its front. The two outside lights were called peripheral lights, and the middle one, the central light.

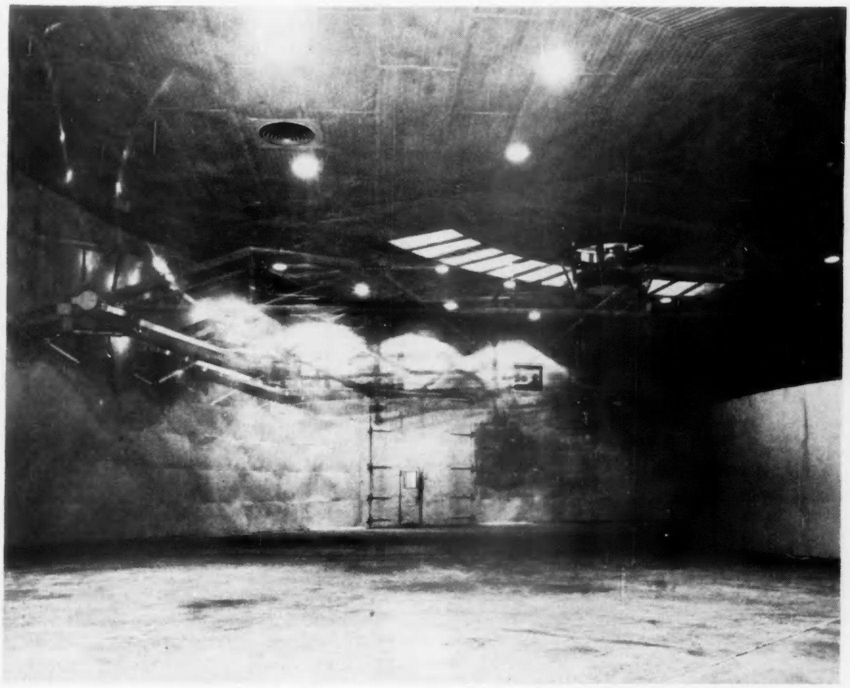
At the onset of blackout, Greco explained, the first thing that happens to a person is loss of his peripheral vision. Next, and this is the danger point, he loses his central vision. During a run the test subject continuously switches the peripheral lights off as an operator in the control room above the centrifuge switches them on. When the subject fails to respond, blackout is setting in. "It depends on how we increase the steps of acceleration," Greco said. "Tolerance varies from day to day, depending on your physical condition and what you were doing the day before."

At my request we went back down to the chamber. Designing the human centrifuge required an unusual combination of medical and engineering skills. Its 50-foot arm of tubular steel, with gondola at one end and counterweights at the other, sits astride the shaft of the world's largest vertical d-c motor. Including motor shaft and armature, the total weight of this load is 125 tons, all of it supported on special roller bearings so frictionless that by exerting a 25-pound push against the gondola you can start the centrifuge moving. While it doesn't take much torque to rotate the centrifuge once it's started, a tremendous amount is needed to accelerate it in a short interval. Torque means a lot of current. And the generators supplying the vertical driving motor can build it up at 160,000 amp a second. With this surge of current, the motor can momentarily develop four times its continuously rated output of 4000 hp. In less than seven seconds it can accelerate the centrifuge from a dead stop to 174 mph—exerting an accelerative force of 40 Gs on the gondola.

Design of the gondola presented some terrific engineering problems. Having a payload capacity of 600 pounds, it can be decompressed to simulate altitudes of 60,000 feet. Air-conditioned also, its temperature is controllable from 44 to 110 F. From inside the gondola the test subject's reaction to accelerative forces and these various climatic conditions is electrically piped to remotely located physiological instruments and recorders. Mounted on gimbals and driven by its



AT REST Described by one engineer as "a piece of equipment hung on an electric motor," the world's largest—and most versatile—human centrifuge took five years to complete and contains the most powerful vertical d-c motor yet designed.



IN MOTION Radially accelerated, tilted, and rotated like a wheel, the gondola simulates an uncontrolled aircraft. Loading platform that is located adjacent to the observation window retracts into the chamber wall during a run.

own motors, the gondola can not only be rotated like a wheel but also tilted inward or outward simultaneously—while the centrifuge exerts its radial accelerative force. Greco explained its importance this way: "If an aircraft is out of control, the G force doesn't remain constant. Tumbling is much more realistic. And that's what makes our machine different from any other human centrifuge."

All the centrifuge's electric equipment—driving motors, generators, and intricate control systems—was designed and built by General Electric. McKiernan-Terry Corporation of Harrison, NJ, built the centrifuge itself. Although simple in operating principle, it was difficult to engineer, needing much in the way of original design and fabrication. The job, I've been told, required unusually close co-ordination between equipment builder, electrical manufacturer, and the Navy. Construction began in June of 1947, and not until five years later, the fall of 1952, did the centrifuge go into operation.

Shortly after lunch, Howard Hunter and I went to the Director's office. Captain Shepler, still dressed in a white laboratory coat, was sitting behind his large cluttered desk. Greeting me courteously, he waved to a nearby chair, removed his glasses, and leaned back. Hunter took a seat at the rear of the room.

Shepler speaks in the pleasing accents of the Midsouth. Thoughtfully, at an almost leisurely pace, he told me that there were certain accelerative problems peculiar to Naval aviation. "A lot of our flying, for example, is done from the decks of ships, which implies catapult launching and very sudden stopping by means of arresting gears. At those times the pilot is subjected to high G forces." Engineering was somewhat ahead of medicine, he went on, in that there were probably a lot of high-performance airplanes on the drawing boards that would be difficult for a human to fly. Certainly there were limitations as to what G forces a pilot could withstand. But he wouldn't say flatly that the human was holding back progress in aviation. "We are continually learning ways and means of meeting the problems so that man is, in fact, able to fly higher and faster all the time. And that's one of our main missions here."

With the centrifuge, Shepler related, they'd tested humans up to 15 positive Gs and animals up to 40 positive Gs, the machine's maximum capability. "We've used it quite a bit on testing equipment, and in the future we'll use it to"—he paused discreetly—"well, let's say to test various types of equipment that will be subjected to considerable strain in aircraft." I asked him if they could observe the test subject during a run, and he replied, "Well, we have a TV hookup whereby I can observe him right here or in various other places throughout the building." Actually, trained observers did that, he explained, and during a test run they guided the operator controlling the centrifuge. Color TV would probably be of some advantage in their work, Shepler thought, but there was the matter of cost. He said they had a very unique instrumenting system at the laboratory.

Through an arrangement of communication and pickups, medical data from the test subject were instantaneously recorded on a graph that passed right before the eyes of an observer in the control room. They could tell at a glance, for example, the rate of the test subject's heartbeat, its rhythm, and any evidence of strain. One instrument called an electroencephalogram traced the subject's brain waves, and they immediately knew the condition of his brain under stress. His rate of breathing, or respiration, was also recorded. Shepler, whose black hair is flecked with white, is normally a composed individual. When I asked him if there were any changes in the test subject's heartbeat during a run, his eyes twinkled. "I believe it slows down. Doesn't it, Howard?"

"Yes, it does," Hunter replied, grinning.

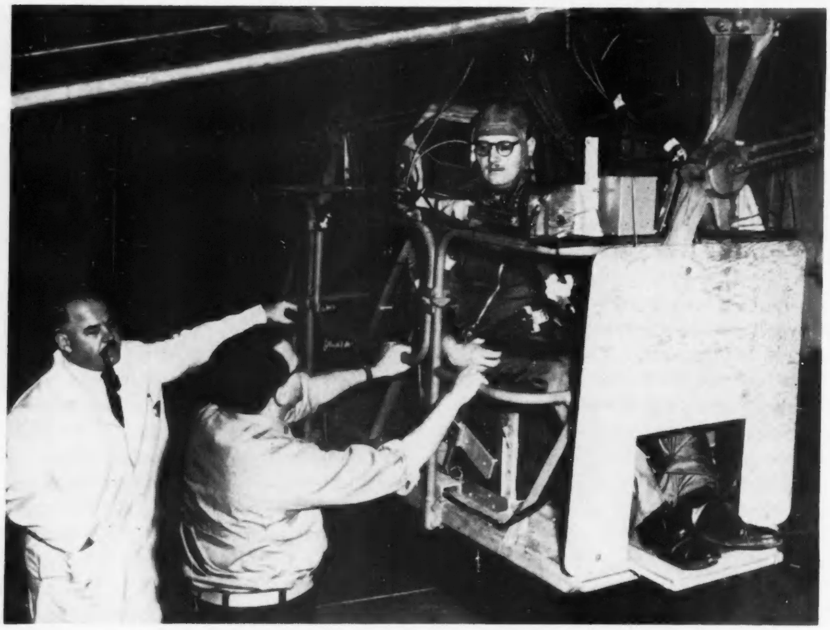
Shepler gestured in the direction of the control room and chuckled inaudibly: "I notice up there they almost stop breathing for a little while."

"It's a lie-detector type of reaction," Hunter explained.

An x-ray tube in the gondola, Shepler went on, gave them a lot of information about what happens to a person's various internal organs when he is under accelerative G stress. He told me that for all ordinary purposes a moderate G force had no side-effects on the test subject. "But it is conceivable that if an individual were to receive a large amount—for instance, if he were subject to something on the order of 20 Gs—he might get a certain damage to his blood vessels, to his muscles, or to his skeletal system," Shepler added quickly.

As he began to explain what happened during blackout, a thick-set man in a white laboratory coat entered the office through a private rear door. Shepler

INSTRUMENTED for ejection-seat test run, chief engineer Howard Hunter yanks protecting windscreen down in front of his face. This would simultaneously eject the seat from an aircraft. Changes in blood supply to head are detected by photoelectric instrument.



STRAPPED in free-swinging car suspended from centrifuge arm is Dr. David Lewis, whose positive G-tolerance is 4¾ Gs for 14 seconds—average for humans. Captain C. F. Gell (white coat), former director of Navy's acceleration laboratory, issues instructions prior to test run.

introduced him as Captain C. F. Gell, the laboratory's former director. "Dr. Gell has been here practically since they broke ground for this group," he said affectionately. An inveterate pipe smoker, Gell sports a precisely clipped mustache and speaks in a deep, friendly voice. Before becoming a doctor of medicine, I learned, he had been an electrical engineer with a midwest utility company for 12 years. A Naval aviator also, he was the first man to introduce the possibility that cosmic rays would hinder space flight.

Gell sat down informally at one end of the large desk and Shepler resumed his explanation of blackout: When accelerative forces are head-to-seat, or positive, blood is forced from the brain. If the brain's blood pressure falls below a certain amount, the retina of the eye becomes ischemic—lacking blood—because its small blood vessels are collapsed by the higher pressure fluids within the eye. "Look at it subjectively," Gell urged. "The retina of your eye has a lot of blood vessels all through it. Now, as positive G is applied, the first vessels affected are on the outer periphery, and as that occurs your peripheral vision becomes constricted—a phenomenon that we understand as grayout. When this condition becomes more prolonged, it results in the loss of central vision and blackout sets in. But you are not unconscious yet. You could ring a buzzer or something like that. Frequently we've even talked to a person blacked out—not for long, though. As the G force is increased, more blood leaves your brain and you become unconscious."

"In other words, they are steps in the same process—graying out, blacking out, and then unconsciousness," Shepler interjected.

Gell pushed his chair away from the desk and leaned back, taking long drafts on his pipe. Eventually, he said, they would have to go to the prone or supine seat to offset the high G forces in advanced aircraft. They'd never been able to black out anybody lying supine even at 15 Gs. It would probably be best to enclose such a supine seat in a single pod, along with other cockpit equipment. Then when the pilot had to ditch his plane, he would eject the pod as a complete unit. Shepler picked up the conversation: Of course, they would have to contrive some means to keep the pod from tumbling or whirling around in such a violent manner that it would injure the occupant. Some work

"G suits increased the average pilot's tolerance only 1½ to 2 Gs."

in tumbling apes through all axes of their bodies had been done with the human centrifuge.

"The extreme for chimps tumbled is less than 15 Gs at 20 rpm," Gell said resonantly. "Normally, a chimp can take 40 Gs lying supine. So you see, if an ape is in trouble when he's tumbled under 15 Gs, we're pessimistic about humans, because anthropologically an ape or chimpanzee is considered 2.5 times as rugged as man."

G suits increased the average pilot's tolerance only 1½ to 2 Gs. Pressure was applied across the abdomen and lower extremities to keep the blood from pooling there, the pressure coming on automatically as soon as the pilot began pulling Gs. Looked at in one way, G suits squeezed blood from the lower extremities to the upper portion of the body.

Gell proceeded to explain physiologically how G stress affects the cardiovascular system: "In the body you have arteries and veins that carry blood to and from the heart. Blood is pumped from the heart to the lungs, brain, liver, abdomen, and legs. The heart has to maintain this constant two-way flow. Now visualize that if you apply 7 Gs for any length of time to the fluid elements of the body, those elements assume the density of iron. You can see immediately that a terrific strain will be on the heart and blood vessels primarily due to the weight of the fluid. In ordinary circumstances the heart pumps blood to the brain only against one G. But all of a sudden the heart—say under 7 Gs—has to pump seven times the weight. The heart isn't built to compensate for this great strain. The whole thing is a massive cardiac insult."

Both Gell and Shepler agreed that the only effective way to offset accelerative force is to properly position the pilot. "Our viewpoint here," Gell said, "is that the future of high-speed, highly G-stressed aircraft lies in so positioning the pilot that he'll always be able to rotate his body to bring it at right angles to the applied accelerative stress." He shrugged. "Of course, the theory's not new."

"It may not be new," Shepler added quickly, "but through the work that's been done here, we come to the conclusion that it is the only sensible way."

By supinating pilot and passengers, Gell pointed out, spacecraft could go to the nether regions of space, follow the rim of the earth's atmospheric belt for 10,000 or 12,000 miles, and return to earth—all in a few hours. This was feasible, "maybe not tomorrow—but in the near future."

In speaking of Gs, there are two factors to consider: the force and the time it acts. You can, for example, jump off a two-foot-high table and sustain an accelerative force of 16 Gs. But then it acts for only a fraction of a second and isn't harmful. In fact, there are instances where people have fallen great heights, surviving impacts of 100 Gs. Only the skeletal structure is affected by accelerative or decelerative forces of short duration. Where the stress is prolonged, the body's circulatory system and organs are affected.

I asked Shepler if the human body could be conditioned to accommodate large positive-G forces. They were convinced, he replied, that with proper training and indoctrination an individual could probably somewhat increase his ability to withstand positive Gs. They had seen many examples of this at the laboratory. After a test subject became experienced and knew how to strain—tighten up his abdominal muscles—he could increase his G tolerance. "But give them 10 Gs and they're going to black out," he declared with finality. "I don't think we'll ever be able to train them so they won't. That's the way our work seems to point—here, now."

A mistlike drizzle enveloped the sprawling Naval Air Development Center the next morning. At a marine sentry station just off the Center's main road, Anthony Greco picked me up and we drove in his car to the laboratory. Today they would continue their series of tests on the psychologist Flannagan Gray, he told me on our way to the centrifuge chamber. Gray, helmeted and wearing the same green summer flying suit I'd seen him in the day before, was already settling into one of the free-swinging cars when we arrived. He greeted me politely. He would try to determine this morning how effective electric impulses were in contracting his muscles to protect against G forces, Flannagan told me distractedly. "The question is, can we do it?"

Greco motioned that the test was about to start, and I followed him up to the control room above the centrifuge chamber from which the tests were directed. A tubular railing ran along one side of the room; beyond it, light from the centrifuge chamber splayed upward through thick observation windows in the floor. Several people were making a final check on their instruments. Bent over a large, tablelike moving chart recorder, a blondish civilian named Paul Edwards, the instrumentation man, hastily adjusted a row of clacking pens.

Farther on down the room, a chief petty officer sat toggling the switch of a portable indicating device that controlled peripheral and central lights on the swinging car below. Taking a seat along the railing, Greco picked up a clipboard scheduling the morning's test, glanced at it, pushed the lever on a wooden teletalk box, and announced, "First run—2½ Gs!" Shortly, Gray's voice blared back, "The peripherals are not staying on!"

While they checked the circuit to find what was causing the trouble, I walked to the far end of the room to a circular depression in the floor surrounded by another guard railing. This was the control blister. It allowed no admittance. Completely glassed in, it projected downward into the chamber. The centrifuge operator, sitting at the elaborate custom-designed desk, watched the activity below. To one side of the desk were several large pressed-board cams, a foot or more in diameter, all having different profiles. With these the centrifuge could be automatically programmed to run through various cycles of acceleration and deceleration, simulating an aircraft out of control.

"Stand by to start the run," Greco directed huskily. It was 10 o'clock. Lights in the centrifuge chamber were extinguished. "Five-four-three-two-one—start!" A din like the sound of a thousand needles scratching on steel roared through the teletalk speaker as the centrifuge started up in the darkness. Then as it reached maximum acceleration, the noise subsided and it whirred around almost without a sound. In a few seconds it decelerated to a stop. Edwards, the instrumentation man, looked up from the moving chart recorder. "Gray looks like a 3-G man today," he said to no one in particular.

As Greco announced the next run would be 2¾ Gs, a tall heavy-set man with a thin mustache entered the room. He was Dr. David Lewis, Naval physician and supervisor of the tests. Looking

"Subject ready—3¼ Gs, 25 second cam. I'm a high-G man today!"

over Edwards' shoulder at the chart, he commented dryly, "Gray went to bed early last night."

Edwards introduced us, and Lewis affably proceeded to explain the wavering inked lines on the chart. He pointed out the beat of Gray's heart and his respiration as he whirled around. The OFF-ON blinking of peripheral lights was inked as a continuous series of rectangular pulses. When the test subject didn't respond to the lights, Lewis explained, it immediately showed up on the chart. In all their studies, he said, they'd not carried a subject to unconsciousness. "Gray has about as low a G tolerance as you'll find. The range for peripheral vision is about from 3 to 7 Gs—a mean of 5. Actually you have to specify G in time. I can go for 13 or 14 seconds at 4¾ G without losing the lights. That's, I guess, pretty close to average," he added thoughtfully.

Two runs later, Flannagan Gray still hadn't reached the limit of his G tolerance. His voice boomed merrily out of the teletalk speaker, "Subject ready—3¼ Gs, 25 second cam. I'm a high-G man today!"

"Right," Greco answered. "Stand by to start run. . . . "

The centrifuge roared again and whirred around silently. "That got him!" Edwards exclaimed. I looked at the chart. The series of rectangular pulses representing the blinking peripheral lights had trailed off to a straight line with only an occasional pulse. "See," Lewis said, pointing to the chart, "he lost the peripheral lights, but he can still detect the central light. Notice that as he loses G he regains his peripheral vision." Gray's voice came breathlessly over the teletalk, a little weaker than it had been. "That's the end of this series. I'd like to try another run and that's all."

"What level—10 G?" Greco inquired humorously, shaking in wonderment.

"Not quite," Gray answered. "Give it to me at 3½. I want to try it with my feet raised."

Edwards took time off from his recorder to explain that Gray wanted to see if he could increase his G tolerance by assuming a partially supinated position. At the end of the run Gray reported that he could. This position—with his feet at the same height as his head—was highly effective. He hadn't even approached blackout, he informed the group. "How high do you want to try it now?" Greco asked.

"Oh—," Gray said undecidedly, "make it 4 Gs this time." The centrifuge accelerated. Through the glass windows in the observation deck, I watched it glide swiftly past, the colored lights on Gray's car blinking like two aircraft beacons.

When the centrifuge stopped, Gray wiggled his toes. His voice crackled over the teletalk: "This is a really effective position. Those lights didn't dim at all. That's ¾ G above my tolerance!"

The tests were completed in 55 minutes. When Gray had extricated himself from the swinging car, I walked down to the control platform to see him. He was sitting on a white hospital cot, his crash helmet removed, and his flying suit stripped from his back. A Navy corpsman unraveled the bandage around his chest that held an electrocardiograph instrument in position. His face, ashen and puffy, reflected the strain of the tests. His movements were torpid. He greeted me wearily.

I asked him why he chose to act as the test subject. Enunciating slowly he said, "It's hard to get people to ride for this particular test. Then when you add electrical stimuli on top of it, it's almost impossible." The tests were not particularly tiring, he continued, although when he went unconscious, he felt a headache afterwards. "With electrical stimuli I get very fatigued. I get similarly fatigued when I strain—contract my stomach muscles. It's quite an energy requirement. Sometimes after a test I feel a little bit nauseous."

By the time Gray finished dressing, the torpor had almost disappeared and his reflexes were nearly normal. He is a tall fellow, lean and supple, with sandy hair. Slipping a white laboratory coat over his civilian clothes, he led me over to the observation window, and we looked out into the darkened centrifuge chamber. Light shafted downward from the control blister. The centrifuge again glided around softly, its colored lights blinking. "That's Dr. Lewis in the sled," Gray commented, putting on a pair of steel-rimmed glasses. He looked scholarly. They would like to find the effect of changing the centrifuge's radii to more closely simulate aircraft, he said. "We have this—this is our instrument." He gestured through the observation window. "Now how do we go about comparing it with an aircraft?"

With one elbow resting on the sill, Gray talked abstractly about the illusions a person experiences under accelerative forces. Subjected to moderate G, a person would see everything at a tilt. At high G, he would see everything lying on its side. Upright perception, Flannagan explained to me, is determined by the inner ear. Any pressure change on it distorts our sense of the vertical.

"Everything in your auditory field tilts. What you know is on the right side appears to be coming from below. A pilot could perceive a movement of his aircraft when actually there is none." He smiled, his blue eyes no longer bleary.

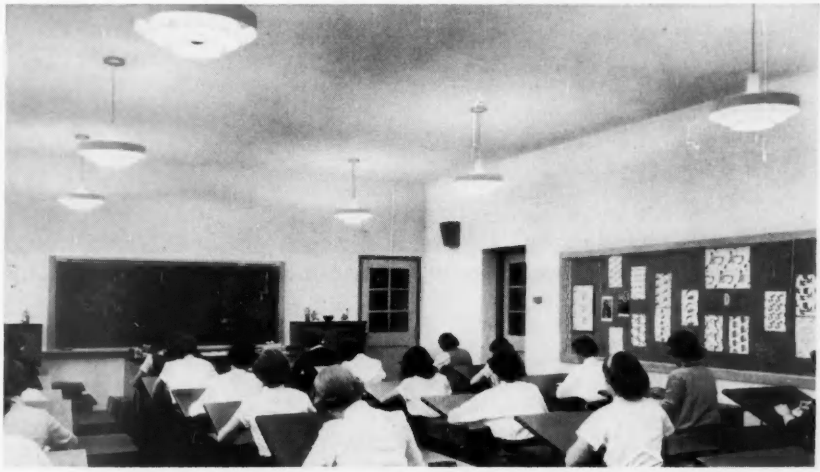
"It's pretty confusing. In the gondola, for example, you know you're sitting upright but you feel that it's tilting. You sometimes do the wrong thing. When you are riding upright, and the centrifuge begins to slow down, you sense that the gondola is falling—that you're rising above it. At the same time, you've tilted to accommodate the swing of the arm." They had some ideas why this happened, Gray went on, but nothing definite. When the centrifuge decelerates rapidly, a person riding in it feels as if he's going into a somersault. This was one of the things that often made people sick. It was also one of the differences between the centrifuge and an airplane.

Gray pointed out that, as applied, their work at the Aviation Medical Acceleration Laboratory was basically a form of human engineering. "A lot of it is just plain psychophysiology," he declared.

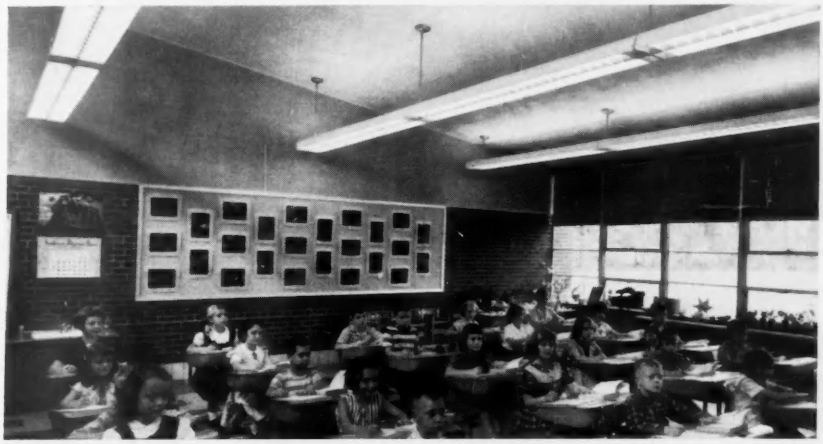
"For example, we study hand tremor and eye movement to get an idea of what forces are involved so that we can relate them to practical engineering applications—our ultimate aim. But we keep running into more and more problems. We want to do studies of gunnery systems exposed to accelerative force. Right now, however, we can't say what the effect will be. Humans are still in the picture, and they haven't been replaced yet. If they ever are"—he chuckled philosophically—"well, then, I don't know!" —JJR

Lighting for Learning

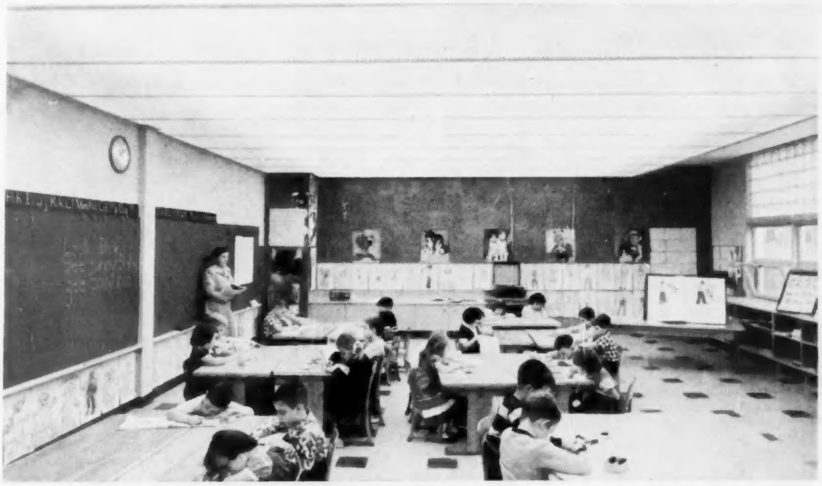
By CARL J. ALLEN



HIGH VISIBILITY IS OBTAINED WITH SILVERED-BOWL INDIRECT INCANDESCENT LIGHTING.



SHIELDED TWO-LAMP FLUORESCENT FIXTURES AID STUDENTS IN THEIR SEEING TASKS.



LUMINOUS PLASTICS CEILINGS INDICATE A TREND TOWARD COMPLETELY BUILT-IN LIGHTING.

Five years from now our schools expect an increase of 10-million students. To properly teach and house them, as well as the 38-million students now in schools and colleges, will require a tremendous school-building program. Needed facilities will exceed 700,000 classrooms at an estimated construction cost of $26 billion. Currently, new classrooms are being built at about one half this rate.

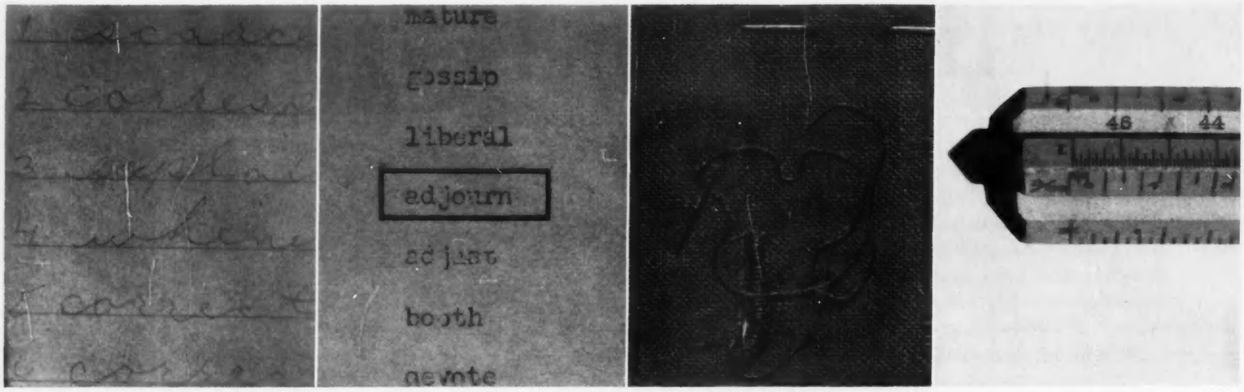
With such an unprecedented tidal wave of students engulfing the school system, maximum utilization must be made of all existing school facilities. This burden can be eased by improving the efficiency of the educational process with the aid of good lighting.

Good school lighting makes seeing easier, creates more lasting visual impressions, and develops an atmosphere of well-being and co-operativeness. Teachers report that after lighting conditions have been improved teaching is easier; the students learn more readily, have more enthusiasm, and cause fewer disciplinary problems. No other service built into the school building contributes as much to effective education at such low cost as good lighting.

Good quality school-lighting cost represents less than one percent of education's cost. Based on a national average, it costs about $45 to operate a 30-student classroom for a school day. Amortizing and operating a modern lighting system in that same classroom costs only about 30 cents a day. The difference between a poor school-lighting installation and a good one that produces better-than-minimum standards represents about one-half percent of education's cost.

The Seeing Problem

Many people experience their most difficult seeing problems in school. A modern education involves reading a mountain of books, plus a large amount of other close visual work. The books that a student will be required to study from kindergarten through high school would make a pile 17 feet high. A study of the visibility of their typography disclosed that, except for minor improvements, they were as well printed as could be expected.



SOME SEEING TASKS ENCOUNTERED IN SCHOOL CAN BE CORRECTED, BUT PROPER LIGHTING WOULD IMPROVE VISIBILITY OF ALL.

STUDENTS WITH VISION DEFECTS REQUIRE 100 FOOTCANDLES OF LIGHT ON THEIR DESKS.

Although book reading represents the bulk of students' close visual work that requires good lighting, it doesn't represent the most difficult seeing tasks encountered. Four school tasks (photos above) were measured and each had a visibility equivalent to three- to five-point Bodoni Book type. (The REVIEW is printed in 10 pt Bodoni Book.) Three-point printing type is about as small as anyone can normally read. Even five-point type is only one half the size of the smallest type generally used in high school textbooks.

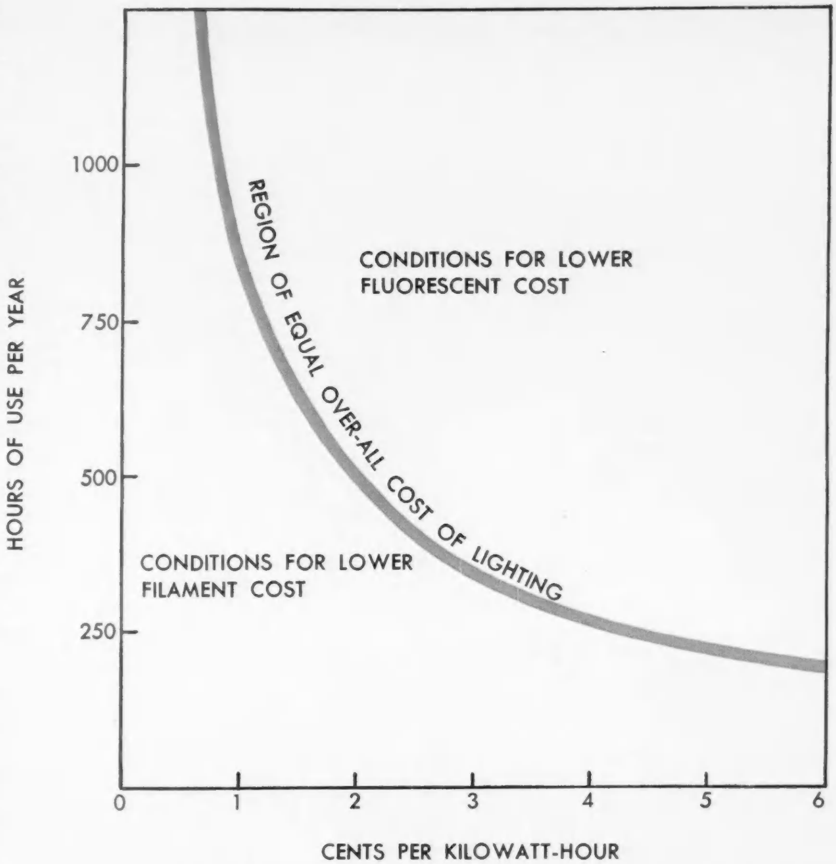
Some tasks can be improved. The penciled spelling list, for example, could be written heavier with a softer pencil. Faulty reproduction caused the poor stencil-duplicated spelling list; a well-reproduced stencil has a visibility of 11-point type, equivalent to that of good high school textbook printing. The buttonhole and architect's scale illustrate the difficult seeing tasks encountered by boys in the high school drafting room and girls in the sewing room. The equivalent visibility of each paralleled that of three-point Bodoni Book type.

Because these tasks are fixed, their visibility improvement can be made only by increasing the illumination. For this reason it is not uncommon to find more than 100 footcandles in specialized classrooms devoted to such difficult seeing activities as drafting or sewing.

Incredible as it seems, the majority of our schools are still lighted with enclosing globes that contain lamp wattages capable of producing about five footcandles on the desks. If higher wattage lamps are used to produce 20 or 30 footcandles—the present minimum recommendations for typical classrooms—the globes become uncomfortably bright.

But the desired rating can be attained by using either incandescent or fluorescent lighting equipment that shields the lamps from view and provides uniform illumination without glare. In classrooms devoted to more critical seeing tasks—drafting, sewing, or typing—the minimum level according to the American Standard Practice For School Lighting is 50 footcandles. But even higher levels are often used. Many school boards plan for future needs by providing higher-than-minimum standards; experience has shown that the lighting system installed today will probably be unchanged 25 years hence. More light is used as lamps become more efficient and costs decrease.

Numerous surveys have been conducted on the visual deficiencies found among school students. In New York State the record among 83,000 students shows a 5 percent deficiency at kindergarten level. These defects increased as students progressed through the school grades, reaching 32 percent among high school seniors. Undoubtedly many factors contributed: inadequate illumination, poor reading habits at school and home, difficult visual tasks, and close seeing for long periods. Nutritional deficiencies and bodily growth characteristics are other possible factors. The surveys have proved that you must light a room not for the needs of a normal-vision child but for the child whose eyes are below normal.



COST ANALYSIS of incandescent versus fluorescent lighting is based on such factors as burning hours, initial cost, climatic conditions, and age of building.

Incandescent vs Fluorescent

To a considerable extent, recent improvements in school lighting can be attributed to the high efficiency of the fluorescent lamp. But incandescent lamps—both the inside-frosted and silvered-bowl types in suitable reflectors—are also widely used. You can see equally well and comfortably under either incandescent or fluorescent lighting, provided the amount of light (footcandles) and its quality (diffusion, distribution, and brightness balance) are equal. The choice between the two sources is primarily one of economics (illustration): long burning hours per year and high current costs favor the fluorescent lamp; short burning hours per year and low current costs favor the incandescent lamp. Heat from the necessary wattages generally limits incandescent lighting to about 35 footcandles or less.

School-lighting Systems

Both direct and indirect fluorescent lighting systems are being successfully used for classroom lighting. Generally, incandescent lighting systems are indirect or luminous indirect. Many new schools use the silvered-bowl indirect type for its excellent quality lighting and low initial cost (photo, top, page 15). Louvered-bottom fluorescent fixtures (photo, center, page 15) represent a practical compromise between the high quality of indirect lighting and the higher utilization of direct lighting with good maintenance. Shielding all fluorescent lamps from view reduces distraction, annoyance, and visual discomfort caused by overbright fixtures.

Luminous ceiling lighting—newest concept in comfortable lighting systems —produces a friendly, pleasant atmosphere (photo, lower, page 15). The excellent quality of the fluorescent lighting, combined with the natural daylight that filters through the ceiling fixtures, contributes to the soft luminosity. This modern classroom demonstrates the great progress in electric lighting since the days of the McGuffey schoolroom and the kerosene lamp.

Lighting Specialized Areas

In the several school areas where specialized seeing problems are encountered, lighting must be designed around specific requirements. This may include high-level high-quality lighting, such as in classrooms for the visually handicapped; low-level illumination to create atmosphere at dance functions held in the high school recreation room; or special fixtures for spotlighting exhibit areas (photo, top, next page).

Lighting schools serves no more humanitarian purpose than in classrooms devoted to students with impaired

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School lighting specialist for General Electric's Lamp Division, Nela Park, Cleveland. Mr. Allen has been with the Company since 1936. Among his many publications that have received wide distribution are "Visibility of School Task," "Making the Most of Your School Dollar," and "Classroom Lighting Techniques."

SPECIAL LIGHTING EFFECTS—IDEAL FOR ILLUMINATING EXHIBIT ROOMS—CAN BE OBTAINED BY USING SEMIRECESSED ADJUSTABLE SPOTLAMPS.

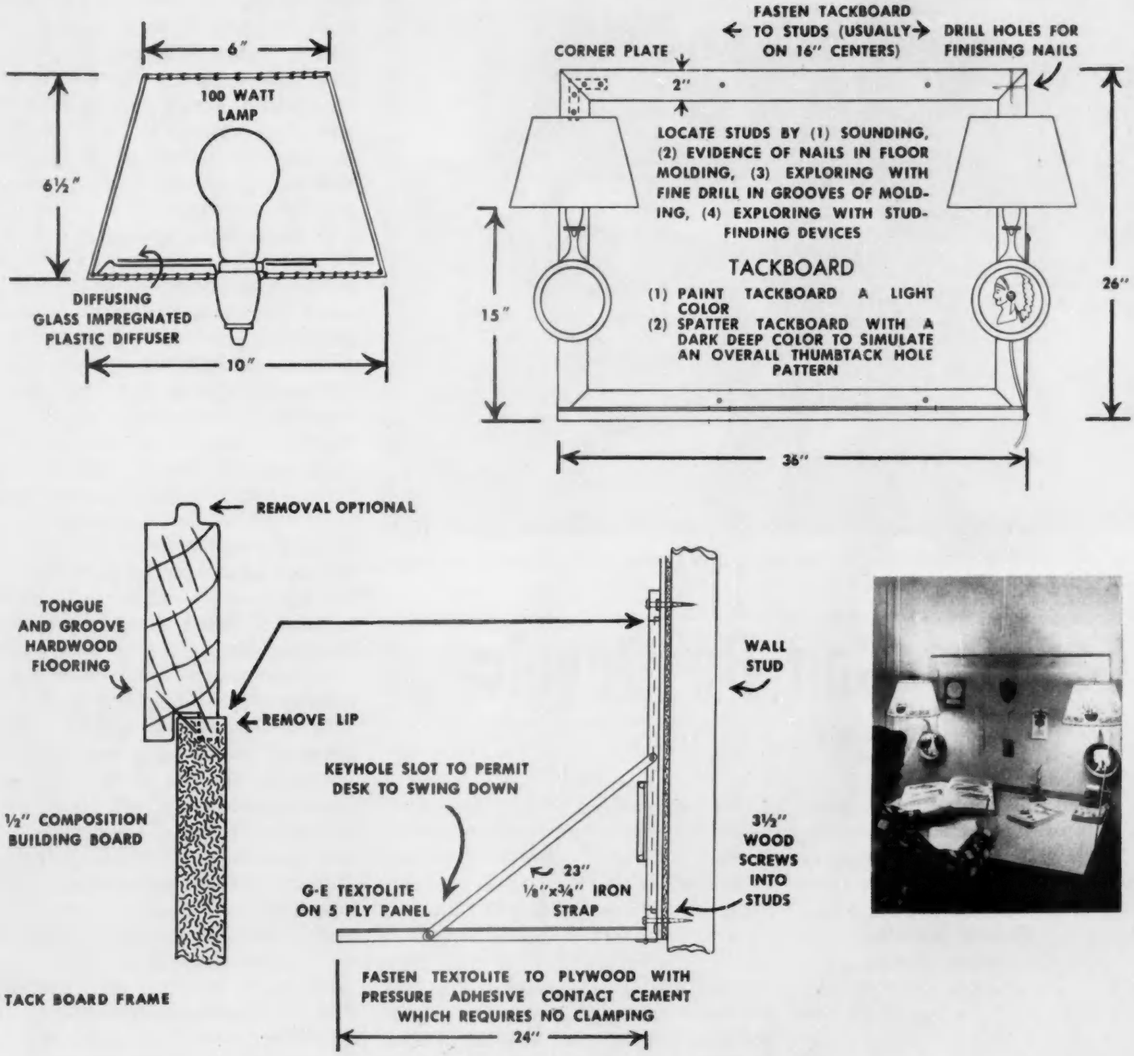

SOFT, DRAMATIC DIMMER-CONTROLLED LIGHTING IN SCHOOL LOUNGE CREATES PLEASING EFFECT FOR STUDENT AND COMMUNITY ACTIVITIES.

vision or hearing. In both areas the goal is to obtain as much light as can be produced economically and still maintain a visually comfortable condition. Without a good lighting level, special jumbo-size chalk, books, and typewriters used by visually handicapped children are ineffective measures. One special classroom for pupils with defective vision provides more than 100 footcandles of illumination on each of the students' desks (photo, lower, page 16). Fortunately, those who need lighting most receive the most help from it.

The high level of lighting widely used in school gymnasiums is as beneficial to the spectators of high school basketball games as to the participants. In this area, good lighting pays for itself through increased gate receipts. And seeing is made faster and surer for the players as illumination levels are increased to 50 footcandles by fluorescent equipment in the gymnasium. Long burning hours from all-day use by the students and evening use by the community make fluorescent lighting more economical than incandescent lighting. The lower brightness of fluorescent lamps also considerably reduces glare, helpful in playing aerial sports such as basketball, volleyball, and badminton.

Many students—even in the lower grades—are now increasingly engaged in dramatic work as their principal extracurricular activity. Usually a multipurpose room accommodates such activities. Stage lighting must be simple to

SCHOOL LIGHTING BEGINS AT HOME—DO IT YOURSELF

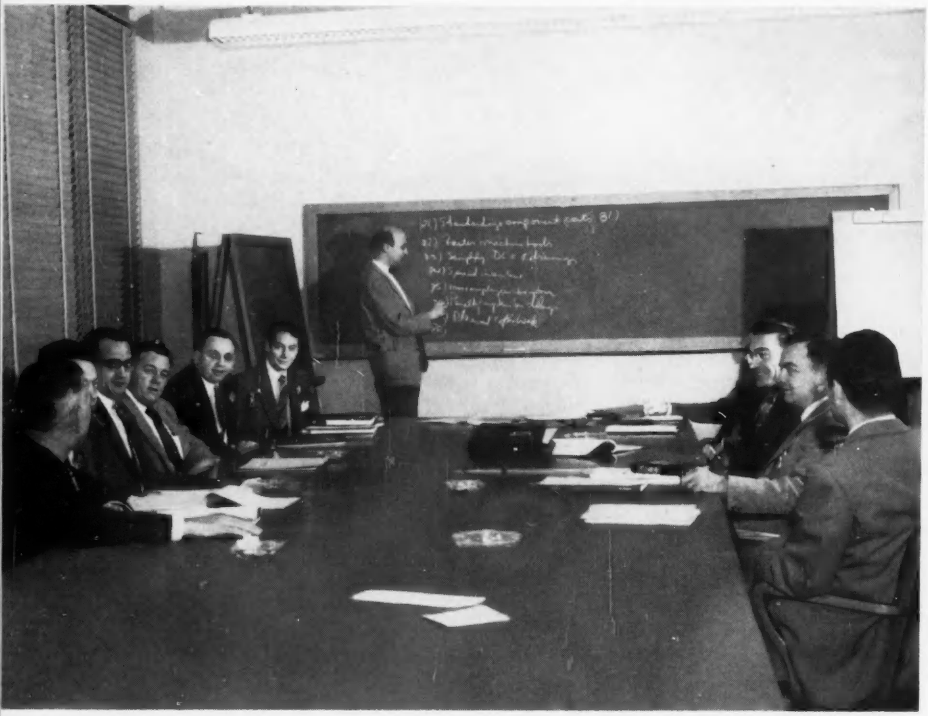


operate and inexpensive. Three groups of spotlights strategically located meet these requirements. A similar arrangement also has many applications in meeting rooms and auditoriums in churches, hotels, and industrial headquarters.

Today's schools teach more than yesterday's three R's. Hardly recognizable as classrooms, some of our modern school rooms can be called classrooms in social living (photo, lower, opposite page). This one in particular—the recreation room in a new high school—serves both the community and the student body. Silvered-bowl lamps in large recessed coffers of contemporary design light the room. And dimmers control the lighting. In this way the room's illumination meets the mood of the occasion.

Lighting for Home Study

Schools are part of your property. If your children go to school, it is part of your home. As a parent, your responsibility lies in promoting proper study habits in the home. And the best place to start is to provide a well-lighted area. Quite possibly you may have the space and the talent to build a wall study desk for your child. As an aid in its construction, you might choose to follow the plan on this page. Certainly a place all his own, where a child is free to study without interruptions and in pleasant surroundings under good lighting, will encourage his own desire to study. Ω



DURING A BRAINSTORM SESSION, 50 TO 150 IDEAS CAN ORIGINATE IN 10 TO 30 MINUTES.

Creativity Can Be Developed

By C. F. HIX and D. L. PURDY

The notion that only a few extraordinary individuals possess creative ability still lingers in contemporary thought. Some believe that an unknown power caused such men as da Vinci, Michelangelo, Bacon, Faraday, and Edison to produce their ideas rapidly and fluently. The feeling that creativity is necessary only to inventors, researchers, and designers minimizes its importance in such fields as engineering analysis. Although creativity is subject to illusive interpretations, in the past 30 years creativity has been recognized as an asset to everyone in all fields of endeavor.

Essentially, all work requiring conscious thought consists of a continuous series of problems or unanswered questions. Men thought to be creative in the past recognized unusual problems and originally and uniquely solved them. However, anyone who solves any problem is being creative to some degree, if he is unaware of the existing solution.

The study of acknowledged creative-problem solutions revealed that all problems are solved in a logical, chronological sequence that we shall call the creative approach. We believe that everyone has a certain innate creative ability that can be developed by teaching a procedural problem approach together with useful techniques for cultivating the imagination. The problem approach not only increases a man's ability to arrive at a unique and original solution but also clarifies his thinking when faced with an unsolved problem. Regardless of where the problem lies—marketing, engineering, product development, research, manufacturing, or human relations—this approach is useful.

To present these concepts to engineers in General Electric's operating departments, the Engineering Education and Training Section developed the Creative Approach Seminar—a two-hour-per-week group discussion lasting 16 weeks. A man's creative techniques and attitudes are greatly strengthened in these sessions because of the conscious thought given to the chronological problem approach.

Our trained thought processes, begun in childhood, make us unconsciously evaluate and judge most actions that we undertake. Practically all formalized education, including physics, mathematics, and logic, teaches us to tread toward our goal on a careful path surrounded by criticism. Our inhibitions burden so many of us that we immediately reject the mere suggestion of an untried idea, letting irrelevant facts or fears blind us. Participants in the Creative Approach Seminar learn to leave the judicial and critical portions of their thinking behind and to work creatively and uninhibited toward a problem's solution. The Seminar leader allows no negative comment in the initial problem-solving stages—the sky is the limit. After some participation in Seminar sessions, plus 8 to 15 hours of outside study every week, a marked improvement can be seen in the group's ability to get to the core of the problem. Soon the class originates and develops unique forward-looking answers to difficult problems.

The participants study many tested techniques that increase the flow of problem-solving ideas. By the end of the Seminar, a class member easily completes at least 20 ideas on a typical design problem. The group learns to use team techniques—a brainstorm session (photo)—where 50 to 150 ideas can be originated in 10 to 30 minutes.

In a recent problem submitted by the Small Appliance Division, a quick method was needed to join two electric conductors together. A brainstorm session on this problem collected 175 ideas in less than 30 minutes. The class members learn how to cultivate inspiration and illumination and how to utilize these phenomena more effectively. Modification techniques show how existing solutions to related problems can be adapted or used as step-off points toward other solutions.

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Mr. Hix joined GE in 1949 and completed the Test Course and Creative Engineering Program. Presently Program Supervisor, Creative Engineering Program, Engineering Services, Schenectady, he is responsible for all the Company's first year engineering education courses. With GE since 1951, Mr. Purdy completed the Test Course and is in his second year of the Creative Engineering Program. He supervised the Creative Approach Seminar for Specialized Technical Courses. He presently is in the Atomic Power Equipment Dept., Schenectady.

A Problem Approach

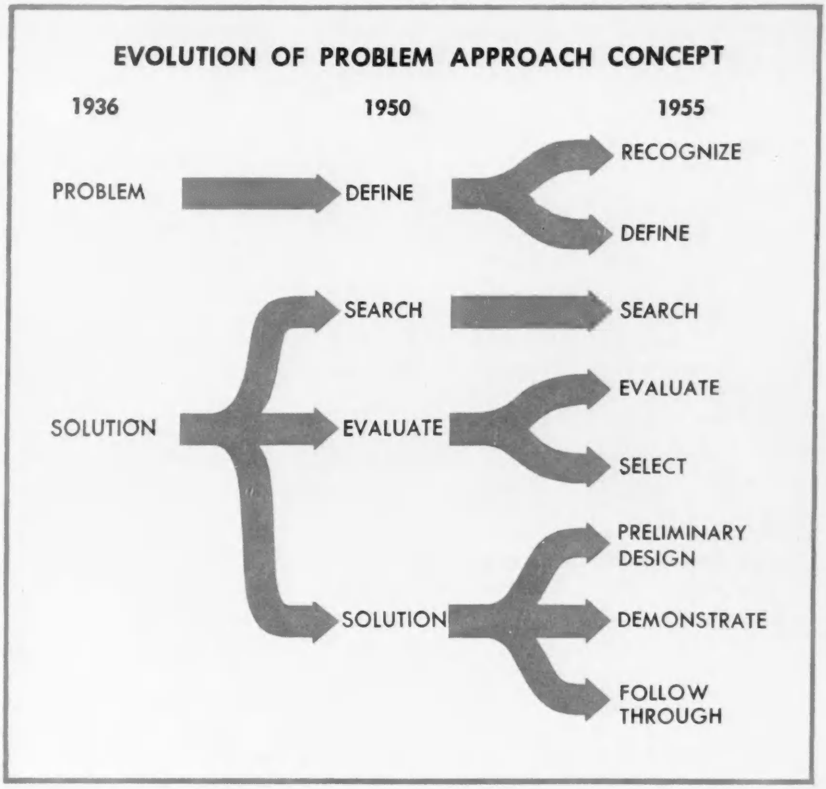
An engineer's responsibility lies not only in accumulating unique ideas but also in organizing and controlling his work in an orderly and efficient manner. Many engineers tend to accept the first thought that comes to mind rather than to carefully define the problem and search for a variety of solutions. For example, a situation existed in a plant producing small, individual items, each separately packed and boxed by hand—an expensive operation. Because the situation was ideally suited to automation, an automatic machine using a novel one-piece insert was designed and built.

One packaging specification stated that the container must satisfy the customer who purchased the items. A check of the marketing organization produced a list of customers comprised of two major types: over-the-counter customers and manufacturers of motorized machinery. When polled, the first group expressed satisfaction with the new package, stating that at least it was not inferior to the old one. To the surprise of everyone, however, the machinery manufacturers were adamant against any individual package. Unpacking each item before they could install it in their product wasted time.

Checking the product distribution showed that 90 percent of the sales were made to the manufacturers. Thus the real problem was not packaging the items individually but packaging them in bulk. The eventual solution utilized a simple pallet type of loading that eliminated the major packing cost. A more careful initial investigation and definition of this problem would have avoided considerable misdirected expense and effort.

The Creative Engineering Program has evolved a system that assists in all problem-solving situations (illustration). When the Program began in 1936, two areas in every question were obvious: the problem and the solution. This developed into the four-step approach, widely publicized from 1950 to 1953 (July 1953 Review, page 55). When the four-step approach was applied to the more technical type of problem, certain areas proved to be weak or lacking, and so a more refined type of approach evolved.

If the experienced engineer analyzes his own problem-solving procedure, he will find that he automatically follows the steps discussed in the Creative Approach Seminar. However, few of us carefully analyze the segments of our thinking, although to do so would greatly improve our own attack on a problem. Often we neglect or are weak in certain areas of our personal approach.



A practical case history of this problem approach can be followed in the early development of an infinitely variable heat control for the General Electric range, as done by the engineers on the Creative Engineering Program . . .

Step 1: Recognize—Although electric range manufacturers have found that five specific heats are sufficient to perform all surface cooking operations satisfactorily, a need has been expressed for in-between heats to compensate for differences in heat transfer that result from the type, quality, and condition of cooking utensils. It is generally the feeling that the consumer will not pay a premium for this additional flexibility, and the problem, therefore, is to develop a low-cost infinite heat control for the surface units of an electric range.

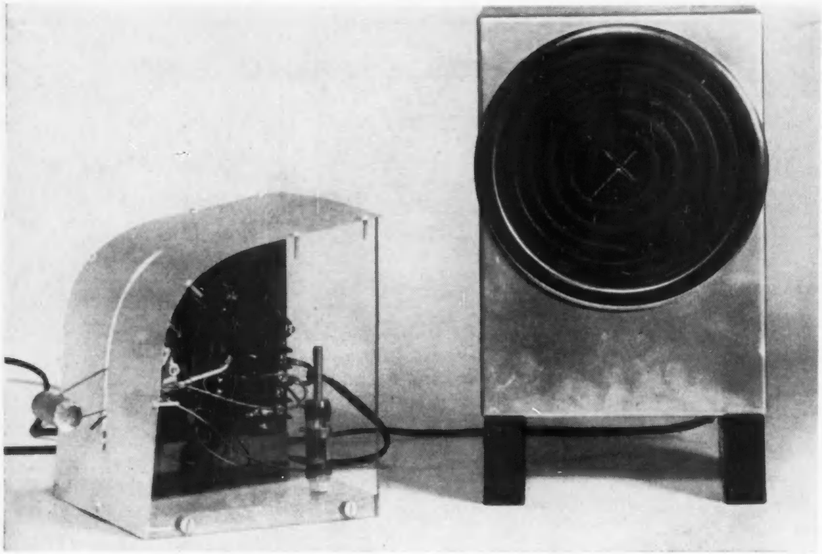
Step 2: Define—The engineers considered the purpose of the device, the necessary functions, and approaches for providing an infinitely controllable supply of heat. A word definition would be: "A new low-cost control for the electric range is desired to promote the ease of cooking and sales appeal." Specifications were . . .

- Infinitely variable control of heat
- Retention of console theme and control-panel design
- Easily cleaned control panel
- Long life
- Reliability
- Low cost ($1.50 per control)
- No radio interference
- Fast heating
- No-burning feature desirable.

The investigation that followed added to the understanding of heat transfer, consumer expectation of a range, required heat magnitudes, and the like.

Step 3: Search for Methods—To find a method that would meet the specifications arrived at in Step 2, the engineers applied creative techniques for making a number of possible suggestions to solve their problems. Of the 65 ideas suggested in the report, a few of the categories and some of their resulting ideas follow . . .

1) Mechanical On-Off heat controls
    - Common cycling methods
        - Motor driven
        - Solenoid driven
    - Constant- or variable-frequency oscillators



CREATIVE APPROACH TECHNIQUES enabled engineers to solve the problem of developing an infinitely variable heat control for the heating unit of an electric range.

Thermal bellows
Time-delay relays
Electrostatic clutch
Thermistors
Bimetal oscillators
Vibrating or resonant devices
Escapement devices
Variable damped resonators

2) Electrical methods of heat control
Potentiometer spanning small increments
Autotransformers
Variable core reactors
Gas-tube saw-tooth generators
Rectifiers
Induction heating

3) Other methods of heat control
Vary losses from heating unit
Vary mass of heating unit

4) Types of actuation
Turn a dial
Move a slider
Press kinky tube
Press hydraulic tube

STEP 4: EVALUATE—A long list of thoughts and ideas has little value unless it can be turned into a useful concept for a final product. Thus a constructive evaluation of the ideas was made. Analytical and empirical methods were used in determining the feasibility of operation of the suggested ideas, and much creative thought was needed to properly combine and integrate the good ideas into worthwhile proposals. Seldom of value by itself, one idea must combine with many to make one composite practical suggestion. In this problem, the engineers, through a series of combinations and recombinations, arrived at six theoretically practical proposals.

STEP 5: SELECT—The selection of the basic idea to be developed later was made by comparing the six proposals of Step 4 with each other, thereby establishing a reference for judgment. The selected idea—a bimetal reed that alternately applied and removed electric power to the heating element—resulted from combining three of the ideas in the Search-for-Methods phase. The reed completed the power circuit at both ends of its oscillation, the total power being varied by changing the reed's length of travel, thereby varying the proportion of on time to off time. The resultant control (photo) was infinitely variable and independent of line voltage and ambient temperature.

STEP 6: PRELIMINARY DESIGN—A prototype was constructed, tested, and redesigned to provide low cost and ease of manufacture. From a sketch of a manufacturing floor plan, the cost appeared to be 38¢ on an annual production of 25,000 units—considerably less than the goal of $1.50.

STEP 7: DEMONSTRATE—After seeing results and model, engineers in the range development section of the Company's Range and Water Heater Department, Major Appliance Division, Appliance Park, Louisville, Ky., were immediately attracted by the low-cost solution to this old problem achieved through application of the creative approach.

STEP 8: FOLLOW THROUGH—Additional work by the engineers at the Range and Water Heater Department has demonstrated the feasibility of the solution that is currently undergoing refinement.

Although this example was a relatively long development problem, the Problem Approach can be applied equally well to short problems in every field—from mathematics to appearance design. For its application to another typical problem, see the Box. All the steps of an over-all approach to a lengthy problem constitute a succession of smaller problems—also solved by the problem approach. Thus the Creative Approach Seminar demonstrates creative techniques and how to plan and organize your thoughts and actions—a guide through uncertainty and indecision. By following an organized approach in any problem, an engineer not only eliminates wasted time spent in disorganized thoughts but also plans and schedules time efficiently. Steps of the problem approach serve as concrete chronological objectives.

Content of Seminar

The Seminar's simple and direct objective—to increase the problem-solving ability of the engineer in his everyday work—can be accomplished by homework and class participation.

HOMEWORK ASSIGNMENTS—Of utmost importance, the homework design problems give the engineer the opportunity of attacking current problems with class techniques and serve as fuel for class discussions. The source of the problem may be any one of the Company's operating departments.

One problem used in the Seminar is the design of a constant temperature device for use in a process-control instrument that must meet rigid temperature-control specifications. Another problem is to originate a new means of deactivating the start windings of a single-phase motor to replace the presently effective but cumbersome and difficult-to-adjust centrifugal switch mechanism. The solutions presented by class members are often incorporated in a product. The interchange of problems from department to department provides a fresh outlook and long-range improvements.

In addition to the design problem, each class member weekly submits an idea for creating a new product or for solving a current problem. In this way the engineer gains experience in recognizing areas of possible improvement in the respective departments and in providing new outlets for development and expansion. Further, it stimulates the student and encourages an open-minded alert attitude. At the end of the Seminar, the ideas are published and distributed to interested departments, thus providing recognition to the participants, as well as a source of new ideas for the Company. The results indicate that this system has noticeably increased the individual's awareness and his desire to improve his department and product, at the same time strengthening his ability to recognize new needs.

Class discussions on assigned literature are valuable. The texts used for the Seminar come from many sources. Some articles are supplied by Company authors or by experienced engineers outside the Company.

Class Discussions—These two-hour weekly sessions draw out every participant. Often the class leader briefly introduces the subject, or an expert in a particular field begins the meeting with a lecture. The class leader then guides the participants toward a more effective problem-solving technique. This active participation challenges each man to think of his own shortcomings, clearly pointing the way toward developing his latent talents. Such topics as specific development methods, value analysis, design and idea problems, creative techniques, and idea stimulators are discussed, forming the backbone of the Seminar topics.

By promoting an atmosphere of open-mindedness, accomplishment, and confidence in one's own creative ability, the Seminar introduces a new concept in engineering work and its co-ordination. The problem approach fosters the ability to plan for the unknown and to meet schedules. Using these principles to manage an engineering organization raises level of performance, resulting in better design quality, new products, and improved existing products.

The broad concepts and understanding gained by the engineers reduces irritation by simplifying liaison problems between manufacturing and engineering and by assisting the engineer in adapting himself to the problems of his associates. Probably most important, the Seminar encourages each class member to originate constructive forward-looking ideas that result in increased satisfaction and greater contribution to his work. The Creative Approach Seminar both enlivens and adds impetus to any department. Ω

TYPICAL PROBLEM SOLUTION USING A CREATIVE APPROACH

STEP 1—RECOGNIZE

Because thrust in a jet engine is a function of mass fuel flow, the Air Force needed a device to measure the mass rate of flow to the engine. At that time the meters used were unsuitable, because compensation had to be made for errors caused by density and viscosity changes of the fluids.

STEP 2—DEFINE

General Electric and the Air Force jointly prepared such specifications as . . .

Flow measurement on a mass basis independent of fluid density and viscosity
Low pressure loss
Small size and weight
Linear response
High accuracy
No temperature error
No vibration error
Long life (2000 hours minimum)
Pass salt-spray test
Be independent of fuel used.

STEP 3—SEARCH

A few of the numerous ideas considered included . . .

Coriolis principle
Variable area nozzle
Flettner principle
Restrained propeller
Rotating propeller
Angular change of momentum.

STEP 4—EVALUATE

The practical and theoretical soundness of these principles was carefully investigated. Mathematical derivations helped to calculate required size, pressure loss, and relationships of output signal. A sample based on the Coriolis principle proved practical, although rather large.

STEP 5—SELECT

The ideas developed to the point of practicality in Step 4 were compared with each other to decide on the one most nearly meeting the specifications. The small-sized angular momentum change device appeared most promising and was selected for its low pressure drop and its promise to give a linear output with input mass rate of flow.

STEP 6—PRELIMINARY DESIGN

A carefully constructed prototype sample based on mathematical calculations arrived at in Step 4 was tested, modified slightly, and retested. It completely fulfilled the rigid Air Force specifications.

STEP 7—DEMONSTRATE

The prototype sample, proved to the engineers' satisfaction, was demonstrated to the Air Force and accepted for production design and manufacture.

STEP 8—FOLLOW THROUGH

Although the engineers had completed their job of fundamental theory and design, they followed the design through its manufacturing and production stages—probably a never-ending phase.

CARD PROGRAMMED CALCULATOR FREES DESIGN ENGINEERS FOR INTENSIFIED CREATIVE EFFORT.

How Digital Computers Aid Transformer Designers

By S. B. WILLIAMS, DR. P. A. ABETTI, and E. F. MAGNUSSON

Consumption of electric energy in America continues to grow at an astonishing rate, doubling every 10 years (Sept. 1953 REVIEW, page 8). To keep abreast of this growth, by 1965 the electrical industry must produce an amount of transformer kilovolt-amperes equivalent to that installed since 1900.

The transformers needed to do this job will be far more complex than those of the past because of the increasing number of power-system interconnections (Nov. 1953 REVIEW, page 28). Multiwinding transformers, autotransformers, and regulating transformers, for example, are increasing proportionately with interconnections. Thus the transformer designer, whose problems are far from simple to begin with, must resort to longer and more exacting calculations. These he must carry out to satisfy industries' standards while meeting the individual specifications of each transformer.

High-speed Computer Needed

Most large power transformers are custom-designed and custom-built. Meeting specifications and insuring absolute reliability require considerable engineering attention. And so a large percentage of the design engineer's time and energy is devoted to calculating the electrical, mechanical, and thermal characteristics of a transformer.

Late in 1952, GE's power-transformer engineers posed the question: Could high-speed digital computers so effectively used in the aircraft industry assist them more efficiently than slide rules or desk calculators? To find the answer, they undertook a project early the following year in co-operation with the Company's analytical engineers, studying ways that a computer could help. Both analog and digital computers were evaluated. But because transformer design consists of sequels of arithmetical operations—adding, subtracting, multiplying, and dividing—plus the use of transcendentals—logarithms, exponentials, and hyperbolic and trigonometric functions—the digital computer seemed ideally suited for the job. What's more, many design variables—such as the numbers of disc-shaped coils and spacers that separate the coils—take only integer values; only a digital machine could cope with this.

Starting in June of 1953, proposition designs for transformer purchasers were obtained by using digital computers. Then in January, 1954, the Company's power-transformer engineers installed a Card Programmed Calculator (CPC) in their own department (photo).

Timesaver

The series of instructions for a computer is called a program. For a CPC, these instructions are punched onto cards that are automatically read and interpreted by the computer. Although it can follow instructions, a computer is still a machine and it can't originate ideas or solve mathematical equations in the true sense of the word. Its value depends entirely on the ingenuity and engineering experience of the people who prepare the calculation program. But once the programs are prepared, the computer performs the long and tedious calculations rapidly. Thus the engineer who formerly did these calculations manually is freed for a truly creative effort. Instead of having to keep track of decimal points and filling page after page with penciled numbers, he can concentrate on ways to improve the transformer design.

How then does a digital computer like the CPC, or punched card calculator as it is sometimes called, assist in designing power transformers? Transformer engineers study the physical behavior of materials with statistical techniques. The successful use of these techniques requires long arithmetical calculations with a high degree of accuracy. Audio noise, core loss, and dielectric breakdown are only a few of the phenomena now receiving considerable attention.

One statistical analysis that previously required over a million arithmetical operations on numbers ranging from 4 to 10 digits now needs only one tenth the operations with CPC techniques. Thus designers get an answer in five hours that would have taken them six weeks by older methods. A one-digit error, incidentally, would easily destroy the significance of the whole experiment. Manually avoiding such errors is almost impossible.

These improved calculating methods greatly reduce time lag between performance of experiments by laboratories on the one hand and analysis of data by design engineers on the other. Efficiency of the laboratory-designer team is greatly improved. For the data's significance is known shortly after the conclusion of measurements substantiating their validity. And the engineer can place a high level of confidence in the results.

Another major way that digital computers aid the power-transformer designer is in analyzing basic design problems, some in the form of calculations of circuit voltages, currents, and impedances. Manually calculating these quantities could take weeks, and only then are the operating and fault characteristics of the apparatus fully known.

Take, for example, a complicated regulating transformer that was recently developed with a combination of in-phase and quadrature windings. (Quadrature voltage lags in-phase voltage by 90 degrees.) Because there were 17 in-phase tap, or winding ratio, positions and 33 quadrature tap positions, 561 different terminal voltages and phase angles had to be calculated. Also, during short-circuit conditions there was the possibility that voltages across transformer windings or portions of them could exceed steady-state voltages several times. To predict the tap connection at which maximum winding voltages would occur and to co-ordinate the insulation structure required over 2200 complicated circuit calculations. An engineer using a slide rule would ordinarily need five weeks for such a project. With CPC he did it in 10 hours without a single error.

No Problem Too Complex

When lightning strikes one winding of a transformer, the high-voltage surge is electromagnetically induced in other windings. Calculating its electrostatic and electromagnetic components in the nonimpulsed windings requires the use of involved mathematical formulas. (This is especially true of multiwinding transformers.) Many such calculations are carried out with CPC. Information is obtained not only for designing the transformer's internal insulation structure but also for recommending adequate protective measures to the customer.

Insulation structure plays a large role in a power transformer's success (March 1954 REVIEW, page 23). And engineers continually analyze the various electric field configurations it will be subject to. In most instances, the shape of electrodes—the beginning and terminal points of the field—are far different from those shown in textbooks. Additionally, the presence of two or more dielectrics within the field complicates the analysis even more.

Consider, for example, the electric field between a plane electrode and a sharp-edged clamp. You can determine the direction of its flux lines by means of a certain mathematical transformation. But the formula for inverting back to the original quantities contains an integral in the complex plane that must be integrated numerically. (A complex integral contains real and imaginary values.) Four numerical equations are contained in each complex integral, and so four tedious numerical integrations are needed to determine a single point of the electric field. To cover all field configurations of interest to the transformer designer, these complicated numerical equations must be repeated hundreds of times.

Because of the uncertainty of results, manual calculation of this problem was never attempted. But by using CPC, engineers were able to compute the voltage gradients for many different field configurations, as well as to check the validity of a simple approximate formula they devised.

New techniques of plotting with the aid of a digital computer are effective and speedy tools for analyzing any type of field: electric, mechanical, thermal, or hydraulic. Thus mechanical forces on winding conductors and temperature rises in all parts of a transformer can be minutely examined using the CPC. Many such characteristics vital to the successful operation of a transformer are not measured during standard customer-acceptance tests. They must therefore be given considerable attention in the design stage.

Designing core and windings of a power transformer to meet all the customer's specifications, and industries' standards as well, is a complicated engineering problem at best. Impedance, energy losses, dimensions, weight, noise, temperature rise, and insulation tests must all be factored into the final product by the designer. And to make the matter more complex, many design variables appear in discrete rather than continuous steps. (The height of the core window, for instance, may vary only in one-inch steps.) Both the interrelation of these design variables and the nonlinearity of most design relationships have long defied a fully analytical solution.

The digital computer, however, with its high speed and disregard for mathematical complexity, is giving excellent results. With a procedure devised for determining the more important design variables, an experienced transformer designer using CPC can now predict weights and dimensions of the core and windings in one hour. He can refine the design and be completely assured that all the desired characteristics of the transformer will be met. And in the process he saves one or two weeks of engineering time.

More Creative Effort

The Card Programmed Calculator utilized by GE's power-transformer engineers is advancing transformer technology in many ways. Solutions to design problems that were formerly prohibitive because of thousands of manual calculations are readily carried out. Those characteristics vital to the transformer but not measurable by standard acceptance tests can be minutely examined. One to two weeks of engineering time is saved on a typical large power-transformer design.

All of this means that transformer designers, because they are freed from routine calculations, are able to devote their valuable time to an intensified creative effort. The inevitable result will be an improved product. Ω

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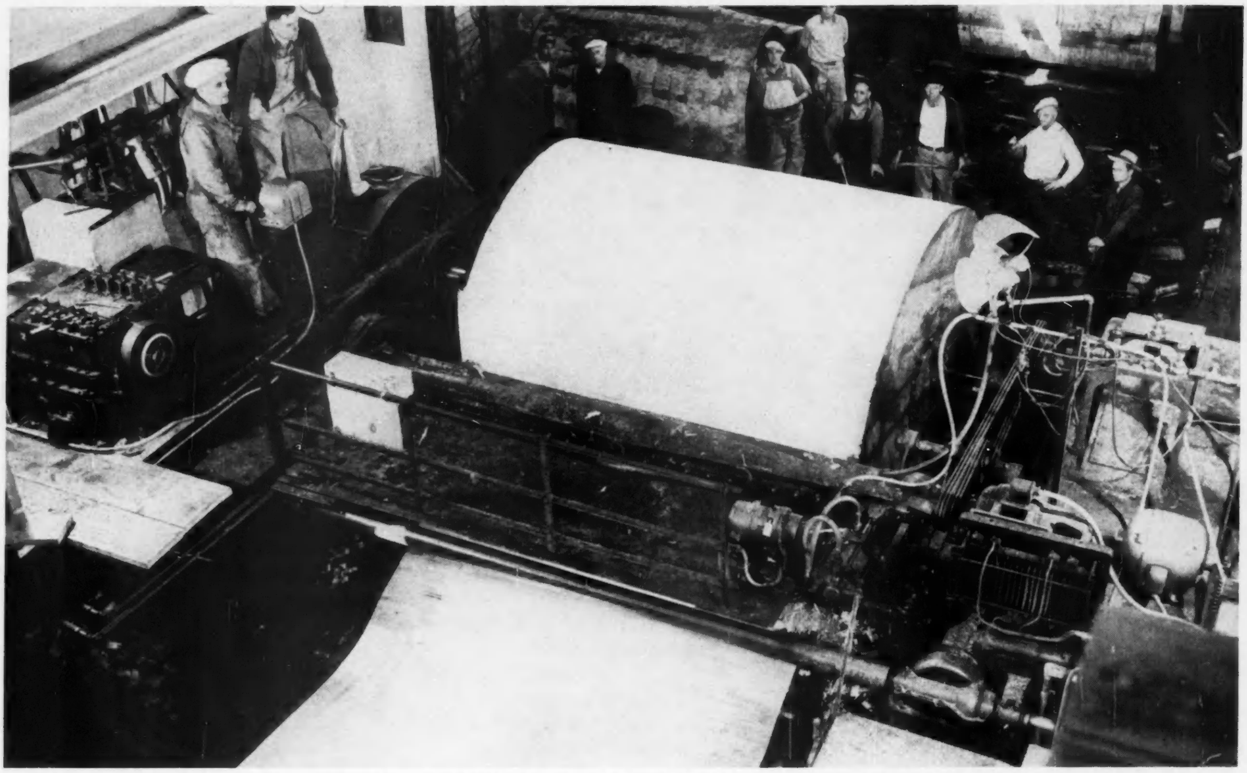
Mr. Williams joined GE's Test Course seven years ago and presently is with the Digital Computer Installation, Pittsfield, Mass. In 1954, he received the Managerial Award for his contributions to transformer design. A frequent contributor to the REVIEW, *Dr. Abetti—Insulation Development Engineer—also joined the Company seven years ago and is with the Power Transformer Department, Pittsfield. A year ago he attended CIGRE in Paris. Mr. Magnusson, an Engineering Analyst, came to GE in 1948, joining the Large Power Transformer Design Group, Pittsfield. He is now with Analytical Engineering in Schenectady.*



ADJUSTABLE-VOLTAGE 100-HP MOTOR PEELS UNIFORM VENEER FROM GIANT LOGS; SURFACE SPEED IS AUTOMATICALLY CONTROLLED.

Electrification of Industry

By L. A. UMANSKY

Electrification of industry has many meanings. A generation or two ago, it meant replacing with electric power inefficient prime movers that were usually operated by steam to drive industrial machinery—a process now substantially completed. Then too, electrification means a more complete mechanization by giving each worker more power to permit him to accomplish a greater task. Or it can mean changes in the design of industrial processes, usually making them continuous, faster, and more automatic. Finally, electrification enters more and more prominently into our industrial life as a chemical and thermal agent, increasing or bettering our industrial output.

Growth of American Industry

Significantly, our industry is still young, vigorous, and fast-growing. As the productivity of each worker rises, a steadily growing amount of power is used. A few statistical facts will explain the romance of our industry.

Our industrial progress has been far more pronounced in the postwar period than during the war when many aspects of that progress were interrupted (illustration, top, page 27). Let's look at the three top curves. The green curve represents the Federal Reserve Board (FRB) index, giving the weighted average production of such basic goods as coal, steel, machinery, textiles, and others. The higher this index the more goods we produce. The gray curve indicates the electric energy used by our industry—manufacturing plants and mines—to produce industrial goods. And the total man-hours our production workers have spent to turn out these goods is shown by the black curve. You'll note that the FRB index and kilowatt-hours are steadily climbing, while the man-hours remain fairly steady in the postwar period.

The derivative curves (lower) reveal the progress we are making. Productivity is best measured by the ratio of FRB index of production to the man-hours worked, as indicated by the green-over-black curve. The dips that appear in this curve during the war years show the effect of the influx of unskilled labor and some unavoidable loss of over-all industrial efficiency. While wartime

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Mr. Umansky, Manager of Engineering, Industrial Engineering Section, Schenectady, has been associated with GE since 1919 when he joined the Test Course. For 15 years he was engaged in the electrification of the steel industry, and now supervises application engineering work in all industries. In 1938, he received the Coffin Award for devising d-c runout table drives for steel mills.

production was high, more people were employed in industry than the volume of work warranted. However, since 1946 the average productivity per man-hour has been steadily rising about three percent each year.

That the dips and rises of the green-over-black curve and the gray-over-black curve almost coincide substantiates the fact that the more energy used per man-hour the greater the man-hour productivity. Of course, the gray-over-black curve climbs much faster: from 1945 to 1953, the value of kilowatt-hours per man-hour has risen from 5.17 to 8.15, an average annual rise of more than eight percent. For each percent of greater productivity, the use of power goes up almost three percent. Each worker used 9100 kilowatt-hours in 1939; 10,820 in 1946; and 18,150 in 1953.

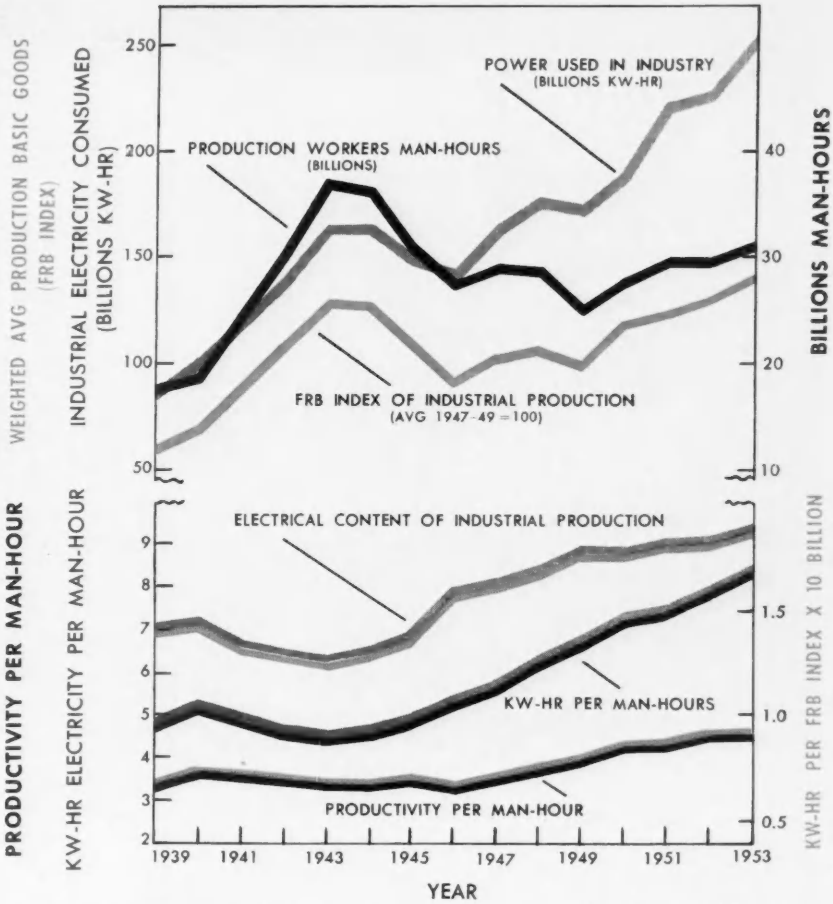
The gray-over-green curve illustrates this change in a still different manner. It expresses the electrical content of our average industrial product, that is, the ratio of total energy used by industry to the index of industrial production. In the postwar period alone this ratio increased 18 percent, from 1.55 to 1.83, showing the added power we are putting into a unit of our industrial goods. Increased use of power does not, by itself, produce more goods; it merely permits new and improved machinery and processes to perform this task.

How does the individual industrial worker benefit from this steady increase of productivity? In 1946 his average earning was $2380; in 1953 it rose to $3770. Taking inflation into account, the average pay went up 14 percent in purchasing power, excluding fringe benefits. In other words, the standard of living steadily rises with greater productivity and electrification of industry.

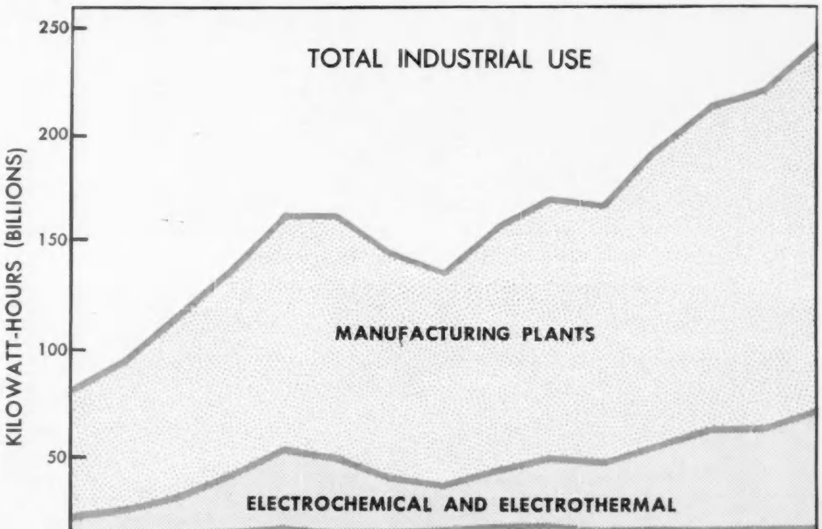
Industrial Uses of Power

How does industry use the ever-increasing amount of electric power?

With the exception of lighting and electrochemical and electrothermal processes, this energy is used as motor power (illustration, lower). Electric motors drive the industrial process machinery; operate materials-handling equipment; and power the countless pumps, compressors, and other utilities. The industrial worker of 1909 used less than 3 hp of motors. In 1929, this number rose to approximately 5 hp; in 1939, to 6½. And today it is probably higher than 10 hp. Since a man's muscle power equals about one-tenth horsepower, mo-

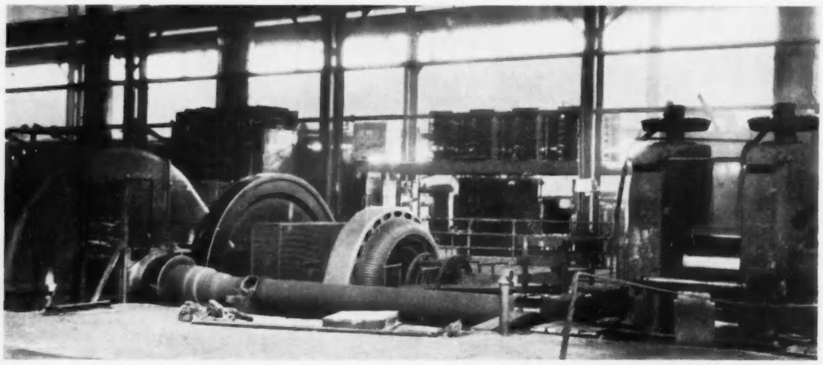


ELECTRIC POWER CONSUMPTION in the ever-increasing quantity of the past 15 years has greatly stimulated industrial production and worker productivity and indicates future trends.

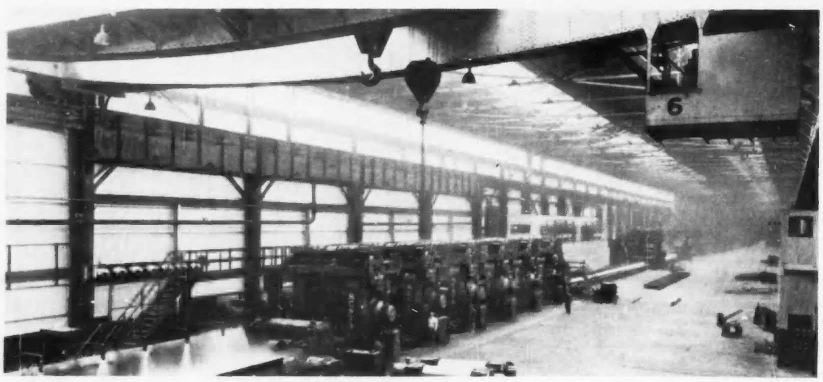


MOTOR POWER in the distribution of electricity utilizes by far the most electric energy, with a rapid rise indicated in the electrochemical and electrothermal use of power.

ELECTRIC CONTROLS MOVE WORK THROUGH 37 STATIONS IN TRANSFER MACHINE THAT MAKES AUTOMOBILE TRANSMISSION CASES.



IN THE 20's SHEET MILLS PRODUCED FLAT-ROLLED STEEL AT HIGH COST AND LOW OUTPUT.



IN TODAY'S HOT-STRIP STEEL MILLS, CONTINUOUS SHEETS EMERGE AT A SPEED OF 2000 FPM.

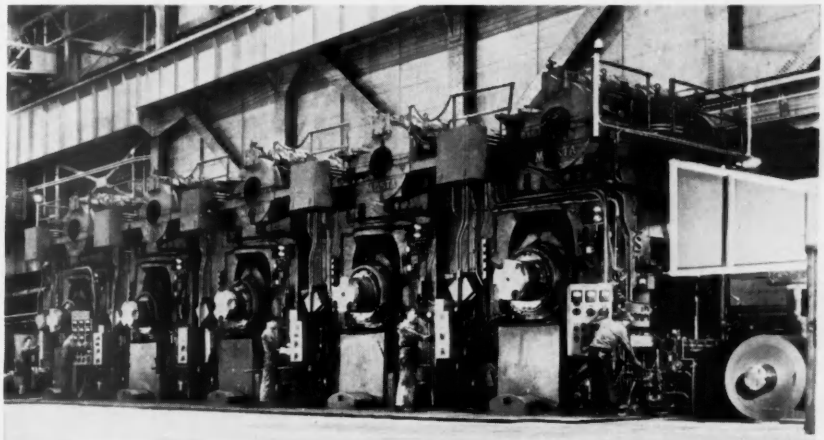
tors multiply man's power more than a hundredfold.

The average industrial motor drive is less than 10 hp, but the capacity ranges from fractional-horsepower size to 12,000-hp blooming-mill motors and 216,000-hp wind-tunnel drives. No account is taken here of the hundreds of millions of fractional-horsepower motors used on electric appliances, business machines, and the like. Constant-speed a-c industrial motors are in the majority, but the trend to d-c drives is unmistakable. Modern industrial processes usually require adjustable speed, and the d-c motor is still the best tool for that purpose.

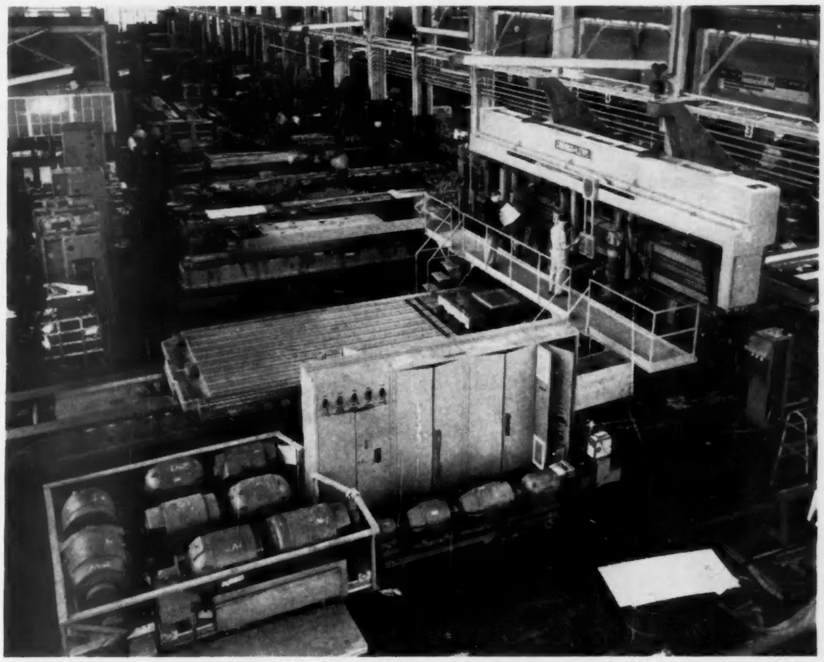
Electrification of industry, however, means considerably more than mere increase of mechanical power per worker. New uses of electricity are also growing rapidly. This applies particularly to the electrochemical and electrothermal processes. While the over-all industrial use of power increased 3 to 1 from 1939 to 1953, electric energy consumption for these processes went up from 10.4 to 55.1 billions of kilowatt-hours, a ratio of 5.3 to 1.

Production of aluminum contributed largely to this growth; it takes 9 to 10 kw-hr to refine one pound in electrolytic cells. The annual U.S. production of aluminum is nearly 2,900,000 pounds, accounting for more than 25-billion kilowatt-hours a year. Other metals and chemicals—chlorine, sodium, copper, and magnesium—are also contributing a constantly increasing share to the industrial load.

With electric heat gaining in acceptance, electric steel melting furnaces now successfully compete in operating costs with fuel-fired open-hearth furnaces. Electric melting of steel has risen from less than two percent in 1939 to about eight percent.



MODERN COLD-STRIP STEEL MILLS require 28,000 hp of motor power, plus intricate automatic control. In a generation, rolling has increased from less than 400 to more than 7000 fpm.



VERSATILITY OF SKIN MILLER, a machine tool used for such operations as making airplane wing sections, is increased by using 12 separate motors that total 350 hp.

Electric Drive vs Prime Movers

A generation or more ago, many industrial plants generated steam in a centralized boiler house, distributed it through the plant, and then converted it into mechanical power by means of steam engines driving the process machinery. However, if an industrial plant neither requires process steam nor has a supply of by-product heat or gas, economics forces steam generation out. Purchased power and electrification have been the answer. When process steam is essential, as in paper mills, or when by-product gas is at hand, as in steel mills, the industrial plant usually generates some of the power it needs, buying additional power from electric utilities.

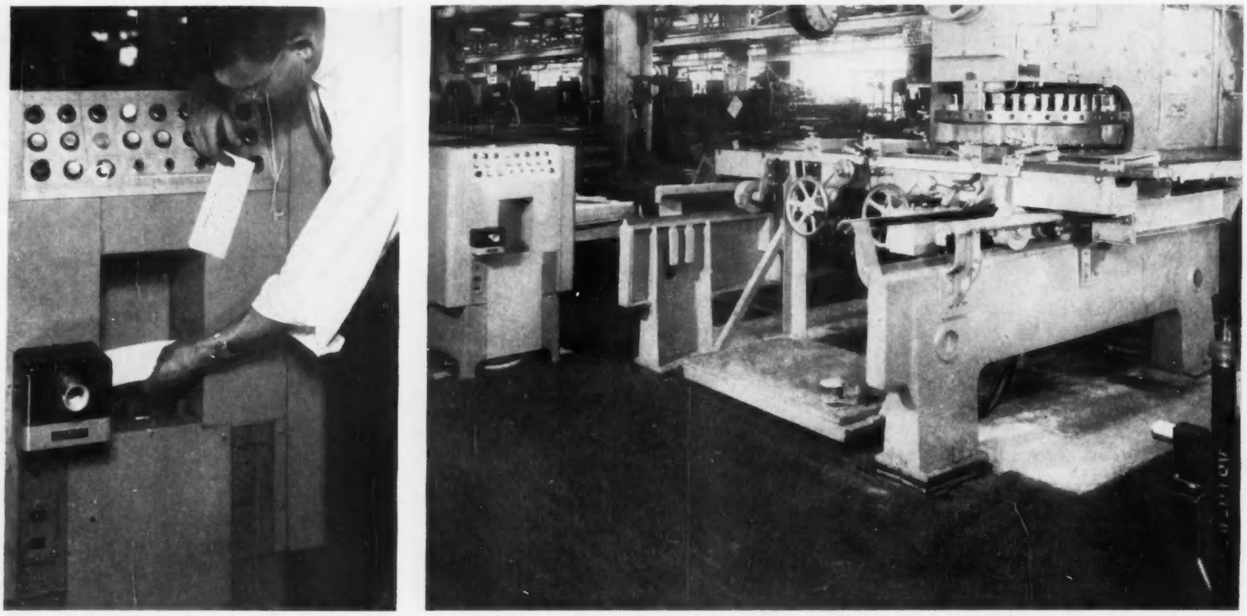
When steam is generated in an industrial plant, it is often converted into electric power and so distributed. But steam can be used directly when a few large drives are installed in close proximity to the boiler plant, as with steam-turbine-driven blowers for blast furnaces in steel mills and turbine-driven paper machines and pumps in a refinery.

The ratio of electric power generated by industry to the total power consumed by it has steadily decreased, dropping from 41½ percent in 1939 to 26 in 1953. This trend can be readily explained. The price of electric power sold by utilities has increased but slightly since before the war. To offset the high cost of fuel and labor, utilities turned to the use of higher steam pressures and temperatures, larger generating units, and modern power-plant design. A smaller industrial power plant cannot adopt all these means to the same degree.

At first glance, electrification does not seem to have made much headway in railroads; practically the same amount—two-billion kilowatt-hours a year—is used by electric trains as was used before the war. However, this applies to only the electric power generated on land and transmitted to the trains through rail or trolley. But in the broad sense, American railroads are now being electrified at a rapid rate. Dieselization should be more properly termed diesel-electrification. The modern locomotive carries its own power plant, generates electric power, and uses this power on the drivers. About 25,000 diesel-electric locomotives are in service, with a corresponding power-plant capacity of approximately 35-million horsepower.

The power generated and used annually in these locomotives is estimated to be more than that used by any other single industry—nearly 75-billion kilowatt-hours. This block of power does not appear in any statistical data for the industrial use of electric energy.

Important as these quantitative effects of electric power have been on industry, its output, and its workers, we will now take up a consideration of still greater importance—the qualitative influence.



TURRET PUNCH PRESS, controlled by cards like those used in business machines, automatically punches predetermined holes in a sheet of metal. Cards are fed into digital computer (left) that also combines a photocell safety control for the press.

Electricity Changes Face of Industry

Industry has undergone extensive modernization through the means of the qualitative influence of electricity on its numerous processes. In this evolution, we discern three major aspects . . .

- Operating speeds are steadily on the increase.
- A greater proportion of processes has been made continuous.
- Industrial processes are becoming more automatic.

The motivating goal and the result of this evolution are radical cost reductions and quality improvements of industrial products. This may well be illustrated by a few examples.

Rolling of Steel Strip

Less than 30 years ago, the greatest bulk of flat-rolled steel was produced in sheet form on old-fashioned rolls (photo, center, page 28). A typical 3/8x8x24-inch bar reheated in a furnace was manually passed several times through and over the rolls by strong and skillful operators at either side. One or more reheatings were required before a sheet of proper width, length, and thickness was obtained. Several sheet mills located side by side were driven at a constant low speed by either a steam engine or a 1500- to 1800-hp induction motor with a heavy flywheel. The rolling speed was limited to about 200 to 250 fpm and each mill produced 1 to 1 1/4 tons per hour.

A large amount of hand labor made the process expensive. Yet the metal fabricating industry clamored for more and more flat-rolled steel in the form of sheets, strip, or tin plate. Automotive bodies, freight cars, refrigerators and other appliances, electric sheets, oil drums, tin cans, and thousands of other applications presented their growing demands to the steel industry.

The answer was provided by the development of a continuous strip mill (photo, lower, page 28). Passing in succession through several tandem rolling stands, a heavy heated slab of four to six inches thick emerges as a continuous wide sheet from the finishing stands at a speed of 2000 fpm. A typical mill produces 150 to 200 tons per hour, or 150,000 tons a month. Each of the mill stands is individually driven by a separate motor rated 3000, 4000, or 5000 hp. The finishing stands that are set on close centers simultaneously process the same steel strip. Driven by adjustable-speed d-c motors, the stands are readjusted from order to order, reductions taken, and relative speeds set accordingly.

After the strip is formed on a hot mill to a thickness of one eighth to one sixteenth of an inch, the thickness must be further reduced by rolling on a cold mill. For instance, in making 0.010-inch tin plate, a strip about 0.072 inches thick is passed through five tandem stands of a cold reduction mill (photo, top, page 29). Here again, remarkable progress was made in the last quarter century. In 1928 a rolling speed of 400 fpm was considered outstanding; in rapid succession, new mills of 600, 800, and 1000 fpm were built. And by 1933, a really "fast" 1200-fpm five-stand mill was installed, with a total capacity of 3250 hp.

After a brief interruption during the war years, the process was resumed; we now have a number of cold mills running at 5000 and even at 6000 and 7000 fpm. A new five-stand mill is being built for still higher speed, and the total capacity of its d-c driving motors will be 28,000 hp. In one hour, such a mill can roll enough tin plate to produce 1,800,000 tin cans!

Economic reasons stimulate the race for higher and higher operating speeds. The higher the speed the greater the mill tonnage output accomplished with substantially the same mechanical equipment operating personnel. While the capacity and cost of electric equipment are materially increased, the over-all investment and labor per ton of output are reduced.

A high-speed mill requires rather involved electric equipment of greatly increased capacity. Each of the several mill stands, as well as the tension reel at the delivery end, is separately driven by a d-c motor. To roll a variety of products requires a wide speed range. Once adjusted, the speed relationship of the drives should be maintained not only at full operating mill speed and at threading speed—when a front end of a new coil is being fed through the mill—but also during rapid acceleration and deceleration between the two. Unless these conditions are met, the strip may be torn apart or a loop may be formed between the stands, resulting in delays, scrap material, or other consequences. Special design of motors and control is imperative. To indicate the strip tension between the stands, electromagnetic tensiometers were developed and are now widely used. X-ray thickness gages were designed to measure the thickness of strip produced on the mill. Then, making the maintenance of thickness automatic reduced the amount of off-gage material. Because of the high speed of this process, only automatic electric devices can respond fast enough to keep the process under control. And only electric motors can provide the ever-increasing capacity of drives and the higher speeds dictated by economics.

Manufacturing Industries

Our way of life depends on the wide use of machines—automobiles, refrigerators, ranges, motors, and lawn mowers. To make them abundant and available to a large number of buyers, we must learn to produce these machines economically. Hence industry's attention has been focused on improvements of manufacturing methods and on the machines that make machines, that is, machine tools.

Not long ago, a typical machine shop included an array of line shafts, sheaves, and belts to drive the various tools by one or a few large motors. This layout was inherited from the days when steam engines or water wheels were used as a driving power. Gear shifts or change of pulleys varied the speed of individual machine tools. The work moved from machine to machine by hand, truck, or crane.

First, electrification provided each machine with an individual motor drive. Line shafts, belts, and the like were replaced by electric lines, permitting machines to be shifted and relocated to better suit the process. And motorized conveyors took a more prominent place in handling work between operations.

Gradually, machine tools were redesigned to take advantage of electric drives. Instead of providing feed drives, lubricating oil pumps, tool adjustments, and others by power take-off from the main drive, separate motors were installed for each, eliminating clutches, spline shafts, and gear trains. The mechanical design has been simplified, maintenance cost reduced, and versatility of the machine tool greatly increased. For instance, the milling machine (photo, lower, page 29) utilizes 12 separate d-c motors totaling 350 hp and requires several supporting motor-generator sets and amplidynes.

The automatic operation of many machine tools was another benefit of electrification. The electronic tracer control permits accurate repetitive machining of intricate shapes from a given template, as in the two feeds of the milling machine. Or, instead of preparing a template, the necessary intelligence is recorded on a magnetic tape, the tool or tools repeating the motions while the tape is played back. Sometimes the information is stored on punched cards, and the tool will automatically follow the program. For instance, a punch press (photos) guided by the cards will punch holes arranged in a predetermined pattern in a sheet of metal. Again, this saves labor, enhances accuracy, and speeds operation. Electrification is paying an extra dividend.

Next, several machines performing subsequent operations were tied together to obtain a continuous flow of production. Special conveyors or other materials-handling facilities were provided to pick up the work from one machine and move it to the next, turn it if necessary, clamp it in a new position, and initiate the next machining operation. Included sometimes is a special transfer machine that has several working positions, or stations, as well as the means of transferring the work between them. An engine cylinder block enters at one end of the machine and emerges in finished form from the other end several feet away after several milling, drilling, boring, tapping, and reaming operations. Elaborate means—99 percent electrical—are required and provided to co-ordinate and synchronize the several machining and transfer motions, properly interlock them, and maintain automatic quality control.

Automation

The automotive industry (photo, top, page 28) was probably one of the first to adopt automatic operation, even coining its name—automation. Now the whole industrial front recognizes the underlying principle. Almost every manufacturer searches for electrical means, old or new, to modernize his processes on a continuous and automatically controlled basis.

A quick glance at our industry could supply us with hundreds of other examples of this over-all evolution. Electronic d-c motor drives for modern printing presses simplify the mechanical design, reduce building costs, and speed up printing. A moisture monitor, built on the principle of the electric capacitor, measures and controls the amount of water in a moving sheet of paper during its manufacture. Photoelectric pinhole detectors spot and reject defective material on a fast-moving processing line. Special synchronized drives permit economical production of our new synthetic fibers. New electric systems make possible quick loading and unloading of ore boats at our lake ports, at tidewater, and even on the Orinoco River in Venezuela. And modern mining machinery, giant power shovels, and such construction tools as cableways, dredges, and many others depend on electric drives.

Mechanization, or application of electric power, vastly multiplies man's effort. Electric instruments supply the intelligence necessary for man to control the processes or machines. When instruments by-pass the operator controlling the processes directly, then we have reached the stage of automation. Relieved of many monotonous tasks, man is upgraded to the status of process supervisor.

We cannot attribute all this progress to electrification alone, yet without electricity it could not be achieved. Electric motors permit a large concentration of power in a limited space for easy subdivision, making it possible to steadily increase the operating speed. The ease of electric speed control simplifies the mechanical design of process machinery and increases its versatility. More than any single factor, electric control provides automatic means and regulates the processes.

Full automation, already feasible in the realm of engineering, is limited only by economic factors. The success of electrification can be attributed to its increasing the productivity of our efforts, thereby raising our standard of living. And there is no natural or inherent upper limit to that standard. As long as engineers continually supply the industry with new ideas and tools, electrification and industry will grow and expand. Ω

Even the best appliances won't operate properly when there aren't enough circuits or when the circuits are overloaded. This unhappy housewife would like an answer to the question . . .

Who's Responsible for Adequate Wiring?

By HAROLD H. WATSON

Adequate wiring means different things to different people:

To the homemaker and her family, it means efficient lighting and satisfactory performance of appliances and other electric equipment.

To the electric utility, it means continued growth of the residential load curve.

To the electrical contractor, it means more business on every wiring job and a great volume of added business on rewiring.

To the manufacturer, distributer, and dealer, it means an ever-expanding market for electric products.

To the engineer in the electrical industry, it means a broadened market for his talent in the development of the electric distribution system in homes, an area where so little engineering has been applied.

To everyone, adequate wiring should mean properly located switches and outlets supplied by branch circuits of sufficiently large wire, plus service and distribution equipment large enough to handle today's loads—and tomorrow's.

On the other hand, many of us have experienced some of the end results of inadequate wiring: appliances that don't operate as they should; TV sets that flicker and grow dim; frequent blowing of fuses; and foregoing the pleasures of such major items as a room air conditioner or a clothes dryer because of the lack of 220-volt circuits. For instance, in 1953, 55,000 room air conditioners had to be returned to dealers, because they were ordered for buildings not wired to carry the extra load. (Other end results of inadequate wiring are related in the Box.)

Mr. Watson—Commercial Engineer of the Construction Materials Division in Bridgeport, Conn.—has been with General Electric for 32 years. He is presently responsible for the application and design of interior wiring systems.

Where Does the NEC Fit In?

In any discussion of adequate wiring, you frequently hear something like this: "I always thought the Code took care of wiring."

And it does, but only so far as safety is concerned. A broad gap lies between adequate wiring and a minimum installation of safe wiring. The National Electrical Code (NEC) is concerned only with setting up a code that will provide protection against fire and accident from electrical causes due to improper wiring methods. In no sense is the NEC a design standard or a basis for layout. It does not, for example, require that a building be wired at all; when wiring is installed, however, it details the safety requirements considered necessary for electric equipment and systems.

For residences, the minimum requirements of the NEC are . . .

- A 2-wire No. 6 Awg service
- General-purpose appliance and lighting branch circuits to supply 3 watts per square foot of occupied area
- A grounding-type outlet in the laundry location
- A 20-amp circuit supplying only the receptacle circuits in the kitchen and laundry
- A convenience outlet for each 20 feet of perimeter of every occupied room.

A glance at these items discloses that the requirements are far below those necessary for the use of the electric components of even the most modest home. No requirement is made for the installation of lighting fixtures. If these are installed, the Code has no requirement for switches to turn these fixtures on and off. Of course, lights without switches to control them are decidedly impractical, but lights without switches are *safe*—the extent of the Code's interest.

Many variations in the basic requirements of the NEC appear in the electrical ordinances of individual cities. Fundamentally, most local ordinances are concerned only with safety—not with convenience, efficiency, or adequacy. Therefore, use of Codes as the basis for interior wiring-system design should be avoided. We must look elsewhere for a set of standards to provide the convenience and efficiency that we expect from today's electric system.

National Adequate Wiring Bureau

Such standards are provided by the National Adequate Wiring Bureau—a nonprofit industry-sponsored activity that formulates promotional programs; provides headquarters' services for technical details of adequate-wiring promotion; and performs a secretarial function for all the adequate-wiring certification agencies and bureaus in the United States. The actual work of implementing the program is a responsibility at the

END RESULTS OF INADEQUATE WIRING

Here are some comments on a pathetic wiring situation as told by a young businesswoman of a large East Coast city:

I live in a garden-type apartment house: two stories for 12 families. Not a new building, it was apparently ahead of its time, because we are quite modern by present standards—in all respects except wiring. The 60-amp 3-wire service entrance for the apartment supplies all 12 families (three to four rooms and bath for each unit), plus basement, halls, vestibules, and outdoor lights. Consequently, my whole apartment has one circuit: 20 amp, and that's all! I know all this because when I wanted to get an electric range, the local utility company investigated the possibility. They not only said I couldn't but also wondered how I managed at all!

However, I first suspected overloaded circuits when I got my new G-E pop-up toaster. Five days a week it made unevenly browned toast; the other two days, perfect toast. I finally figured that on work mornings, breakfast was telescoped into an extremely short period of time. Consequently, the refrigerator, toaster and coffee maker were all running at the same time. Week ends, being more leisurely, meant that the coffee maker was off (waiting to drip back into the bottom bowl) and the refrigerator was off before I popped the bread into the toaster as the final preparation for breakfast. This means that the toaster has little competition for the power on Saturdays and Sundays. On weekdays, however, the split-timing of breakfast preparation means that I open the refrigerator door just enough times to start it running while using all my appliances at the same time. I might explain that my weekday coffee isn't as good as it is on week ends; instead of letting it drip through at the proper timing, I speed things up by taking it off the heating element to let it drip immediately. This means I make coffee and toast at the same time—and neither one is particularly good.

Another episode warning me of inadequate wiring was that the fuse has blown every Christmas Eve for 12 years now. I don't mean my individual 20-amp fuse, but the larger one that takes care of a group of six apartments. This has become a seasonal event because of the holiday lighting load. It's become a game figuring out just how many times the fuse will blow on Christmas Eve.

When I told our utility man about this, he said that we were just fortunate that the families in the apartment house apparently never spend much time at home or do things at the same time. Even so, whenever the iron or toaster or what have you is plugged in, all lights dim.

But there isn't much we can do about it. The landlord gives us electricity up to a point, but he isn't interested in modernizing. I imagine it's also lucky that only four families have TV sets. And none of us can have a room air conditioner, much as we'd like to.

Business Week magazine wraps up all such situations in this portrayal:

Here's a day in the life of Consumer Able. After he has left for the office, Mrs. Able puts the breakfast dishes in the electric dishwasher, empties scraps into her garbage-disposal unit, checks the time on her electric clock, turns on the radio to get the weather forecast, puts the milk in the refrigerator, puts the laundry in the automatic washer. Her well-equipped home has all of the 56 "common" appliances.

Before going upstairs to make the beds, Mrs. Able decides to have another cup of coffee. She plugs in her electric coffee maker.

Immediately, a fuse blows.

This minor catastrophe sets up a chain reaction. Mrs. Able may report her appliance dealer to the Better Business Bureau or write a nasty letter to the manufacturer. She may tell her friends that she wouldn't have another coffee-maker from X Electric Company as a gift.

She will probably call her power company and complain that she's getting inferior electricity. As a public relations gesture, the power company may send a serviceman around to change the fuse—although in most instances it's not the company's responsibility. (Last year Consolidated Edison Co. of New York, Inc., answered more than 200,000 calls on blown fuses at a cost of about $1 million.)

If Mrs. Able lives in a rented apartment or house, she takes out her wrath on the landlord. If it's her own home, the next time she's in the supermarket she picks up some giant fuses . . . . She puts these in place of the correct ones in her control box.

This is about the most dangerous thing she could do. An educated guess by electrical engineers puts the nation's electrical fire loss for last year at $97 million. A major cause is tampering with fuses.

High-Energy Electrons—
Lethal Agent and Catalyst

By J. W. RANFTL

Recent advances in engineering have made high-energy electron beams readily available for research and development. As a free agent, the electron can be a powerful tool for industry, and work done so far reveals great promise for commercial application of this source of energy.

Electrons accelerated in a vacuum tube and emerging into air through a thin metal window in the tube (photo and illustration, next page) constitute a high-energy electron beam. As a lethal agent, it destroys bacteria, molds, and yeasts, thus effectively pasteurizing and sterilizing food and drug products. The electrons can participate in chemical reactions to produce new materials and beneficial changes in already existing materials.

Discovery of x rays 60 years ago prompted an interest in utilizing the bactericidal properties of radiation. However, electron beams are of particular interest, because they possess much more energy than do x-ray beams.

As early as 1926, under the direction of Dr. William D. Coolidge in GE's Research Laboratory, research and development demonstrated that electrons could not only effectively destroy bacteria but also, in intense doses, solidify gaseous chemicals. But space requirements for high-voltage apparatus and other technical difficulties prevented general commercial use of electrons at that time.

First Commercial Application

Shortly before World War II, high-voltage x-ray apparatus was developed for inspection of heavy metal sections. These units incorporate sealed multisection tubes and high-voltage components that have no moving parts in the high-voltage field. Extremely reliable, this equipment often works three shifts a day—an amazing feat of continuous inspection. More than 100 of these x-ray generators are now operating in industrial inspection.

After the war, one of these million-volt units was fitted with a permanently evacuated electron-beam tube in the General Electric Research Laboratory in Schenectady. Research indicated that a dependable electron source would permit commercial application of the electron beam.

Many interesting studies at the Research Laboratory suggested broad fields of application. To develop apparatus and to further study such radiation, General Electric's X-Ray Department installed equipment in its Coolidge Laboratory in Milwaukee for all industry to use in application studies. The X-Ray Department has placed its electron-beam generators on the market, dispelling any doubt about the feasibility of commercial electron irradiation.

The electrons so generated (illustration and photo, next page) are similar to those that sweep the face of a TV tube and produce a picture. However, to give the electrons enough penetrating power to effectively treat material, considerably higher voltage is utilized.

In material of unit density, such as water or many foods and plastics, complete absorption of a one-million-volt electron beam occurs at a depth of 0.2 inch (illustration, page 37). By irradiating appropriate thicknesses of material from two sides (green curve), relatively uniform electron absorption results. Electron penetration is proportionate to the voltage applied. Thus material twice as thick requires twice as much voltage.

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During World War II, Mr. Ranftl worked at the Los Alamos Laboratory of the Manhattan Project, joining GE's Engineering Section, X-Ray Department in 1947. A year later he transferred to the Marketing Section, working with x-ray diffraction. Now Mr. Ranftl—Supervisory Application Engineer, Industrial Sales, X-Ray Department, Milwaukee—develops marketing programs for electron-beam generators and radiation-level and thickness gages for industry.

Electron Bombardment

The exact mechanism that electrons use to produce changes in matter is unknown. Two actions are generally thought possible: 1) a direct hit whereby the electrons passing through the material are slowed down or absorbed by an organism or molecule and 2) an indirect effect when the electron causes certain chemical changes in the surroundings, resulting in a secondary reaction with the organism.

These two actions can be compared rather broadly to the effect of a stone striking a pool of water. The stone causes a rather violent force at the direct point of contact; the indirect effect occurs simultaneously as ripples, or waves, that agitate the surrounding water. These waves disturb an object on the water's surface, just as the agents produced by the collision of electrons change surrounding matter. Sterilization and other electron-beam processes are generally a combination of such indirect and direct electron absorption.

The effect of electron bombardment is proportionate to the amount of energy absorbed. The common measure of treatment dosage is Roentgen Equivalent Physical (REP). In terms of everyday power units, a dosage of one-million REP means the absorption of slightly over one kilowatt-hour per 1000 pounds of material processed. Doses vary considerably. Some food stuffs need 10,000 REP for effective treatment, yet some chemical changes require doses of 100-million REP or higher.

Irradiation Affects Insects . . .

Experimental work with high-energy electron beams has uncovered interesting applications. Doses of 25,000 to 100,000 REP kill insects in grain. Treatment as low as 10,000 REP effectively deinfestate grain and cereal products, because these low doses render the insects sterile. This prevents an increase in the number of insects and resulting contamination.

local level, generally assigned to an Electrical League or some similar agency interested in the specific local operation.

By adequate wiring, the Bureau means a wiring-installation design that conforms strictly to the requirements of the Handbook of Residential Wiring Design, published by the Industry Committee on Interior Wiring Design or to some approved equivalent derivative of this Handbook. (See Box for a summary of the minimum wiring standard approved by NAWB.) The National Adequate Wiring Bureau is not concerned with the installation methods of the wiring requirements that they recommend, because this falls into the realm of safe installation practice—a function of the NEC and local electrical ordinances.

Why Inadequate Wiring?

What is the background of the lack of adequate wiring? Let's examine the factors and influences responsible for the estimated 30-million inadequately wired homes in this country.

American ingenuity, engineering skill, and mass-production methods have provided the American public with more and more power-consuming products for homes, offices, stores, and factories. Many of these products are relatively new—most of them much newer than the wiring systems expected to furnish the power to operate them. But because engineers and designers have done such an excellent job of including circuit overload capacity, the pinch of inadequate wiring wasn't felt as quickly as might be expected: The products still operated, and the inconveniences and inefficiencies resulting from inadequacy weren't readily apparent to the uninitiated.

Thus one of the factors accountable for bad wiring was simply the fact that the public did not realize its existence. They did not ask about the wiring in the homes they bought; so the merchant builder concentrated on the features in demand—a fireplace, second bathroom, colored bathroom fixtures, and tile floors.

Most electrical contractors estimated costs on the basis of the specifications without trying to sell bigger wiring systems. Appliance dealers sold their products without inquiring about the buyer's wiring system. No one was against adequate wiring. The electrical era had just grown so fast in a few years that the end product—not the wiring—was what everyone wanted.

A few years ago, industry couldn't get attention focused on wiring, because most people weren't having serious trouble with their wiring.

Today we face a rapidly changing situation. The public does know that wiring is important. So do the appliance dealer, the appliance manufacturer, the merchant builder, the lending institution, and the electric utility. Quick acceptance during the last two years of air conditioning units, laundry dryers, and built-in electric-range units—often with two ovens and broiler—brought home the fact that a large wiring system is required to operate all this equipment.

Then too, the technical knowledge of the average man, particularly in regard to things electrical, has increased tremendously in the last several years.

The ex-GIs of World War II, fast becoming the solid bulk of home owners or renters, fought a mechanized war, much of it electrical. The factory workman uses electric equipment and sees electricity used everywhere he turns. Farms are partially electrified. A large share of the housewife's work is done by electricity. Deny them, for example, the use of a room air conditioner, not for economic reasons but because of insufficient wiring, and they are aroused. Their knowledge of electricity now having a practical aspect, the adequate wiring story finds a receptive and understanding audience.

NAWB STANDARDS FOR RESIDENTIAL WIRING . . .

. . . a 3-wire 100-amp service entrance, requiring that three wires come into the house from the utility pole. The wires from the house to the panelboard in the basement must be large enough to handle its present load, as well as all future loads.

. . . two 20-amp branch circuits for the kitchen, laundry, and dining areas to handle portable appliances—fans, toasters, coffee makers, and mixers.

. . . a separate circuit of correct size for each appliance, such as clothes dryer, range, water heater, and room air conditioner.

. . . a 20-amp general-purpose branch circuit for each 375 square feet of floor area to handle lighting fixtures and convenience outlets for lamps, radios, TV, high-fidelity record-playing equipment, and clocks.

. . . enough convenience outlets in any room perimeter so that no matter where lamps or other appliances are located the standard six-foot cord length will reach to an outlet.

. . . enough switches to prevent walking in the dark to turn a light off or on or, better still, enough remotely located switches so that lights outdoors and in the garage and basement can be controlled from other rooms.

Note that these are minimum wiring standards advocated by the National Adequate Wiring Bureau. Additional information is in the booklet, *Getting the Most from Your Home's Electric System*, available for 15¢ from the National Adequate Wiring Bureau, 155 East 44th Street, New York 17, NY. Also available is *The Residential Wiring Handbook* for 25¢.

Relief in Sight?

Now that we are encountering the crisis, here's what is being done to relieve and remedy the situation.

Many banking plans were generated in the past few months to ease the burden of home owners when they want to rewire or modernize their systems.

The General Electric Credit Corporation has announced such a plan. Banks, the Federal Housing Administration, and other lending agencies have become aware of the need for providing against electrical obsolescence to maintain property values.

Recently, the National Home Builders Association has taken remedial action against inadequate wiring, and have asked their members to voluntarily adopt a wiring standard that closely parallels that of the Handbook of Residential Wiring Design.

Several towns have revised their electrical code and require a 100-amp service.

Through their trade associations, contractors, distributers, and dealers have come to the rescue of ailing wiring systems. Magazines and newspapers are filled with articles and advertising, all telling the need for adequate wiring. Utilities, with but a single product to sell, are giving greater attention to the adequate-wiring program.

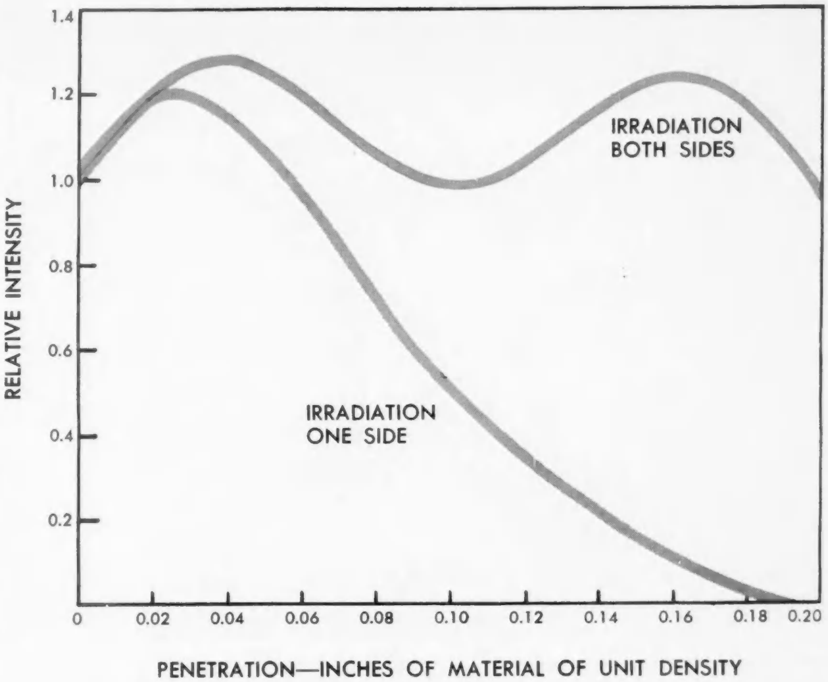
Likewise, manufacturers have suddenly found a new rallying point for an industry-wide promotion of the electrical idea. A number of producers of materials used in the electrical industry are telling the adequate-wiring story in their advertising.

Therefore, it is apparent that everyone—from the electrical contractor to the electric utility—is responsible for seeing that America is adequately wired.

Adequate wiring is not a deluxe extra among the mechanical components of a home. It is the wiring required to make modern living efficient and comfortable.Ω

However, electron sterilization also has undesirable effects. Often, as sterilization takes place, certain other changes can be noticed in the material's color, flavor, and odor, the intensity varying with the individual product. For example, irradiated foods generally have a somewhat scorched taste. Milk is extremely sensitive to flavor change, whereas bread, flour, and grain are relatively insensitive. Color changes that bleach a food product are also undesirable. Such variations probably result from the electrons' indirect action caused by free radicals, or chemical agents, produced within the material.

Not all the applications of electrons to foodstuffs are aimed at producing a product that will keep indefinitely at room temperature. Many products that now require freezing could be more available if refrigerated storage would suffice. Likewise, the shelf life for many products could be extended a week or two, resulting in considerable economy of transportation and handling.



COMPLETE ABSORPTION of a one-million-volt electron beam occurs at a depth of 0.2 inch. Irradiating material from two sides results in uniform absorption.

. . . and Plastics

High-energy electrons can also be applied to chemical products and processes. Irradiation of plastics' properties generally requires much higher dosages than those used for sterilization. A range of 10- to 20-million REP is not uncommon, although lower and higher doses can be used to produce desired changes in specific cases. Electrons can cross-link certain plastics, such as polyethylene and nylon, and various natural and synthetic rubbers. This cross-linking process so strengthens the plastics by knitting together the large molecules that it becomes impervious to solvents that affect unirradiated material.

Polyethylene, a plastics used for electrical insulating purposes in industry, and for many everyday articles—cups, bowls, and food bags—will normally melt to a blob at temperatures slightly above that of boiling water. Yet when irradiated, polyethylene products retain their shapes at considerably higher temperatures. For instance, irradiated bottles (photo, lower, page 38) maintain their shape after being subjected to 250 F for 20 minutes. Polyethylene can even be heated to its charring point without losing shape. At these elevated temperatures, its strength is not high, but applications are possible because it does not melt.

Irradiated polyethylene stays flexible and its physical properties, other than the melting point, remain similar to the unirradiated product. Even thick sections of polyethylene can be irradiated effectively.

Electron generators now permit further study of plastics other than polyethylene. Irradiation effects will vary with the particular plastics. Some, like polyethylene, are cross-linked and their properties improved. In others, the chemical bonds are broken and the plastics degraded. Some solids will be reduced to a powder, completely losing their plastics properties. Degradation can cause gas liberation and bubbling of the plastics. The possibility of producing expanded plastics by using low irradiation dosages and heat has aroused much interest.

However, interest extends beyond the treatment of solid plastics materials. Sufficient irradiation can transform oils and paraffins into rubbery solids, and change monomers—the intermediate liquid materials in the manufacture of plastics—into solids. Taking part in chemical reactions in the vapor phase, electrons help produce new chemical compounds. Sometimes when the required dosages using electrons only become so high that a process is uneconomical, the electrons can be used as a catalyst and the process is then brought to completion by conventional means.

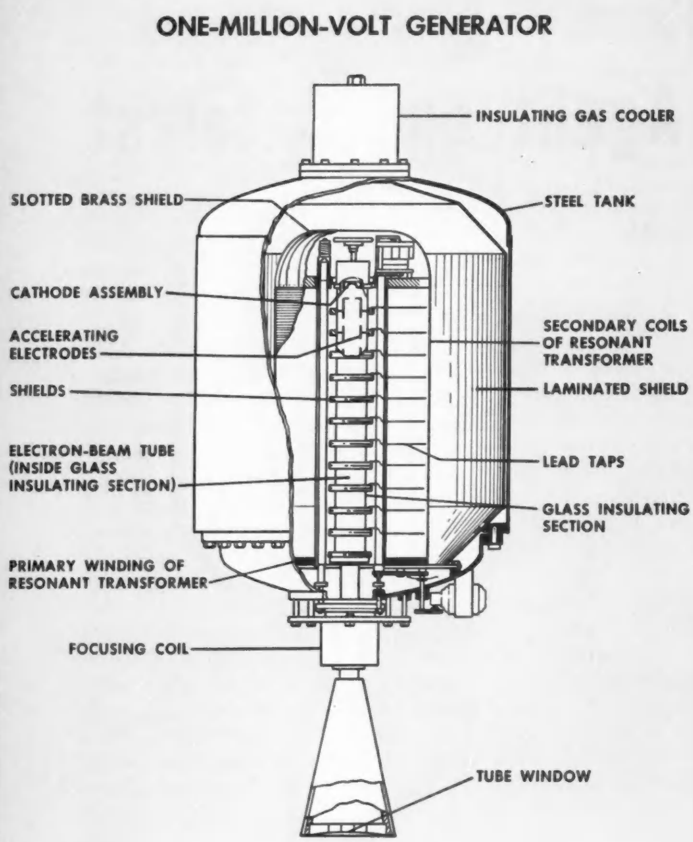
X Rays and Gamma Rays

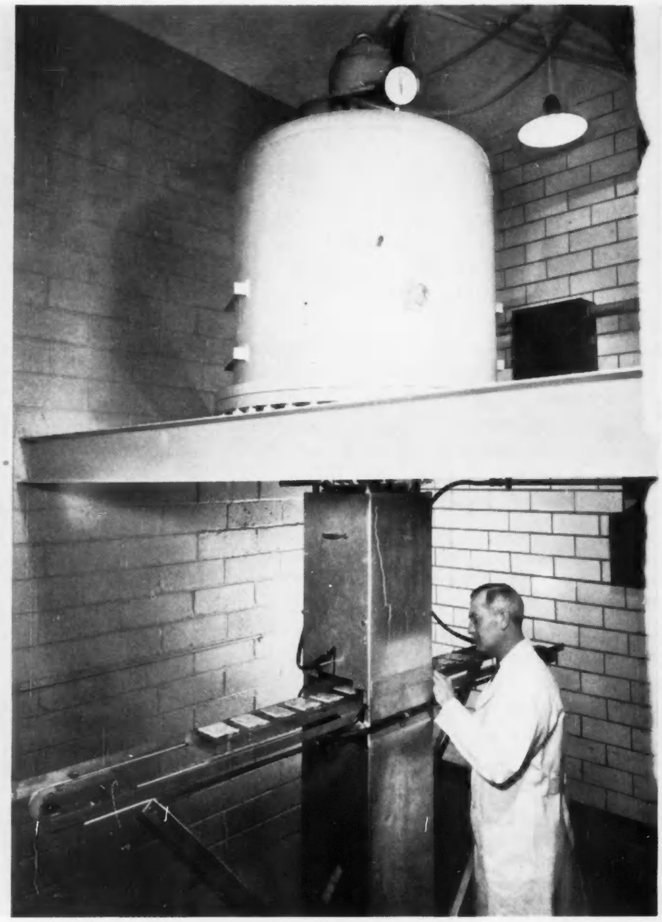
Sterilization and chemical change can be produced not only with electrons but also with x rays, radioactive isotopes, and fission products. X rays and gamma rays have greater penetrating power than electrons but considerably lower radiation-output intensity.

To use x rays for this purpose is uneconomical because of the x-ray apparatus's relatively low efficiency. Only about one percent of the incoming power is converted to useful x rays; the rest of the energy produces heat in the target of the tube. The greater efficiency of supervoltage x rays—one-million volts and higher—is offset by the fact that their penetrating power exceeds that required for most treatment.

Isotopes and Fission Products

The idea of using isotopes and fission products for sterilization purposes has caused considerable speculation and experimentation. In the radioactive source sizes now available, isotopes are a relatively slow radiation producer. Existing sources of 10,000 curies have a dose rate per hour that a 500 microampere generator produces in seconds. To produce practical quantities of irradiated material, radioactive sources would have to be in the range of 1- to 100-million curies. Perhaps such sources are realistic





Tuned coils permit the resonant transformer of a one-million-volt electron-beam generator to operate without the iron core necessary in conventional transformers. Eliminating the iron core—too large for transformers in this voltage and current range—reduces the size and weight of the transformer. Sulfur hexafluoride gas, used instead of conventional oil insulating, further decreases the weight. In the center of the transformer is the multisection electron-beam tube, with its glass insulating section inside the tank while outside is the end section for electron emission. A hot wire filament in the tube gives off a stream of electrons. Accelerating voltages produced by the transformer's secondary coils and applied to the tube's sections move these electrons through the tube. As they leave, the focusing coil controls their direction to give a desired beam pattern.

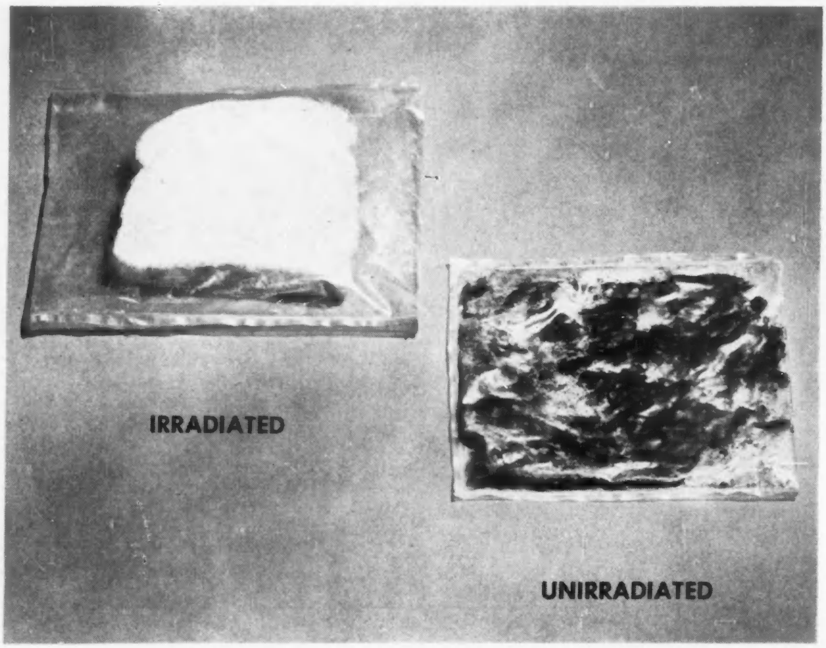
The electrons, continuing through the external tube extension, pass through the tube's thin metal window into the treatment area.

. . . Food and Drugs

Slices of bread treated at 250,000 REP and kept for many months at room temperature showed no signs of mold growth (photo, top, page 38). But samples not irradiated and kept under similar storage conditions became a moldy shapeless mass. To greatly lengthen shelf life of bakery products, even lower radiation doses could prevent mold growth over a period of many days or a few weeks. Bacterial action on exposed surfaces is a contributing factor to meat spoilage. Thus irradiation of fresh meats and meat products, such as sausage and luncheon cuts, is of considerable and stimulating interest.

Treatment of drugs, particularly the newer antibiotics, also presents a challenge. Because many of these are sensitive and subject to change with heat, long involved sterilization procedures are required under current practice. The same is true of fats, oils, and emulsions. Doses in the range of 1.5 to 2.5 million REP effectively sterilize and destroy contaminating microorganisms in such drug samples as various forms of penicillin.

The fact that electron sterilization is a relatively heatless method—one-million REP produces only a few degrees F temperature rise—accounts for the keen interest in its use on drugs and meat. Normal heat-sterilization methods involve temperatures above the boiling point of water. For example, the prolonged cooking periods for canning meat change its physical characteristics.



IRRADIATION greatly lengthens shelf life of bakery products. After many months at room temperature, bread irradiated at 250,000 REP shows no sign of mold growth.

POLYETHYLENE BOTTLES melt at temperatures slightly above that of boiling water; if irradiated, they retain their shape even after being subjected to 250 F for 20 minutes.

in terms of the future, but they are unavailable at the present time.

When commercial atomic power plants start operating, it may be possible to utilize their radioactive by-products for sterilization and other purposes. Of course, technical difficulties such as shipping and storage are anticipated in handling large sources. Also, because these by-product sources cannot be turned off, one must always be on guard against radiation. Maintenance of conveyors and other auxiliary apparatus in the vicinity of the irradiation source would be complex and costly.

Electron Sources

Apparatus other than the resonant transformer can be used for generating electrons. In the Van de Graff type of static generator, the voltage builds up by accumulating the electrons' charge on a rapidly moving belt. In capacitor-discharge equipment, large capacitors are charged in parallel and discharged in series to give a high-voltage current of short duration.

The resonant transformer as a source of high-voltage power has unlimited capacity in terms of realistic electron-tube output. The absence of moving parts in the high-voltage field means stable operation over long periods of time with minimum maintenance. The laboratory generator has an external electron current of 1000 microamperes with a beam power of 700 watts.

Engineering development projects now under way will result in high-current and high-voltage apparatus for production application. Exact production-treatment cost will not be accurately known until irradiation methods have been established, proper dosages determined, and apparatus of suitable capacity in production.

Irradiation cost per pound will be much lower than that from the present-day laboratory-size generators. Sterilization at a dosage of one-million REP will probably cost about one-half cent per pound of material processed, including the cost of apparatus and power but not of building facilities and handling apparatus. Lower doses for deinfestation and pasteurization processes will cost even less. Large doses for chemical treatment and plastics' modification will be proportionately higher.

To realize these low processing costs, any one installation must be utilized at its highest rate of efficiency to be equalled by machine and process capacities. Ω

Cost Reduction—A Corporation Asset

By DR. A. V. FEIGENBAUM

A nation's standard of living depends to an important degree on its ability to produce the wide variety of goods that people want, at prices they are able and willing to pay. A progressively rising standard of living—believed basic for our national economy by Americans—depends on a continuous year-by-year increase in the value of these goods per price dollar.

Manufacturing companies achieve increased value per price dollar in several ways. They provide consumers and industrial purchasers with a considerably better product at the same price—for example, by incorporating greatly improved convenience features in appliances or by establishing substantially higher quality levels for motors. Another important way is through progressive reduction of prices of products, maintaining the same or bettering product quality.

A manufacturer who wishes to remain in business, however, cannot reduce prices beyond the point that retains a fair margin of profit for him. Therefore, prices generally cannot be reduced unless the manufacturing cost of the goods has also been reduced.

Thus the concept of a continuous cost-reduction program is important to the concepts of continuous industrial progress and a constantly rising living standard. This means improving industrial operating effectiveness through finding and applying better and more economical methods.

Cost reduction has indeed played an important role in the business history of the United States. Historically, perhaps the most outstanding cost-reduction effort was the Industrial Revolution. Popular terms, such as American knowhow and Yankee ingenuity, are expressions describing the successes enjoyed in increasing productivity. Automation describes one of the 1955 phases of American cost-reduction programs.

History clearly shows that effective cost-reduction programs and greater job opportunity for employees go hand in hand. The manufacturing companies that have most effectively reduced cost have also been leaders in rapid growth. Broader opportunities and more secure jobs have been a natural result.

What Is a Cost-reduction Program?

Everything done in a business to make it more efficient and profitable could be called a cost-reduction, or profit-improvement, activity. But extremely broad activities that are everybody's job could become nobody's job. This concept of cost reduction can thus be advantageously formalized to include only planned, measurable improvements that result from genuine effort.

The concept of a cost-reduction program in a modern corporation like the General Electric Company refers to a definite activity. Its objectives are to stimulate, evaluate, and assure speedy adoption of ideas and methods that will make a specific cost saving.

Such a cost-reduction program has four major elements . . .

- Budgeting to determine the program's financial objectives and scope and the responsibilities for achieving these objectives
- Organizing to establish the work and teamwork required to meet the objectives
- Developing new projects to create a continuous stream of new ideas and programs for reducing costs
- Stimulating to encourage and measure the cost-reduction efforts of all members of the organization.

BUDGETING

A tough well-defined target is crucial for the program's success. This cost-reduction budget is top management's tool to define for all key supervisors the job to be done and the responsibilities and accountabilities for getting it done.

Determining the Budget's Size

A balance between cost-reduction needs and available opportunities should determine the size of a company's cost-reduction budget. Of course, the decision that opportunities are less than needs is equivalent to a decision to go out of business.

Determining needs involves analysis of the contribution that a cost-reduction program must make toward achievement of company profit goals. The company will probably start the analysis by comparing its current profit position with 1-, 2-, 5-, and 10-year profit objectives. Market position, percentage of market sales, going prices, and their trends will be considered. The company will also lay heavy emphasis on both the expected action of competitors and future market requirements.

The resulting dollar figure for the profit-improvement requirement will then be broken into its components. How much profit improvement is to be gained purely from secular growth in the company's markets? How much profit improvement will be realized from introducing new products and penetrating new markets? And how much profit improvement must accrue because of cost reduction?

This dollar figure for cost reduction will then be expressed in annual terms and will be related to an appropriate base—probably output at manufacturing cost. The resulting percentage, 5, 8, or 12 percent, reflects the company's minimum acceptable cost-reduction bogey.

Surprisingly enough, it has not always been recognized that cost-reduction budgets should be integrated with company profit goals and should balance needs with opportunities. One business whose earnings were in the red in 1954 was satisfied with a 6 percent cost-reduction budget because it was well above the 3 to 4 percent cost-reduction average for that industry. They are rapidly appreciating the trap of such a comparison in an era of strong competition when high prices and high costs mean loss of customers and profits to competition. Analysis has shown its bogey of minimum needs to be approximately 12 percent.

Where Are the Opportunities?

Cost-reduction opportunities to meet and even increase these bogeys are as broad as a business itself. A company will analyze all elements of cost, including trends of labor costs with particular

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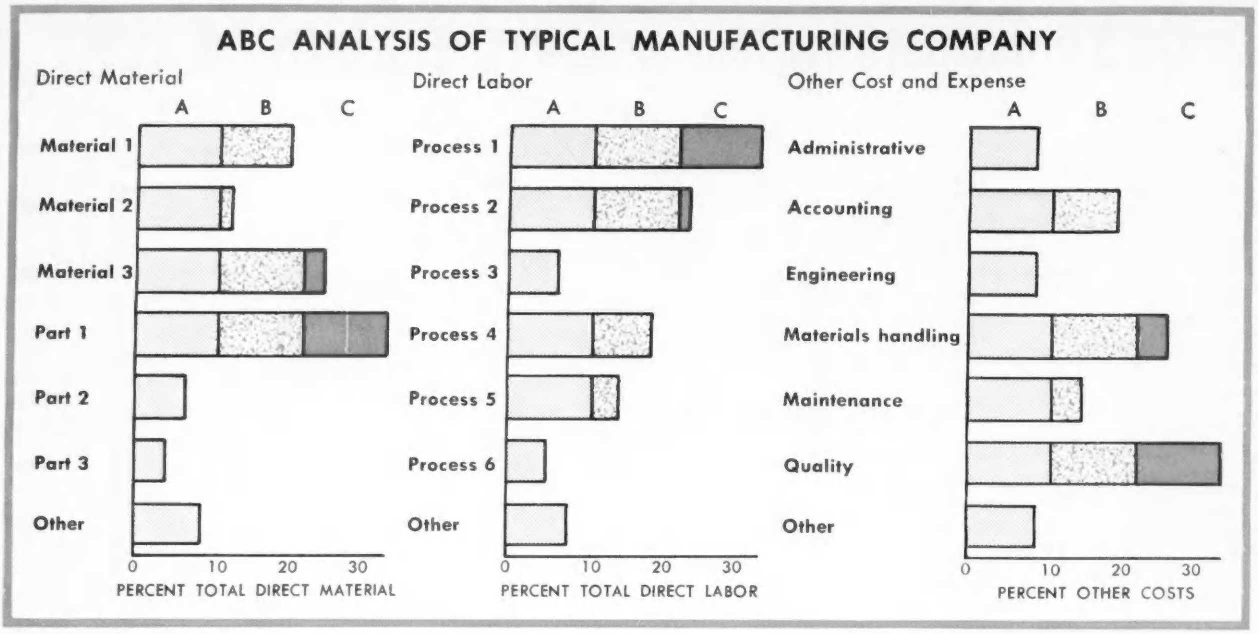


emphasis on productivity; examine material costs; review the trend of specific overhead items; and determine the potentialities of technological advances in packaging, materials handling, maintenance, finishing, and inspection.

Sometimes labor may represent no more than 20 percent of total manufacturing cost, while materials and overhead represent 80 percent. In the past, too many cost-reduction programs have spent 80 percent of their time seeking opportunities in the labor area, and only 20 percent in materials and overhead—the areas of greatest opportunities.

Chiefly, this has resulted from the overnarrow concept that a formal cost-reduction program is solely the activity of front-line supervisors and foremen. Material and overhead costs are somewhat harder for foremen to attack because they are closer to labor costs. But a genuinely broad cost-reduction program includes effort not only by front-line supervisors but also other key members of the organization: engineers, methods men, buyers, and production-control managers who have material and overhead facts at hand. They have opportunities for substantial cost reductions in materials and in overhead on their own part as well as through feeding appropriate facts to front-line supervision for their action.

Who Is Responsible?

The analysis of the size of a company's cost-reduction budget provides top management with a measure of the over-all cost-reduction par. The detailed budget itself, however, will be built up from the grass roots; if a man is expected to meet a budget, it is only fundamental that he have a substantial voice in its initial determination.

Every function, subfunction, organization component, and individual in a supervisory or equivalent capacity will establish cost-reduction bogeys and then become responsible for meeting them. Each budget will be based on analysis of cost-reduction needs and opportunities in a specific organization component. Some of these bogeys should and will be much higher than others because of particular needs and opportunities.

A foreman will include in his bogey the cost reductions on daily items of labor and material expended in his area because he controls these expenditures. In contrast, cost reduction of a product line involves items controlled by many individuals and groups. Here, a team drawn from these groups would establish the bogey.

All the individual cost-reduction bogeys should add up to or exceed the dollar total needed for company cost reduction. If not, then management must require more planning for added project development and resubmission of bogeys at the higher dollar levels needed.

How Is the Budget Prepared?

The cost-reduction budget buildup will take place while a company is establishing its other annual budgets for expense, output, and sales. This permits cost-reduction analysis during preparation of the investment budget to determine the dollar savings that are planned for new equipment purchases. It permits careful item-by-item examination of other budgets to identify potential areas for expense cost reduction.

Actual administration of a cost-reduction program requires the formal, written documentation of each proposed cost-reduction plan—a project that identifies the task, designates the participating personnel, and lists the anticipated savings.

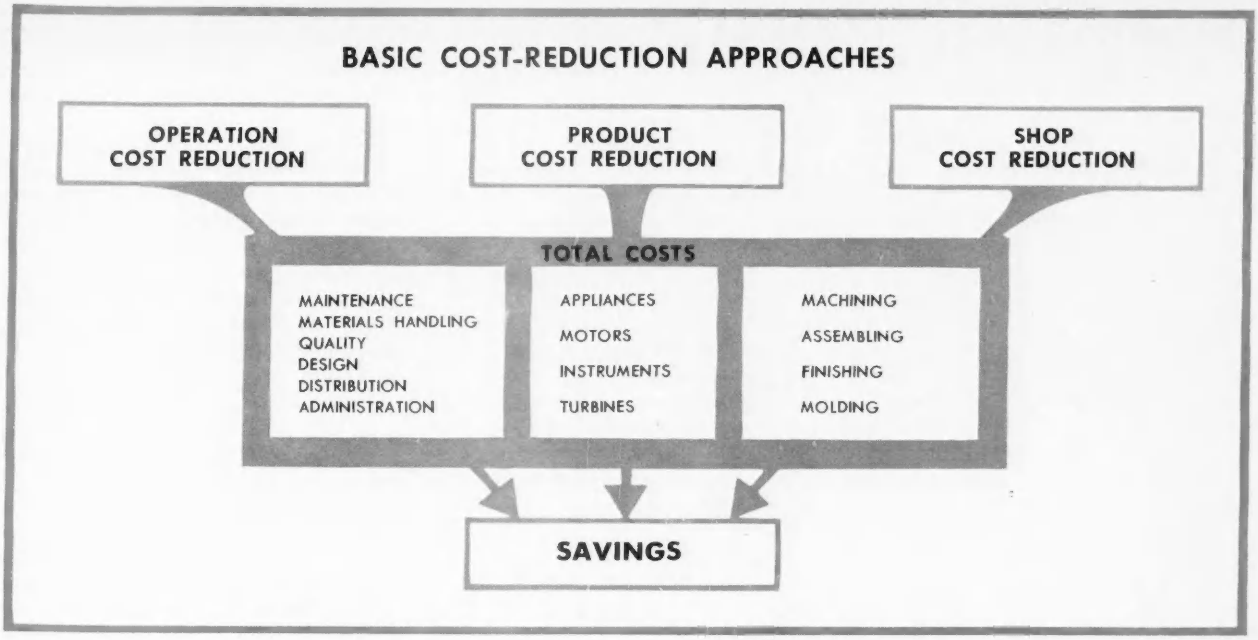
Each project will be assigned a number, followed to completion, and finally evaluated by the company's financial function to establish actual final dollar results. Realization of a supervisor's cost-reduction bogey normally requires that several projects be completed per year. The planned but incompleted projects presented for review at budget time form the hard core for building the budget for next year's cost reductions.

But a substantial allowance in the budget will make room for the additional projects sure to result from new ideas and developments formulated during the year.

ORGANIZING

The objective of organizing for cost reduction is to create a team for directly applying a company's know-how to the problems of reducing costs.

Six key elements are normally present



in successful company organization for cost reduction . . .

• As many individuals as possible should have a cost-reduction job.

• Normal organization channels are followed. Basic cost-reduction responsibility is on direct and functional supervision as a recognized, daily part of their jobs.

• Direct supervisory channels are supplemented by the use of teams to attack broad problems that no individual can adequately handle. These teams are usually composed of three or four individuals from the organization's components and specialists directly concerned. The teams are basically of two types: one, Product Teams organized to assist in reducing costs of specific company end products—such as motors or toasters—or the costs of specific, major in-process parts, such as shafts or heating units; and two, Process, or Operation, Teams organized to assist in reducing the cost of major, common plant processes—grinding, plating, or annealing—or to reduce the costs of such common expense operations as maintenance and administration.

• Over-all cost-reduction program effort for a Company's department is guided by a central steering committee that focuses attention on those items requiring maximum attention. The program is thus able to use the rifle approach rather than to spread its shots on a scatter-gun basis.

• The cost-reduction program involves continuous effort comparable with production and sales programs—not merely a periodic fireworks' display.

• One person is assigned as a spark plug—a specialist helping to integrate, measure, and stimulate—usually the secretary of the central steering committee. His duties are to establish and maintain means of regular reporting on the performance of each supervisor and each item relative to their cost-reduction budget; assist in establishing prompt contacts among company functions, getting cost-reduction plans adopted in minimum time; arrange for publicity and program stimulation; and set an example by finding projects for cost-reduction effort.

Cost-reduction activity will involve major and enthusiastic effort on the part of all key functions in a company. Marketing, engineering, manufacturing, finance, and employee relations are particularly in a position to achieve substantial reductions of cost. The chairman of the Steering Committee will usually be a member of the manufacturing management group. The cost-reduction specialist will also be found in the manufacturing function—the group who normally spends the greatest proportion of the cost-of-sales dollar.

DEVELOPING NEW PROJECTS

A cost-reduction program must first select its projects, then generate a continuous flow of significant, new cost-reduction ideas, and concentrate its efforts on the various areas that will pay off.

The first step is identification of major expenditure items requiring cost-reduction analysis.

The approach followed here is comparable to *ABC* Inventory Control (illustration, opposite page). A large part of the cost dollar is confined to a small number of elements—75 percent of the dollars in 15 or 20 percent of *A* items, for example. A second group, *B* items, may represent 30 percent of the items and 15 percent of the dollars. The final group, or *C* items, may be 50 or 60 percent in number but only 5 or 10 percent in dollars.

A good cost-reduction program seeks to identify first the *A* items, then the *B*, and only then the *C*. Are the *A* items in handling, spoilage, packing, machining, maintenance, finishing, or in plating? The company's financial group can give the steering committee these important answers.

The expenditures' trends are then reviewed. The *A* items that have had no recent substantial reductions are given top priority.

Basic Approaches

With this information available, basically different approaches (illustration) will be used to develop specific cost-reduction projects . . .

• Shop cost reduction involves the development of projects for attacking those day-to-day elements that are under the control of front-line foremen, supervisors, and specialists.

- Product and operations cost reduction involves the development of projects for reducing those broad costs that may require teamwork, long-range effort, and management attention.

Many areas of the business will be covered by the shop as well as the product and operations cost-reduction projects that have been thus developed. Here are a few current examples of how this works:

Box, Pack, and Ship—An electronic plant redesigned its packaging of radio tubes to take advantage of mechanical packing equipment, saving $19,000 a year, and allowing 18 out of 24 people to be placed on other more productive jobs.

An appliance manufacturer uses automatic packaging machines that will save $210,000 a year.

Quality Costs—These are recognized as one of the major cost elements in modern business. Quality-control programs are not only effective in improving the quality of the product but also as tools for minimizing quality costs.

A metal-products company completely renovated the inspection element of its quality-control program, placing inspection on a preventive rather than after-the-fact basis. Manufacturing losses were reduced by more than 50 percent, while inspection costs were cut by almost one half, saving $90,000 a year.

Materials Handling—An aircraft manufacturer will save $225,000 this year by an outstanding example of cost reduction. The company installed power tow chains and tow cars to deliver materials to the receiving dock, rail conveyors, and racks to carry materials through to inspection and to stock, and general conveyors to carry them to the point of use.

Nondurable Tools and Shop Supplies—One large business spends $72,000 a year for gloves and $1,225,000 for shop supplies—a potential field for cost reduction, with the company anticipating a $100,000 annual saving for its efforts.

Paperwork—The man who first suggested "don't say it, write it" might be startled to see how thoroughly his suggestion has been heeded by modern industry. Paperwork costs represent millions of dollars. By means of procedures analysis, office-methods improvement, and other techniques, the cost-reduction efforts of many companies are being concentrated on reducing them.

Maintenance—As more and more mechanized equipment is installed in line with the current trend, more and more maintenance effort will be required. Much cost-reduction effort is profitably being employed in this particular area.

Automation—Automation opportunities for cost improvement are only now being recognized in a number of companies.

Plant rearrangement; power, heat, and light conservation; recovery of waste materials; water purification; and inventory reduction suggest a few of the many additional technological areas in which cost-reduction projects are being put to work.

STIMULATING

It is not easy to create new cost-reduction ideas and then follow them through. After all, the great majority of cost-reduction projects are carried on by men and women for whom cost reduction is an additional element in their various jobs—production control, accounting, metalworking, quality control, product assembly.

These employees do good cost-reduction work because they want to, because they know it is important and that good results are expected, and because they believe that these good results will be recognized. This positive attitude toward cost reduction will be assured on the part of all company employees by stimulating four key factors:

The right atmosphere
Wide participation
Good communications
Individual recognition

Atmosphere—Real enthusiasm for cost reduction and a willingness to devote time to the activity must begin with top management. Only in this way can enthusiasm thread its way through front-line supervision to all plant employees. Management deeds, not words, set the cost-reduction climate.

Participation—The desire of employees to feel "part of it" has been long appreciated as an essential element in their effectiveness. Grass-roots budgeting, everyone-has-a-job organization, emphasis on widespread new project development gain much of this participation result for a cost-reduction program.

These steps are not mere perfunctory door-opening gestures on the part of top management. A company's greatest cost-reduction resource is the know-how and skill of its employees—a resource effective in direct proportion to the extent that it is applied to their individual jobs.

Communications—"What's going on in cost reduction?" is a question that can best be answered by a man's boss on a regular, voluntary, and factual basis. A plant's newspaper, poster campaigns, and informational meetings are valuable but supplemental to, rather than a substitute for, the face-to-face supervisor-employee relationship in cost reduction.

Recognition—Individual recognition for a job well done is perhaps the most important factor in cost-reduction stimulation.

Cost-reduction accomplishment should be a major consideration in decisions relating to bonuses, salary increases, and promotions to bigger job assignments. But these more spectacular rewards can never do the total job. Genuine praise, a handshake from the boss, conspicuous posting of performance charts showing individual contributions—all are extremely important in the experience of many cost-reduction programs.

Some companies find special events valuable. One aircraft organization awards special certificates for cost-reduction successes in the form of Cost-reduction Bucks. Gifts are awarded at the end of the cost-reduction year in proportion to the total sum of Bucks held by individuals.

An appliance organization carries through much the same plan by awarding points. At the end of the year, an auction of sporting goods, household appliances, and other items is held. Bids on these articles are made in proportion to the number of cost-reduction points that individuals hold.

Cost-reduction's Contribution

An effective cost-reduction program is a major company need for growth, health, and profitability in the severely competitive economy of the mid-twentieth century.

A cost-reduction program properly budgeted, adequately organized, effective in new project development, and enthusiastic in stimulation will become one of a business's greatest assets. Such a program will permeate the entire company with an attitude basic to cost improvement in American industry: There is always a better way—and our company can find it. Ω

Public Relations and the Engineer—Or Anybody

By KENNETH G. PATRICK

Many years ago in Cambridge, Ralph Waldo Emerson addressed the annual meeting of the Phi Beta Kappa society. Although the same title was always given to each speaker, only Emerson—who had a genius for thinking straight, and who was not much awed by a lot of Phi Beta Kappas anyway—is remembered for his address, "The American Scholar." Emerson did not merely extol the American scholar and review his achievements in the flowering of New England; he put the scholar to work, showing him that he had a continuing responsibility to develop and improve his fellow men.

Responsibility of the Engineer

A few years ago, Charles E. Wilson made a similar presentation when he addressed a meeting of the American Institute of Electrical Engineers (AIEE) in New York. He maintained that the engineer is a professional man—a member of a professional estate—not only by virtue of a license that had been granted him but also by his responsibility to break open the technical shell surrounding him. In this capacity he must apply himself, his disciplines, his standards, and his community's respect as he relates himself to all the world's problems: its politics, its economic tangles, its human relationships, and even its survival. Wilson said that the scientist and the engineer must do more than produce the hydrogen bomb; it is also their responsibility to help keep men from destroying themselves in a world that lives in the shadow of atomic weapons. Membership in a professional estate is thus not simply a license to practice a profession; it commands the professional man to assume stewardship and leadership—always required of the strong in any well-integrated society.

The key to conscious leadership and to the assumption of obligations, whether they be moral or professional, lies in the development of attitudes. And the main business of public relations is attitude development of a company, a profession, or any other of the special segments that go to make up the whole public. Here, much misunderstanding arises about the function of public relations, stress being mistakenly placed on the pitcher of ideas rather than on the catcher.

No public-relations counselor, regardless of his certifications, can by his own efforts make a sick company well or make a bad company good in the eyes of its employees, customers, and neighbors. He can't sit in an ivory tower and create speeches, statements, advertising, and business policies that will alter the situation in the slightest. Some think they can. Unfortunately, too many business executives think they can. Bad human relationships are not cured so simply. Tools and tricks are in every trade and probably in every profession, but to develop positive attitudes of the fellow who dislikes a company involves making changes in the people, products, and habits at his level. For his association in these areas aroused his dislike in the first place.

Two things relate to the subject of engineers—or anybody—and public relations: communication and definition of real public relations.

Communication

Among people engaged in advertising, public relations, editing, writing, industrial relations, and related fields, the interest in communication has heightened in the last few years. And communication simply means reaching another person through the spoken or written word and having your message understood. You make your pitch, but it's important that somebody catch it. This is really an old problem, but businessmen first discovered their communication deficiencies during the New Deal. For many years, management was too busy producing and selling to be interested in either examining their social obligations and behavior patterns or explaining them to the public.

After prolonged periods of hurtful attack, they began the slow, painful process of introspection and exposition. For a long time they just talked to each other—many still do. Their advertising and speeches were unrealistic, ineffective, and uninteresting. Ultimately raising the cry, *Fortune* first posed the problem of effective communication in a series of articles, "Is Anybody Listening?"

Business and the competitive system aren't evil; basically, they abound with good works. But their spokesmen have been tongue-tied. Busy improving techniques of research, production, and distribution, they neglected the fundamental need for winning the confidence, respect, and friendship of the common man.

Much lost ground has now been recovered, for the problem has been recognized, defined, and tackled. In this process the competent public-relations man has played a major role. For our purposes we will emphasize techniques rather than the results, because when the end becomes more important than the means, business grows more illiterate—it talks but no one listens. Written and oral communication is a means to an end, not the end itself.

Successful communication can be carried on without agreement. For example, we have excellent communication with the Kremlin, and they with us, but we do not agree. Further, good communication will not necessarily resolve all human conflict. And again, one of the major communication problems in more large businesses exists between the management and the employees—an area where we have no illusions about getting complete agreement. Ralph Paine of *Fortune* says: "The inclination to spit in the boss's eye is a very deep-seated human urge and neither the science nor the art of communication is going to change it much in, say, the next 10 generations." The primary tool of public-relations practice, communication is neither a fancy word nor a new science. As practiced over the back fence, effective communication occurs when someone tells you something about himself, his family, problems, or ambitions, and you listen and comprehend. One man tells another. It's as

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simple as that. Trouble arises when one of these men is a manager of a billion-dollar business, a political leader, or the head of a union and the other man is multiplied by 1000 or 10,000 or a 100,000 scattered about the country in various economic and social circumstances. And so the job of efficient communication takes on complexity. Credibility retreats, familiarity turns to cynicism, language itself becomes a barrier instead of a bond. Yet, big jobs of communication can be done just as well as the small ones, if we remember that results are obtained at the grass-roots level and that the big jobs are just multiplications of the small ones.

Real Public Relations

Now let's get down to the business of definitions and mechanics. The principal complexity in practicing public relations lies in keeping any adequate definition of the job from sounding grand and high-flown before it's put on paper. For we sometimes forget that the various jobs required to achieve good relationships with the public are usually ordinary and simple.

We can define public relations as the design and manufacture of a good reputation—a concept with manifold implications. Before you know it, you find yourself talking about trust, confidence, and credibility. And you realize that to obtain desired public opinion you must create a proper climate at all levels of the economy and society. After spending hours with the social scientists and the opinion researchers, you get so lost among high-sounding ideas and statistical measurements that you are muscle- or perhaps brain-bound. Boil it all down, and you'll find that you are trying to get people to like you, respect you, believe you, or at least listen to you.

Today, scientific and mechanical devices analyze an advertisement or a piece of writing and score it for its technical performance. We can measure rather accurately, but expensively, whether people watch a television program, how many of them change their minds and shut the program off, and even how many leave the room when the commercial goes on the air. But no mechanical measurement ever tells you whether people like you—even when you pay professional researchers to ask them. Maybe they are just afraid to be candid. Getting so enamored of our machinery that we lose sight of the end product continues to be a pitfall in this business.

Know Your Audience

The public is a lot of people—a little frightening en masse—and best taken one at a time. You begin by dividing it into smaller groups of special publics, or audiences, who have a personal interest in what you say and do and in whom you have a complementary interest. They may own stock, work in your plants, live in a community where you operate payrolls, buy your products, sell you something, teach school, run the banks, operate the city government, and the like.

Once you identify these audiences, you study their habits, location, likes, and dislikes. On the basis of these, you try to make friends with them. Perhaps you do it by paying regular dividends on their investment—giving you a foot in the door. This recognition of their ownership in your business reminds them of their responsibilities as investors in the American economy. If it is a good product, well-sold and well-serviced, you may be able to sell them something—another foot in the door. In the market place, businesses are elected everyday, with all of us doing business at the public's pleasure. Often the greatest service you can do for your special publics is regularly and promptly providing them with reliable information, although embarrassing at times.

Tools of the Profession

The public-relations business has many professional tools: Advertising, publicity, radio, and television are in one category; open-house tours and scientific demonstrations in another; and participation in community affairs, development of teaching aids on paper and film, co-operation with educational institutions, speakers' bureaus, books, and pamphlets are among many others, depending on the nature of the organization and the job to be done. Relatively few professional public-relations people in an organization develop and use these tools that, taken by themselves, are only a drop in the bucket.

A company does not exist on paper, on film, or in the speeches of its top men—but in every contact it makes with each man, woman, and child. A company's reputation does not lie solely in the hands of its officers, managers, and advertising agencies. Every employee and each of his relatives and neighbors, as well as every product distributed, influence reputation. And a lot of people who aren't even on the payroll—independent merchants, contractors, servicemen, telephone operators, truck drivers—determine what millions think about a company.

Even if General Electric were to disregard these people, we still have 210,151 employees who go out of our offices, plants, and laboratories to live their own lives among other human beings. What any one of them says about the Company over a bridge table or a back fence carries far more weight than anything we would say officially in the *Saturday Evening Post* or the *Cleveland Plain Dealer*.

And thus we come back to the art of communication. Today we can prove that primarily most people's opinions result from person-to-person conversations and only secondarily from something they read, see, or hear. Some may rely on formal media such as advertising or news to support their opinions.

Everybody's Business

When you make your living in the public-relations business, this important fact can discourage or scare you—or even make you smarter. In our Company, as probably in many others today, we say public relations is everybody's business. We probably spend more than half of our time and energy on our own people, making them understand the importance of what they do and say because they are co-proprietors of our common undertaking.

Over the years, engineers have conducted their public relations with some measure of success. Little boys grow up wanting to be engineers; movie-script writers cast engineers as heroes; and the engineering profession carries a connotation of uprightness and trustworthiness. The real significance between engineers and public relations is that engineers are people—with a responsibility to share.

A professional mystery does not surround the practice of public relations. Its success depends on effective communication, on mobilizing the understanding help of everybody in an organization, and on never forgetting that the public is people—one at a time. Ω

RESIDENTIAL YEAR-ROUND AIR CONDITIONER WITH AIR-WALL SYSTEM IS QUIET AND COMPACT.

Trends in Residential Air-Conditioning Systems

By C. M. toeLAER and T. N. WILLCOX

Nearly everyone in this country has experienced the benefits of air conditioning. Although people like it and want it at home as well as in public places, they want to know what comfort to expect from residential air conditioning, how to get the best performance from the air conditioner, and why cooling costs are reduced by good home-building practices.

Growing Competitive Market

Air conditioning for indoor comfort won initial acceptance on a profit-making basis. Humanitarian benefits were secondary. For instance, competition made cooling almost mandatory in theatres, restaurants, hotels, and other public places. Enlightened manufacturers are using summer cooling to improve quality and quantity of output, as well as to attract and hold better workers.

The typical growth pattern of the residential-cooling market started with a few high-cost custom-designed and custom-installed systems. Then residential-cooling manufacturers borrowed the concept of packaged cooling systems from the well-established commercial cooling industry. And now, standardization and volume-production techniques retell the old familiar story of cost reduction and mass-marketing.

Careful estimates of the national market for control-system residential cooling indicate less than one percent saturation at the end of 1954. In other words, of the millions of home owners who annually swelter in summer but could afford to be cool, less than 10 percent have cooling systems. Forecasters predict that 7-million homes will be centrally cooled within the next 10 years—a forecast fully supported by the present geometrically accelerating sales rate. And of utmost importance to the industry is the investment of about $1000 in each residential cooling installation that has aroused keen competition among dozens of new manufacturers in the business.

ABC's of Comfort Cooling

Who has ever seen so much as a single Btu of heat? And yet, this invisible and indirectly measured form of energy is what the air conditioner takes out of the indoor air to make it more comfortable.

Who can predict what temperature will be comfortable? Only by trial can the ever-changing personal preferences for indoor temperatures be best established. For instance, infants, children, and elderly people prefer warmer temperatures than do active adults. Health, time of day, and weather are other reasons why air conditioners must be capable of producing a range of conditions.

A complete residential air-conditioning system automatically cools the house, removes excess humidity, filters and circulates indoor air, and conditions infiltrated and ventilated air from outdoors. Each of these essential features performs a useful function.

The unit's adjustable thermostat maintains a preset temperature that can be selected from broad indoor temperature range. So far, demand for humidity control has not justified the added cost. For during damp weather when outdoor temperature is lower than on a dry day, the cooling unit can be set to hold a lower indoor temperature. Two benefits occur: More indoor moisture is removed when the cooling unit runs longer; and a slightly lower temperature adds to body comfort when the air is humid.

By understanding how summer heat invades his home, the owner can help reduce the cooling unit's operating hours, sometimes making the difference between a successful cooling installation and a poor one.

Heat enters a cool house by conduction through the windows, walls, and roof. If the space under the house is warmer than the air inside, heat flows up through the floor. Hot outside air may blow in through cracks around doors and windows, and sunshine through windows adds heat. People and household appliances also radiate heat.

WATER-COOLED AND GAS-HEATED UNITS WORK SIDE BY SIDE TO KEEP THIS NORTHERN NEW JERSEY HOME COMFORTABLE YEAR ROUND.

Most heat loads can be substantially reduced with a minimum of expense. Insulation in the attic floor, side walls, and under the house can cut in half the respective conduction heat gains. Attic ventilation, reducing the high attic temperature, gives less heat flow through the attic floor. Storm sash on the windows or other types of double glazing will reduce the heat conducted through glass. Weather-stripped doors and windows are recommended. Window shading that prevents direct sunlight from entering—such as a roof overhang on south walls—can reduce solar load 50 percent or more. Not all these load-reducing methods can be used on older homes, but new homes in the planning stage should include each one.

Even though the inside temperature is low, indoor humidity may cause discomfort. While the cooling unit runs, the humidity stays low. However, as soon as the house temperature reaches the thermostat setting, cooling stops and humidity begins to rise. One of the best ways to slow down moisture migration into the house is the use of vapor barriers between the floor and the ground of crawl-space homes, between concrete-slab floors and moist, tamped gravel, and between inside walls and their insulation. Weather stripping is another effective means of avoiding high indoor humidity. A kitchen exhaust fan, equally important, removes cooking and combustion moisture from a gas range. Also, laundry driers must have outdoor vents.

Much emphasis is placed on keeping moisture out of the house not only because humidity causes discomfort but also because the air conditioner must work longer and may even have to be bigger just to eliminate the extra moisture.

Size Selection

The well-informed home owner will insist that all practical means are used to reduce cooling load before the unit is selected. And a good selection is based on carefully estimated room loads.

Oversized cooling units will cycle on and off frequently, especially during mildly warm weather. And every time the unit goes off, indoor humidity rises. Because of thermostat time lag, each cooling cycle with an oversized unit sends the room temperature below the desired setting, resulting in appreciably wider temperature variations than with correctly sized units.

Undersized units show up poorly during the warmest days of the cooling season, when units run constantly during the midday heat, but indoor temperature continues to rise too high for comfort. During the milder parts of the cooling season, the undersized equipment performs exceptionally well, reducing humidity and maintaining temperature.

Although residential cooling units are expected to give comfort 24 hours a day, 7 days a week, home owners are critical of high owning and operating costs. Therefore, residential cooling units should have only the capacity needed to hold the desired indoor temperature on hot midsummer days. Oversized units, big enough to pull down the temperature of an overheated house, not only cost more initially but also give less comfort after the temperature is down. Undersized units run more hours and sometimes have trouble maintaining a low enough temperature.

Depend on the Thermostat

All too often the user waits until indoor temperature feels uncomfortable before turning on the cooling unit. By then the house has acquired so much heat that the cooling unit runs all day and late into the evening before catching up. The home owner should let the thermostat work for him by leaving power connected to the cooling unit and the thermostat on guard at the desired temperature setting.

Advancement in Design

Only four years ago, residential cooling units for central-system installation did not exist. The so-called residential units at that time were merely modified commercial air conditioners built for upward air delivery in high headroom space. The unnecessarily tall cabinet contained a built-in fan, an open-type motor compressor with belt drive, costly industrial-type electric controls, inconvenient duct connections, and unnecessary weight. In three short years, under the pressure of competition and consumer needs, residential cooling units have attained full stature as independent products designed for a specific market.

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Both authors are with General Electric's Home Heating and Cooling Dept., Bloomfield, NJ. Mr. toeLaer—Manager of Commercial Engineering—has been with the Company since 1940. A recipient of the Coffin Award in 1946, Mr. Willcox, Application Engineer, has been with GE since 1936.

Physical appearance of modern cooling units gives the immediate impression, "How small!" For example, volume of the G-E three-ton upflow cooling unit has been reduced from 34 cubic feet to 21; the three-ton downflow and horizontal air-delivery models are only 15 cubic feet. And as volume was reduced, so was the weight.

Test temperatures and the flow of air and water are specified by the American Society of Refrigerating Engineers (ASRE). An air conditioner's cooling capacity is customarily stated in Btu's per hour while operating under standard ASRE test conditions. For convenience, cooling unit sizes are often expressed in "tons" of cooling capacity, a ton being 12,000 Btu's per hour, or the amount of cooling obtained from melting a ton of ice in 24 hours. The obsolete practice of rating air conditioners by horsepower is rapidly being abandoned, because units with air-cooled condensers (photo) take entirely different power inputs than do units with water-cooled condensers.

A new freedom of installation was created by the two-foot-high downflow and horizontal home-cooling units. Installed in a closet or alcove of the living space, the downflow cooling unit fits under the downflow or counterflow warm-air furnace, making a year-round air conditioner (photo, page 45). The horizontal cooling unit can be joined in series with a horizontal-flow warm-air furnace. The resulting year-round air conditioner takes up no floor space at all when installed in crawl space under the house, suspended overhead in a utility or laundry room, or mounted in the attic. The upflow cooling unit joins with a matching warm-air furnace to make still another year-round air conditioner.

The interior of a new home-cooling unit shows remarkable changes. A compact, hermetically sealed refrigerant system has replaced the belt-driven compressor. Cooling outputs are available in a carefully selected range of sizes, permitting the best possible matching of cooling capacity to load. Once considered indispensible, the blower and air filter are now missing from all but the five-ton units. Furnace fans and filters circulate air for both heating and cooling. The occasional application requiring a self-contained cooling unit can be supplied with a factory-built accessory fan and external air-filter frame.

Within the last year, electric-powered home-cooling units with air-cooled condensers have become popular. When we recall that many cooling units use water to dispose of the condenser heat, this sounds like getting something for nothing. However, the extra electric power required to air-cool condensers may offset the cost of water. A well-rounded product line has both water-cooled and air-cooled condensers so that users can select equipment ideally suited to their individual needs, with due consideration for utility cost.

Air Circulation

Air ducts and registers are used in a central air-conditioning system to circulate air throughout the house, making each room equally comfortable from wall to wall on a year-round basis.

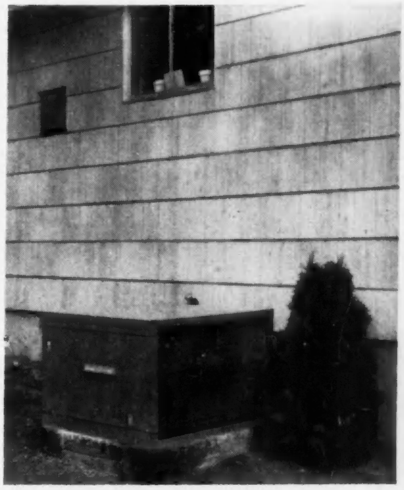
The duct system connecting the air conditioner with the room has two parts: supply ducts for freshly conditioned air and return ducts for stale air. Easily concealed between floor joists or wall studs, modern ducts are round tubes four or five inches in diameter or rectangular ducts of equivalent cross-sectional area. Sometimes, a trunk duct can be used in the basement or crawl space to save running many long lengths of small duct to a remote part of the house.

Supply ducts in unconditioned space, such as in attic or open crawl space, must be insulated and the insulation covered with a vapor barrier to prevent moisture condensation on the metallic surface of the cold supply duct. Condensed moisture aids corrosion, destroys insulating properties, and might damage interior decoration.

A minor adjustment, or balancing, requiring a damper at the beginning of each supply duct is almost always needed to give about the same temperatures in all rooms.

Room air—already cooler, cleaner, and drier than outdoor air—requires less conditioning to prepare it for delivery to the occupied space. Although this air should be returned to the air conditioner for reconditioning, some outdoor air is also needed to ventilate the house. This usually enters through cracks around windows and doors. Sometimes a controlled amount is brought in through a separate duct with an adjustable damper. The air conditioner then filters and conditions this air before delivery to the occupied space.

Outer walls and their windows and doors account for 75 percent or more of the heating and cooling load. To offset this and make all parts of a room equally comfortable, conditioned air should enter the room at the outer wall and actually "wash" the exposed glass area. For this reason, modern wall registers designed to give a fan-like pattern—are usually located under windows on outside walls.



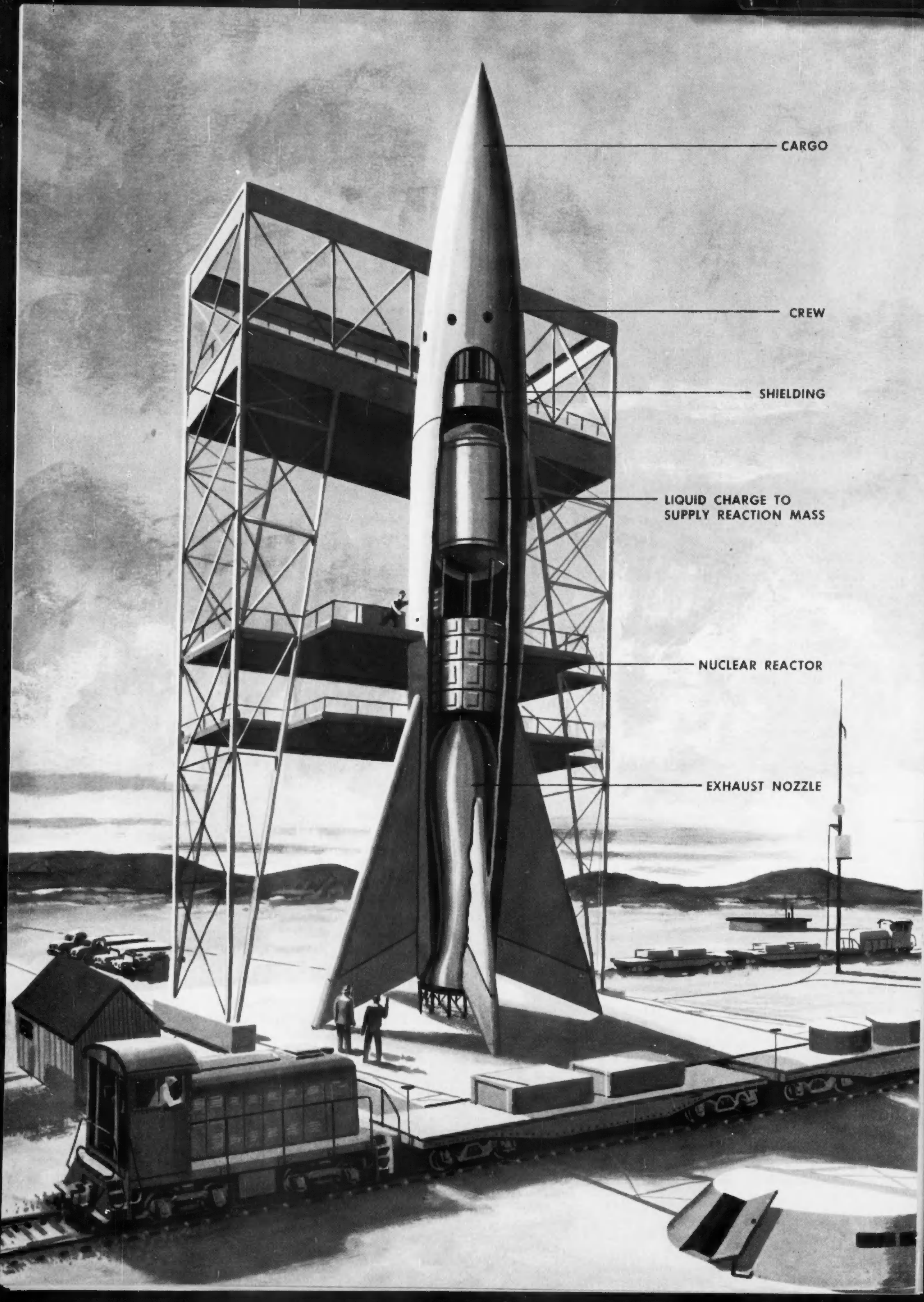
AIR-COOLED CONDENSER REDUCES WATER BILL.

To achieve maximum comfort, temperatures of room walls and room air should be nearly equal. If they differ, the density of the air near the wall will change. Heavier cold air will drift downward, causing drafts that in winter are particularly noticeable near windows and across the floor. Also, cold walls make people feel cold, just as in summer people are heated by a warm wall.

A successful way to control the wall temperature is to spread a layer of conditioned air over the inside surface of the outer wall. The air blowing upward in a fan-like pattern prevents cold downdrafts in winter. And in summer the cool, heavier air from the register is thrown upward to mix with the room air instead of separating into a layer of cool air at the floor and a warm layer at the ceiling. No uncomfortable blast of conditioned air need ever strike the occupants.

Comfort for All

The cost of residential air conditioning has been so reduced by popular demand, volume production, and competition that an ever-increasing number of home owners now use it. Central-system installations that air condition the entire home are constantly setting higher standards of performance and comfort. Installation and servicing are becoming simpler. More and more satisfied users claim better health, cleaner homes, and more pleasant living—all assuring the expanding future of residential air conditioning. Ω


CARGO
CREW
SHIELDING
LIQUID CHARGE TO
SUPPLY REACTION MASS
NUCLEAR REACTOR
EXHAUST NOZZLE

Can Nuclear Energy Drive Interplanetary Rockets?

By CLIFFORD MANNAL

Today, rocket engineers look toward distant horizons. Studies indicate the feasibility of interplanetary missiles. A frequently expressed hope is that the new force of nuclear power will supply the thrust for rockets, just as 40 years ago the internal combustion engine solved the power-plant problem for airplanes.

Whether this may ultimately be true is not clear at this time. This article is an assessment of where we are now and where we may be in a few years.

First, let's look at the magnitude of this problem—essentially different from ordinary flights. An elementary calculation shows that to leave the earth behind a rocket must possess a velocity of approximately seven miles per second, or about 21-million foot-pounds of energy per pound. For instance, a rocket weighing 100 tons (a V-2 weighed only 14) would require about 0.4×10^{13} foot-pounds of energy—about the same kinetic energy as 21,000 medium-sized cars going 60 mph.

Early Ideas

For almost a century, this problem of imparting such enormous velocity and energy to a large rocket has provoked much discussion in rocket circles. Historically, the first proposed solution was to shoot the vehicle into space through an enormous gun—a hole bored in the earth. Probably the most thoroughly discredited of all, this theory posed the practical problems of making a straight tube of appropriate bore and length and achieving a breech strength capable of withstanding the force of the powder charge. And beyond these lies the fatal objection that the acceleration of a vehicle in any tube of reasonable length would destroy equipment and passengers. For example, if the tube were 1000 feet long, the acceleration would have to be 20,000 Gs for the duration of the flight through the tube. Even increasing the tube's length to 10,000 feet would still leave accelerations in the order of 2000 Gs. A man subject to accelerations in excess of 10 Gs for more than a fraction of a second will suffer permanent physiological damage. (See "The Invisible Force," page 8.) Thus the shooting approach would be useful only if we wanted to bombard planets with inanimate matter.

TOMORROW'S nuclear-powered rockets may look something like this artist's conception. (This drawing shows the rocket before it has been energized with atomic fuel.)

Advantages of rocket propulsion make the rocket principle a much better approach. First, the propulsion device can work as well in a vacuum as in a gaseous atmosphere, because forward thrust is entirely the result of the individual gas molecule's recoiling from the walls of the reaction chamber. Further, because the magnitude of the thrust depends on the amount of gas ejected from the rocket, the thrust and therefore the acceleration can be controlled by regulating the rate of combustion. Both in theory and practice, a thruster can be made to deliver accelerations well within the limitations of the human organism. Finally, the thrust of the device remains constant, independent of the velocity of the rocket. Considering the rocket's reaction chamber as the frame of reference, the same force will continue to be exerted by a gas molecule's bouncing around at the same temperature whatever the relative speed of the reaction chamber with respect to a planet. In such a rocket we can attain practically unlimited velocity simply by continuing the acceleration long enough.

Solid Fuel

The oldest rockets appeared as early as the Middle Ages, and possibly even before this in China. Until the last few decades, the propellant was some variation of gunpowder, satisfactory for limited military applications. In both rifled ordnance and rocket development, the rocket was once the superior weapon in mobility and range and only slightly inferior in accuracy.

However, the powder-propelled rocket had serious limitations. The rate of burning depended critically on the history of the powder charge. Cracks or imperfections in the densely packed charge might cause wide variations in the burning rate. As the charge in the reaction chamber was consumed, the chamber became larger, changing the rate of burning. Thus the volume of hot gases emitted varied, resulting in a variable thrust. Added to the technical difficulties is the unsolved problem of satisfactorily changing the rate of combustion once the charge is ignited. Compared with the liquid-fuel rocket, the large-scale powder rocket seemed to be a dead-end street.

But problems that appear difficult or even insuperable to one generation are frequently solved with ease in the next. Much work is under way at the present time with solid propellants, and recent advances indicate that rockets propelled by these means are superior in performance for certain applications.

Liquid Fuel

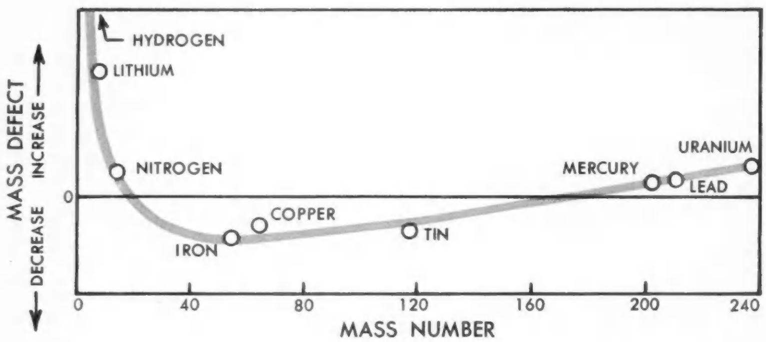
About 30 years ago, investigators discouraged by the limitations in the then existing solid propellants began experimenting with liquid fuels. Robert H. Goddard in this country and Willi Ley in Germany were among the first to create successful models of liquid-fuel-propelled rockets using gasoline and liquid oxygen. For a variety of reasons, Goddard's work was largely neglected. Rocket research in this country was carried on at a relatively low level before and during World War II. On the other hand, the German military establishment began considering the long-range rocket as a major military weapon in about 1938. During the last part of the war, as many as 12,000 people were working at the Peenemunde Experimental Rocket Station. And probably three times as many production workers were actually constructing V-2s. Some 2000 of these devices, each weighing 14 tons and standing 47 feet high, were built and fired. Of these, more than 1300 reached England from a cross-channel base located 180 to 190 miles away.

With this rocket background, extrapolation to a liquid-fuel free-space rocket is straightforward—but expensive. To establish a satellite base 1075 miles above the earth's surface, Dr. Werner Von Braun proposed a rocket that would stand 265 feet high, weigh 7000 tons at launching, and carry 36 tons of cargo. This rocket would consume 5280 tons of propellant in the first 84 seconds, costing more than

FUSION AND FISSION

Einstein's famous equation, $E=mc^2$, converting mass into energy, appropriately begins any discussion of nuclear reactors. Interpreted literally, it says that one teaspoon of water is the energy equivalent of 4×10^5 hp delivered continuously for one year.

Unfortunately, we cannot now and possibly never will be able to convert all the mass of common elements into their energy equivalents. While Einstein's equation is true for any degree of mass-to-energy conversion as far as is known, we can apply it, or hope to apply it, only when a so-called mass defect exists in the nucleus (illustration). The vertical scale plots the difference between the mass of the nucleus or atom and a perfect multiple of unit atomic mass. If all the nuclei were perfectly constructed of identical building blocks, then all the atoms would weigh exactly this amount times some exact integral multiple. However, this is not true. In relation to the atoms near the center of the curve, the light atoms (left portion) are much too heavy, and those in the vicinity of uranium (right portion) are slightly too heavy. Therefore, if you combine two light atoms, forming a somewhat heavier atom—for example, if you took H^2 and He^4 and made Li^6—0.0017 units of mass would be left over. Or if you subdivided a heavy atom such as lead or bismuth into two atoms of about half the previous weight, you would have, say, cadmium and tin atoms, with about one fourth or one fifth as much mass left over as in the first example. Only this leftover mass is converted into energy.



With mass defects for the light atoms being so much larger than for the heavy atoms, you might expect this region of the curve to be the most fruitful for power production. But the joining, or fusion, process is much more difficult than the splitting of a heavy atom. Theoretically, the temperatures required for this fusion process are believed to approach those existing on the sun. Obtaining and controlling such temperatures to liberate energy at a measured, or desired, rate is impossible at this time.

The heavy end (right) of the curve shows, for example, that the teaspoonful of water can now yield some 20 hp continuously for one year—a remarkable figure when compared with conventional fuels. But even though practically all heavier elements would have a smaller total energy if subdivided into lighter elements, only a few divide readily: the so-called fissionable materials, such as U-235 and plutonium. With powerful particle accelerators, we can create highly energetic projectiles that might split an atom into two new lighter elements. However, so much energy is spent arriving at the necessary speed, and because the atomic nuclei are such small targets that few reactions actually occur, this over-all process yields only a minute fraction of the input power. In practice, therefore, it is highly unfavorable—even though the individual mass-defect process might show a positive balance for converting mass into energy.

The fissionable elements differ importantly from the nonfissionable in that when they break apart, or fission, they emit between two and three neutrons. These particles are of nearly the same mass as the hydrogen atom but with no charge, and they are shot forth with great velocity. Further, when the nucleus of a fissionable atom is struck by one additional neutron, it disintegrates into two pieces, plus two or three neutrons, some gamma rays, and the mass-defect energy.

A self-sustaining reaction cannot occur unless a certain amount, or critical mass, of fissionable material is present in the assembly. The neutrons necessary for the reaction must come from atoms that have just fissioned; we only need one but actually have two or three for each fission. Ultimately, the neutrons not used in the reaction either escape from the reactor or are absorbed in the structure. Each different arrangement of fissionable material and each arrangement including materials that either absorb neutrons—and therefore do not contribute to the reaction—or reflect them back into the reacting region will require different critical masses.

The significant part of the critical-mass concept is simply this: Any design of nuclear reactor requires a certain amount of fissionable material to make it react. If, for example, we put in a large amount of structural material that absorbs neutrons, we must counterbalance this by adding more fissionable material.

More important to your understanding of the application of this remarkable fuel, however, is tracking down exactly what happens to the mass-defect energy. Where does it go? How can we turn this fabulous energy release directly into useful power? First of all, it goes into the kinetic energy of the fissioning uranium atom's two fragments. For the most part, rather than split into two nearly equal portions of mass, say, 117 and 118, the uranium atom prefers to form fragments of about 90 and 145. That is, an individual fission may produce a krypton and a europium atom or a zirconium and a neodymium atom. Each of these relatively massive atoms has approximately 100-million electron volts of kinetic energy. (An electron volt is the energy acquired by an electron after it has fallen through a potential difference of one volt. Giving this much energy to an electron by heat would require a temperature of 11,400 C.) In the fission process, the two particles fly apart with a velocity that if obtained by heat would require 10^{12} C—a temperature of roughly one-million-million C.

Before the fission fragments go very far, they collide many times with other atoms, each time losing some energy. The net result is a little cylinder, perhaps 100 atoms in diameter and 10,000 atoms long, that is for a brief instant at some tens of thousands of degrees. Thus we have gone from a single atomic fragment at an almost incredible temperature to a little rod of atoms that are briefly at a temperature 10 or more times greater than the vaporization temperature of a highly refractory metal, such as molybdenum (boiling point: 3620 C).

$500,000 per ascent. Major limitations are thus tied to fuel efficiency, and the need for a better fuel is obvious.

That some new chemical compound of vastly superior potency will suddenly be discovered does not seem promising. The nature of the use of a liquid fuel in a rocket requires that it be reasonably inexpensive, as well as highly stable to prevent disastrous predetonation. Also, to provide a large volume of high-temperature gas, it should be able to combine with some other liquid having these same properties. The Von Braun rocket would use hydrazine and nitric acid as the propellant. Other designs plan to use alcohol and liquid oxygen, gasoline and liquid oxygen, or analine and nitric acid. Within 50 percent, energy releases of all these materials are the same. From what we know about chemical binding forces and the possibility of combining simple compounds that have all the desired characteristics, it seems highly improbable that we can improve the present situation by as much as 10 times.

Nuclear Power

Could nuclear power—now being used to drive submarines and possibly battleships and aircraft in the near future—solve the problem of propelling large rockets?

Before we can give a definite answer, we must survey atomic power plants, including their operating temperatures, heat removal, control, shielding, and refueling. Then we can draw some broad conclusions concerning the applicability of such power plants to rockets. (A discussion of the fundamentals of fusion, fission, and nuclear reactors appears on the opposite page.)

A nuclear reactor—the heart of an atomic power plant—releases heat energy at very high temperatures. Unfortunately, we don't know how to convert this heat directly into the rotation of a shaft. Instead, we must be content to allow the heat from atomic "fire" in the reactor to be drained away and diluted by a surrounding mass of metal to temperatures more practical for modern technology—1000 or even 1500 C. By controlling the number of fission events per second as well as the rate of heat removal, we can control both the thermal power delivered by our nuclear reactor and the temperature level at which we use the power.

One of the primary questions is: How can we make this heat useful? Fundamentally, a transfer medium—air, helium, water, or liquid metals—must be moved through the heat-generating body rapidly enough to carry off the heat. Because this medium obtains its heat primarily by contact with the hot surface, the fissionable material must be fabricated to give maximum surface area, yet retain sufficient structural strength and offer a minimum of flow obstruction. Obviously, it would be extremely desirable—but entirely impractical—to have the structural members as thin as tissue paper. Thin parallel plates placed close together obstruct flow; if far apart, the size of the reactor, or critical mass, must be increased, thus raising the investment of fissionable material. Any practical reactor is the result of a design compromise, as in most fields of engineering, between conflicting requirements.

Thus we can conclude that a nuclear power plant is a special kind of heat engine and that the preferred reactor design is a heat exchanger with a large surface area.

For several reasons, the product looks appealing for rocket propulsion. Elementary arithmetic on published nuclear and heat-transfer data can quickly show that a desk-size device might be designed to produce tens of thousands of thermal horsepower. Also, the heat-exchanger type of reactor serves as its own fuel bin and can run for hundreds or even thousands of hours on a single loading.

Biological Problems

Unfortunately for the nuclear-reactor designer, man is largely made up of a complex chemical structure of protein molecules easily damaged by neutrons, high-energy x rays, or gamma rays. The reactor gives off these damaging radiations while operating and even after it has been shut down following an extended period of operation. Generally, the more complex the molecule the slighter the disarrangement required to produce a significant change. Although nuclear efficiency might be only negligibly lowered by a small leakage of neutrons from the core, this cannot be tolerated biologically. These unwanted particles and rays must therefore be reduced several million times to eliminate undesirable effects on personnel in the vicinity.

The process of shielding the reactor is not complex: A bulk of material sufficient to absorb the unwanted neutrons and gamma rays is simply placed between the reactor and the operator. Because tolerable biological levels are so low, the amount of shielding material must be large. Thus all reactor designs include a biological shield comprising many feet of concrete, lead, steel, or the equivalent —a massive structure compared with the reactor.

The art of shielding is so new that we can expect improvements in the future. However, fundamental, sound technical reasons indicate that today's shielding thicknesses of many feet will never be reduced to inches. The processes of neutron and gamma-ray absorption have been studied and analyzed for about a quarter century. These processes are elemental in that they relate to the number of electrons around a nucleus and to the number of nuclei that can be packed in a given unit volume. You can only ascertain what these numbers are, not change them.

We can construct a reactor shield of superior size and weight when we discover how to make metal that weighs 30 pounds per cubic inch rather than 0.3 pounds per cubic inch. However, there is no evidence that we even begin to know how to make such material.

Nuclear Waste Disposal

One final critical problem of nuclear-reactor operation—the disposal of the waste products—must be considered in any application. In radiation intensity, the waste products of a large nuclear-power reactor that has been in operation for some time may exceed the world's supply of radium by hundreds or even thousands of times.

The amount of waste fission products, of course, depends on the number of fissions that have occurred and thus on the total power removed from the reactor. If the power has been drawn at a low rate over a long time, some of the short-lived fission products will have decayed to negligible values. However, we cannot expect to outwait the waste products of such a reactor, because there are many intrinsically powerful emitters whose lifetimes are in the order of months and years.

How then do waste-disposal problems affect application of nuclear power to rocket propulsion? Obviously, the con-

"The use of nuclear fuel for rockets is intrinsically expensive."

sequences of a mishap in a nuclear-propelled rocket could be highly serious. If a rocket were to explode while passing over a densely populated region or to land explosively in or near a large city after an extended flight, the results would be highly unfortunate. Besides a considerable mortality, people might at the very least have to evacuate valuable property for an indeterminate period of years.

Fuel Recovery

A nuclear reactor will stop reacting as soon as its fuel content drops slightly below the critical mass. Thus to construct a reactor whose properties do not change appreciably over the duty cycle, the critical mass plus a small excess must always be present. The consequences of this are not serious for a land- or ship-based reactor, because the unused fuel is unloaded and reprocessed to remove the radioactive wastes. However, the problem of recovering a large rocket that might land at random on the earth would certainly be difficult. Further, the fine mechanical tolerances necessary for convenient unloading would probably not be preserved after a crash landing. In short, the use of nuclear fuel for rockets is intrinsically expensive.

Besides these two serious drawbacks, a still more fundamental one exists: Can we do anything with nuclear rocket fuel that cannot be done with chemical fuels?

A true rocket is projected only by the exchange of energy between a portion of its mass and the remainder. The reaction of the hot exhaust gases against the reaction chamber drives the rocket forward. Unfortunately, the nuclear reactor offers negligible mass to be ejected. Nuclear-power rockets could, of course, carry tanks of suitable material such as water that could be ejected after passage through the reactor. Still, if the rocket must carry water, it could equally well carry other liquids that weigh about as much as water—such as gasoline or liquid oxygen—but which on mixing will give gaseous products at high temperatures. Chemically active liquids weigh no more than inert ones. To this the advocates of atomic rockets might cite the potentially high temperatures produced by nuclear reactors. However, because temperatures associated with chemical fuels are already beyond those that metals can withstand, the advantage of still higher temperatures to be provided by nuclear reactors seems dubious.

In one respect the liquid-fuel-propelled rocket has a definite advantage. Rocket designers have learned how to use the liquid fuel as a sheath on the walls of the reactor chamber so that the hot gases never play on the walls directly. In the nuclear-reactor rocket drive, this does not appear possible. The exhaust gas can be heated only if the walls are at a higher temperature than the gas.

Propulsion-engine Efficiency

A useful criterion for judging efficiency of propulsion engines is the horsepower per pound—always an important index in the efficiency of naval vessels and in aircraft propulsion. Published figures indicate that the horsepower-per-pound ratio of a conventional reactor geared for jet propulsion—that is, for propulsion using a reaction medium already on hand—is from 10 to 100 times poorer than with a chemically fueled engine. If, in addition, it is necessary to carry a dead load of inert material for reaction purposes, the horsepower-per-pound ratio as contrasted with conventional chemical engines becomes still more unfavorable.

Interplanetary Travel Problems

Examination of the details of rocket design shows that the rocket-propulsion problem is essentially a dual one: escape from the earth's gravitational pull and travel through interplanetary space.

Strangely enough, in certain ways the requirements of the second category are much less severe than the first. The absence of air removes large aerodynamic and thermal stresses that accompany the passage through the earth's gaseous envelope. Then too, because the passage between planets can be assumed to be a lengthy journey, a gradual force continuously applied by the rocket's thrusting mechanism can build the speed up to an extremely high value. Even the smallest acceleration if applied for a long enough time will give any desired terminal velocity.

This offers at least a theoretical solution to the propulsion problem for a satellite-to-satellite vehicle. Ejection of highly charged elementary particles, such as electrons or protons, could serve as the reaction medium. The average energy of a gas molecule in the thermally excited state is less than one electron volt. Therefore, by shooting the same particle through some sort of electrostatic accelerator and ejecting it at, say a million volts, we make the effectiveness of the mass recoil per pound of matter ejected correspondingly that much greater. If electrons—approximately 2000 times lighter—were used for this purpose, the same principle would apply.

However, the realities of apparatus construction must be weighed against such far-ranging speculation. The transition from the simple heat engine to the more complex device required to convert the reactor energy to electric energy is straightforward though bulky and cumbersome. Conversion from electric energy at ordinary voltages to highly accelerated particles, or electrons, again involves massive and complex apparatus. Some day a direct means for converting nuclear energy to high-voltage electricity will probably be found, thus eliminating these intervening steps and bringing satellite-to-satellite rockets closer to reality.

Long-range View

In the history of every major development are people of little foresight or courage, always eager to point out to the technologists the difficulties, uncertainties, and dangers in a new and untried path.

On the other hand, no responsible engineer or scientist allows his fancy such free rein as to assume that he can change Newton's laws of motion or find profitable exceptions to the second law of thermodynamics. Imagination untempered by an appreciation of harsh realities may create poetry, but it will never create a nuclear power plant, ship, or rocket.

Discouraging as these observations seem, they should not be looked on as a set of insuperable barriers but rather as a measure of the challenge confronting the engineers and scientists. Ω

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Mr. Mannal joined General Electric in 1937. Since its formation, he has been a member of Knolls Atomic Power Laboratory, Schenectady, operated by GE for the U.S. Atomic Energy Commission. He is presently in charge of an instrumentation study for the Submarine Advanced Reactor Project.

ENGINEERING SOCIETIES OF AMERICA

FOURTEENTH OF A SERIES

UNITED ENGINEERING TRUSTEES, Inc.

By JOHN H. R. ARMS

Turning the pages of history back to 1887, we find four national engineering societies with a total membership of 3600, representing the fundamental branches of engineering. Farseeing members talked of housing these several societies under one roof, for they believed that the resulting co-operation from such close association would greatly benefit the profession. In 1895 Andrew Carnegie was asked to assist in this project, but although he was interested, no action resulted.

In 1901 Dr. Schuyler Skaats Wheeler purchased the Latimer Clark Library in London—then the second most important electrical and scientific library in the world—and presented it to the American Institute of Electrical Engineers (AIEE), provided that a suitable building be obtained within five years to house it. Carnegie was again asked to help because of his deep interest in the spread of knowledge through libraries, actually giving many library buildings. He immediately gave a modest sum for bookshelves and cataloging, and invited the committee to keep him informed on their progress.

Carnegie's Gift

The idea of the common home for the engineering societies continued to be discussed whenever engineers assembled. Carnegie attended some of these meetings when Dr. Charles F. Scott was AIEE president and Dr. Calvin W. Rice, vice president. Early enthusiasts of a unified home for the engineering profession, both men were active in interesting Carnegie in eventuating an Engineering Societies Building. He was so impressed that in 1903 representatives of the four societies were invited by him to call and discuss a "union engineering building." As a precedent of co-operative action among the societies, they cited the groups' establishment and award in 1902 of the John Fritz Medal. Following the discussion, Carnegie offered to contribute a million dollars for a building and the establishment of a national engineering library.

The American Society of Civil Engineers, having completed their own building in 1897, decided against abandoning their new project to join the other societies. Although disappointed in this break in consolidation, on March 14, 1904, Carnegie wrote . . .

Gentlemen of
The Mechanical Engineers,
Institute of Mining Engineers,
Institute of Electrical Engineers,
Engineers' Club of New York,

It will give me great pleasure to devote, say, one and a half million dollars for the erection of a suitable union home for you all in New York City.

With best wishes,
Andrew Carnegie

This gift was divided by mutual consent on a basis of 70 and 30 percent—\$1,050,000 for Engineering Societies Building and \$450,000 to the Engineers' Club, a separate corporation. This history refers only to that part of the Carnegie gift that went into the Engineering Societies Building.

Early History

Early records indicate: "Pursuant to that gift the societies took appropriate official action by appointing three representatives from each organization to form a Joint Committee. That Committee, acting under legal advice and through its own Committee on organization, drafted and introduced into the legislature of the State of New York a bill to create a body corporate to conduct the trust created by the gift. The Bill became a law by the signature of the Governor, the Honorable Benjamin B. Odell, on May 11, 1904, and the organization received the name of United Engineering Society (since 1931, United Engineering Trustees, Inc.), to hold title to the land on which the proposed building should be erected, and to carry out the purpose of the donor as respects the activities both of the national societies named in Mr. Carnegie's letter and of other organizations of scientific and educational character having engineering or other constructive arts as their basis." The Charter states that "objects of the Corporation hereby created shall be the advancement of the engineering arts and sciences in all their branches and to maintain a free public engineering library."

Issued to the participating societies, Founder's Certificates included the statement: "Andrew Carnegie, in the year 1904, created a trust for the engineering profession of America, by giving the sum of one and a half million dollars for the erection of buildings to be used for the advancement of the engineering arts and sciences, and all their branches, and for the maintenance of a free public engineering library."

Engineering Societies Building

Property for the Engineering Societies Building (photo, next page) was purchased with contributions from members and friends of the societies, including industry. This land—five lots wide—is located at 25 to 33 West 39th Street, New York 18, NY. A plan was selected from the many submitted by paid architectural contestants. Mrs. Carnegie officiated at the laying of the cornerstone on May 8, 1906. Although the building—composed of 13 stories and 2 basements—was not formally opened until December, a United Engineering Society meeting was held there in November, 1906. The combined libraries of the Founder Societies were housed on the top floor.

Formal dedication ceremonies were held in April, 1907. On this occasion, notables from this country and abroad presented learned papers, medals and honors, and felicitations.

Ten years later, recognizing the excellent results of the co-operative housing, the American Society of Civil Engineers accepted the cordial invitation to become a Founder Society. This united all the original societies as Founders—most gratifying to Carnegie. The addition of three stories, financed equally by the societies, provided the space required for the fourth Founder. The Civil Engineers were formally welcomed

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Mr. Arms has been Secretary and General Manager of United Engineering Trustees, Inc. since 1933.

ENGINEERING SOCIETIES BUILDING, a gift of Andrew Carnegie and built in New York City in 1906, provides an engineering center for the various societies.

into Engineering Societies Building on December 17, 1917.

The original building had not been designed for expansion. And when the problem of additional stories arose, some unusual construction became necessary. Inside, openings were made and four columns set from bed rock to the roof. The additional three floors were constructed on these columns, making a new building on stilts over the old building.

The Engineering Societies Building houses many memorials: bronze busts and tablets honoring outstanding engineers and distinguished national leaders, portraits in oil, and national and regimental flags from World War I.

Growing Membership

At the time of Carnegie's gift, members of the four engineering societies totaled 12,341. In the three years until dedication of the building, membership increased 30 percent—representing practically all members of the profession—and by mid-1954 membership had grown to 144,562. In addition, thousands of engineers are members of other societies that have headquarters in the Engineering Societies Building. But to create the engineering center of Carnegie's dreams, many other engineering societies should be housed here.

Growth of the profession and the increasing number of highly specialized branches of engineering have made the headquarters building entirely inadequate for today's need. To acquire necessary working space, growing associate societies have moved from the building, and even two of the Founder Societies have been forced to expand to other quarters.

Because expansion in the present building is not considered economically feasible, removal to another location or city is being studied, with a solution to the problem expected soon.

New Location Sought

Being subject by Charter to the New York State Supreme Court, United Engineering Trustees, Inc. (UET, Inc.) must obtain its approval to use the proceeds from the sale of the present building for a new headquarters outside New York City. Such money, together with the depreciation fund that has been built up over the years, will not be sufficient to erect an adequate building at today's costs. Several cities have offered gifts of land or money to attract the engineering headquarters. The decision soon to be made depends largely on which location is most advantageous for the Societies.

Society Assets

The Engineering Societies Building and land represent an investment of $2 million. A growing depreciation reserve of half that amount sustains to some extent the value of the property for future engineers. Fire insurance and extended coverage on the building above foundations is carried at $1,904,000. Each member of a Founder Society can consider this professional headquarters a personal gift from Andrew Carnegie and other earlier engineers. And it is his personal responsibility to enhance its value for the benefit of coming generations of engineers.

United Engineering Trustees, Inc. is titular owner of the Engineering Societies Building and funds of Engineering Societies Library, Engineering Foundation, and others of common interests to the Founder Societies. It has 12 members—three appointed by each Founder Society as its representatives in combined interests and activities. A broad Charter establishes UET, Inc. as the legally appointed agent of the Founder Societies for any combined activities for "the advancement of the engineering arts and sciences and to maintain a free public library."

Besides owning and operating the Engineering Societies Building for the Founder Societies, the Corporation has two departments—the Engineering Societies Library and the Engineering Foundation.

Libraries of the several societies were maintained in the same room although managed separately until 1913 when they were merged under one director. As authorized by its charter, UET, Inc. maintains this Engineering Societies Library. Operated by a Board of 11 members, with a professional librarian as Director, the Library contains 170,000 engineering and scientific books

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

• Encouraging and directing Young America's efforts in making wise career choices can be a major adult contribution.

• Following the adventurous profession of the scientist or creative engineer brings a lifetime of rich satisfactions.

One year ago this issue, the REVIEW began the present series of reprints from a highly successful group of articles directed to teen-age America. Since then, four of the individual articles that we reprinted—"Why Study English?", "Why Read?", "Why Work?", and "Why Stick to Your Studies?"—have been published in one booklet titled "The Four Why's."

And now the first of our reprints, "Why Study Math?"—and one of the most popular of the articles—has been published in a booklet titled "Three Why's." This booklet also contains two articles "Why Study Science?" and "Why Look into Engineering?" that are reprinted on the following pages.

The booklets are designed to inform and motivate boys and girls who are vitally concerned with one of the biggest decisions confronting them—choosing a career. Each article emphasizes to the student the importance of preparing for the challenging tasks that lie ahead.

General Electric believes that young people should be encouraged to make the most of the tremendous educational opportunities offered them in school. In this way their adult life will reflect the greater satisfaction and richer rewards that come with increased knowledge.

The fraction of Young America who comes under your influence may be asking: "Why look into engineering or science?" All around we see evidence of our exciting age, and largely contributing to its wonders are the discoveries of the scientist and the works of the engineer, whether electrical, chemical, mechanical, civil, or metallurgical. To be a part of what is yet to come in the generation ahead can be a consummation of one's highest ambition. If you can encourage any young people to follow either of these professions, you'll lead them along a road of high adventure.

For free copies of the reprints on the following pages, send your request to Public Relations Services, Dept. 107-2, General Electric Company, Schenectady 5, NY. —EDITORS

United Engineering Trustees, Inc.—*(Continued from page 54)*

and magazines and annually serves 38,000 readers and mail requests.

In 1914, an eminent engineer, Ambrose Swasey, gave a considerable sum of money to the engineering profession. Made custodian of the funds, UET, Inc. appointed a committee to "establish and administer a Foundation for the conduct of engineering research." The gift ultimately totaled nearly a million dollars; other contributions were added "for the purposes of the Engineering Foundation."

Foundation Researches

A Board of 16 members, representing each of the four Founder Societies, controls the Foundation researches. Although autonomous in the disbursement of its income, the Board is subject to the ultimate approval of the Board of Trustees. Since its organization in 1914, it has expended about a million dollars from its own income. And it has attracted about $15 million of financial aid from industry and government, as well as laboratory facilities and college personnel. The Engineering Foundation endeavors to start projects of fundamental engineering interest that might otherwise not be undertaken. When sufficiently advanced to attract industrial contributions or others, these projects are usually financed by industry.

Several well-known current projects of the Foundation are: Alloys of Iron Research, Welding Research Council, Column Research Council, Research Council on Riveted and Bolted Structural Joints, Reinforced Concrete Research Council, Research Council on Corrosion, Effect of Temperature on the Properties of Metals, and Engineers' Council for Professional Development (ECPD).

Committees and Awards

Assisted by professional financial advisers, a Finance Committee composed of five or more members of the Board of Trustees—all four Founder Societies being represented—takes care of the funds. An enviable record has been achieved in holding the principal intact while earning a reasonable rate of income to finance the Board's many projects. A leading New York bank is custodian of the investment securities. The Corporation is exempt from federal and local taxation.

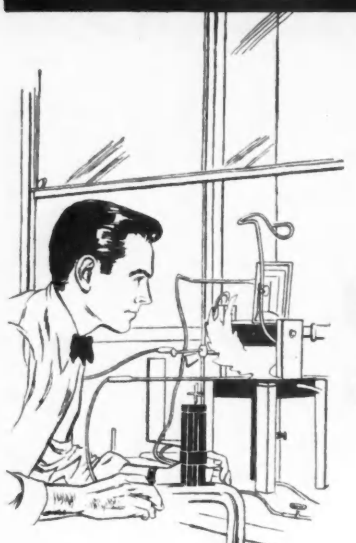
The Board of Trustees holds the funds for the John Fritz Medal—often called "the highest award in the profession of engineering." Awarded jointly by all four Founder Societies since 1902, the Fritz Medal acknowledges "notable scientific or industrial achievement" in any field of pure or applied science.

The Board also owns funds for the Daniel Guggenheim Medal, the highest award in aeronautics, "for honoring persons who make notable achievements in the advancement of aeronautics." Custodian of monies given to aid in financing projects of the Engineering Foundation, the Board also serves as treasurer for ECPD. This organization includes the Founder Societies, plus other educational and engineering organizations. One of ECPD's important assignments is accrediting engineering curricula in the engineering schools.

A Real Estate Committee of five or more members of the Board of Trustees, again so selected that all the Founder Societies are represented, advises the Board on Corporation property investments. This committee also reports, in conjunction with the general manager who is the principal administrative officer of the corporation, on the condition of the Engineering Societies Building and space allotment.

United Engineering Trustees, Inc., created to act for the Founder Societies, actively promotes and assists in educational and research work, as well as other combined interests of the four Founder Societies. Its Charter empowers UET, Inc. to act legally for the Societies in even a wider scope of activities for "the advancement of the engineering arts and sciences in all their branches," thereby serv ng not only the societies but also all engineers. Ω

GENERAL ELECTRIC'S ANSWER TO . . .



Why Study SCIENCE ?

At least 20,000 General Electric engineers, scientists, and other employees in management positions, would like to tell young Americans why they should study science. If this short essay, however, had 20,000 authors, the results might be a little confusing. The words that follow summarize some of their beliefs. These are the beliefs, not only of our scientists, but all of us who are very happy to share the challenge and excitement of this technical age.

MANY of you have already written the General Electric Company something like this: "You tell us repeatedly to master math, English, and all the other basic subjects. On top of that you tell us to stick to the school job, work hard, take part in group activities, and develop the behavior habits of angels. Aren't you asking us to spread ourselves a little thin?"

We have no simple answer. If we said you were born 50 years too late, we would be joking.

What has happened is that the sum-total of accessible knowledge, and the opportunity to apply it, is several times greater than the knowledge and opportunities of past times. The recorded knowledge alone of the last 50 years, in quantity and quality, is perhaps 500 times greater than that of the previous years. At the rate the world's students are discovering things, in all fields of knowledge, in these times—well, we would hate to guess how big the feast of knowledge will be when *your* children tackle the job of becoming the all-American boy or girl.

General Electric is concerned but not alarmed about the caliber of youth who will come to us to discover, engineer, manufacture, and sell new marvels. We have big plans for tomorrow. We know we can make big plans because today's youth are smarter than we were when we attended school and college. We know that today's teachers are ahead of those who taught us.

When industry looks ahead, it assumes that its younger employees will tangle successfully with all problems and challenges—and then ask for more.

Science and the Years Ahead

Call this the Age of Electricity, the Electronic Era, the Atomic Age, or something else, and you have a good headline for the story that is now being written by men who get things done, who advance our progress.

A 40-year-old man or woman today grew up without advantage of television, Cinemascope, air conditioning, automatic washing machines, automatic transmission, jet engines—an almost endless list. Coming up, in your adult years, are color television for everyone, faster, more comfortable planes, electric power plants with atomic fuel, advanced medical drugs and techniques and—you imagine it, and it will probably become fact.

So far we have alluded only to *things*, to end results. They are but a part of the management of our affairs. The true progress of the future can become possible only if mankind can develop enough knowledge to will and to produce a favorable climate for advancement.

An atomic airplane is a paltry device if its usefulness is limited to the destruction of life. What government and industry aim to achieve in science is the minimizing of suffering and despair, for all people everywhere, and the maximizing of true comfort and security, the making of a beautiful world.

The challenge is magnificent. In a sense, most constructive thinking is scientific. It is thinking which proceeds like a proposition in plane geometry—yet the Q.E.D. is never quite arrived at, for what appears at the moment like a final solution is but one of the earlier steps in a brand new series of problems.

You'll never hear of a scientific thinker who's caught up in his thinking to the point of boredom.

Lest you believe we are carried away with our subject, let's say right now that science is not more important than English, history, math, shop, or gym. But science, like those blood-relation subjects, is a base from which grows a whole lifetime of progress.

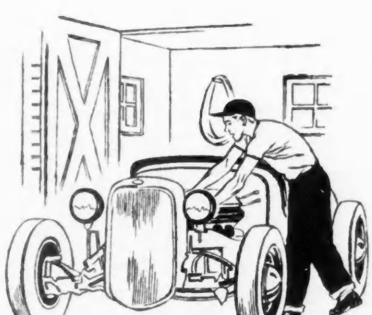
Jose Ferrer covered this thought very well when he advised a youngster about going into the theater: "Learn as much as you can, about as many things as you can . . . You can never tell when the things you learned come in handy."

Science Is Fun

The story has come down to us that when the Westward-ho explorers were stopped by the Pacific, they felt rather miserable. There was nothing left to discover. We have read that someone suggested, several decades ago, that the U.S. Patent Office close down because man had discovered or invented everything.

Everyone knows, now, that there is no Pacific shore barring mankind from further discoveries. If a person is so geared up in his thinking that he must make vast areas of space his workshop, he can figure out how to travel to the moon. If he can be contented with less than the Universe, he can explore the mysteries of life as evidenced by all the creatures that burrow deep in the earth, crawl or walk upon its surface, or fly in its atmosphere.

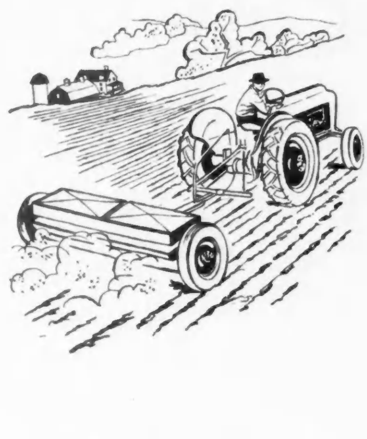
And if he is thrilled in this Age of the Atom by the tremendous forces locked up in the invisible particle, he won't have accomplished all his discoveries before suppertime. No indeed! We who know so many of the 12,000 General Electric people employed in atomic work, and even more thou-



Many an old jalopy has served as a sort of backyard laboratory for the boy who knows his science and likes to see just what makes things tick.

sands employed in all our research and engineering laboratories, like to say: "It appears that our scientists know more and more about less and less." The fun of exploring the invisible is not new. No one has seen electricity. No one has seen an atom; yet when our scientists talk about it, we know that in their minds each one is a vast thing in size somewhere between a pumpkin and the world itself.

Have you never pecked away at a limestone cliff and with jackknife pried out the fossils—which were once, ages ago, living things? Or discovered in a piece of coal the perfect pattern of a fern leaf which



Like the butcher, the baker, and the candlestick maker, the farmer with scientific know-how winds up with a better product and a better life.

once found the source of its growth in the same sun that gives us our light and warmth?

What we are trying to say, and want you to believe, is that science is fun. It is the same kind of exploring fun that thrills you when you guide your canoe up a narrow stream, bordered by exotic plant growth, not yet trampled by man intent upon despoiling with sharp ax or careless in his disposition of a lighted match.

Your sciences—all of them—are the keys to understanding, and that in turn is the key to the delight of exploration.

Where Science Is Not Fun

General Electric is not in favor of a science-only concentration in our country's schools. Yet we know these things well: to live fully and to succeed well in a technical age, it goes without saying that both the methods of science and an understanding of its subject matter are prerequisite to almost every person's growth and progress.

Russia has a clear, cold-logic understanding of the value of science today. We expect never to see our schools adopt the Soviet system (heaven forbid!), but this is what happens there. All elementary school children devote a third of their time to the pre-sciences. Before leaving the elementary school, the child is well-started in algebra, geometry, natural science, introductory physics, and the elements of chemistry.

And at the secondary level, about 40 per cent of the time is spent in the sciences. Mathematics is stressed heavily. In the college, the usual rule is a five-year-program in concentrated technical subjects.

The result? An output of graduate engineers, which exceeds the number of American graduate engineers by a ratio of 2½ to 1. Russia's

Each Age has its so-called miracles. Hardly a decade ago, it was jet flight. Today, men in protective suits parry the sword of an unseen force—the atom.

engineering force (as reported by NEWSWEEK) is close to our total of 500,000 and soon will be larger.

But This Is America

We know that the American scientist, in university, government laboratory, and industry has done much to give us our incomparable way of life. We are more than a bit sorry that more of our boys and girls do not experience the delight of mastering at least one area of scientific knowledge. For we know that youth with such background has limitless opportunity—and as long as he lives, never a dull moment!

GENERAL ELECTRIC'S ANSWER TO . . .

why look into ENGINEERING?

DO I want to be an engineer? Almost every student, at some time during his high school years, asks himself that question. What we say on these pages may help you make up your mind . . . may send you off for more information from other sources.

In fact, if you are potentially an engineer, you will naturally think of your career as a problem worth solving. You will not jump at a conclusion, but will dig for facts, listen to and weigh opinions, examine sharply your own abilities—then you will check and recheck.

You will want to listen to what your subject and guidance teachers have to say. You will want to visit with engineers in your community. You will want to read carefully the career articles in magazines and books.

For the sake of convenience, as you read this article, we ask you to think of the word "engineer" as *including* scientist, physicist, chemist, metallurgist, and so on. And we ask you to *exclude* locomotive engineers and other operators of machines from your thoughts as we look ahead, together, at engineering as a career opportunity.

All of us know that our qualifications and wishes are different; that one profession is not necessarily better than others. And we do know that engineering has given our country's people the material things that make their lives so full and interesting, and that what we call progress will not cease, because engineering flows strong in the bloodstream of American youth.

The technical engineer is the designer and builder of machinery, turbines, bridges, radio and television equipment, home appliances, motors, chemical plants, steel mills, mining apparatus, automobiles, and all the myriad of devices and systems which are necessary to our complex civilization today; who will invent and develop innumerable new devices and systems, as yet undreamed of, but certain to come, to make life even more wonderful than it is today; who will continue easing the burdens of man's physical toil; who will continue taking the materials and forces of Nature and converting them for the use of mankind.

The Constant Challenge

Just think of the engineering required today in the development and design of automobiles, locomotives, and airplanes—the fantastic machine tools which manufacture them; the plants which produce the steel; the oil refineries, the tire factories, the cement mills, and all the other activities involved in providing us with transportation. Think of the developments in chemistry, in communication, in heating and cooling our buildings, in building and street lighting, in farm industry, in military science—and behind them all is the engineer.

We sometimes say that it is the scientist's job to discover something new and the engineer's job to turn that something new into something useful.

An engineer doesn't grow overnight. To begin with, he started out life with mental ability and alertness of a high order. In high school his grades ranked him in the upper third of his classes. He demonstrated an aptitude for, and attained a high standing in, mathematics and science—the languages of engineering. In college, he did not select the easy courses. In fact, to get by creditably, he had to have initiative, reliability, energy, a sense of responsibility, good judgment, and mental honesty. As a human being, with a keen sense of fun, he became involved in extracurricular activities. He knew that one day he would rub shoulders with men in the world, and the way to learn how was to play cooperatively and in competition with his fellow students.

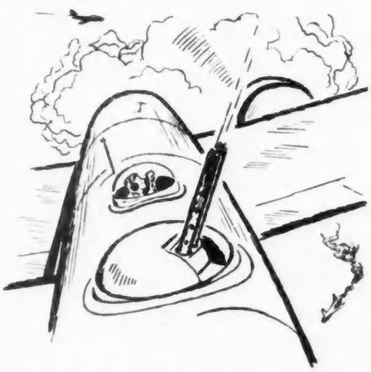
Chances are he worked on the outside to pay part of his college expenses. When he took his first job, he found himself up to his neck in working and training—it takes time to learn the detailed techniques of engineering operation. Somewhere along the line he began to make his contribution. In World War II, for example, several hundred General Electric engineers just like him, with an average age under thirty, shouldered the responsibility of carrying the B-29 gun-computer from an idea in someone's mind to the development of a marvelous weapon. Many of us will never forget that *impossible* feat of courage, brains, and determination.

And whatever else we have, come peace or war, is a result of his training in the cool, orderly, and planned manner of thinking that distinguishes the engineering method.

Engineering is a profession for strong men (and women) and don't let anyone tell you differently.

An intelligent question for you to ask is: What if I start out to become an engineer and change my mind? That is a good question to ask about any career.

Normally an engineering student becomes an engineer. Many young people decide early that they want to become mechanics, nurses, salesmen, ministers, lawyers, doctors, and so on through the list of wonderful opportunities in America. It is not unusual for a young person—or an adult—to change his mind. If you read biographies of great Americans, you will discover that often changes of mind led to remarkable achievements.



(Incidentally, and more often than not, when an engineering graduate comes to General Electric, his supervisors do not pin him down to a specific project, but keep spreading the feast of Company opportunities before him, so that he too can change his mind about his engineering interest.)

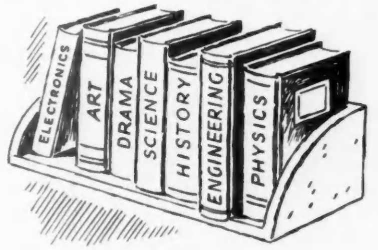
Although there is not universal agreement on this point, many people are saying that an engineering course is the best training for the greatest variety of careers. We will not make the claim that that course is the best training, but we can think of many examples within the General Electric Company which show that such training has been broad enough to fit men for important positions in accounting, in advertising, in manufacturing supervision, in sales work, in market research. An interesting fact, in this connection, is that about half of the officers of General Electric have had engineering educations.

Too, it is a matter of statistics that many leaders in American business today have engineering degrees. As preparation for general advancement, engineering is a *good* program of study. A recent Columbia University survey of all industry in the United States tells us that "forty percent of industrial management is engineer-trained, replacing both the lawyer and the banker in top industrial posts."

Engineers Are Taught to Think

It is the conclusion of many of our own personnel experts that the reason for this success is that engineering students "learn to think." Much of their school work is the solving of problems, and the right answers are very definite things. Sharing this belief, apparently, are several nonengineering companies that send out their recruiters to the college campuses. These recruiters tell us that they show a preference for students in engineering and science because these students have learned to stick with a problem until they come up with the one definite answer.

It would be unwise and unfair for us at this point to make light of those college courses in programs leading to academic degrees. The fact is that when we are asked, we encourage students to take as many nonengineering courses as possible, such as English, history, and the languages, to name just three, because we know that all knowledge is useful; that one of the engineering student's prime objectives is to round out his interests so that he will become a better citizen in the company,



community, and country. Also, a run-down of occupations in companies like our own shows that there are important career opportunities for people with an almost limitless variety of training.

When we say that engineering is far from being an overcrowded profession, you are likely to ask: But how about tomorrow? As an engineer would say, there are too many variables to allow us to forecast with certainty.

If you are looking for a firm guarantee of security from cradle to grave, you are probably not potentially a good engineer. But if you have the courage to take the calculated risks, you will no doubt come out on top, in spite of unforeseen difficulties.

If you really never had the "feel" for engineering, if you are accustomed to content yourself with minimum effort, if you have no bounce left after a temporary setback, if you are most comfortable rolling along in a comfortable rut,

the rigors of any profession will become intolerable. If you see yourself as such a person—and there is no real harm in being a cautious person—you will probably find more job satisfaction as a follower than as a creator, leader, and solver of problems. It is important to know your own abilities and the goal which you are likely to reach.

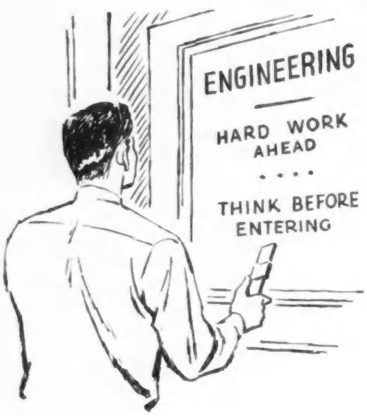
What's in the Future?

With that moralizing behind us, let's take a look at what seems to be today's and tomorrow's prospects for the American boy and girl who are trying to make up their minds about engineering.

Engineering is and no doubt will continue to be our country's third largest profession, following teaching and nursing. But large as the profession is, we are beginning to find its numbers desperately small.

Investigators from government and industry have traveled about the country, trying to determine why engineering colleges are short on enrollments, why more high school boys—and girls too—are not preparing themselves for this opportunity-laden profession. The answer does not lie in low salaries; for Bureau of Labor statistics places it among the top major professions. The answer obviously lies in a false notion that there's an overabundance of engineers; that they're a dime a dozen.

But in 1951, something like 80,000 engineers were needed by industry, while only 38,000 were graduated from college to fill these jobs. In the year 1952, only 29,000 were available. This number continued to drop in 1953 when only 21,000 were graduated, and in 1954 the number was 16,500.



Past statistics and careful studies made by the U.S. government and others clearly indicate there will be an extreme shortage of scientific and engineering personnel. This has always been the case except for a very brief time during the depression years. Even then there was but a short period of waiting, and industry found it necessary to reach back for the graduates of those difficult times and to pick up practically all those available.

None of us at General Electric wishes to persuade a potentially successful insurance man, a preacher, a doctor, a teacher, etc., that he should give over his future to a profession antagonistic to his cravings for job satisfaction. We just want the thousands of young people who naturally fit into the engineering and science pattern to follow their inclinations; and to work hard—but in a very satisfying way—so that one day they can fill the ranks of those who discover the new and put that something new to the service of all of us.

Do engineers like engineering? The question sounds so naive that you may have hesitated to ask it.

We believe that engineers everywhere like engineering. The following statements are extracted from questionnaires filled out by General Electric engineers with ten years' experience. . . .

"There are plenty of chances of getting into the type of work you will thoroughly enjoy. Because of expansion, transfers, and retirements there are many opportunities—and there are more opportunities for potential managers than there are candidates."

"Training is unlimited, and it is a good bridge between college and industry. And most of that training is in association with established experts in their fields."

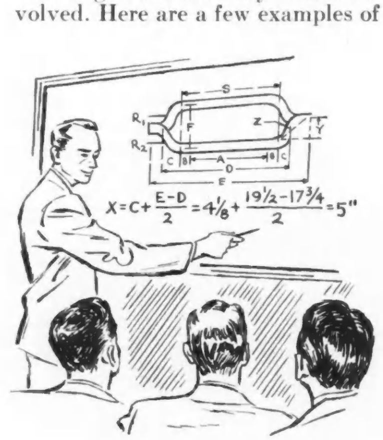
"If one of your ideas has merit, there are adequate resources of men, material, and financial backing to try it out."

"The engineer experiences friendships all over the country among people of his own background and education."

Engineering: Opportunity Unlimited

Certainly, the good deeds of engineers are real things. No one knows better than they that their achievements are only beginnings; that in spite of their impressive list of past gains these are but tiny stepping stones to the greater things to come. And for that reason, too, we believe that a young person's opportunity in engineering is practically unlimited.

Although we do not have at hand an actual count of the number of General Electric products now being manufactured, we know that there are about 200,000 of them. Each new one has to start out as an idea, has to be developed and then manufactured, has to be marketed—and throughout all these activities engineers are very much involved. Here are a few examples of



products to give you an idea of their importance in our way of life and of the variety of engineering skills needed in their development.

For the country's utilities, we design and build turbine-generators that produce electric power, and the power-line equipment to transmit it to home, industry, store, street—even the stadium.

For industry, our electric equipment provides power for mines, steel mills, lumber and paper mills, and textile plants.

To help transport America, we build electric, gas-turbine, and diesel-electric locomotives.

To help light America, we make more than 10,000 types and sizes of electric lamps.

To help build American homes, we produce such materials as wire, switches, and wiring devices.

To help your mothers and to make your family's life more comfortable, we build a broad line of appliances—refrigerators, washers, ranges, toasters, and irons.

For our nation's radio and television stations, we build studio and transmitting equipment; and to carry entertainment into homes, radio and television receivers.

For public buildings, as well as homes, we construct heating and air-conditioning equipment.

These are only a few examples, but any one of them stirs the engineer's imagination; for he knows that great as our engineering successes are, they are but pale shadows of the magnificent developments which the new engineer is bound to make when he takes his turn in the workaday world!

There are probably more, but we think of engineers in the following group classifications: the quiet, studious, patient fellow who is happiest—and therefore at his best—solving problems at a desk or in a comparatively small area of activity; the engineer who moves easily among his fellow men, who has natural leadership talents, and who will move restlessly up through the ranks, accepting more and more responsibility; the engineer who is at his best as a salesman, who because of his knowledge of his company's products and his quick understanding of his customer's problems can become—not an order taker—but in a sense a part of the customer organization he serves; the engineer with more than a touch of romance in his

blood who is at home with his company's products in the air, on the high seas, in the mountain vastnesses of far-off countries, in mines deep in the earth, even in the undeveloped lands where he is a kind of advance agent for our technological civilization.

It is not enough to wish to become an engineer. What about your preparation for engineering?

Since you are now in high school, you will realize that just as the college prepares you for a profession, so now does the high school prepare you for college.

There is no fixed set of rules. We believe that you should familiarize yourself with college entrance requirements. We know of no college that will not be pleased to send you its bulletin of requirements for entrance, and if you will call upon its director of admissions, he will be glad to advise you personally. Naturally, an engineering program has different admissions standards from pre-law, pre-medicine, or a straight academic course.

You should ask your guidance teacher which colleges are *accredited*—that means the ones whose diploma is looked upon with favor by companies like our own.

You will find, generally, that there is, in these colleges, a belief that to do creditable work with them you must have a background in mathematics and science. Our own belief is that you cannot take too much mathematics. By all means, take all the math your high school offers. Admissions officers tell us that at the present time nearly fifty percent of those seeking admission to college on an engineering program can't be accepted because of too few credits in mathematics.

You will naturally take a high school course in physics—and later, when you are an engineer, you will find every page of your physics text coming to life as you practice your profession. Chemistry, too, may be a requirement, especially if you wish to become a chemist or a chemical engineer.

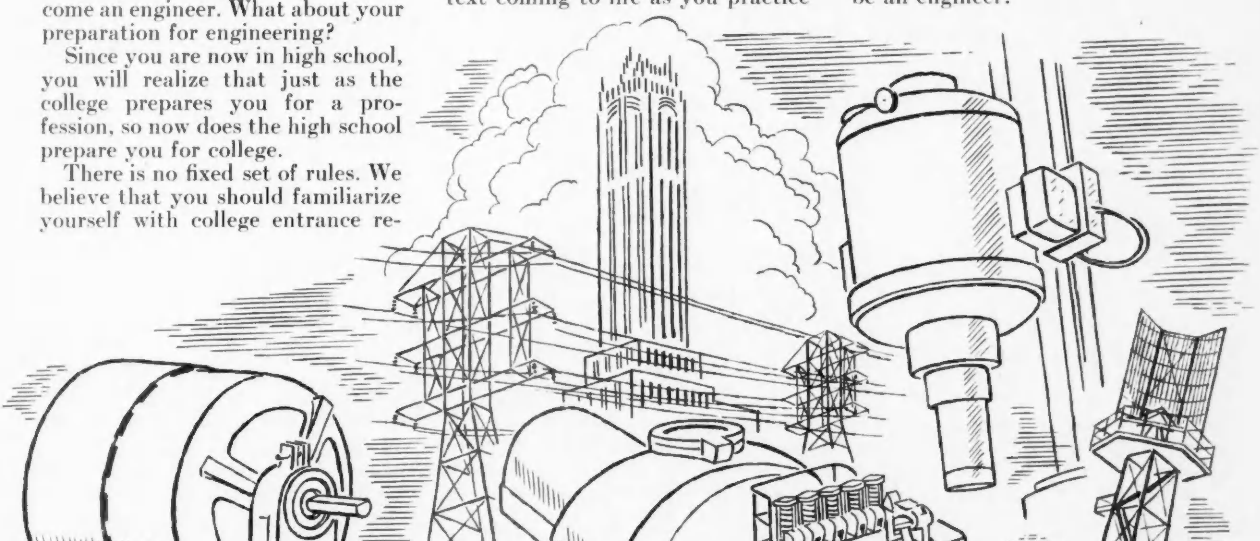
Good work in English is more important than you may suspect; an engineer is lost if he can't communicate his ideas. How you express what you think is an advertisement of your ability.

An Ever-increasing Need

Do not be afraid, when scheduling permits, to reach out into the languages and the social studies, for today's engineer is a man who carries his abilities to think and to do into many fields—into his community as well as into his company.

Our country is in a period of vast expansion. In population we are growing at the rate of about a quarter million a month. It is very plain to us that an increasing population, in simple proportion alone, will require the services of more engineers. But it is not a simple proportion, for as our dynamic system of living speeds up, the number of engineers needed is in an ever-increasing proportion.

The challenge is there for those who recognize it. Do *you* want to be an engineer?



. . . another advance in mercury lighting from G. E.

Now 54% more light from G-E 400-watt mercury lamp

New General Electric H400-RC1 gives top color balance, too

In another mercury lighting first, General Electric has raised the light output of the H400-RC1 mercury lamp from 12,300 to 19,000 lumens! This 54% increase in efficiency results from using a special fluorescent phosphor as a reflector as well as to improve color balance. Its color characteristics are best of any mercury lamp for general lighting. Color rendition approximates a mixture of ⅓ filament light and ⅔ mercury light.

The new G-E H400-RC1 mercury lamp has a life rating of 6000 hours at 5 or more hours per start. It operates on the same equipment as all other 400-watt mercury lamps and is interchangeable in most reflectors.

With its controlled beam, good color, easy maintenance, and high light output, it is first choice for most mercury lighting applications.

For more information on how this new mercury lamp can fit your operation, call your G-E Lamp supplier, or write General Electric Company, Lamp Division, Dept. 166-GE-5, Nela Park, Cleveland 12, Ohio.

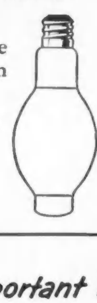
COMPARE NEW G-E RC1 WITH OTHER 400-WATT MERCURY TYPES

NEW RC1 VS H400-E1

- Light on the work equal or greater in most equipment
- Adds color balance
- Less maintenance

NEW RC1 VS H400-J1

- Delivers 10-20% more light on the work in most equipment
- Has somewhat better color balance
- Lower cost of light



NEW RC1 VS H400-A1

- 35% more light on the work in most equipment
- Has good color balance
- Lower cost of light

Progress Is Our Most Important Product

GENERAL ELECTRIC