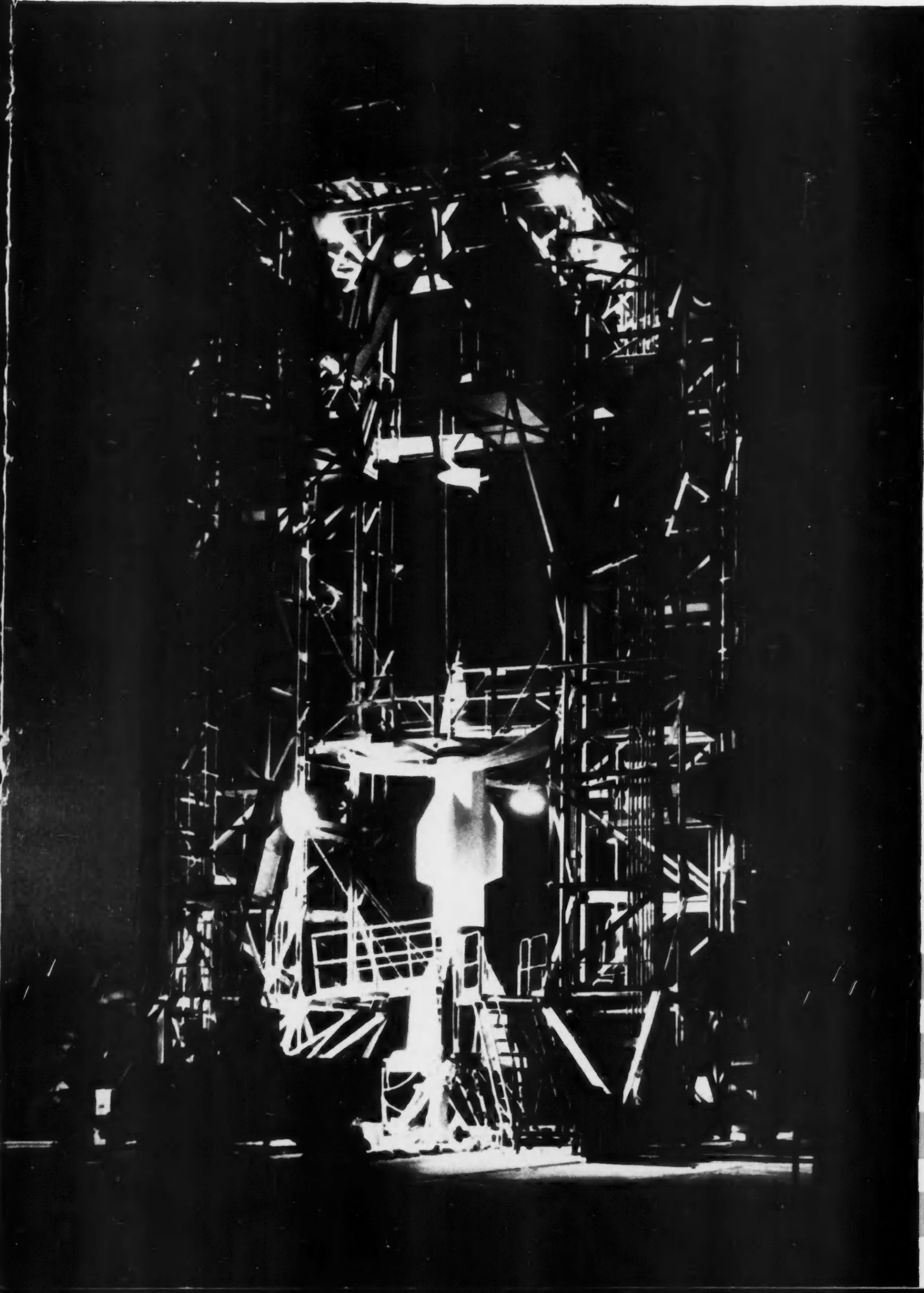
GENERAL ELECTRIC Review



"MISSILE OFF—
ON MONEY!"
PAGE 8

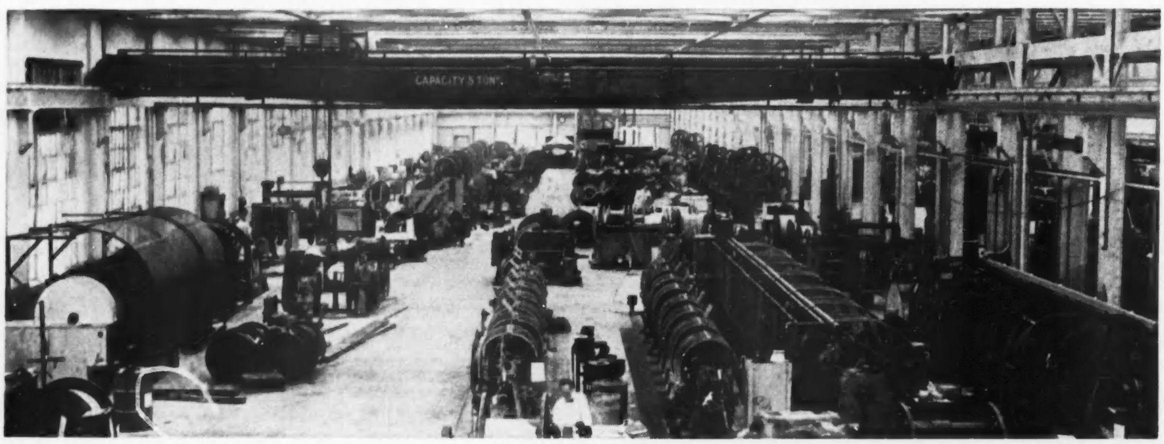
MARCH
1954

INCREASING USE OF ELECTRIC POWER CALLS FOR MODERN DISTRIBUTION SYSTEMS

General Electric's expanding wire and cable facilities and services can help you handle new or greater loads

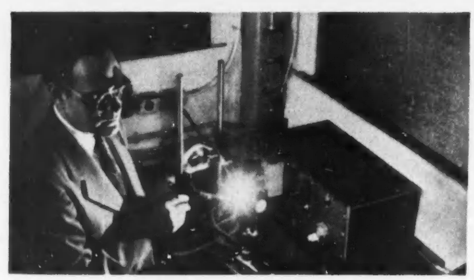
The continuing development of new electrical equipment, processes, and materials handling methods doubles the use of electricity about every ten years—according to the findings of qualified authorities. In industry, this increasing use of power makes it important that you plan, install, and maintain bigger and more flexible distribution systems to handle these growing loads. To assist you, General Electric has expanded its facilities, and is prepared to help you in the application, use, and maintenance of modern distribution systems.

1 PLANNING AND APPLICATION.
G-E wire and cable specialists are ready to help you select and plan cable systems with the capacity and flexibility needed for growing loads.



2 WIRE AND CABLE AVAILABILITY.
General Electric is adding a new wire and cable plant to its facilities in Bridgeport, Connecticut, to continue to supply you with the products on which cable systems depend. This new plant will be able to produce more cable faster, and will supply you with new cable products to meet new needs.

If you want help NOW . . . just call your G-E wire and cable specialist, or write Section W121-337, Construction Materials Division, General Electric Company, Bridgeport 2, Connecticut.



3 MAINTENANCE OF CABLE SYSTEMS.
General Elcctric's test facilities help minimize maintenance problems. Thorough production-line testing, coupled with research and developmental testing, give you wire and cable products with longer life and coordinated insulation levels. Also, the flexibility designed into G-E wire and cable systems make it possible for you to alter and expand these systems as loads change and grow. (This spectrographic test for copper conductor purity is one example of G.E.'s laboratory testing.)

You can put your confidence in—

GENERAL ELECTRIC

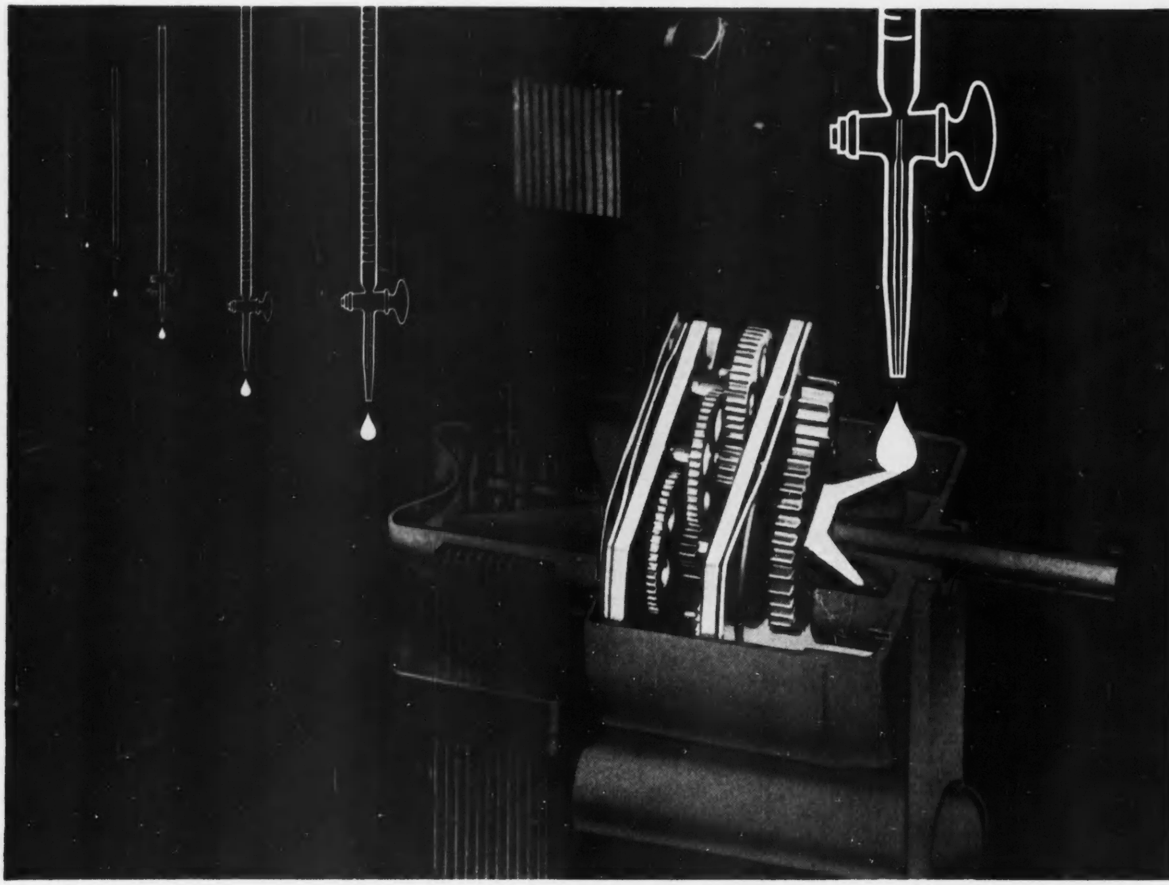
MARCH 1954 • VOLUME 57 • NUMBER 2

GENERAL ELECTRIC Review

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

COVER—While dawn breaks over the desert, General Electric technicians work over a Project Hermes guided missile at the White Sands Proving Ground, NM. Designed and constructed by GE under the sponsorship of the Army Ordnance Corps, the missile will be launched a few hours later. On page 8 begins an exclusive story of GE's participation in Project Hermes, the first time the story has been told in an unclassified document. Many of the photographs have been recently declassified and are appearing in print for the first time.

THE GENERAL ELECTRIC REVIEW IS ISSUED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER, AND NOVEMBER, BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NY, AND IS PRINTED IN THE U.S.A. BY THE MAQUA COMPANY. IT IS DISTRIBUTED TO SCIENTISTS AND ENGINEERS THROUGHOUT INDUSTRIAL, CONSULTING, EDUCATIONAL, PROFESSIONAL SOCIETY, AND GOVERNMENT GROUPS, BOTH DOMESTIC AND FOREIGN. . . . THE CONTENTS OF THE GENERAL ELECTRIC REVIEW ARE ANALYZED AND INDEXED BY THE INDUSTRIAL ARTS INDEX, THE ENGINEERING INDEX, AND SCIENCE ABSTRACTS. . . . SIX WEEKS' ADVANCE NOTICE, AND OLD ADDRESS AS WELL AS NEW, ARE NECESSARY FOR CHANGE OF ADDRESS. . . . ADDRESS ALL COMMUNICATIONS TO: EDITOR, GENERAL ELECTRIC REVIEW, SCHENECTADY 5, NEW YORK.



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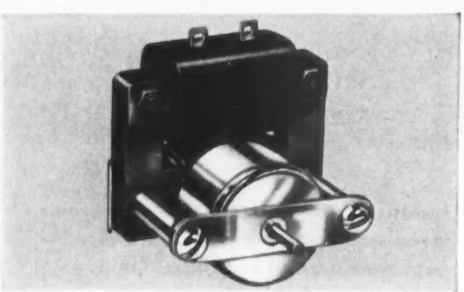

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Each Telechron motor carries a lifetime reservoir of oil sealed in its rotor unit. Capillary action carries the oil to bearings, where its flow is controlled to all moving parts.

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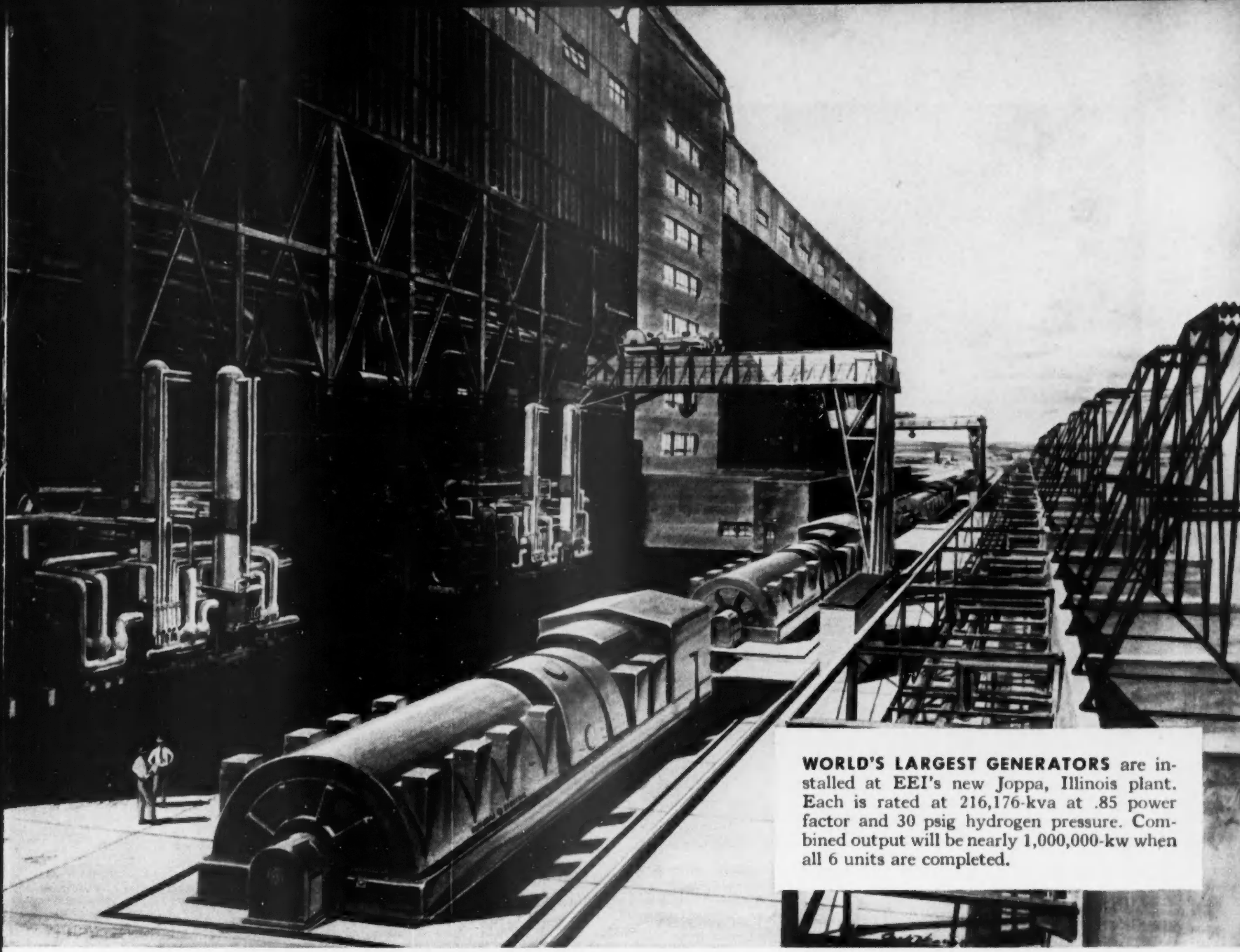


WORLD'S LARGEST GENERATORS are installed at EEI's new Joppa, Illinois plant. Each is rated at 216,176-kva at .85 power factor and 30 psig hydrogen pressure. Combined output will be nearly 1,000,000-kw when all 6 units are completed.

THE ENGINEER AND HIS CAREER

Modern industry is a fabric of many patterns and many threads. One thread running through all the designs is the engineer. He has grown with industry to be among its leaders. He is established throughout it in the development and design of its products. He builds in its construction. He directs its processes. He establishes its tools. He installs and operates its utilities. And he sells many of its products. Take him from industry, and industry would collapse.

Each year our engineering schools bring to industry the young engineers who would add their contributions to the complex structure of engineering achievement which undergirds our ever-increasing standard of living.

Industry will be watching these young engineers. It will be looking to them for those same qualities which characterized the engineers who preceded them. It will be looking for men who are honest, loyal, and dependable; for men who have knowledge and understanding of the phenomena involved; for men who can conceive of the new and who have the strength and the courage to carry it through to successful accomplishment; for men who are enthusiastic in their work and who know how to work with other men—men who are leaders. It will be looking for men who have knowledge even beyond the special, men who have skill even beyond the skillful, men who have judgment as to action, men who have wisdom as to compromise, men who respect human endeavor and human safety, men who have personalities that are pleasing and inspiring, men of character who live righteously to serve their fellow men with distinction, men who can think clearly, write understandingly, and speak with conviction. These are what industry looks for in those engineers newly coming to their doors.

The early years of engineering training in industry, while offering every opportunity, are often long and hard and wearisome. The young engineer discovers the discipline of learning to adapt himself—and the transition is sometimes so abrupt that the way seems hard. But if he will continually keep in mind the fundamental concept that his is a great opportunity because of what has gone before him—often extending over many years and including many people—then he will realize the need and the reasonableness of this discipline. As a result, he will master it as quickly as possible in order that he can put his energies into moving onward to apply himself to the new things that need to be accomplished. The unsolved engineering problems of today outnumber the solved.

So the young engineer, as he begins to establish himself in industry, has the opportunity to apply himself to problems waiting to be solved. And if he can give promise of solving them, he will find industry ready to provide him with the means for so doing. Thus the young engineer develops hand-in-hand with industry, and industry appraises him in accordance with his development and his contributions. As he grows into positions of responsibility and trust, he will in turn be helping to develop and to appraise even younger engineers.

In this fashion does one's engineering life progress. And with this progress come the friendships of fellow engineers and associates. These make one's engineering life a joy. The young engineer must not neglect them, but rather he should cultivate them. And he must learn to play.

While the fundamentals of all industries are generally the same, the detailed organization arrangements and concepts differ greatly. This is to be expected in an economy whose greatest fundamental is freedom—and where a multitude of considerations come into each individual industry situation to influence the result. The young engineer should learn what these individual characteristics are and evaluate them as they apply to his individual ability. He must accept them and live along with them, until as he lives with them he becomes a part of them, and with the increase of days he finds himself in a position where he is contributing to their direction.

The engineer can well be proud of his achievements. For those achievements run through all the fabric of industry. In the forefront of all the construction stands the civil engineer. In all of the metallurgy we find the mining and metallurgical engineer. In all the machinery there is the mechanical engineer. In the chemical processes we see the chemical engineer. And in all of the electric power and machinery, and electronics, and communications, and lighting—in all the forces which move and direct industry, there stands the electrical engineer. As the careers of engineers have taken them into the many fields of fundamental engineering, so have they established themselves in every position where they could make the materials and the forces of nature available for man's continuing use.

The career of the engineer is comprehensive, diversified. And it begins, continues, and ends with service.

Everett S. Lee

EDITOR

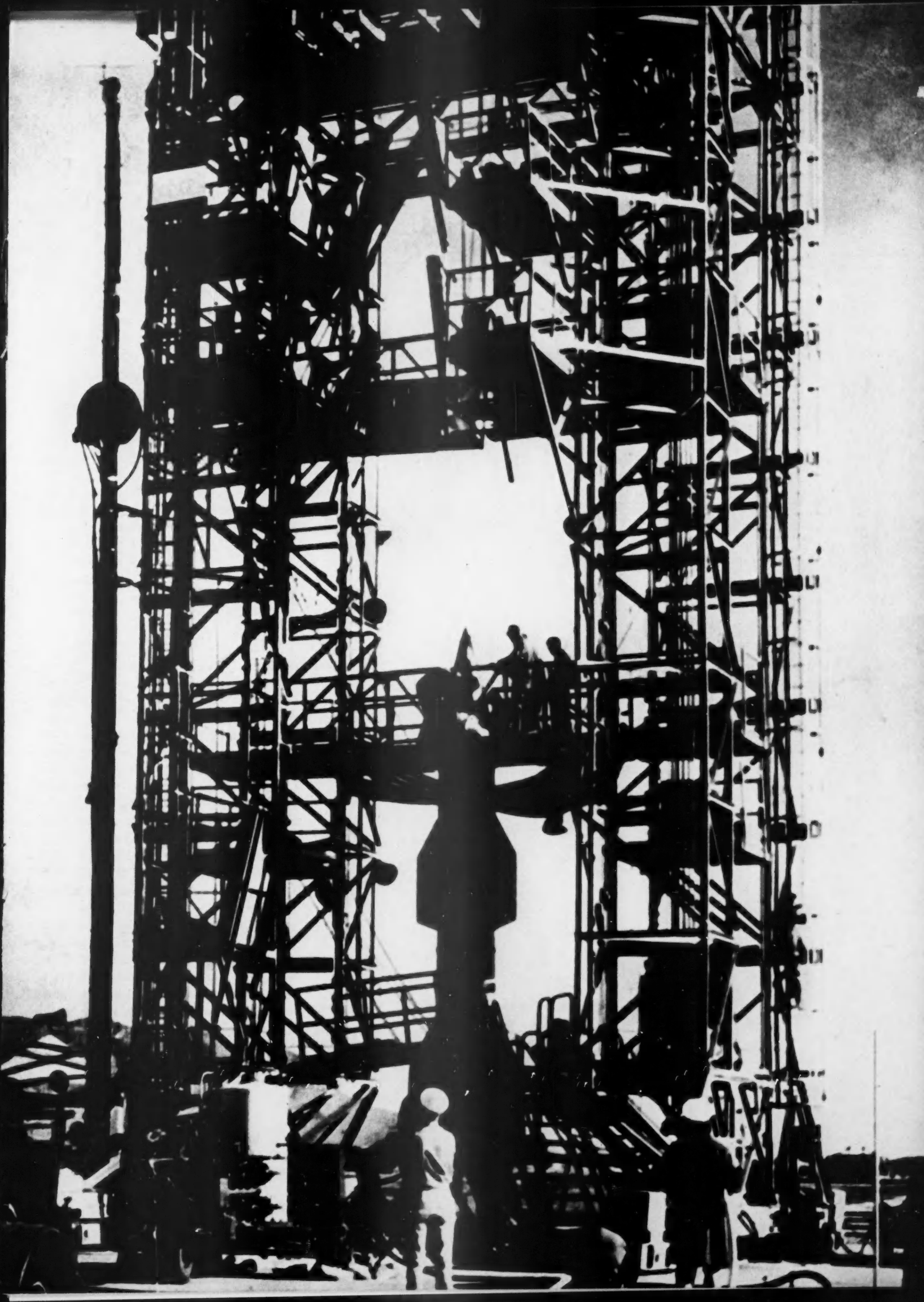
"Missile Off—On Money!"

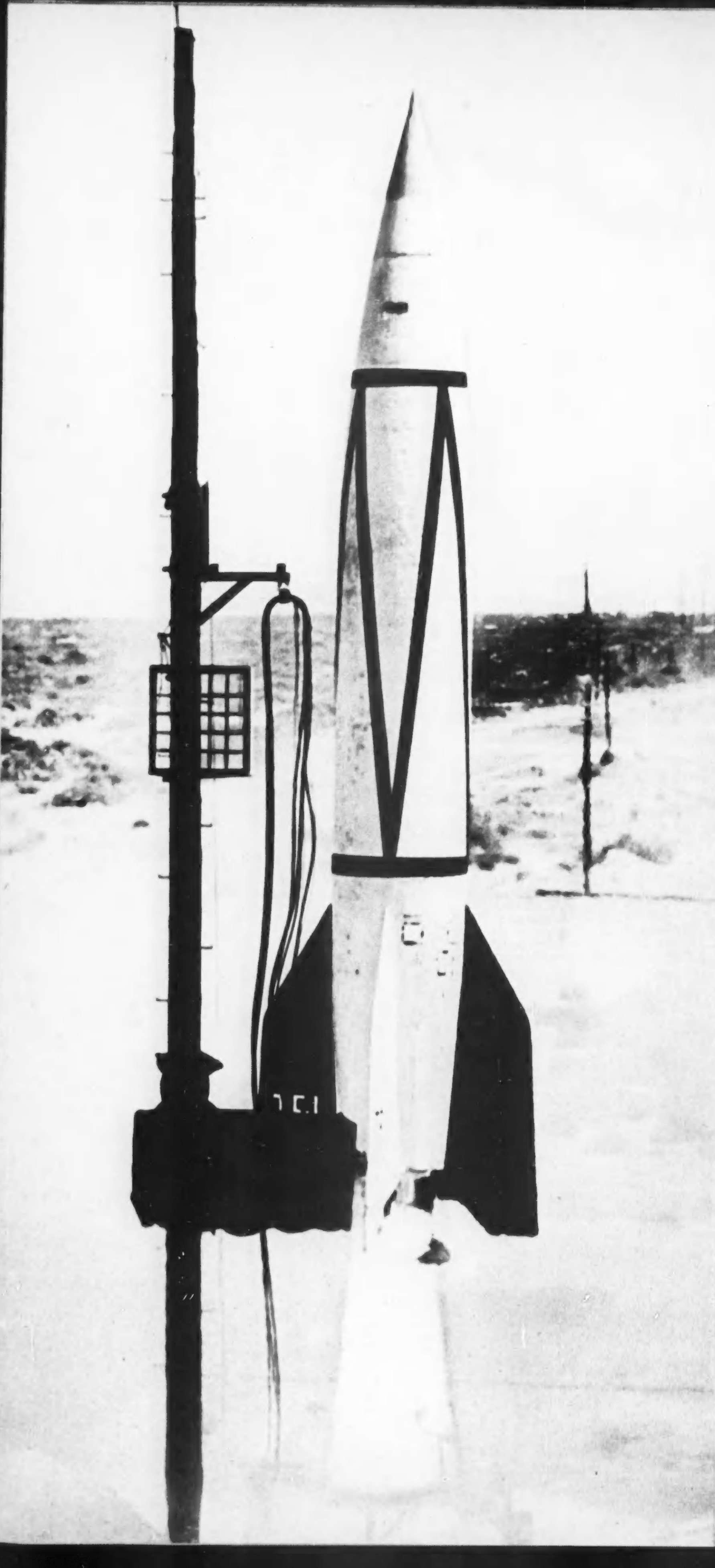
Review STAFF REPORT

Las Cruces, NM, an overblown farm town some 40 dusty miles north of El Paso and the Mexican border, has been burdened with blessings and headaches caused by the people and money from the huge, sprawling White Sands Proving Ground 30 miles or so away.

The town's broad Main Street is now a one-way street to handle bumper-to-bumper traffic of homeward-bound shift workers. On its outskirts near the Rio Grande River, motels, garages, restaurants, and gas stations have grown up in an unzoned jungle. The influence of the Proving Ground's guided-missile work is everywhere. Drugstores sell gaudy decals with V-2s on them, a drive-in theater has a neon-outlined rocket on its sign, and the side panels of dusty Chevrolet Carryalls bear the insignia of Douglas Aircraft or Cal Tech's Jet Propulsion Laboratory.

East of Las Cruces on the other side of the Organ and San Andres Mountains is the Tularosa Basin and the towns of Tularosa and Alamogordo, the latter claiming the somewhat sinister distinction of being the birthplace of atomic energy. There are also large quantities of alkali flats, lava beds, sand, cactus,





yucca plants, jack rabbits, and rattlesnakes. It is a most suitable place to try out guided missiles.

The Army Ordnance's White Sands Proving Ground started out in 1945 to be a temporary testing facility, but three years later it was reclassified as a Class II Ordnance installation. A lieutenant colonel was the first commanding officer; the second and present ones, brigadier generals.

One day last summer I landed at the Las Cruces airport and went to the Kilby Kourt motel on the southern edge of town. There I met a group of G-E engineers from the Guided Missiles Department in Schenectady, NY, who had come to Las Cruces to conduct a "shoot," as a missile launching is called. It was further designated as a certain "round" of a series, such as, "This shoot is Round IV of the D-4B series of vehicles."

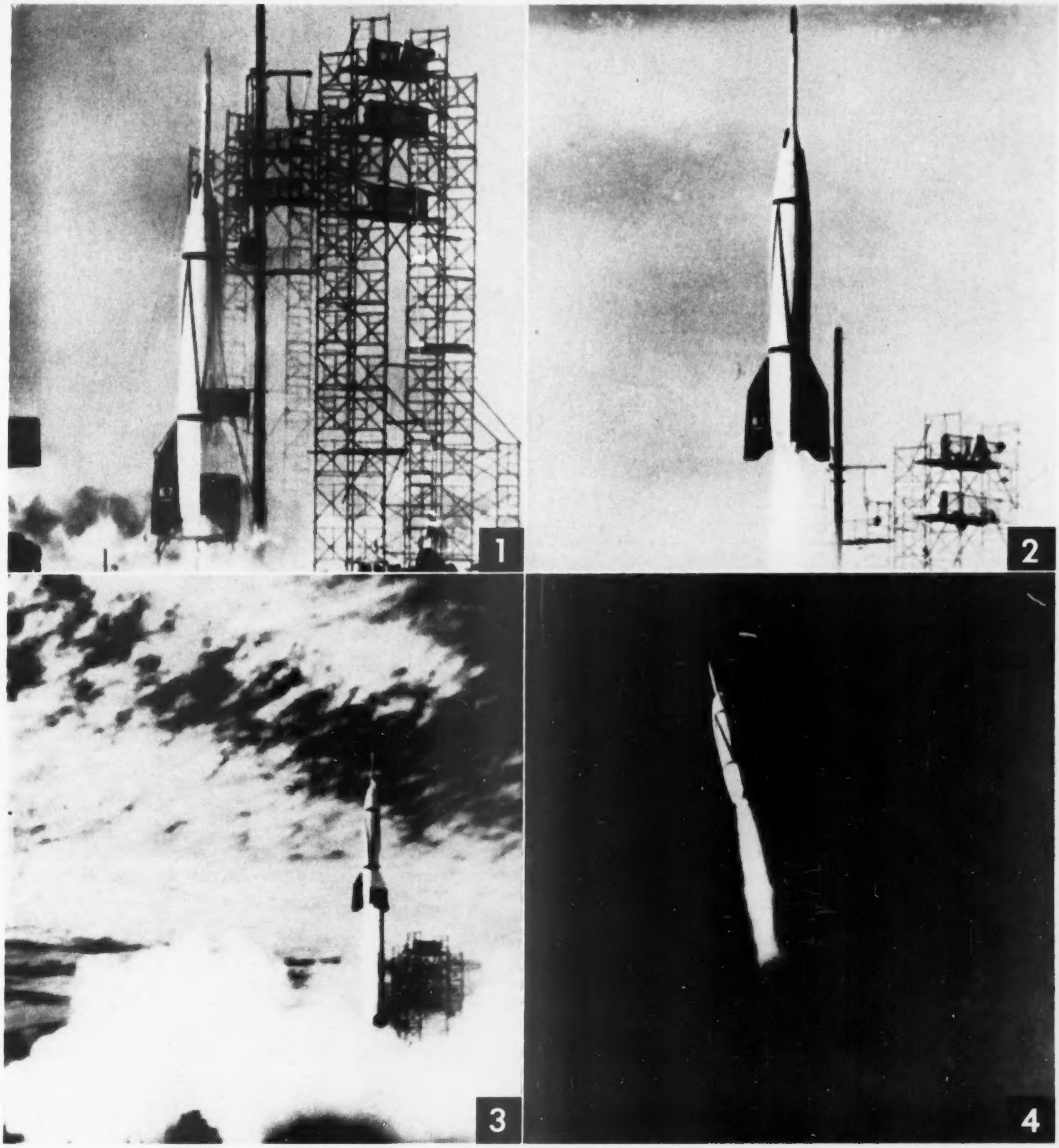
(Rocket is an ordinary and respectable term, but oddly enough, the men engaged in this work—rocketry—seldom use it. To them a rocket is a missile, or a vehicle. Oftentimes they refer to it by the project designation, such as Hermes, Corporal, Honest John, or by the missile's model number, such as B-1, D-2B, or C-2-3. Some writers claim they have heard the use of such terms as "beast," "bird," or "monster.")

From the engineers I learned a number of interesting things—for instance, that General Electric has been in the guided missile business a lot longer than many people realize. In November, 1944, Army Ordnance initiated with the Company a broad program calling for the investigation of all phases of guided missile research, development, and manufacture. Significantly and consciously, the over-all program was named Project Hermes after the figure of Greek mythology who was herald and messenger of the gods.

The major emphasis was on "tactically feasible surface-launched missiles," to phrase it in the vernacular. This, engineers soon discovered, covered a tremendous amount of ground.

In the first place, no large liquid-propellant rocket had ever been built, aside from the German V-2 (official German designation: A-4). There was very little information available on the

V-2s WERE WORKHORSES at White Sands Proving Ground, often carrying 47 percent more than their payload of 2200 pounds.



BUMPERS WENT THE HIGHEST AND FASTEST AND HELPED SOLVE THE PROBLEM OF STARTING ROCKET MOTORS AT HIGH ALTITUDES

subject; captured German documents sometimes proved to be aggravatingly inaccurate. Knowledge of supersonic aerodynamics was thin in this country, and wind tunnels and other facilities for such testing were practically nonexistent. Also, no suitable telemetering or guidance systems were on hand.

One phase of Project Hermes involved General Electric with the German V-2 rocket. In the waning days of World War II, G-E engineers and scientists went to Europe and studied captured V-2s. Later, at White Sands under the sponsorship of the Army Ordnance Corps, G-E engineers and scientists co-operated in the launching of 67 V-2s during a five-year period.

Of the 67 launchings, 68 percent officially were classified as "successful," although the definition of the term may be open to various interpretations. For instance, one definition says a successful flight is "one in which there was no malfunction in any operating component or unit of the rocket." Although crystal clear and uncompromising, it fails to take into account the number of missiles that had steering trouble, yet managed to get to an altitude of 80 miles or so and furnished some good data.

Another definition, proposed by a

"OPERATION SANDY" SAW THE V-2 GETTING OFF TO A BAD START, BUT IT DID PROVE THAT LARGE ROCKETS CAN BE LAUNCHED AT SEA.

G-E engineer, states that when a missile passes a certain altitude—50 miles or more in the case of the V-2—it is a success. The 68 percent figure is derived from this definition.

Missile failures in the V-2 program, it should be noted, were divided almost equally between steering and propulsion difficulties. In the latter, the system either blew up, or stopped.

The V-2 soon proved to be the workhorse of rocket research. Originally designed to handle a payload of 2200 pounds, it was carrying 47 percent more than that by the time tests were completed in 1951.

While many of the captured rockets shipped into White Sands were complete, some were missing important parts. If cannibalizing or captured spares didn't provide enough components such as gyros, automatic pilots, valves, computers, or tail structures to make up a complete rocket, new parts were fabricated.

But there was more to the V-2 program than just firing them into the air to see how high they would go. Much of the present-day knowledge of the composition and behavior of the upper atmosphere was obtained by elaborate instrumentation of these V-2s. Components of developmental rockets were tested, including a G-E flight-control system and a G-E telemetering system that was not only used on future Hermes missiles but was also adopted by other projects.

One of the most spectacular offshoots of the V-2 was the "Bumper" program begun in 1946. A WAC Corporal, so named because of its trim profile, was attached to the nose of a V-2. After the V-2 burned out, the WAC Corporal fired and ascended under its own power. The fifth of these two-stage missiles reached a velocity of 5000 mph and a height of 250 miles. As far as is known, this is the highest and fastest a man-made object has ever gone. The WAC Corporals were designed by the Jet Propulsion Laboratory of Cal Tech and built by Douglas Aircraft.

Two Bumper firings were also carried out at the Banana River Long-range Proving Ground in Florida.

The Bumpers helped solve the problem of starting rocket motors at high altitudes, and much was learned about aerodynamic heating at high speeds.

Also, because of the limitations of present-day fuels, engineers believe that a three-stage rocket will be the only means of getting up to a space station, and thus to the outer regions of the universe.

Not all of GE's activity with the V-2 was confined to White Sands. "Operation Sandy" involved the launching of a V-2 from the deck of the aircraft carrier USS *Midway* in September, 1947. The main concern was what would happen if the missile should topple over onto the deck during the launching, or if it should flop back because of power failure after it was up a few feet in the air. Also, V-2s have been known to "walk" 100 feet on the ground before falling over. The fuels—liquid oxygen and alcohol—are particularly dangerous when mixed.

"Sandy" was a success, although momentarily harrowing. The V-2 took off at a 45-degree angle, straightened out for a few seconds, and then went completely haywire, tumbling over and over and finally breaking up into three pieces. Even so, it did prove that large rockets could be launched at sea.

"Operation Pushover," conducted at White Sands and handled by G-E engineers at the request of the Navy, determined the effect of a missile's exploding during launching on a warship.

"Operation Blossom" involved V-2s in upper-air research: composition of the atmosphere; temperatures and pressures at high altitudes; the nature of "soft" X-radioactivity; voltage breakdown of electric equipment; and photographs of the sky, sun, and earth.

The V-2 program was discontinued when there were no more rockets to fire.

By May, 1950, the first G-E designed missile was launched at White Sands. Known as the Hermes A-1, it was based on the design of the German Wasserfall (Waterfall) antiaircraft weapon. This decision was made so that G-E engineers could take advantage of the extensive German research on the project. Smaller than the V-2, it had four midsection wings for fast maneuverability, a critical requirement for an antiaircraft missile. Within the next year a series of missiles was launched.

At the same time, other groups within the Hermes project were working on the Hermes B supersonic ramjet missile and the Hermes C-1, a three-stage long-range (thousands of miles) glider-type guided missile. These projects were confined primarily to the study stage, although full-size supersonic ramjet diffusers were mounted on the nose of two V-2s for actual flight testing. In 1950, both the B and C-1 projects were turned over to the Army Ordnance Redstone Arsenal in Huntsville, Ala., and GE concentrated its efforts on the development of other important missiles.

Throughout the entire Hermes program, research and development programs have been carried on at the Company's Campbell Avenue Plant on the outskirts of Schenectady; at Electronics Park in Syracuse, NY; and at the Malta Test Station, an extensive and fairly isolated area 20 miles from Schenectady, where rocket motors are static tested and combustion and fuel experiments carried out.

Rocket engineers, I soon found after a few hours with them in Las Cruces, are smart and aggressive, and have enough youthful confidence so that they're not appalled by some of the problems they constantly encounter in the design, development, and manufacture of accurate, highly reliable missiles.

Here are some examples of what they have to cope with . . .

- Gas temperatures in the rocket motor run from 5000 to 6000 F. (The turbine of a turbojet aircraft engine operates at about 1800 F.)
- Speed of the missile is many times that of sound. (Jet aircraft have barely cracked the sonic barrier.)
- As the fuels are burned, the missile's center of gravity changes. This poses a definite control and guidance problem.
- Electric and other equipment must operate at pressures from atmospheric to a near vacuum.
- Because the launching velocity of a large missile is so slow—starting from zero—guidance is difficult without rails on the launching platform or solid carbon vanes in the exhaust stream.
- Control and guidance of a missile with fins must be done in the first—or last—30 to 40 seconds of flight. At high altitudes the fins have no air to act against.
- The ionized exhaust stream absorbs, reflects, and diffuses radio waves. This makes it difficult to send information from the missile and to send guidance signals to it. At high altitudes it is particularly troublesome because the exhaust tends to grow "bushy" or "blossom out" as atmospheric pressure decreases.
- At high supersonic speeds, aerodynamic heating may be high enough to cause certain portions of the missile's skin to glow red. WAC Corporals on Bumper flights have landed with fused control surfaces.
- Static testing an assembled missile requires facilities of unprecedented magnitude.
- Even though a rocket is a one-shot proposition, components must be designed with reliability approaching 100 percent. So much depends on each element in the chain of events that each must operate successfully. There is no human aboard to make last-minute adjustments.
- Rocket flight is not particularly smooth. Equipment, therefore, must not only be self-powered, self-running, and self-controlled, but it must also be stable under conditions of high acceleration, vibration, heating, and considerable tossing and turning. Occasionally, when the rocket reaches the top of its flight, it begins to fall, tumbling over and over like a big silly puppy, until it strikes the top of the atmosphere. There the air acts on its tail fins, and it oscillates wildly with gradually decreasing frequency until it is pointing earthward. Sometimes they oscillate so wildly they break up.

After more talk with the G-E men about some of their engineering problems, we discussed the event that would take place in a couple of days.

The shoot, I was told, would be of a Hermes missile of a considerably advanced design.

DAY X MINUS 2

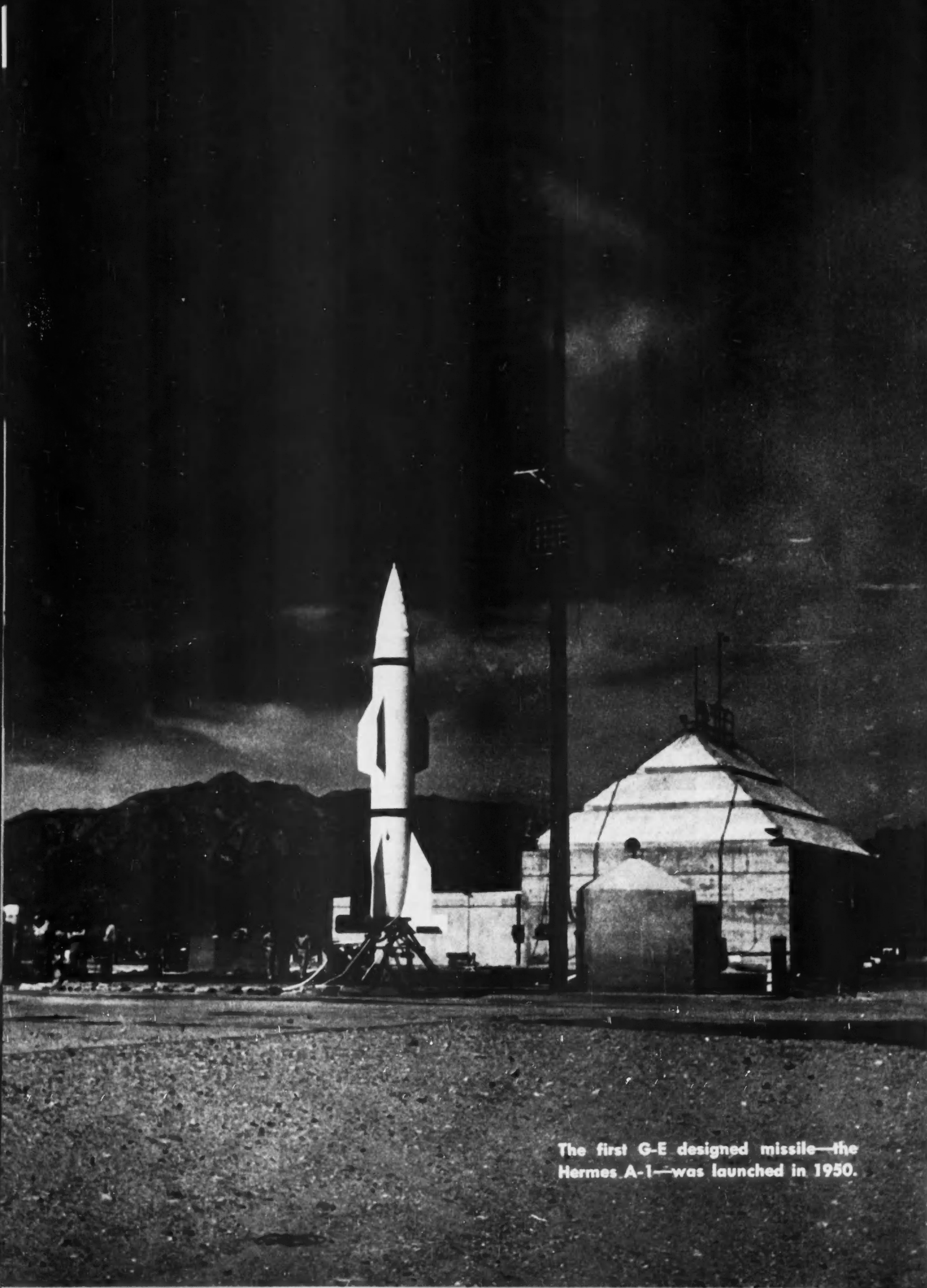
The next morning at 6:30 o'clock a Chevrolet four-door and a Carryall picked us up at the motel; we went downtown to Las Cruces to eat, and were on our way by shortly after 7 o'clock.

The drive on Highway 70, up the long climb to the St. Augstin pass in the Organ Mountains, is interesting the first few times. From that point the White Sands National Park is barely visible almost straight ahead; to your right in the distance are the buildings of the Proving Ground. Near the foot of the mountains an access road leads to Gate 1.

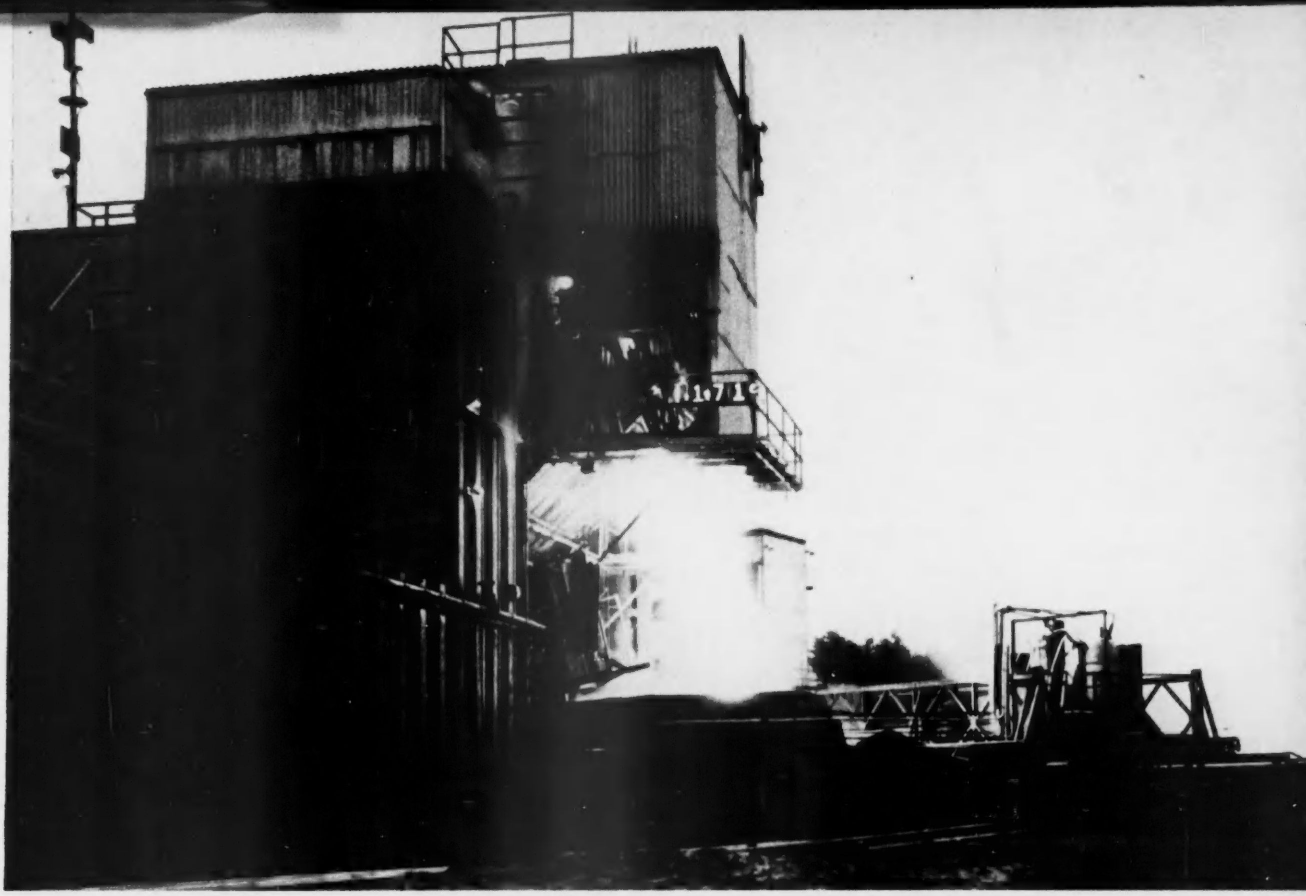
After checking into the security office, we proceeded to the Technical Area—a large fenced-off group of hangar-like buildings where missiles are worked over prior to launching.

In the G-E building I met L. D. "Pappy" White, an amiable soft-spoken Southerner, who's been at the Proving Ground almost since its beginning.

He and 30 other G-E Service Engineers stationed there under the direction of Army Ordnance are responsible for the launching operations. Seventeen of them have been there more than five years.



The first G-E designed missile—the Hermes A-1—was launched in 1950.



ROCKET MOTORS ARE STATIC TESTED IN A VARIETY OF MAMMOTH "PITS" AT THE MALTA TEST STATION, 20 MILES FROM SCHENECTADY.

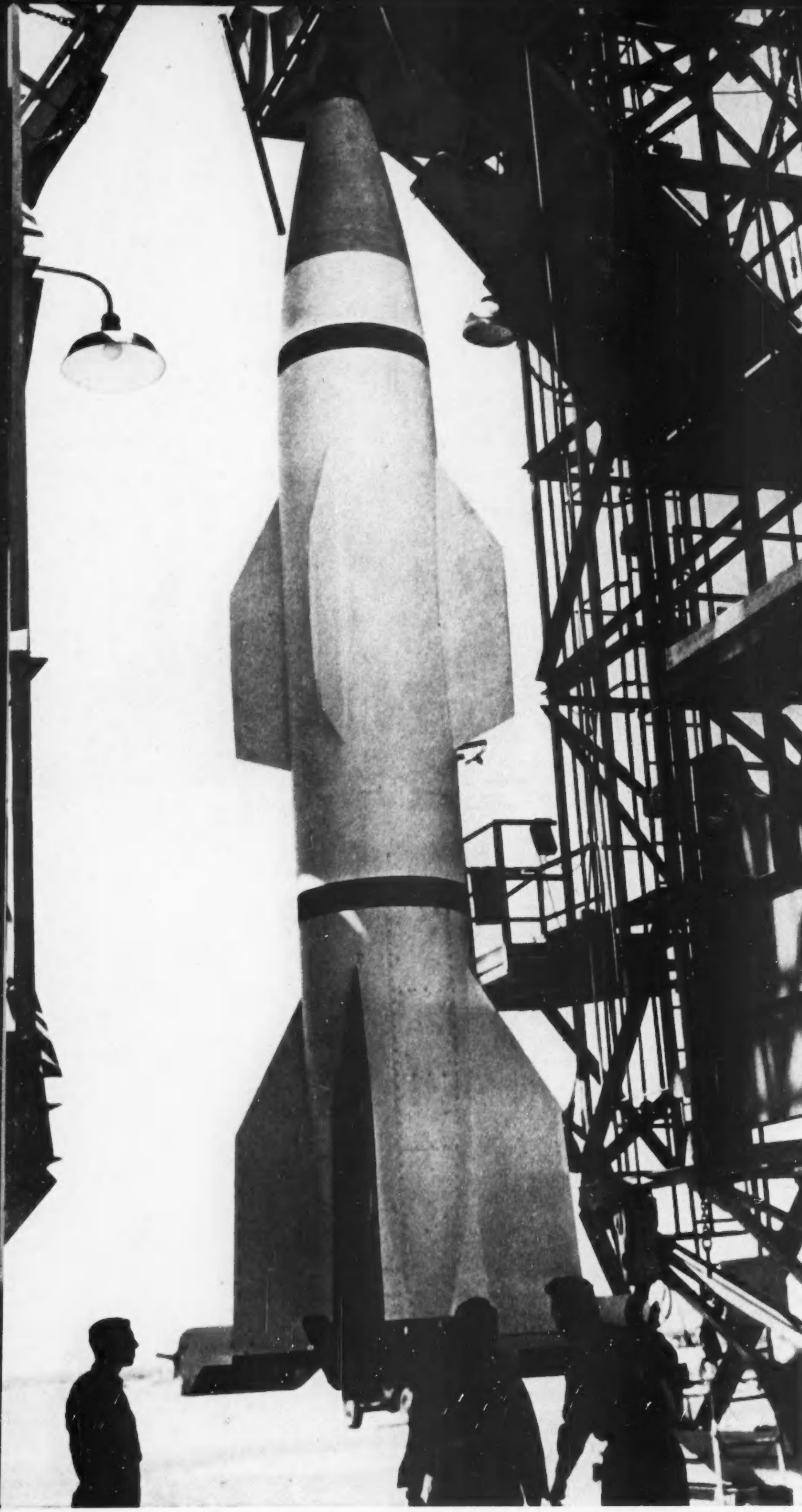
White has seen many firings. "The more you see, the more respect you have for them," he told me. "And when you see one go wrong, you have a lot more respect."

He recounts the time that one V-2 screamed into a hillside cemetery at 3000 mph outside Juarez, Mexico, just across the Rio Grande from El Paso. No international fuss developed, but it did point up the aggressiveness of the Mexican townfolk. Concession stands were soon established at the site, and small boys were peddling pieces of the missile as souvenirs. Unwary tourists soon found that their purchases were distressingly similar to odd pieces of wrecked autos, easily procurable on any city dump.

White told me of some other incidents, and soon after, in another Carryall, we drove the six miles down a blacktop road from the Base to the Army Blockhouse and the firing site.

In the early days of the Proving Ground the V-2s were launched from a large concrete pad in the middle of the desert. A few hundred feet from that, the Fortification Division of the Corps of Engineers built a structure that was

TODAY, WHITE SANDS PROVING GROUND IS A CLASS II ARMY ORDNANCE INSTALLATION.



POSITIONING ON THE LAUNCHING STAND IS A CRITICAL OPERATION FOR THE TESTING CREW.

labeled the Blockhouse. It is perhaps 50 feet square, has walls that are 10 feet thick and a pyramidal roof of solid reinforced concrete that has a maximum thickness of 25 feet. I encountered no one who doubted that it could sustain a direct hit from an errant missile.

Inside the blockhouse is a communication center that ties together the various range stations and other facilities of the Proving Ground. Control rooms with thick, slit windows face the launching site.

Leaving the blockhouse, I walked the few hundred feet to where the Hermes missile was standing with its thin nose pointed into the bright morning sky. It was still shrouded in its night clothes—large tarpaulins loosely draped around its form and secured with ropes. It looked somewhat like an ancient Roman official with his toga in a mild state of disarray.

Days before, the missile had been towed from the Technical Area to the firing site, carefully raised by a nose ring to a vertical position, and then gently placed on the steel launching cone.

Surrounding the missile was a medium-sized gantry, a lacy structure of welded steel pipes that would be pulled away during the actual firing. Stages were located at important positions up and down the side of the missile.

At another firing location some distance away and facing another side of the blockhouse was a Corporal. It was surrounded by the elaborate gantry that is often seen in newsreels and still pictures of V-2 launchings.

Around the other side of the blockhouse were a series of Nikes (rhymes with Psyche) on their launching racks, some pointing skyward, some horizontal.

Many miles away on the desert floor I could barely make out the features of the Naval Ordnance Missile Test Facility. The "Desert Navy" is not looked upon as a poor relative by the Proving Ground Command—the work is co-ordinated to a high degree. The commanding officer is a captain, and there are more than 70 buildings in the Navy cantonment area.

Looking through glasses toward the foothills of the Organ Mountains, I saw a monstrous structure cut out of the solid rock wall and reinforced with huge steel girders, not unlike some fantastic symbol of a lunar landscape. This was the static stand for testing very large rocket motors. When operating, its

CONTROL CONSOLE in the blockhouse serves as nerve center for Project Hermes. Orville Jones (*left*) observes operations on missile through slit window (*upper left*).

V-2 MOTORS burned liquid oxygen and alcohol, developed 50,000 pounds thrust.

mighty bellow can be heard many miles across the desert floor.

Back at the Hermes missile I watched a large number of the G-E scientists and engineers working on it. Two trailers housing workshops, supplies, and tools were parked nearby, along with a liquid-oxygen "buggy" and other necessary equipment. On the top platform of the gantry, electronic engineers were working on the missile's antennas and telemetering equipment. Lower down on the missile the various access doors were swung open, revealing a close-packed maze of boxes, wires, tubing, and AN connectors. A large connector about the size of a man's fist tied the missile's control system to the console in the blockhouse. Two engineers with telephone headsets were nearby, relaying instructions from the engineers at the control console in the blockhouse to the men working on the missile.

At the edge of the concrete firing apron, some 40 feet away, technicians were setting up gun cameras to take color movies of the firing's initial stages. Three camera platforms about 30 feet high and 200 feet away were located 90 degrees apart. Signal Corps cameramen would install remote-controlled color cameras there to get the first few seconds of the missile's flight.

Back in the cool confines of the Hermes control room in the blockhouse I watched Orville Jones, a big pleasant six-footer, work at the control console. It's about the size of an office desk top, slightly tilted for better visibility. On it, by a fast count, were 105 indicating lamps of various hues and a multiplicity of knobs, control handles, and dials and meters and gages.

During the day two important tests were run on the missile. The telemetering equipment that would transmit to ground stations vital bits of information concerning various aspects of the flight was checked out.

During the morning the propulsion system was pressure tested. Although the missile had been given a static firing at the Malta Test Station, it was still necessary to check the system. Instead of the actual fuels, compressed air was used. The area around the missile was cleared, and the tests started. A half hour later Jones noticed that the pressure was falling off more rapidly than normal. He ordered the supply cut off. The air was released, engineers investigated, and a short time later the report filtered into the control room: a flare fitting on a quarter-inch line had pulled out of a sleeve. A new line was fabricated in the Tech Area and installed that afternoon.

By the time the pressure check was completed it was noon, so we straggled over to the mess shack a short way outside the firing area. There, over the usual Army fare, Jones told me about rocket propulsion systems.

Solid propellants, he said, have historically been confined to small missiles, often of the air-to-air type.

For some larger missiles, such as the Hermes, V-2, and others, liquid oxygen —"lox" as it's always written and spoken—and alcohol are the fuels used. Experiments have been conducted with gasoline.

"You can get the fuels to the combustion chamber by one of two methods," Jones said. "Either you pressurize them so that they flow to the combustion chamber, or you pump them there. A gravity fuel-flow system won't work."

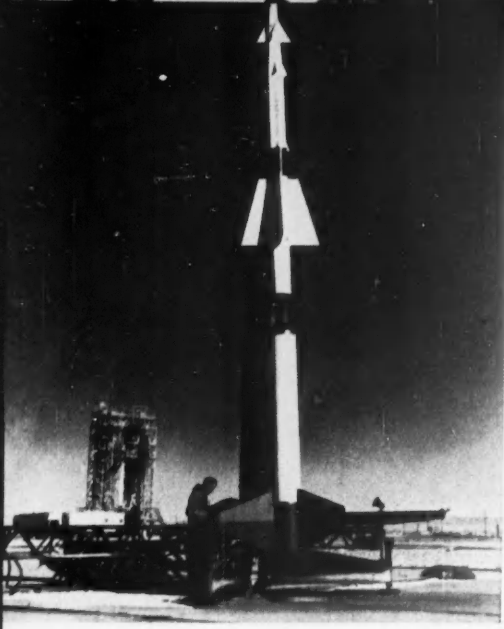
The V-2, he said, was an example of a system using a turbopump. In this instance, the Germans forced the fuels into the combustion chamber with a two-stage steam-driven turbopump about the size of a 16-inch table-model television set. It developed 460 hp and spun at 3800 rpm. Steam to drive the turbine was generated by the decomposition of hydrogen peroxide when it was mixed with potassium permanganate, a catalyst.

For the V-2, Jones said, the firing was done in two stages—preliminary and main.

The control operator first fired a pyrotechnic igniter that was located in the motor's combustion chamber. He then began the preliminary stage by letting the alcohol and lox, both under low tank pressure, flow into the combustion chamber where the igniter was burning. (The resulting violence blew the remains of the igniter and the ignition wiring far away.)

If the control operator saw that burning was satisfactory, he began the main stage by opening valves leading to the hydrogen peroxide and the potassium permanganate. They mixed, and the resulting steam was fed to the turbopump. As the pump increased its speed, more and more alcohol and lox were pumped into the motor, and the thrust increased rapidly. When the thrust exceeded the weight of the missile, it took off.

Regenerative cooling is one trick to increase motor life. Alcohol goes from the storage tank through coils that are wrapped around the motor and then into the combustion section of the motor. This not only helps to keep the



1 Nike is 20 feet long, one foot in diameter. Booster rocket gives missile . . .

2 . . . impetus for first few seconds of flight. Missile uses liquid fuels, is . . .

3 . . . guided to target by radar that tracks target and guides missile until . . .

motor operating at a lower temperature, but warming up the alcohol means it burns at a higher efficiency.

To give you some idea of size, a V-2 rocket motor is about the size of a large oil drum and is shaped somewhat like an elongated, inverted cuspidor. Maximum thrust developed is 50,000 pounds.

About midafternoon the Command loudspeaker ordered the blockhouse area to be cleared for a Nike firing.

To see the Nike shoot, a group of us walked out of the firing area across the access road to a large sand dune a few hundred feet away. Two Signal Corps cameramen nearby had a small loudspeaker tied into the command system that kept us informed of the latest test details. The blockhouse was slightly to our right, the Nike immediately in front of us. At X minus 15 minutes a red smoke bomb was fired from the peak of the blockhouse. Roadblocks on the roads leading to the firing site kept vehicles out of the danger area. Miles away on Highway 70, travelers were delayed in a similar fashion.

The loudspeaker kept up the usual minute-by-minute count, interspersed by chatter between the blockhouse, control center, and the various range stations. Two minutes before the firing time, a red Very flare plooped skyward from the blockhouse.

We waited.

On schedule, the Nike got away in one big hurry. It was hundreds of feet into the air before the first sound wave hit us. For the first few seconds of flight, it's an ungainly looking bird because of the large booster rocket. When that falls off—something you always want to be sure of, especially at steep trajectories, because spent boosters have been known to drop alarmingly close to observers—the actual missile keeps on climbing the radar beam to its target. Its speed is most alarming. Of all the missiles I observed at White Sands, the Nike was the most exciting.

DAY X MINUS 1

Further tests on the Hermes missile were run off during the day. There was a certain urgency to get things wrapped up by early afternoon so that the crew could leave. With the shoot scheduled for 10 am the next day, and with six to eight hours of preparation needed immediately before that time, it was imperative that the men get some sleep.

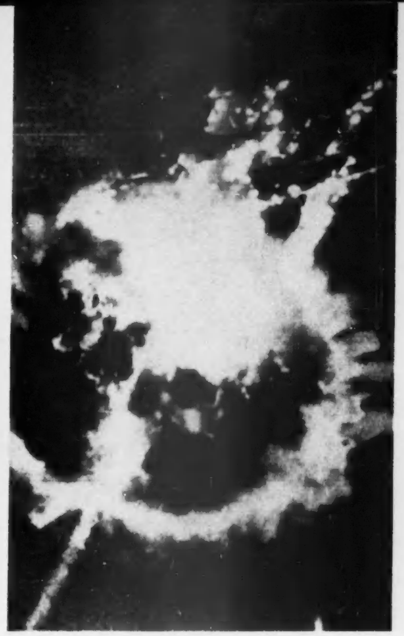
During the day a group of us drove to the General Electric radar station a few miles south of the firing site. Located in the desert off the main road, it was a one-story concrete-block building filled with workbenches and electronic gear. Nearby was a modified Signal Corps trailer with a large radar antenna on the top for tracking the missile. Other pieces of electronic tracking equipment of strange shapes and configurations were around the station. I was told that the complete Hermes guidance system wouldn't be used for this shoot, but that the telemetry circuits would record the vital information on 35 mm film.

After leaving the G-E group, we drove more superheated miles further south to C Station, a long, narrow building topped with an array of radar antennas. Inside the building, keyed in high-frequency sounds and metallic chatter, was a vast tangle of radar and communications equipment. In the plotting room large tinted windows gave observers a clear view of the distant firing site. The plotting tables were tied into the tracking equipment and automatically charted the course of the missile; other stations of the skyscreen helped to further pinpoint the flight. These facilities are operated by the Signal Corps under the supervision of an Ordnance safety engineer. For a large shoot it takes about 150 men to handle all the tracking details.

Optical tracking is done by large telescopic cameras with lenses that resemble long cannon barrels.

Driving back to the blockhouse in the heat, the subject of the weather came up. Although the temperature was around 106 F on the range and wind conditions were favorable, a high overcast had been coming in from the west for the past few days. It had already held up a Corporal firing and, if it continued, would delay the launching of the Hermes vehicle. Good weather, I learned, is critical from the standpoint of optical tracking. Although radar can follow the missile regardless of the weather, experience has shown that optical tracking is always advisable. The films show the performance of the rocket and, in case of a failure, often give valuable clues concerning the

4 . . . they converge. (Smoke pot on drone was to aid photographers.)



5 Nike can outmaneuver any aircraft. It was developed by Army Ordnance . . .

6 . . . Western Electric, Bell Telephone Laboratories, and Douglas Aircraft.

reason for the mishap. Cameras can't track through clouds.

I also learned that if the missile is lost by both optical and radar tracking, it is blown up in flight by a small internal explosive detonated by a radio signal, or the motor is cut off by a radio signal to prevent the missile from falling outside the range. The same procedure applies if the missile should become too rebellious and start wandering.

Back at the blockhouse I checked the latest weather reports with Charley Botkin, supervisor of GE's Flight Test Unit, a serious-faced harrassed young man. He wasn't too encouraging. "It looks like more of the same," he said glumly. It was up to him to determine if the preparations should be halted or continued for the anticipated 10 am shoot. He had decided to go ahead.

Work was called off late in the afternoon, and we left for Las Cruces, supper, and bed.

DAY X MINUS 0

It was 2 o'clock in the morning when the knock came on the door. A Carryall picked us up, and we got fed in some fashion at an all-night diner in Las Cruces. There were no stars in the sky and there was little conversation on the way to the Proving Ground. By 4 am we were at the General Electric building in the Tech Area.

Weather was the main topic in the office. White wasn't optimistic. "The 1 o'clock forecast was bad, the 3 am is horrible," he said, with a shudder. The overcast was still blowing in.

One-half hour later we were at the blockhouse. Floodlights on the gantry outlined the missile and the engineers working on it. There was only a faint breeze; a desert is chilly just before dawn.

I found Botkin in the control room passing out a two-sheet mimeographed launching schedule. At the top was the official designation of the missile, the job order number, the launching time, and the date.

Two columns filled the pages. The left one was headed X-TIME: the other, OPERATION. The entries under X-TIME were in minutes; under OPERATION were items like "Start inspection," and "Connect test panels."

In all there were 38 time designations spread over six hours, and a total of 92 separate operations to be performed. Within that period two half-hour "contingencies" had been set aside so that time could be made up if any delays occurred.

At 5:45, with the sun well into the sky, the clouds were still coming in. Botkin, White, the young Ordnance lieutenant assigned as the "command officer" for the shoot, and others conferred. The decision was made to keep going with the preparations, to proceed as far as possible with the hope that the weather would break later in the morning.

At 6 o'clock in the mess shack we had our second breakfast. There was a noticeable air of tension, and the food was consumed hurriedly.

All around the firing area camera crews were setting up still and movie cameras. The ones close to the missile were remotely controlled; the others, safely outside the firing area, were manned by Signal Corps photographers and G-E personnel.

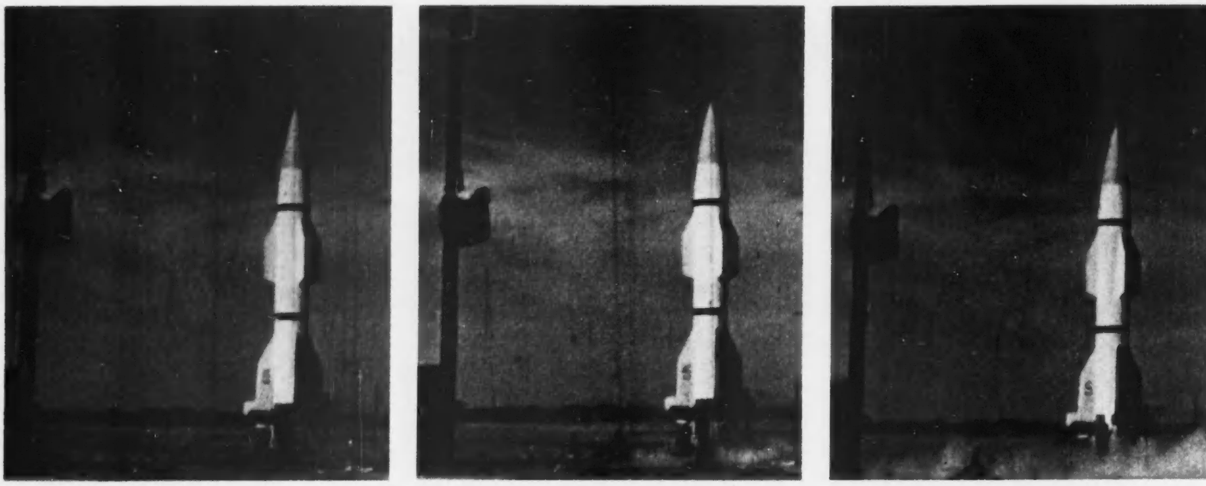
7:00 AM—Two fire trucks arrived at the site. Tripod-mounted nozzles were set up near the missile and attached to high-pressure water lines.

Later I went to the control room in the blockhouse and found the usual last-minute preparations. Technicians were checking over the pens and paper rolls on the photoelectric recorders that would trace a record of the vehicle's flight. Motion-picture cameras and floodlights were being mounted in the ceiling directly above the control console. On color film, a complete record of Jones' movements at the controls and a registering of all lights, dials, and gages would be made.

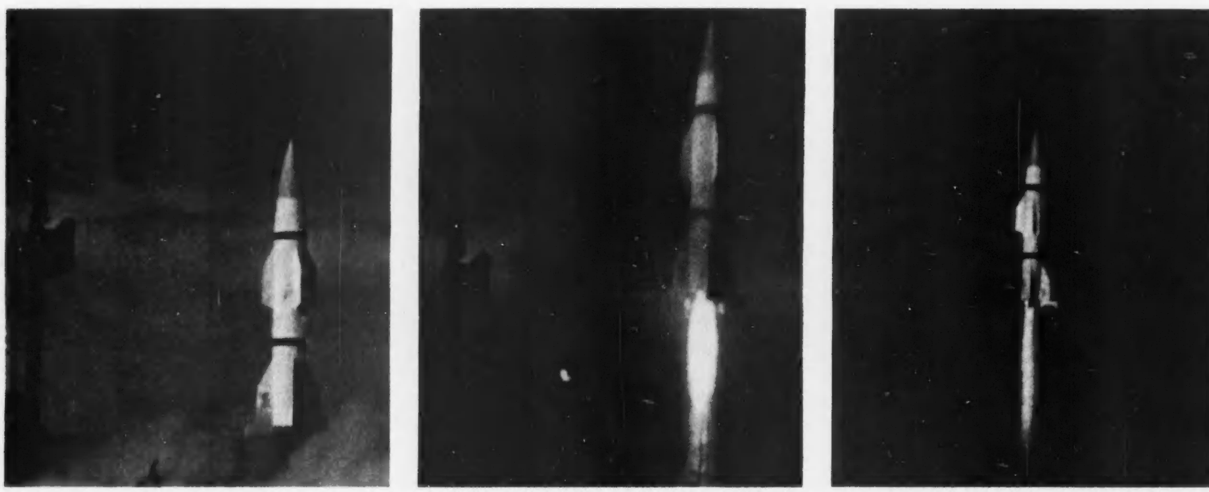
To Jones' left sat Walter McQuade, another long-time veteran of G-E service at the Proving Ground. Wearing a telephone headset, he worked at a chair-desk with a large logbook, noting the time and a description of every operation. Behind him was a tape recorder tied into the communication circuit.

9:15 AM—The weather had improved only slightly. Once in a while a large hole would drift over, but the outlook was discouraging.

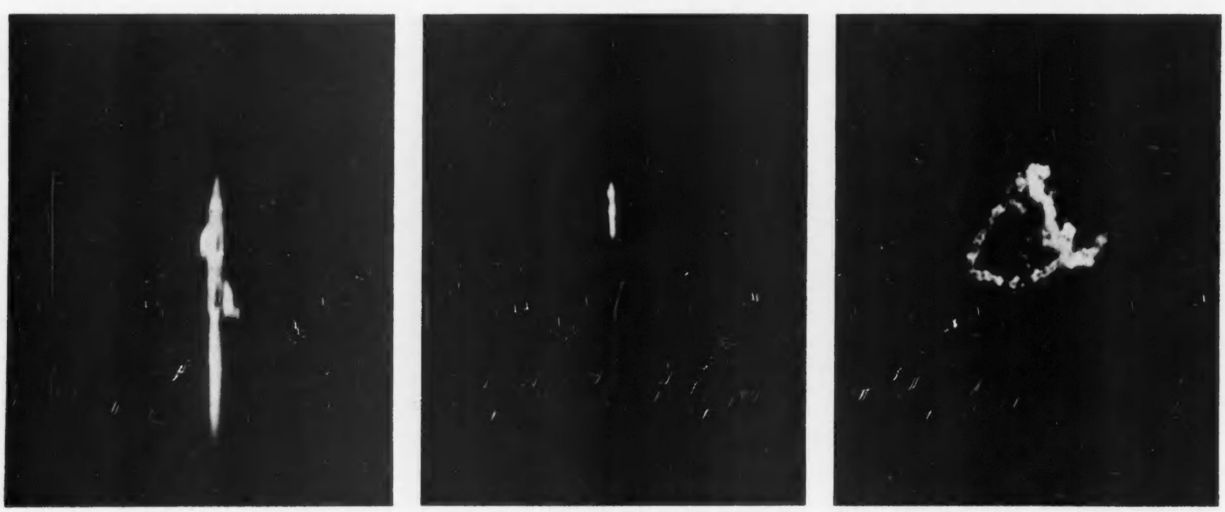
"Every time you guys come down from Schenectady," I overheard White say in a joking tone, "you bring this kind of weather. The same thing happened the last time." He was referring to an earlier shoot that had been held



LARGE ROCKETS SUCH AS THIS HERMES GUIDED MISSILE TAKE OFF IN A PONDEROUS FASHION THAT IS AWESOME TO BEHOLD . . .



. . . BUT MAKES INITIAL GUIDANCE DIFFICULT. SOON THE MISSILE IS BEATING SKYWARD AT EVER-INCREASING SPEED UNTIL IT'S A . . .



. . . PINPOINT, AND ONLY AN ERRATIC CHALK-LIKE VAPOR TRAIL MARKS ITS PATH. THESE PICTURES WERE TAKEN FROM A COLOR MOVIE.

up a number of days because of rain and overcast conditions.

10:15 AM—Time-wise, the operations were more than an hour behind schedule; actually, the procedures had been purposely slowed because of the poor weather.

But the decision evidently was to go ahead, because I heard, "This is Project Hermes Command. The time is now X minus 65."

X MINUS 50—The gantry staging around the missile was slowly pulled away in two sections.

The missile stood small, sleek, and alone under the desert sky. Without the framework of the staging nearby, it seemed to lose some of its impressive proportions.

X MINUS 30—The loudspeaker blared a warning to clear the firing area of all personnel. With one of the cameramen, I drove over to the boondocks—scrub brush and sand dunes—about a quarter of a mile away where movie and still equipment were located behind an impressive dune. It is doubtful that it offered much protection, but at the moment it seemed reassuring. Even from the distance the Command loudspeaker could be heard clearly; it reported that they were going right ahead with the shoot. I learned later that it is less costly to sacrifice a load of oxygen if the weather shouldn't break, than to delay preparations and be caught short if the weather should clear.

X MINUS 15—A plume of red smoke blossomed from the top of the blockhouse. The desert was quiet except for the blare of the Command speaker counting off the time at five-minute intervals. Auto traffic had been halted some time before. There was only the sigh of wind through the scrub brush. A large piece of blue sky was coming over, but it was doubtful that it would get there in time.

X MINUS 9—The voices over the Command system were not encouraging. One of the eastern range stations of the skyscreen reported that with optical tracking coverage from their area was doubtful. There was no report from the western stations.

X MINUS 5—Range control at C Station gave the firing a green light. The decision obviously was to go ahead. The liquid oxygen vent stopped smoking.

X MINUS 2—A red Very signal arced skyward from the blockhouse. C Station said optical tracking was still doubtful from all stations.

The final count was in seconds. It was 11:15.

X MINUS 0—A cloud of dust and sand blossomed from the base of the missile. Then we saw the red flames and the roar swept over us. The missile lifted slowly, ponderously, majestically from the stand. (A large one doesn't "take off like a rocket.") A few hundred feet above the desert floor, with a red-white flame beating out of its tail, it seemed to pick up speed and really move.

I was tracking with a pair of high-power glasses. A missile many thousand feet up looks like it's almost directly overhead. All you can see is the white-hot spot at its tail, a spot somewhat like that of a welder's torch at a distance. It is an awesome sight.

Just before it reached the overcast, the vapor trail appeared and curled away in an erratic chalk-like spiral. Then it broke through the overcast. I could faintly see the pinpoint of the exhaust through the clouds, and then it was gone. Soon its sound, too, was lost in the sky.

All this time the Command speaker had been counting off the seconds in five-second intervals. There was a happy note in his voice. He got well into three figures and stopped.

Figures appeared from the blockhouse, and soon after, the cars and trucks, penned up behind the roadblocks, began their ceaseless ramble back and forth.

A little later I drove over to the blockhouse and walked out to the firing site and the launching stand. There was little evidence of the terrific heat. Streaks of grey powder sloped off the cone, and the asphalt in the cracks of the concrete was blown in long, gooey threads. That was all.

At lunch in the mess shack I talked to Jones and other G-E engineers. They were quite a bit more cheerful than they had been the past few days.

By 1 o'clock there was a variety of reports as to where the missile had landed. About the only thing that was known was that it was "down range" a good number of miles. Optical tracking had lost it when it went through the cloud deck; for that and other reasons, recovery would probably be difficult.

(A large missile, the V-2 for instance, leaves a big hole some 30 feet deep when it rams the earth at well over 3000 mph. What is left can be shoveled into the trunk of your car. "In order to improve the recovery of experimental equipment, it was necessary to destroy the good aerodynamic shape of the missile," a report on V-2 firing states. This was usually done by breaking the missile up into a couple of parts before it entered the earth's atmosphere. One-pound TNT charges located in various parts of the missile did the job. Although the sections were damaged as they struck the earth, there was usually enough left to determine what had failed if the flight were faulty.)

At 1:25 the recovery group left the Proving Ground. We were led by a radio-equipped 6x6 truck that would bring back any parts found. A Chevrolet Carryall with the G-E engineers followed. I was in a jeep with two sergeants.

We took Highway 70 east past the White Sands National Monument through Alamogordo and to Tularosa, a distance of about 60 miles, traveling as fast as the jeep could go.

At Tularosa we turned off the highway and headed west into the Proving Ground territory. The road was gravel and dirt and looked as if a bulldozer had pushed through to make it. After a while I sat up on the metal wheel well because it felt so good when I moved down onto the back seat.

At 4 pm and about 30 miles into the range, we saw the liaison plane that was to locate the missile and then give us direction by radio to the impact site. He signaled a halt and then landed on the road ahead. There were yucca blossoms on his wingtips when he taxied up.

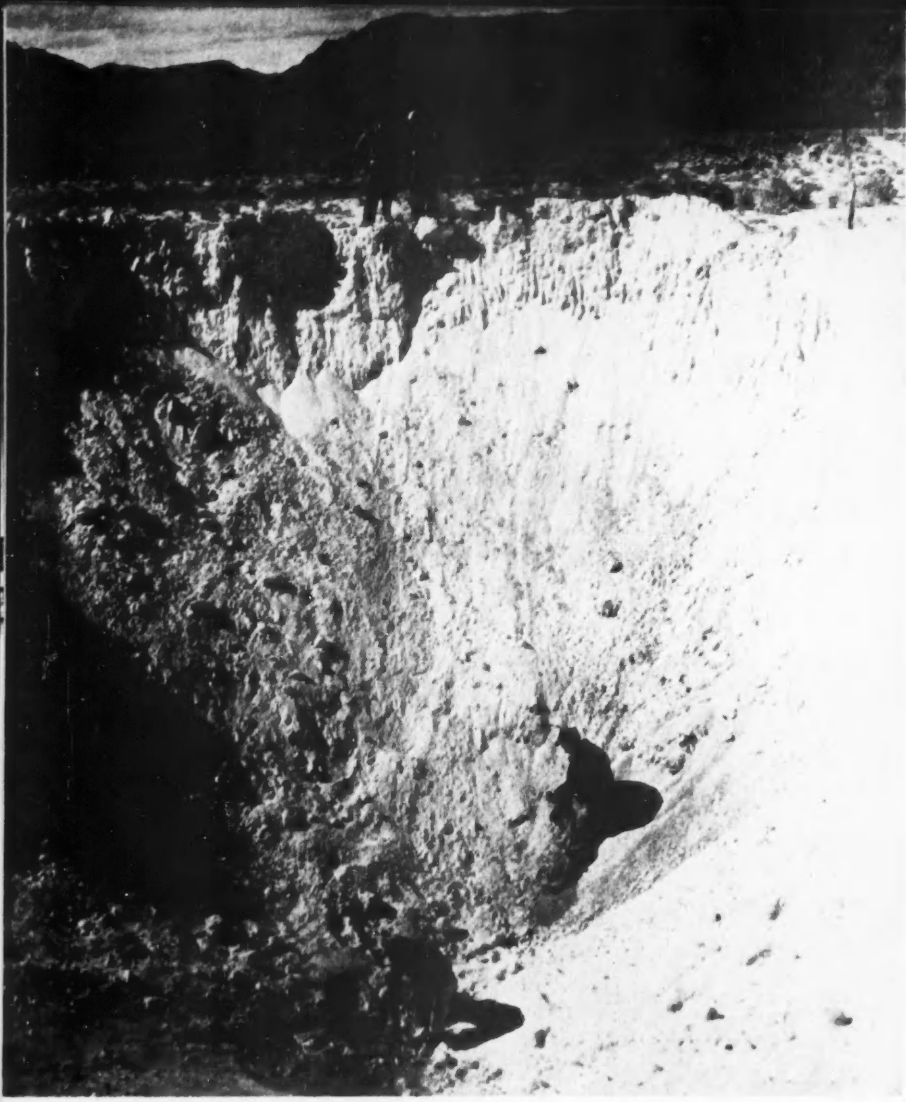
The pilot and observer, both lieutenants, climbed down and reported no luck. "With those poor radar fixes, it could be most anyplace. If it's in the mountains it'll really be tough. If it landed in a bog, we'll never find it." They said they'd check again in a 20-degree cone and report back. They took off; our convoy waited. The sky had cleared, the sun was bright, and the desert was quiet.

At 4:45 the L-19 buzzed the 6x6 and we heard the report over the Command radio. It was negative. The pilot said it was getting too late to do much more and they'd continue the search in the morning.

It was a weary drive back to the Proving Ground and then to Las Cruces. We arrived at 8 pm.

DAY X PLUS 1

The next morning I checked into the G-E office in the Tech Area. The day was windy and a pall of dust hung over



LARGE ROCKETS LEAVE LARGE HOLES WHEN THEY RAM THE EARTH AT MORE THAN 3000 MPH. . .

. . . AND MAKE ACCURATE IDENTIFICATION OF PARTS AT IMPACT SITE SOMEWHAT DIFFICULT.

the desert floor. Because of this the recovery plane hadn't been able to conclude the search.

In the office a complete post-mortem of the shoot was taking place. Spread out on desks were the tapes from the recorders, film from the telemetering instruments, and movies of the launching.

Botkin and others were looking over the telemetering film. There were seven long rows of hills and valleys, somewhat like the perforations on a postage stamp. In all, 94 separate bits of information had been recorded constantly during the flight. Later they would be studied more closely, but a brief inspection showed that all had been functioning properly.

The movies were uninteresting. A small camera with telescopic lens had been mounted on the dish of one of the radar antennas at the G-E range station. It showed the missile in flight, but the film was erratic because the system was hunting part of the time.

In a corner McQuade was playing the tape recorder back and checking it against his log book. We heard the Command officer give the final counts; his voice had a faraway quality as it came from the little speaker. An interval of silence followed, and then there was the distorted roar of the blast-off. McQuade smiled.

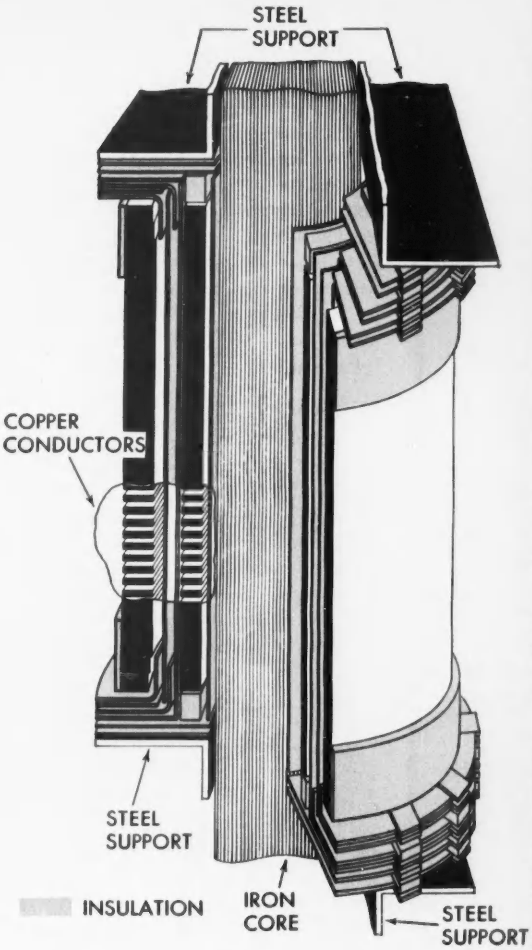
I looked at the entry for X MINUS 0 in the log. It read: "Missile off, on money!"

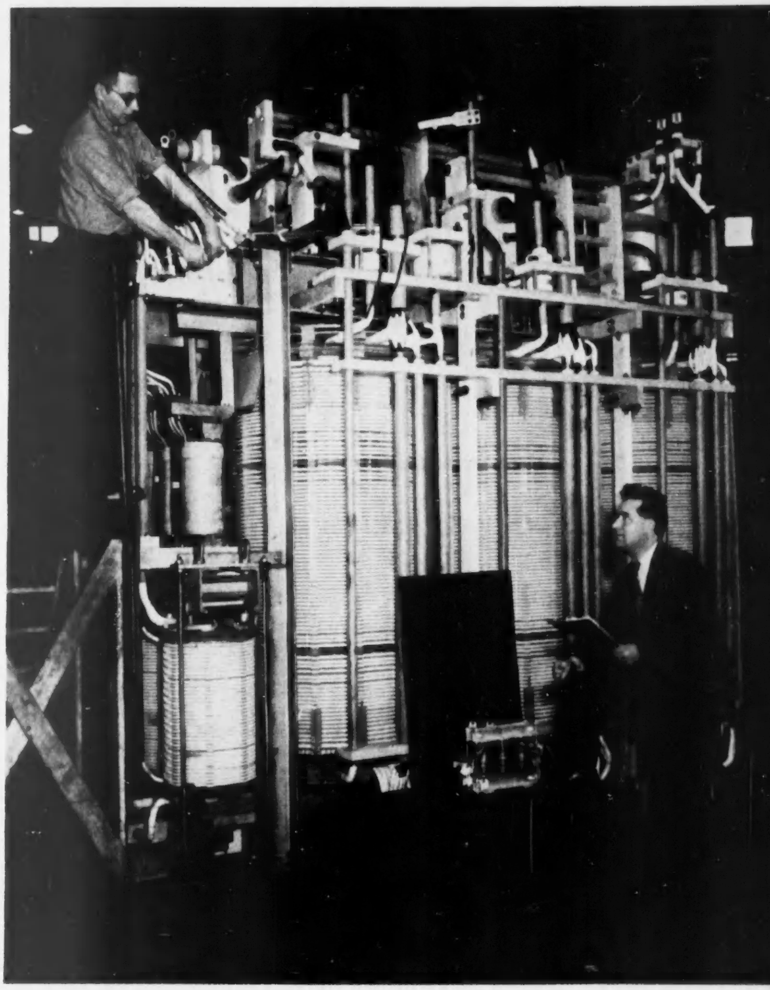
By noon the weather was just as bad and no search was under way. The plan was to have a plane definitely locate the wreck and then direct the recovery party to it.

Soon afterwards I left the Proving Ground, headed for El Paso, and planed East.

A few weeks later I called Botkin to find out if the missile had ever been found. He said it had, a few days after the shoot, in the foothills of the San Andres Mountains. It was difficult to spot, he told me. "If one lands on the desert it's not much trouble to find because you can easily see where the ground has been chewed up. But when they get into rocky ground, it's harder. And if they land in the mountains, you never do find them."

I asked him if the recovered parts had shown anything of importance. "Only," he said, "that everything was working perfectly." —PRH





PLACEMENT OF INSULATION IN THIS 20,000-KVA TRANSFORMER WAS AIDED BY ONE-TWELFTH SCALE MODEL OF UNIT. AUTHOR IS AT RIGHT.

ELECTROMAGNETIC MODEL— POWER TRANSFORMER UNVEILED

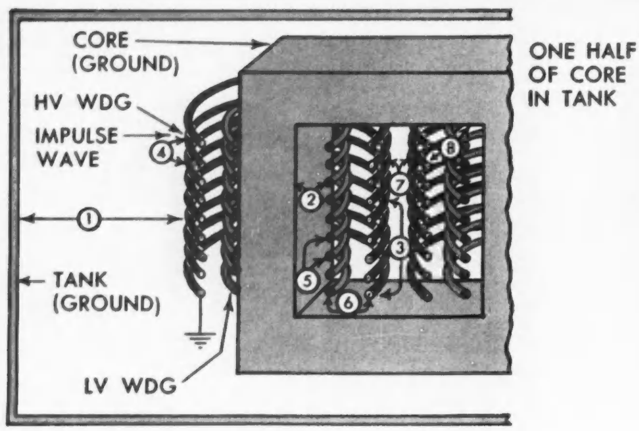
By DR. P. A. ABETTI

Great progress in designing modern high-voltage power transformers—20,000 kva and up—has come about despite insulation problems.

For insulation in power transformers is a costly necessity. Not only is it expensive, but the space it takes up increases the transformer's size because more copper, iron, and oil are needed (illustration, above). What's more, insulation increases the reactance and interferes with other functions such as cooling.

In the past, engineers have usually based their transformer designs on experience with smaller units, increasing the insulation—and the safety factor—wherever it seemed advisable. Obviously, if the amount and placement of insulation could be determined with more precision, large savings would be realized in the form of reduced size, weight, and cost. Some of the power transformer's operating characteristics would also be improved. And one direct effect would be to raise the kva limit of units presently transportable by rail without dismantling—a thorn in the side of many transformer manufacturers.

But there is more to designing insulation than meets the eye, because insulation is determined to a great extent by the transient voltages that occur in the transformer's windings. Transients are higher-than-normal voltages of short duration—less than a second—caused



MAXIMUM VOLTAGES THE TRANSFORMER DESIGN ENGINEER MUST KNOW . . .

1. VOLTAGES FROM THE IMPULSED WINDING TO GROUND
2. VOLTAGES TO GROUND TRANSFERRED TO THE NONIMPULSED WINDINGS
3. VOLTAGES ACROSS LARGE PORTIONS OF THE IMPULSED WINDING
4. VOLTAGES BETWEEN SMALL PORTIONS OF THE IMPULSED WINDING (GRADIENTS)
5. GRADIENTS AND VOLTAGES BETWEEN PARTS OF THE NONIMPULSED WINDINGS
6. VOLTAGES BETWEEN WINDINGS OF THE IMPULSED LEG
7. VOLTAGES BETWEEN LEGS
8. VOLTAGES BETWEEN PARTS OF ACCESSORIES; FOR EXAMPLE, TAP CHANGERS

by lightning, switching surges, and other abnormal conditions.

Practice and Theory

In practice, a power transformer is designed to withstand commercial impulse tests: Its insulation is stressed by man-made transient voltages comparable to or larger than those encountered in the field. And to determine the proper amount of insulation you must know: 1) the maximum voltage and its wave shape as a function of time for all types of applied impulses—full-, chopped-, and steep-front impulse waves, switching and lightning surges, and 2) the ability of the insulation to withstand a given voltage and wave shape (illustration, above).

The response of a transformer to impulse voltage is, of course, highly complicated. The transient voltage distribution is often entirely different from the uniform distribution during its normal operation. And though several theories and methods do exist for the calculation of these transient voltages, they are far too complicated, lengthy, and inaccurate for design applications. They require considerable computation for even the simplest uniform winding in air (photo, opposite page) impulsed by the simplest type of wave—one with an extremely steep front and an infinitely long tail.

For many years a network of resistors has been used to determine the electrostatic voltage distribution in a transformer by simulating the various capacitances between windings and the transformer's structure or ground. Though this network provides useful information for the correct design of shields and other devices, it represents only the transformer's electrostatic field. It gives no quantitative information on the subsequent winding oscillations caused by interaction of the electrostatic and electromagnetic fields. Yet in most instances these oscillations create the highest stresses across the insulation to ground and between winding parts. Neither can the resistance network take into account the fact that impulse waves do not have infinitely steep fronts. And so, while a satisfactory electrostatic distribution is necessary in modern transformers, it is by no means sufficient to insure that insulation is adequately and economically designed.

Interpolation

Accordingly, transformer insulation is designed primarily from results of tests on completed transformers and developmental full-size windings. Once experiments and service records prove the adequacy of a certain number of designs, new transformers are usually constructed by interpolation between known structures. Depending on the changes to be made, safety factors—and the amounts of insulation—are varied according to the designer's judgment.

This procedure is adequate for transformers below 10,000 kva, but it is definitely insufficient for large modern high-voltage power transformers. In the past five years, for example, the capacity of transformers that can be shipped assembled has approximately doubled—from 150,000 to 300,000 kva in a three-phase unit—and power system voltages have increased, too. Also, factors other than insulation—noise, leakage reactance, and cooling—can influence a transformer design. Modern power transformers may therefore require winding arrangements and structures that have been seldom used, if at all. Under these circumstances you can't let insulation requirements dictate your solution. You must attain the best over-all balance in design.

How Much Insulation?

Limited knowledge of transient voltages under all impulse-test conditions forces you to use more insulation. This, of course, is always an expensive approach because insulation may be placed where it isn't needed. What's more, the increase in insulation is often only an illusion; it doesn't guarantee a corresponding increase in the safety factor. On the contrary, it may even increase the transient voltages. For instance, because capacitance is inversely proportional to the distance between the high- and low-voltage windings, more insulation is needed with each increase in voltage. This vicious cycle can be broken only by a radical modification of transformer structure.

(As an example, let's consider the electrostatic transferred voltage between two concentric windings having a high-voltage winding with large series capacitances. If you apply a unit voltage E_1 to the outer winding, the voltage on the inner low-voltage winding will rise to

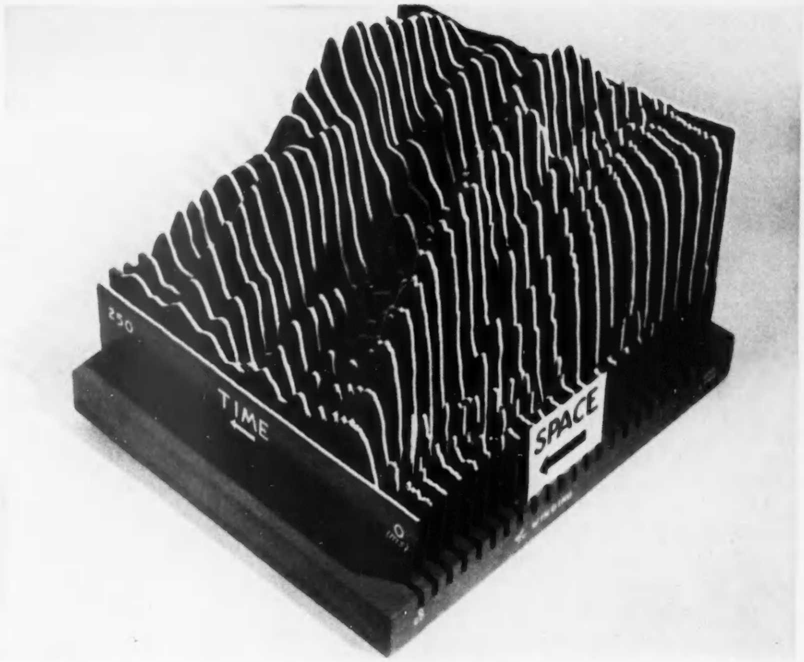
$$E_2 = C_{12}/(C_{g2}+C_{12})$$

Assume, first, that C_{12} equals 10 percent and C_{g2} equals 90 percent so that E_2 equals 10 percent. If you double the insulation distance between the inner winding and ground, C_{12} equals 10 percent, C_{g2} equals 45 percent, and E_2 equals 18.2 percent. By doubling the insulation you've increased the safety factor little, if at all.)

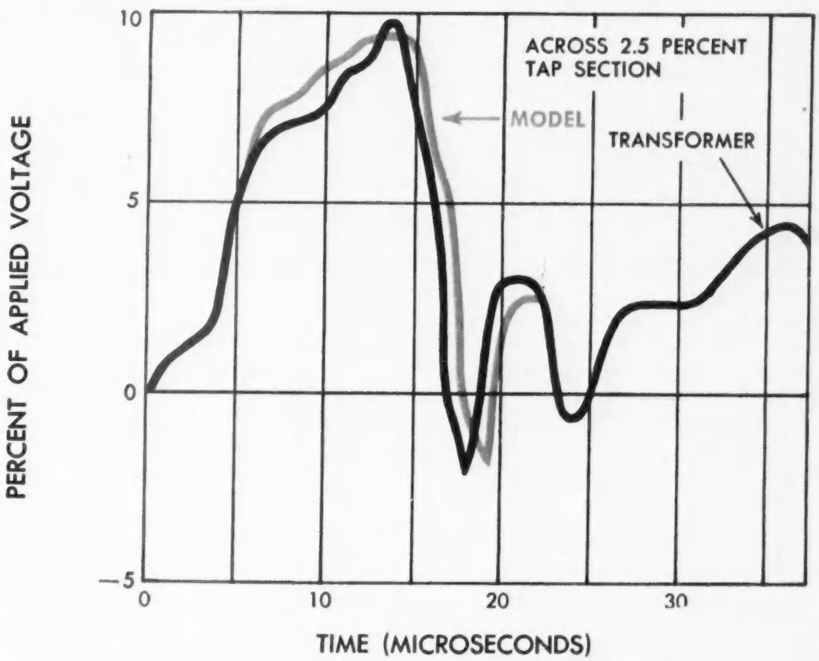
And so it appears that an increase in insulation is always a costly solution. In a paper published 17 years ago, K. K. Paluev, an authority on the design of large power transformers, stated . . .

"The need for precision in calculations cannot be reduced by mere addition of materials. . . . In the application of a lightning impulse to a transformer, increasing the insulation between turns or between coils may increase the impulse voltage stress between them nearly in proportion to the increase in the strength of the insulation. Furthermore, it has been demonstrated that the use of stronger dielectric materials can cause apparatus to fail at lower 60-cycle voltages as the result of less uniform voltage stress distribution."

The only way you can actually prove the impulse strength of a transformer, then, is to build a preliminary full-size coil unit, and test it. If the unit fails, another must be built with modifications and tested; this procedure is repeated until you reach a satisfactory solution. Obviously, this method is involved, costly, and time-consuming. Nor does it assure that the proper amount of insulation is even located in the right place.



VOLTAGE DISTRIBUTION along length of simple helical coil in air—from conductor to ground—when the coil is impulsed by simplest type of transient voltage wave.



COMPARISON of impulse voltages in 30,000-kva transformer (138/69 kv) with those of its electromagnetic model. The model reproduces both magnitude and wave shape.

Electromagnetic Model

Experimentation on convenient-size scale models is fairly widespread in areas of civil and mechanical engineering—particularly in the branches of elasticity, hydrodynamics, and aerodynamics. But in electrical engineering there has been little use of the scale model until now.

Four years ago we began a comprehensive development program to find a better method for determining transient voltages in power transformers. The outgrowth of this program is the electromagnetic model (photo, page 23). Essentially, it consists of . . .

- A geometric model in reduced scale of the transformer's core and coils that simulates all self and mutual inductances, even if nonlinear
- A network of capacitors that simulates all transformer capacitances from windings to ground, between parts of different windings, and between parts of the same winding.

Information furnished by the electromagnetic model is obtained quickly and simply with the same testing procedures used on a full-scale transformer. The model of a large power transformer has a time scale equal to the $\sqrt{LC}$, where L is the inductance scale and C is the capacitance scale. Its length scale varies between one-sixth and one-fifteenth, and its weight between 0.5 and 0.03 percent of the full-size core and coils. (Weight of the model is inversely proportional to the cube of the length scale.) The time scale may vary between less than unity and one thousand.

Electromagnetic models are but a small fraction of the cost of finished transformers. And they can be built from design data in about one month—a relatively short period compared to manufacturing time of a large transformer. The Table shows the deviation in voltage measurements made on 16 different models and their parent transformers; 640 measurements were taken at corresponding points. Typical oscillograms obtained from a 30,000-kva transformer and its model (illustration, preceding page) show how the latter reproduces not only the magnitude of the maximum voltage stress across the insulation but also the voltage wave shape. This is important because the dielectric strength of an insulating material depends on how long it is under stress; the model indicates where less insulation can be used for stresses of short duration.

Transformer design and development are the most important applications of the electromagnetic model. Improvements can be made in present designs to establish uniform safety factors, and in new structures to obtain the best solution to the varied problems arising from the characteristics of a modern transformer. The proper amount of insulation can be placed precisely where it's needed. Conversely, useless insulation that increases the weight, size, and cost of a transformer is avoided. Other characteristics—reactance and cooling, for example—would be improved, too. Thus, you obtain a better and more economic design from all points of view.

Applications

Typical of electromagnetic models is the one of a proposed three-phase 250,000-kva transformer. Having a length scale of one-tenth and a weight scale of one-thousandth, it was built with four different winding arrangements to find the most economical structure best suited to a customer's specifications.

SUMMARY OF DEVIATIONS OF 16 MODELS AND THEIR PARENT TRANSFORMERS

Type of Voltages	Number of Points Measured	Average Deviation (Percent of Applied Voltage Wave)
To ground in impulsed winding	189	3.9
Across large parts (6 to 50 percent) of impulsed winding	192	4.3
Across small parts (1 to 5 percent) of impulsed winding	205	1.7
Transferred to non-impulsed windings	54	2.8
Total	640	3.1

Such models—there are many others—are used to determine transient voltages in new types of transformers and to study the effect of design changes.

Naturally, the model's reproduction of the parent transformer's internal characteristics is its most interesting and useful property. But an electromagnetic model reproduces the external characteristics of the transformer as well—that is, the transformer's performance as a power-system component. If, for example, the constants of an impulse generator are converted to the constants of a transient analyzer—a device for measuring transient voltage—the impulse wave applied to the model must correspond to that applied to its parent transformer. This is found to be true.

It follows that you can predict many external effects of a transformer with an electromagnetic model. For example, you can study surge voltages transferred through a transformer located in a substation, and thus the transient voltages that are applied to lightning arresters, capacitors, circuit breakers, and similar devices.

Special customer applications can be solved, too. Electromagnetic models have been used to determine the impulse voltages transmitted to large turbine-generators connected in a power system and then to verify the analytical results.

Other possible applications involve detection of failures and their location within a transformer. This is done by simulating faults on the model, and comparing oscillograms of wave shape obtained from it and the faulted transformer.

Psychological Effect

It's a fact, in science and industry, that as soon as a new tool is available the engineer finds many new uses for it. The purely psychological advantages of having it at his disposal can't be overlooked either. For he begins to think in terms of the new tool and its possibilities and is persuaded to attack new problems.

Progress in one field of endeavor often spurs progress in other fields. A greater knowledge of internal transformer voltages made possible by the electromagnetic model will require more accurate data on how insulating materials behave under electric stress. And this is but one example. The same technique will undoubtedly be extended to the study of internal voltages in other electromagnetic apparatus. Ω

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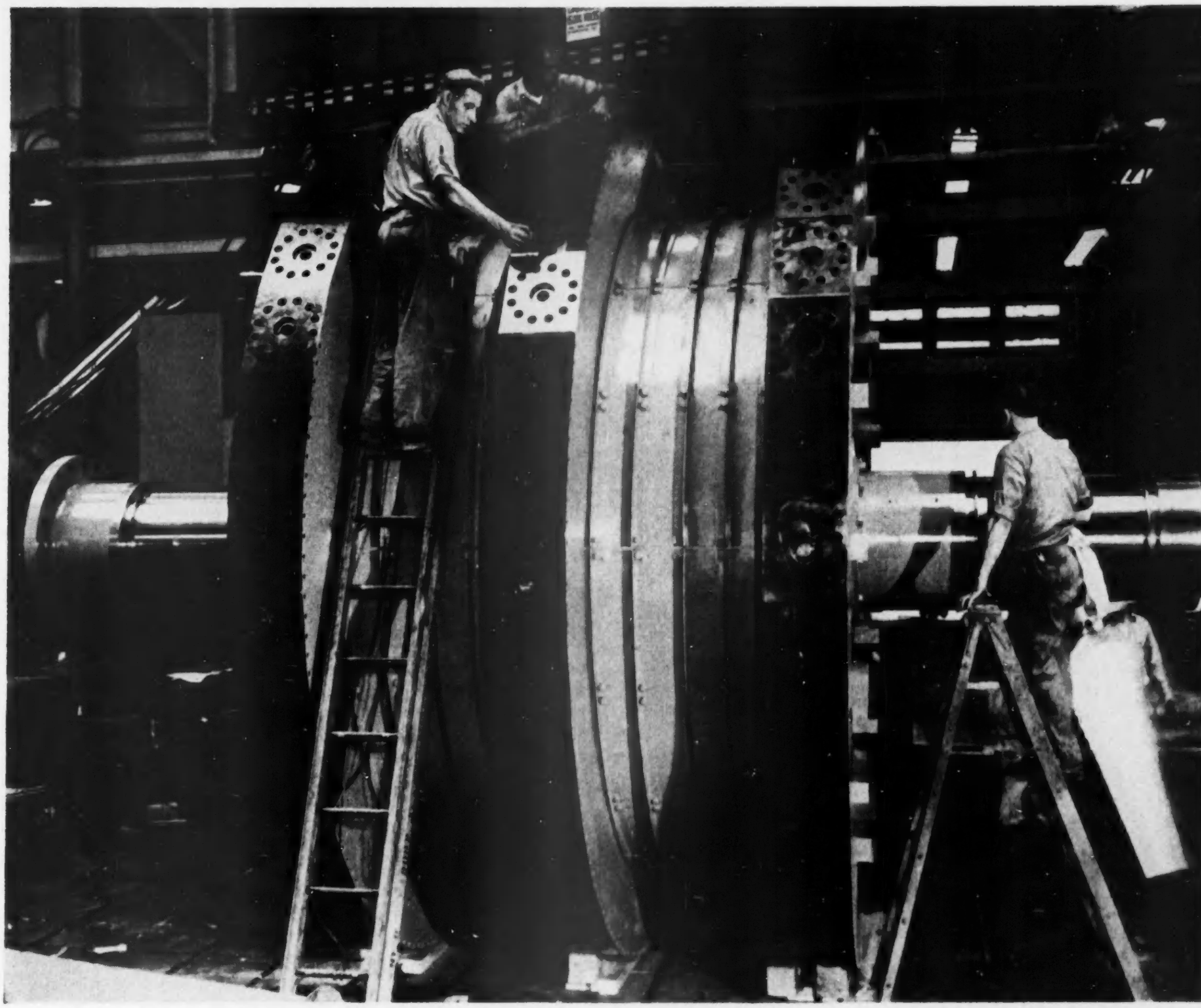
Dr. Abetti—Insulation Development Engineer—came to GE six years ago and is with the Power Transformer Dept., Pittsfield, Mass. He was awarded the Eta Kappa Nu Recognition as the most outstanding young electrical engineer of 1953. He was a 1952 Coffin Award winner. Not a newcomer to the REVIEW, *Dr. Abetti authored "Engineering Behind the Iron Curtain" in the May 1953 issue.*



PROTECTIVE TECTYL COMPOUND IS APPLIED TO THE 122½-TON WIND-TUNNEL FAN ROTOR BEFORE IT BEGINS THE 4750-MILE JOURNEY.

How 122½-Ton Fan Rotor Traveled to West Coast

Review STAFF REPORT

Engineering large pieces of electric equipment involves more than stresses and strains and rotational speeds. You also have to think about how you're going to move the equipment from your plant to the customer's. And with equipment becoming increasingly larger—and heavier—the transportation problem also grows in magnitude.

Shipment of a 122½-ton fan rotor to the West Coast posed such a problem, not so much from a weight standpoint, but because it was 14 feet wide—the widest piece of equipment ever shipped from General Electric's Schenectady Works.

Two-and-a-half years in the making, the rotor will be installed in the 16-foot wind tunnel of the Ames Aeronautical Laboratory operated by the National Advisory Committee for Aeronautics (NACA) at Moffett Field, 40 miles south of San Francisco.

There, 32 5½-foot fan blades will be put on each of the rotor's three wheels.

The fan shaft will be powered by three General Electric motors lined up in tandem to generate supersonic winds in excess of 900 mph for research in aircraft and guided-missile design.

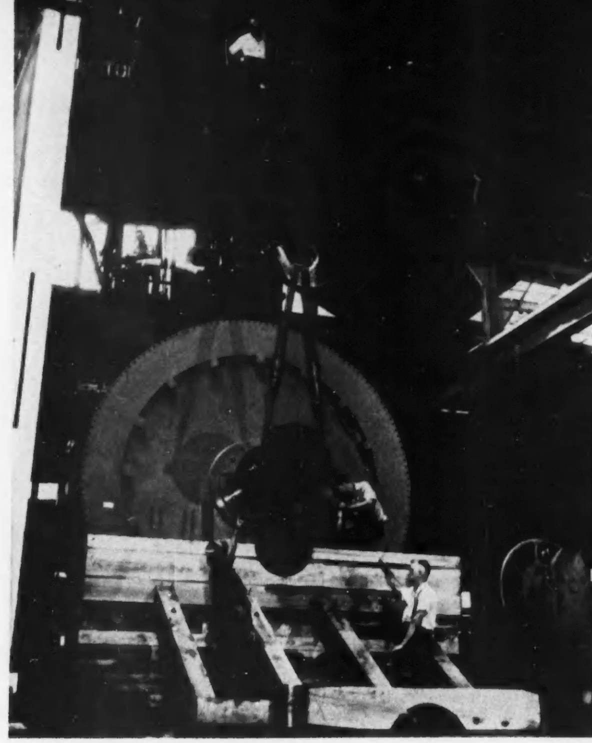
Rated 110,000 hp, the new drive unit replaces the 27,000-hp drive installed there by GE a few years ago. Power will be supplied by two 41,500-hp and one 27,000-hp adjustable-speed a-c induction motors. Combination slip-regulator and Clymer System speed control will be used.

Five transportation companies were used to transport the rotor on its 4750-mile journey to the West Coast. Because of its size it was impossible to ship it to California by rail.

On the next four pages you'll follow the travels of the rotor in pictures. . . .

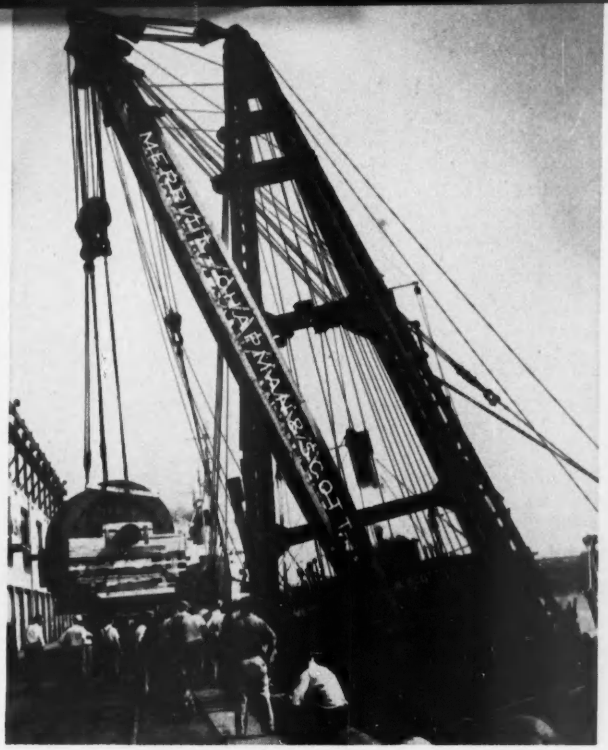
How 122½-Ton Fan Rotor Traveled to West Coast

CONTINUED

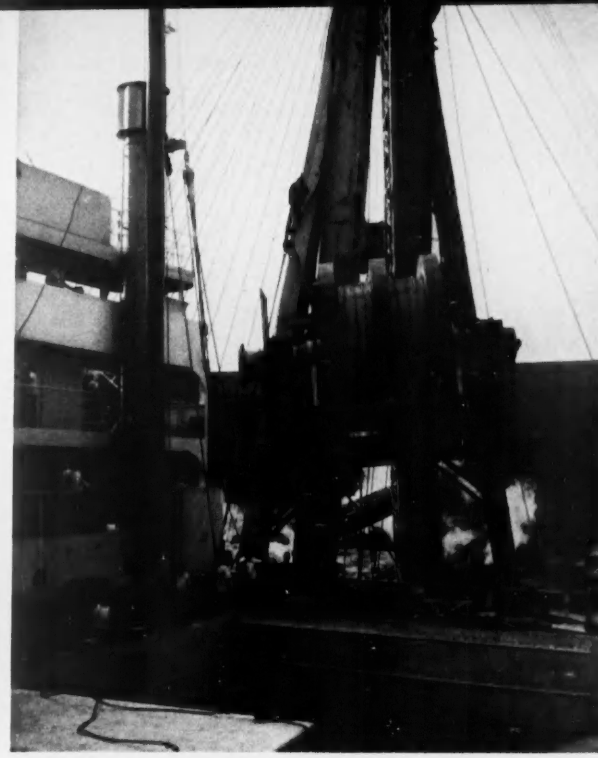


SCHENECTADY—Special drop-bottom flatcar took the fan rotor to Albany, 15 miles away. But because of width, car was routed almost to Binghamton; trip took four days. Normal run: one hour.

SAN FRANCISCO—At the Mission Rock Terminal, the rotor was unsealed in the hold of the *Garfield* (*below*) following the trip through the Panama Canal to San Francisco. Two floating derricks of the Smith-Rice Co. of San Francisco swung the rotor over the side of the *Garfield*, backed away, and waited nervously (*right*) for a barge to be moved in underneath. Then the rotor began another trip over water, shown on the next two pages . . .



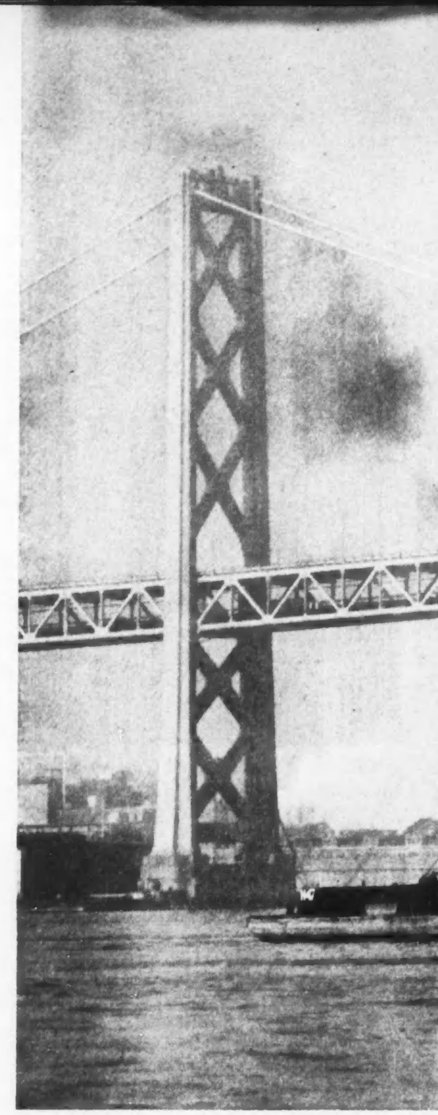
PORT OF ALBANY, NY—The *Monarch*, of the Merritt, Chapman and Scott Corporation, the largest floating derrick on the East Coast. lifted the rotor for its trip down the Hudson River to Jersey City.



JERSEY CITY—Aboard the SS *President Garfield*, the rotor rode in the hold to prevent atmospheric conditions from affecting the finish and balance on its long voyage via the Panama Canal.

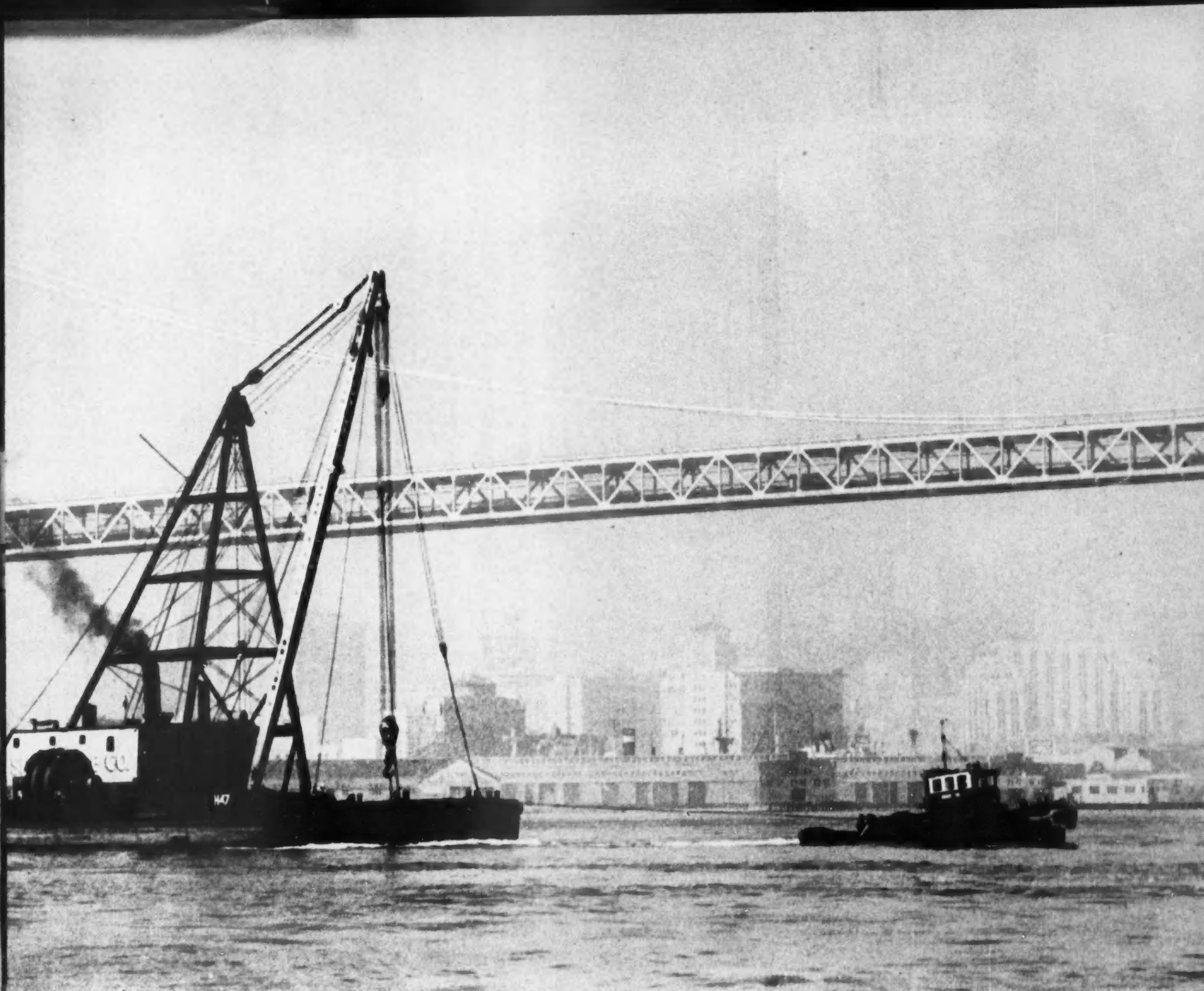
How 122½-Ton Fan Rotor Traveled to West Coast

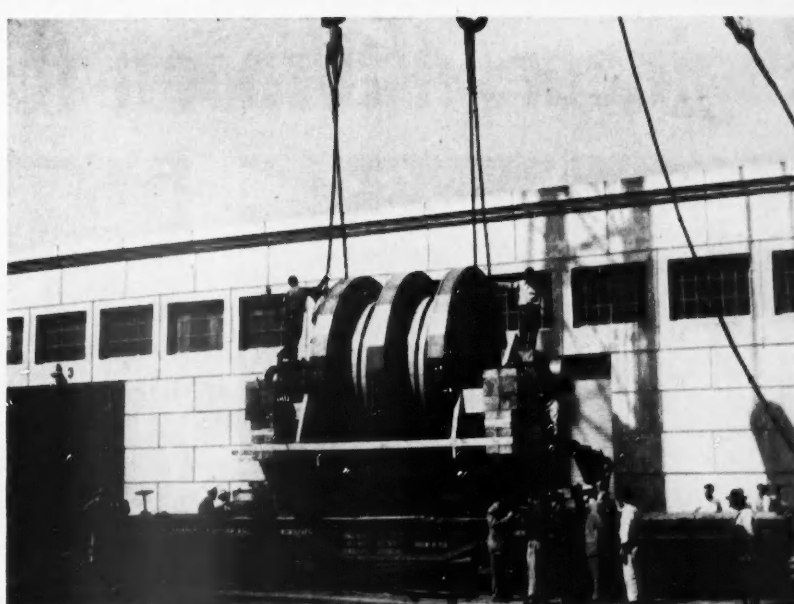
CONCLUDED



SAN FRANCISCO TO OAKLAND—A tug towed the barge with the rotor and one of the derricks across the San Francisco Bay to the Quay Wall of the Howard Street Terminal in Oakland. San Francisco-Oakland Bay Bridge in background.

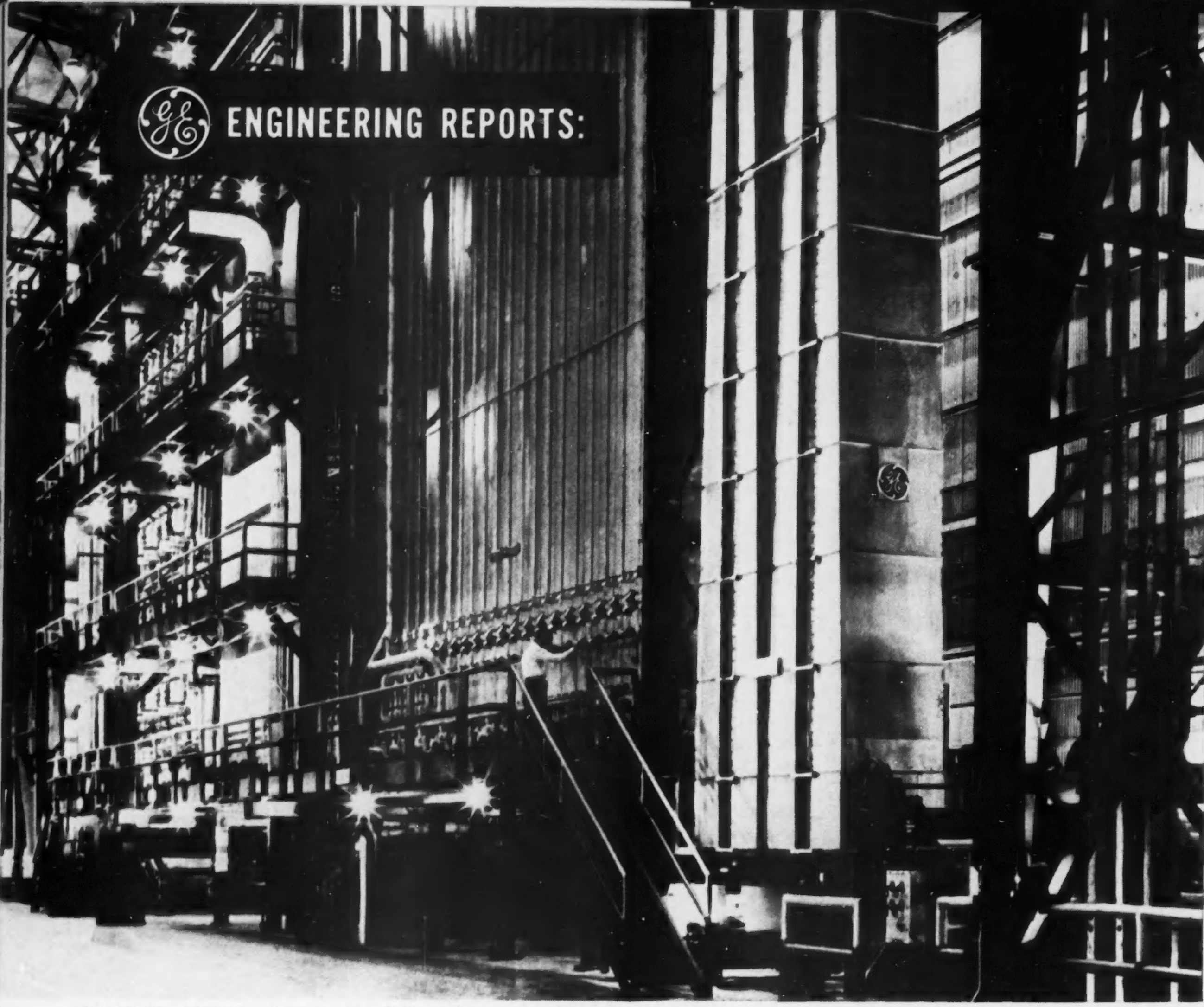
OAKLAND—With another floating derrick on hand, the rotor was swung aboard a special Southern Pacific flatcar that was routed in from El Paso, Texas, for the 49-mile trip to Moffett Field. It took only 15 minutes to lift the rotor from the barge to the flatcar, but. . . .





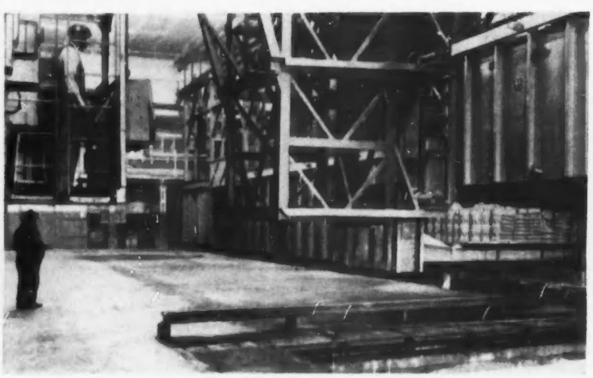
. . . more than 1½ hours were spent in lowering the rotor to the flatcar and getting it into position. It had to be placed within a fraction of an inch by the two derricks. Then, in a special four-car train, it began the final leg of its 4750-mile trip from the East. Ω

ENGINEERING REPORTS:



TO SPEED OUTPUT of steel strip, G-E engineers co-ordinated this huge G-E electric furnace with the drive system for a continuous cleaning and annealing tinplate line. This system approach helped operators get 30-tons-per-hour production.

Engineers "turn on the heat" to

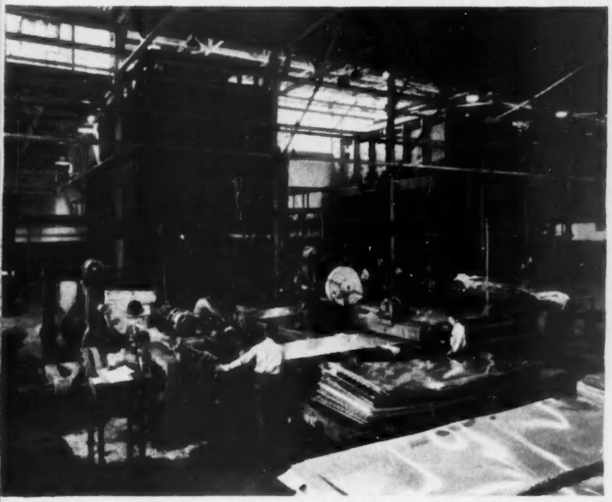


TO CUT ANNEALING TIME by 75 per cent for a large producer of malleable iron castings, G-E engineers "packaged" a complete annealing system—including furnaces, power equipment, and auxiliaries. Operating costs were reduced by 50 per cent.

G-E ENGINEERS E. W. Cunningham (left), General Manager, Industrial Heating, and H. M. Webber, heating application engineer, check an assembly part to be processed in a new copper-brazing furnace being installed in an automotive plant.

TO SAVE PROCESSING TIME for a manufacturer of textile-shrinking machinery, G-E engineers used Calrod* heaters for easier installation, more precise temperature control.

**Reg. trade-mark of General Electric Company*



TO PROMOTE PRODUCT QUALITY, G-E engineers apply furnaces with protective atmosphere for better finishes.

TO IMPROVE WORKING CONDITIONS, G-E engineers concentrate heat required to treat these axle housings, reducing radiation.

shorten your processing cycles

Electric heat is another example of how G-E system engineering helps you cut production costs

Electric heat in many forms—from 5-story continuous furnaces to tiny heating devices—is one of the many tools used by General Electric application engineers to help you solve production problems. In almost every industry using annealing, galvanizing, enameling or brazing, G-E engineers have applied electric heat to eliminate processing steps, cut production costs.

G-E engineers have co-ordinated electric furnaces into steel-mill drive systems to anneal strip continuously—at 1000 feet per minute. In metal-working plants, they have applied induction heaters to improve product quality—often cutting processing costs up to 80 per cent. And they have helped hundreds of machinery manufacturers build a variety of heating devices into equipment for greater reliability, faster operation.

You can put this engineering skill to work for you by specifying "G.E." when you buy electrical systems. G-E application engineers will draw on this engineering leadership in working closely with you and your consultants. Contact your local G-E Apparatus Sales Office early in the planning stage. General Electric Co., Schenectady 5, N. Y. 672-11C

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GENERAL ELECTRIC

The Nation's Economic Circuit

By VERNON G. LIPPITT

How can an economic system avoid a crack-up if workers do not receive incomes, or purchasing power, equal to the value of goods produced?

Can inflation be stopped by an increase in the output of goods?

Correct analysis of problems such as these is important, because only if we understand our economic system can we use the system effectively and modify it intelligently.

As with other complex systems, comprehension of our economy can be aided by grouping elements into component parts. Block diagrams, flow charts, and organization diagrams can represent electric control networks, production processes, and structure of a business, and there's no reason why the same techniques can't be used to represent our economic system. This article presents in diagram form the basic economic circuit—the circular flow of money and goods.

National Economic Accounts

In the past 20 years economists have made considerable progress in measuring the flow of money and goods in the economic circuit. To simplify the problem they classified the millions of economic units in our country into three groupings: consumer, business, and government. The results of their attempt to measure the income and spending of each of these three sectors of the economy is presented in two summary tables: Gross National Product and Gross National Income.

Gross national product is the total flow at market value of all the goods currently produced by our economy. Usually, it is stated as so many billion dollars; actually, it is a flow and should be expressed as billion dollars per year, or billion dollars annual rate. The distinction is analogous to that between a quantity of water measured in gallons, and a flow of water measured in gallons per minute.

Because the flow of goods is measured only when it's sold to final users in the three sectors, intermediate sales of raw materials and semifinished manufactures from one business to another are not included. Note also that gross national product is a flow of *currently produced* goods, excluding sales of existing goods—old houses or used cars—and sales of stocks and bonds.

In addition to summarizing the flow of goods to final users in the three sectors of the economy for 1952, Table I also summarizes the reverse flow of money from the purchasing sectors to the businesses producing the goods.

Most of the gross national product—nearly 63 percent—flowed to consumers for such things as food, clothing, housing service, furniture, automobiles, medical care, and amusements. However, businesses took about 15 percent of the national output in the form of investment goods—buildings, machinery, and additions to inventories. National, state, and local governments bought the remaining 22 percent in the form of planes and tanks, services of military and civilian personnel, public construction, and equipment and supplies.

When the goods constituting the gross national product are sold to the final users, an equivalent stream of money income flows back to the persons and businesses that produced those goods. This stream—gross national income—is equal in magnitude to the value of gross national product and provides the incomes from which gross national product can be purchased. Table II shows how the gross national income in 1952 was distributed among the consumer, business, and government sectors of the economy.

Disposable income, that is, total consumer income remaining after payment of taxes, amounted to more than two-thirds of the total and arises from wage and salary receipts, dividends and interest, plus proprietor and rental incomes. Business income retained consists of undistributed corporate profits plus capital consumption allowances, mainly depreciation. Net government income is equal to total receipts from taxes and social security contributions less government payments of benefits and interest; it is the flow of funds that remains available to governments for purchases of the gross national product.

By comparing the two tables you'll see that income does not equal spending for any of the sectors. In 1952, consumers received a flow of disposable income averaging $235 billion per year, but they spent at the rate of $218

TABLE I

GROSS NATIONAL PRODUCT, 1952

Components	Billion Dollars Per Year	Percent
Personal consumption expenditures	$218	62.7
Gross private investment	52	15.0
Government purchases	78	22.3
Total	$348	100.0

TABLE II

GROSS NATIONAL INCOME, 1952

Components	Billion Dollars Per Year	Percent
Disposable income (consumers)	$235	67.6
Business income retained	38	10.8
Net government income	75	21.6
Total	$348	100.0

billion per year. So their savings flow amounted to $17 billion. Businesses absorbed $14 billion of this flow because they invested more than the business income they retained. Governments took the remaining $3 billion of the savings flow. So the national accounts balanced, as well-behaved accounts should.

Transfer of savings flow from one sector to another is made through our banking and other financial institutions and through the sale of securities. These capital transactions that connect the money flows in capital fund markets of the economy are not shown in the gross national product and income accounts because the accounts include only transactions involving currently produced goods.

Basic Economic Circuit

These national accounts provide the necessary elements for constructing the nation's economic circuit. Basically it is this: The money you pay for a suit of clothes represents the payments made to those who helped in the production of the suit, all the way from the retail store to the sheep raiser or producer of chemical raw materials. Each person or business that added to the value of the materials, and of the suit, received an income for his contribution. The sum of these incomes equals the retail value of the suit—and constitutes sufficient purchasing power to buy the suit. If you total all purchases of consumer goods in the economy and all the incomes paid out for their production, you have a picture such as that in Fig. 1. Consumers send a flow of money counterclockwise down to the business sector in payment for durable goods, nondurable goods, and services that they buy. Businesses pay out this stream of money as income to those who assist in producing the goods and services. And this return flow of incomes—labor income, proprietor and rental income, dividends, and interest—closes the flow of money counterclockwise around the economic circuit.

Because money and goods change hands in opposite directions in a sales transaction the flow of real goods and services is clockwise in the circuit. Productive services arise at *AA′* and flow down to the business sector. Production processes within that sector convert the services of labor and capital into an output of goods (gross national product) at *CC′*. These flow up to the consumer sector at *BB′* where they are purchased, breaking the flow of real

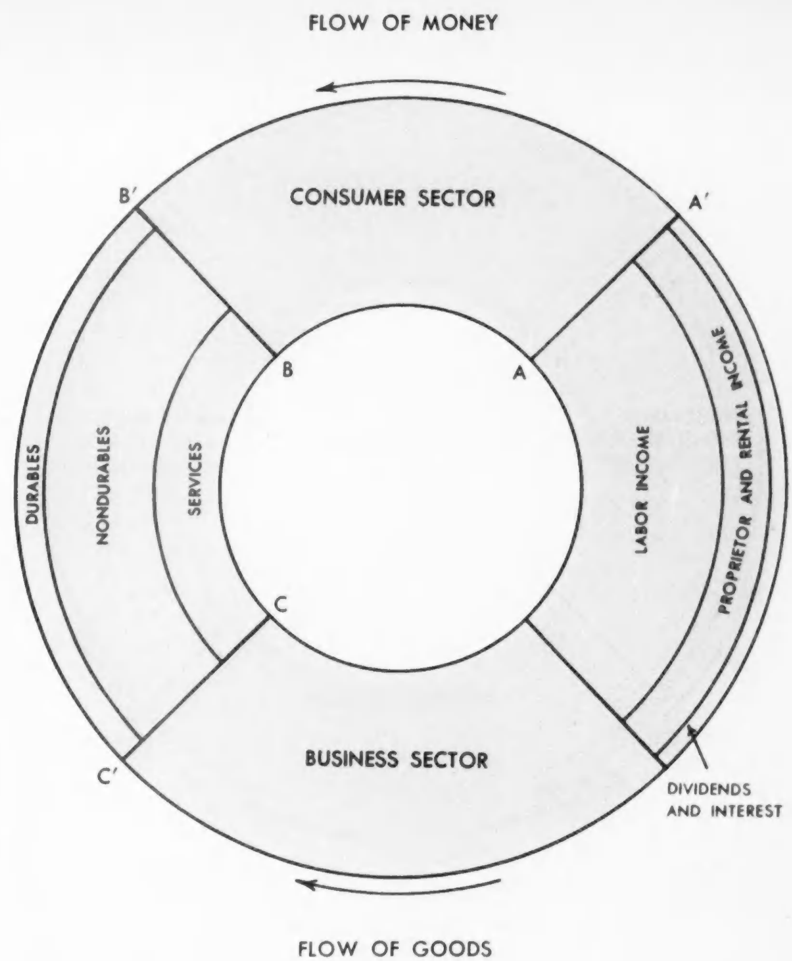

FIG. 1. MONEY AND GOODS FLOW IN OPPOSITE DIRECTIONS IN ANY SALES TRANSACTION

goods. (At least we do not usually regard the consumption process as a conversion of consumer goods into an output of productive services. Human beings are regarded as ends in themselves.)

At this point it may be well to point out that the economic flow differs from a hydraulic circuit in these respects . . .

- Some channels represent equal and opposing flows of money and goods. Such a situation, of course, is physically impossible with fluids.
- No money exists "in the pipelines"; it snaps instantaneously from reservoir to reservoir when a transaction is completed. The channel widths merely represent the flows that take place between the sectors linked by the channel.

Balanced Economy

If our economy were as simple as that in Fig. 1, we should have no problem of economic balance, for the full value of goods produced returns to consumers as income, and they spend all they receive. Actually, of course, consumers do not receive the full value of goods produced. And usually they choose to save part of what they do receive. How can such an economy be kept in balance?

Fig. 2 shows a circuit representing our actual economy, with the government sector omitted.

You start with the consumer sector and trace money flows counterclockwise. As before, personal consumption expenditures flow down from the consumer sector to the business sector. (The radial width of the channel is proportional to the magnitude of the flow. See scale in lower left corner of Fig. 2.) Business purchases of buildings, machinery, and inventory investment add a flow of money to the central circuit; it is labeled gross private in-

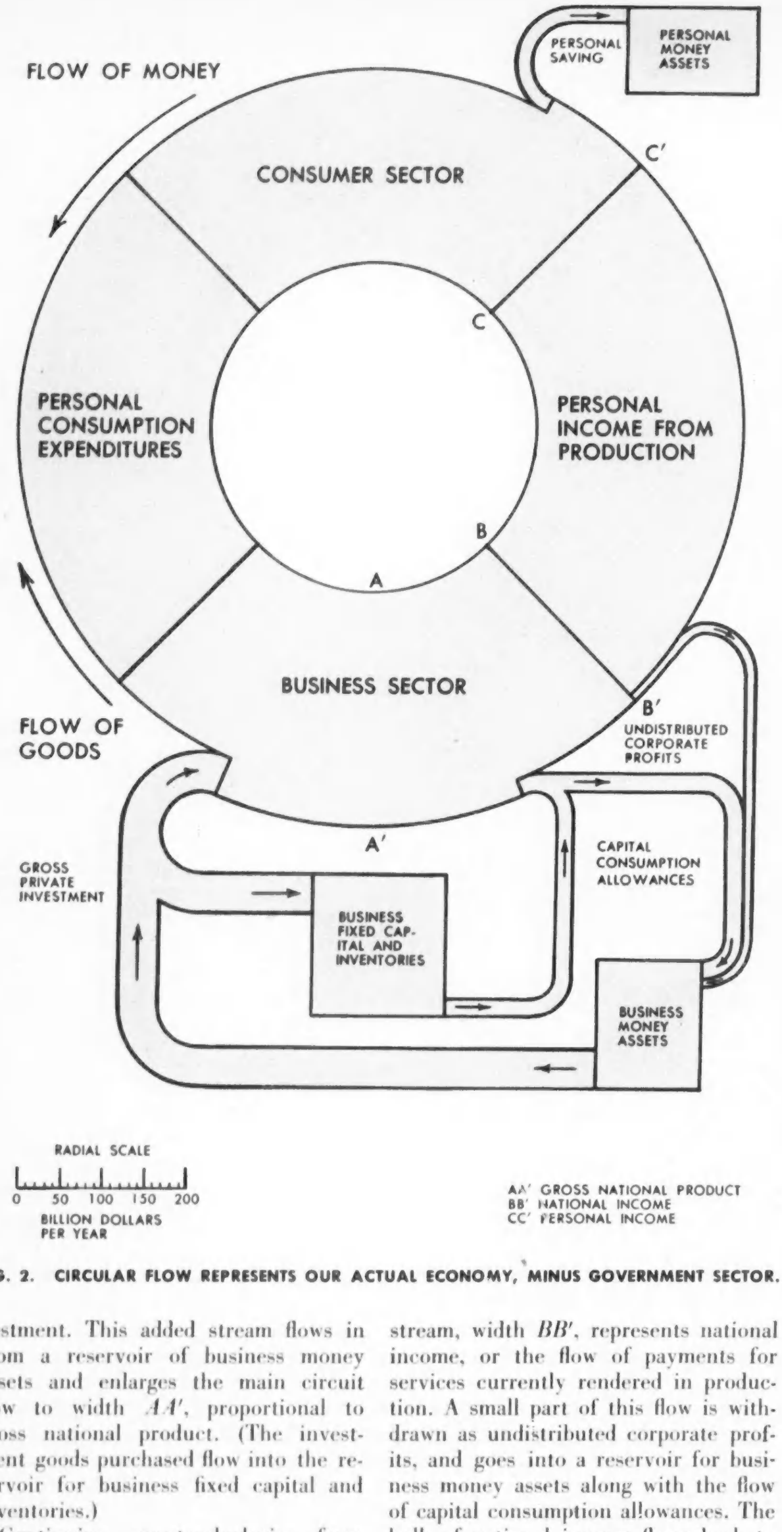

FIG. 2. CIRCULAR FLOW REPRESENTS OUR ACTUAL ECONOMY, MINUS GOVERNMENT SECTOR.

vestment. This added stream flows in from a reservoir of business money assets and enlarges the main circuit flow to width *AA'*, proportional to gross national product. (The investment goods purchased flow into the reservoir for business fixed capital and inventories.)

Continuing counterclockwise from *AA'*, you can trace the distribution of gross national income. First, businesses withdraw a stream of funds for capital consumption allowances. The remaining stream, width *BB'*, represents national income, or the flow of payments for services currently rendered in production. A small part of this flow is withdrawn as undistributed corporate profits, and goes into a reservoir for business money assets along with the flow of capital consumption allowances. The bulk of national income flows back to the consumer sector as personal income from production (width *CC'*).

Even in a cheerful taxless economy such as represented by this flow chart, consumers would probably choose to save part of their incomes. To provide for this a stream of personal saving is withdrawn into a reservoir of personal money assets.

Stability of the Economy

Now we are in a position to answer the question regarding the inability of consumers to purchase the total gross national product. They don't need to. By following clockwise from *AA'*, you'll see personal consumption expenditures are less than gross national product by the amount of gross private investment. And by looking counterclockwise from *AA'* you'll see that consumption expenditures are less than gross national income *BB'*, by the sum of capital consumption allowances, undistributed corporate profits, and personal saving—a sum that might be called gross private saving. Thus, the withdrawal of gross private saving from the consumer expenditure stream is matched by the equal withdrawal of gross private investment from the total stream of goods flowing toward consumers. And so the system's stability doesn't require that consumers receive full value of what they help produce and then spend all they receive. The economy can avoid a crack-up if desired purchases for gross private investment match the desired flow of gross private saving at high levels of employment.

The government sector can be worked into this flow chart without changing its fundamental features, but it soon begins to look a little like a plumber's nightmare (Fig. 3). Essentially, governments siphon off part of the income stream from the business and consumer sectors and also withdraw a portion of the gross national product for government use. The net effect is to shift purchasing power from private to government control, and to shift part of our national output from private to government goods. And governments, too, may spend more (or less) than they receive. The balance of the national accounts then requires an equality between gross

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Mr. Lippitt joined General Electric in 1948 as a market analyst specializing in business economics. Late last year he was appointed Consultant—Business Economics, Marketing Research Services, Schenectady. An electrical engineer and Rhodes scholar in economics, he recently left the Company to do further graduate work at Harvard University.

national saving (including that by government) and gross private investment. Table III shows this balance for 1952, as derived from Tables I and II.

This balance between saving and investment provides the clue for solving the second problem raised at the outset of this article: Can inflation be stopped by an increase in output of goods?

Cure for Inflation

Suppose the balance between saving and investment flows is shifted because businesses increase their purchases of investment goods. An increase in investment spending may produce inflationary pressures in the economy—an over-all demand greater than the supply of goods. Can such pressures be relieved simply by increasing output of goods by the amount of added demand for investment goods? Probably not.

If you imagine that the flow of gross private investment (Fig. 2) is widened, you are then faced with the necessity of following counterclockwise around the circuit the income paid out for the production of the added investment goods. Part of the added income will be withdrawn as capital consumption allowances and undistributed corporate profits, but most of it will flow to the consumer sector. There, part will go to personal savings, but most of it will increase personal consumption expenditures. And this requires a greater output of gross national product, over and above the original increase in output of investment goods. The added output of consumer goods will send more income back around the circuit, give rise to added consumer spending, and so on—round and round the circuit in decreasing increments.

Ultimately, a new balance can be attained at which larger savings flows will match the larger spending for gross private investment. However, in this process gross national product may well rise by two or three times the amount of the original increase in investment spending. The rise will depend inversely on what proportion of additional gross national income is saved as it flows around the circuit. To obtain a complete analysis of the problem you should, of course, add the government sector to this.

The circuit diagram forces you to "think around the circle" and to more adequately analyze the whole problem. It helps you analyze possible effects of wage and price rises, changes in government tax rates, increases in productivity, and declines in farm income.

And the circuit diagram serves to give you a perspective on the whole economy and a framework for tracing the effects of economic stimuli throughout the whole system. Of course, you still have to think! The national accounts and economic flow charts are simply tools to aid understanding and analysis. However, our feeble minds need all the assistance they can get in analyzing problems of such a complex system as the national economy. Ω

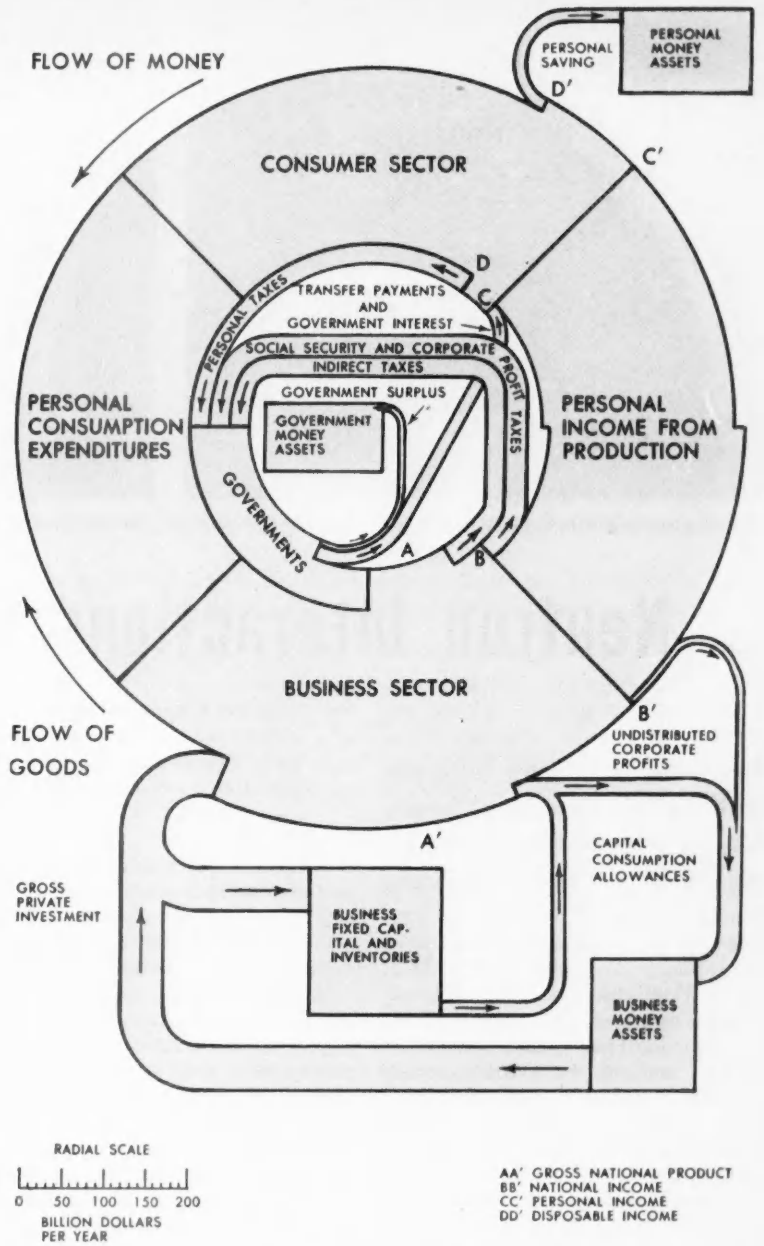
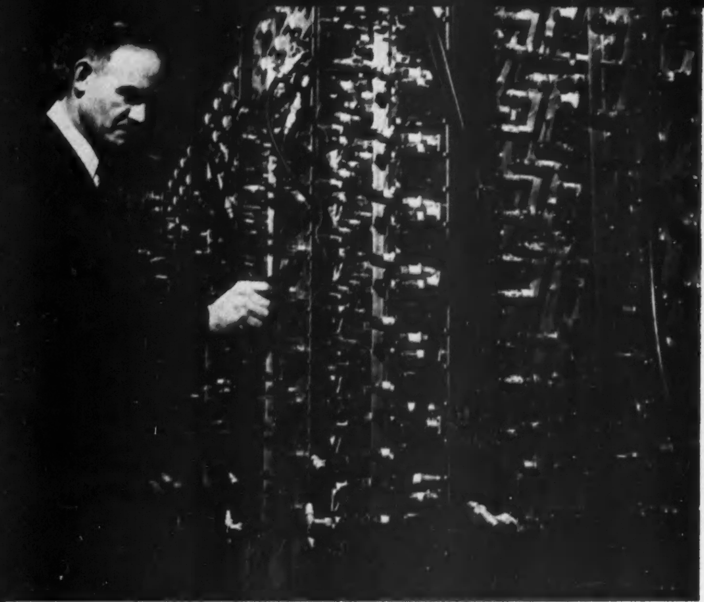
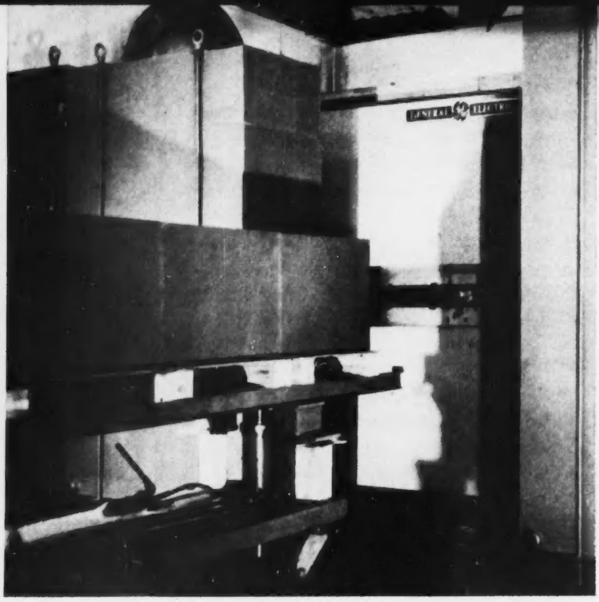


FIG. 3. ADDITION OF GOVERNMENT SECTOR COMPLETES FLOW CHART OF NATIONAL ECONOMY.

TABLE III—BALANCE BETWEEN SAVING AND INVESTMENT, 1952

Components	Billion Dollars Per Year
Personal saving	$17
Business income retained	38
Government saving	−3
Total	$52





AUTHOR ADJUSTS NEUTRON-COUNTING ELECTRONIC APPARATUS USED IN CONJUNCTION WITH THE 100-MEV BETATRON (*RIGHT*) TO DETERMINE . . .

Neutron Interactions with Matter

By DR. E. R. GAERTTNER

How do neutrons interact with reactor materials? Scientists are learning with the aid of a 100-Mev betatron.

Beneath the University of Chicago's West Stands, on December 2, 1942, Enrico Fermi and his co-workers successfully operated the world's first nuclear reactor. Thus a device that would produce neutrons by a self-sustaining chain reaction became a reality.

But even before this time scientists throughout the world had accumulated a considerable amount of information on the interaction of neutrons with matter. Most significant of their discoveries was that heavy elements—uranium, for one—fissioned when bombarded with neutrons. Other important phenomena were known, too—the mechanism of slowing down neutrons with moderators, for example, and their parasitic capture by elements such as boron and cadmium. (Fission is defined as the splitting up of an element into two fragments of approximately equal mass accompanied by the emission of neutrons. For each fission there are 200-million electron volts [Mev] of kinetic energy released.)

Today the search for more information continues. To completely understand a nuclear reactor, the scientist must know how neutrons interact with the materials that constitute it.

Basic Interactions

The fate of two high-energy neutrons liberated in the fission of a fuel nucleus (illustration, opposite page) shows the basic types of neutron interactions in a reactor—the fuel nucleus may be U-235.

Neutron *A*, shown in motion to the right, is slowed down by elastic scattering, or billiard-ball-like collisions with other nuclei, until it fissions with another fuel nucleus. The result is the production of new high-energy neutrons. Also slowed in a similar fashion is neutron *B* to the left, but it is lost by parasitic capture in the nucleus of a reactor contaminant—manganese in the structural material, for example. Here the result is the emission of gamma rays that are of no help in sustaining fission, or chain reaction.

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Dr. Gaerttner came to GE in 1946 and since 1951 has been with the Experimental Nuclear Physics Unit at Knolls Atomic Power Laboratory, Schenectady, operated by GE for the U.S. Atomic Energy Commission. He is in charge of the experimental program in nuclear measurements of interest to KAPL and the AEC. Dr. Gaerttner is a Fellow of the American Physical Society.

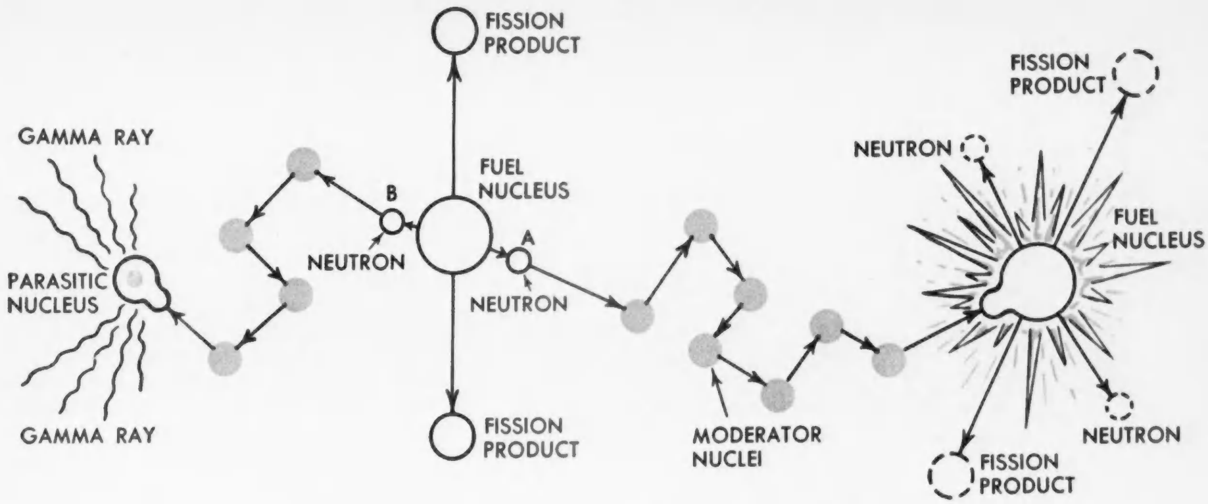
In this simplified picture you see the three basic types of neutron interactions with matter: fission, elastic scattering, and parasitic capture.

Cross Sections

Neutrons in a reactor possess a wide range of velocities. These vary from a maximum at fission (about 14-million meters per second) to a minimum at thermal motion (2200 meters per second).

To understand how the interaction of neutrons with a material is dependent on the neutrons' velocities, you should know something about interaction probabilities, the so-called *nuclear cross section*. Suppose, for example, that neutrons impinge perpendicularly on a sheet of material with a total number of nuclei n_t, a surface area A, and a thickness x. If you consider each nucleus a sphere of radius r, then the chance of a neutron's hitting any one of the nuclei of projected area πr^2 is simply the projected area of all the nuclei divided by the material's surface, $\pi r^2 n_t / A$.

The effective target area of a nucleus is in general larger than its geometric area. If you designate this effective area as σ, the chance of a collision is now $\sigma n_t / A$, usually written $n\sigma x$, where n is the number of nuclei per cubic centimeter and x is the sample's thick-



PARASITIC CAPTURE BY OTHER ELEMENTS, ELASTIC SCATTERING, AND FISSION WITH A FUEL NUCLEUS ARE BASIC NEUTRON INTERACTIONS.

ness in centimeters. When N_o neutrons of a certain velocity impinge on the sample, the portion that gets through—the number that do not collide with nuclei—is therefore

(1) $$\frac{N}{N_o} = 1 - n\sigma x$$

where N is the number of neutrons transmitted through the sample and σ is the nuclear cross section in square centimeters.

This equation describes the situation accurately as long as there is only a small chance for collision and, accordingly, the portion of neutrons N transmitted through the material is large. If the portion is small, the fraction of neutrons transmitted is found mathematically to be

(2) $$\frac{N}{N_o} = \epsilon^{-n\sigma x}$$

Obviously, this equation can be solved for σ in terms of the quantities N and N_o. An apparatus for determining these quantities will be described shortly.

Where more than one type of interaction is possible, the total cross section σ of a nucleus equals the sum of its partial cross sections, represented by the three basic types of interaction. Each of these partial cross sections can have a different dependence on a neutron's velocity.

A nuclear cross section can sometimes present a larger target than the geometric cross section of a nucleus. The reason is that for a correct description you must regard neutrons in motion as having wave-like properties similar to light—they travel in waves and thus can be looked upon as billiard balls only in certain cases. Accordingly, neutrons may suffer effects similar to diffracted and dispersed light. And these effects lead to nuclear cross sections that are frequently much larger than the geometric cross section of a nucleus.

Interaction Probability

The velocity dependence of the nuclear cross section of an element that captures and scatters neutrons has some general characteristics.

For example, in the neighborhood of one Mev—the kinetic energy with which fission neutrons are produced—the primary nuclear interaction is elastic scattering. The nuclear cross section is then about equal to the geometric cross section of a nucleus: 5 to 10 $\times 10^{-24}$ square centimeters. As the motion of the neutron decreases (Fig. 1) the average cross section increases in approximately inverse proportion to the neutron's velocity.

Through the intermediate range of velocity there exist strong resonance effects—narrow regions of velocity in which capture or scattering of a neutron can rise to large values. Near the kinetic energy of thermal motion (1/40 ev) the cross section does not, generally speaking, show resonance effects but continues to increase. In some instances it reaches high values—700,000 times the geometric cross section of a nucleus for Xe-135.

And so a neutron produced in the fission process with an energy of about one Mev must run the gauntlet of capturing nuclei if it is to reach thermal energy where the probability of fission with a fuel nucleus is greatest.

Velocity Selector

Because the cross section of a sample material may be velocity dependent, it is essential that the velocity of the bombarding neutrons be measured with precision—the chief problem in determining interaction probabilities. And the apparatus for accomplishing this, a high-resolution neutron velocity selector, was developed primarily to gain high precision in neutron velocity measurements (photos, opposite page).

With the selector, the velocity of neutrons is determined by the time-of-flight method—the time needed for a neutron to travel a fixed distance from a source to a detector. Thus a thermal neutron (1/40 ev) traveling 2200 meters per second requires 4550 microseconds to travel 10 meters; a one-Mev neutron requires 0.72 microseconds to travel the same distance.

The neutron velocity selector (Fig. 2) utilizes a 100-Mev betatron as the source of neutrons. Electrons accelerated to 50 Mev—they move with the velocity of light—in the betatron bombard a one-cubic-inch block of natural uranium to produce neutrons. (High-energy x-rays given off when the electrons strike the uranium target excite and disintegrate the nuclei—partly by the direct emission of neutrons and partly by a different kind of fission than that caused by neutron bombardment.)

Neutrons are emitted in bursts of 0.3 microseconds duration every 1/60 of a second, corresponding to the 60-cycle excitation of the betatron. They have

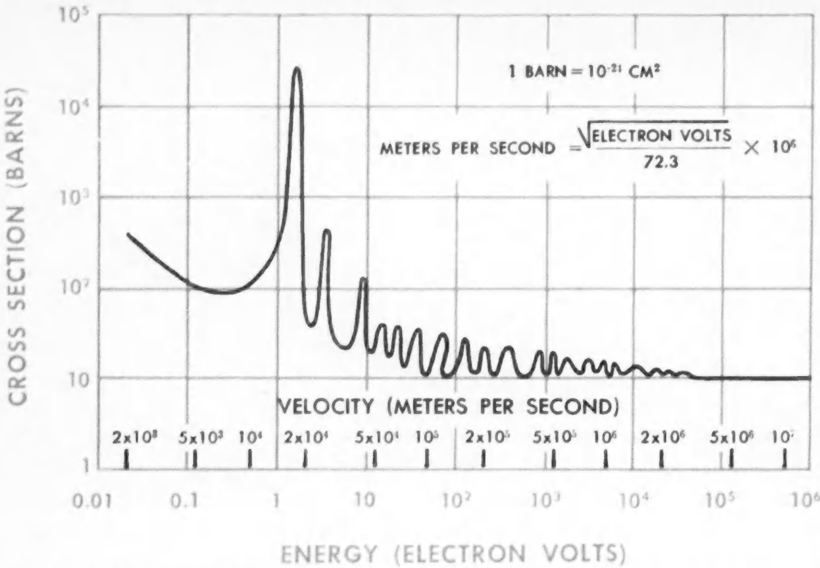


FIG. 1. VELOCITY DEPENDENCE of nuclear cross sections observed with velocity selector. Peaks are points of resonance where capture or scattering of neutrons is large.

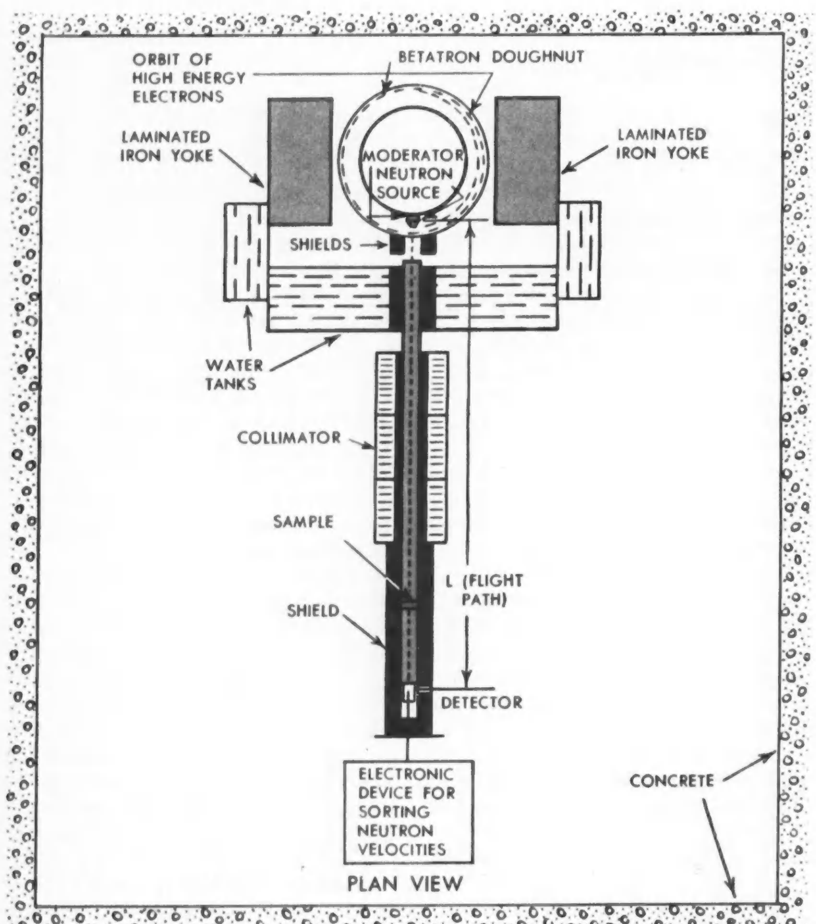


FIG. 2. VELOCITY SELECTOR measures time of flight of neutrons traveling fixed distance *L*. Betatron rated 100 Mev emits bursts of neutrons every one-sixtieth second.

an average kinetic energy of about one Mev—too high for the purpose at hand. To decrease their energy, the uranium cube is partially surrounded with a polystyrene material that slows down the neutrons by successive collisions with hydrogen and carbon nuclei. The result is a spectrum of neutrons with all velocities from one Mev down to the energies of thermal motion—an average energy of 1/40 ev at room temperature.

From the uranium source neutrons pass down a collimator—a device for shaping the beam of neutrons—to a detector. Their time of flight from the initial burst to arrival at the detector is measured by specially arranged electronic circuits. Of course, there will be many such times because a wide range of velocities is involved. The time of flight for the slowest neutron of interest is much less, however, than the time between bursts—1/60 of a second. Flight times can therefore be measured for every cycle of the betatron, or 60 times a second.

In practice, many velocity groups are measured for each neutron burst. This way it's possible to cover a wide range of the neutron spectrum at once. Each neutron, depending on its velocity, is recorded by one of a series of electronic time channels—64 of them, each 0.5 microsecond in duration. Obviously, precision in measuring velocities is reduced to precision in determining time intervals.

Measuring Cross Sections

Cross sections are determined by electronically counting the number of neutrons that arrive in each of the 64 time channels—first with a sample in beam N and then with it out N_o. The ratio N/N_o gives the transmission coefficient of the sample. And the cross section corresponding to the transmission for each channel is simply calculated from equation (2).

An example of this type of measurement for manganese clearly indicates regions of strong resonance: in this case, regions where the scattering of neutrons is large. These occur at 340, 1100, 2500, 8000, and 25,000 ev. The 340-ev resonance is a particularly strong one, because a relatively thin sample (.005 inch) reduces the transmission to practically zero at resonance.

Versatile Tool

Although the apparatus described deals primarily with measurements of nuclear cross sections for reactor technology, it has some other possible uses.

With it you can identify an unknown impurity in a material by observing its resonance structure when it is subjected to neutron bombardment—much the same as infrared waves are used to analyze materials in spectroscopy. In reactor design, specific examples of its use are the identification of hafnium in zirconium, manganese in aluminum or iron, and cobalt or manganese in steel. It is also likely that as experimental techniques are developed, a quantitative analysis of impurity content in a material may be possible when its resonance structure is well-known—the 1.44-ev resonance in indium, for example. With this knowledge you can make a quantitative analysis of the indium contamination in tin.

Another feasible application is measuring the thickness of thin films of electroplate that are strong neutron absorbers—silver, gold, rhodium, and cadmium. For when these metals are electroplated to such base materials as iron or copper, nearly all the neutron absorption occurs in the surface film.

In binary mixtures where one of the elements has a relatively high neutron absorption, quantitative analyses can also be made. An example is cadmium present in lead, bismuth, or tin.

Before the velocity selector can be extensively applied in such analyses, however, it is necessary to accumulate data for many elements. And its instrumentation must also be simplified. For though it has the advantage of high precision, at present it is much too expensive and complicated for widespread use. A number of laboratories are already working on the development of more compact and efficient pulsed neutron sources. And development is under way on a more simplified electronic timing apparatus. (The present apparatus requires about 1000 vacuum tubes.) When these activities are completed, there's considerable promise of an economic neutron spectrometer for chemical analysis.

But the immediate task is obtaining the wealth of information about nuclear resonances that bears directly on nuclear theory, because nuclear theory can't predict in detail the characteristics of nuclear energy states. Further progress in this field will no doubt depend on increasingly accurate observations of the interaction of neutrons with matter. And in this sense, a high-resolution neutron velocity selector is indeed a basic tool of the nuclear scientist. Ω

SCIENTISTS NEED MORE KNOWLEDGE OF NEUTRON INTERACTIONS WITH THESE REACTOR MATERIALS . . .

FUELS	**These elements at the foot of the periodic table—uranium and plutonium, for example—fission when a neutron is captured. The information required includes the velocity dependence of fission, parasitic capture without fission, and elastic scattering.**
MODERATORS	**Predominantly scatterers, such as hydrogen, deuterium, carbon, and some other light elements, they are used to slow down the fast fission neutrons. A few of the heavier elements like bismuth also belong in this group. Capture in moderators is undesirable because it depletes the supply of neutrons.**
CONTROL MATERIALS	**These capture neutrons strongly and include such elements as boron, cadmium, hafnium, and some of the rare earths. Reactor control is usually achieved by inserting these materials into the reactor in the form of rods or sheets.**
COOLANTS	**They extract heat from a reactor and may form part of the moderator. Examples of coolants are water and liquid-sodium metal.**
STRUCTURAL MATERIALS	**Capture is undesirable in the internal metal structures of a reactor, or in any contaminant within the metal.**
POISONS	**These are elements with large capture cross sections. In small amounts they will deplete the neutron supply. They may be naturally present in the reactor material, such as hafnium in zirconium, and manganese in steel. Also, they may be fission-product poisons that, like Xe-135, are generated by the fission process itself.**

THIRTY-THREE ACRES OF NORTHERN MICHIGAN'S FARMLAND BECAME THE SITE FOR CARBOLOY'S NEW PERMANENT-MAGNET PLANT AT EDMORE.

Mechanized Plant Boosts Nation's Magnet Capacity

Review STAFF REPORT

Deep in the pickle and potato country of northern Michigan, 140 airline miles northwest of strategic Detroit, a new, highly mechanized plant is turning out permanent magnets on a straight-through production-line basis.

Just outside the city limits of Edmore (population 801), Carboloy's new $4½-million plant produces 12,500 to 40,000 pounds of finished magnets each week, depending upon which of the 2200 different sizes and shapes are made. Their uses will range from military radar and radio to magnetic hardware for kitchen cabinets. Magnets for radio and TV speakers and radar equipment account for 50 percent of the present business.

Seventy percent of the 325 employees are farmer-workers. Plowshares stand idle during the day, but at night and early morning employees work their farms. When maximum output is reached next year, the plant will employ 500, all from within 15 miles.

The location has other advantages besides being outside the heavily targeted Detroit area: A railroad runs 50 feet from the property, sand supplies are plentiful, two power companies serve the plant, and good highways network the area. One-hundred percent of the magnet production can be shipped by truck. In some cases, one truck can handle the day's production that can be a sizeable amount dollar-wise.

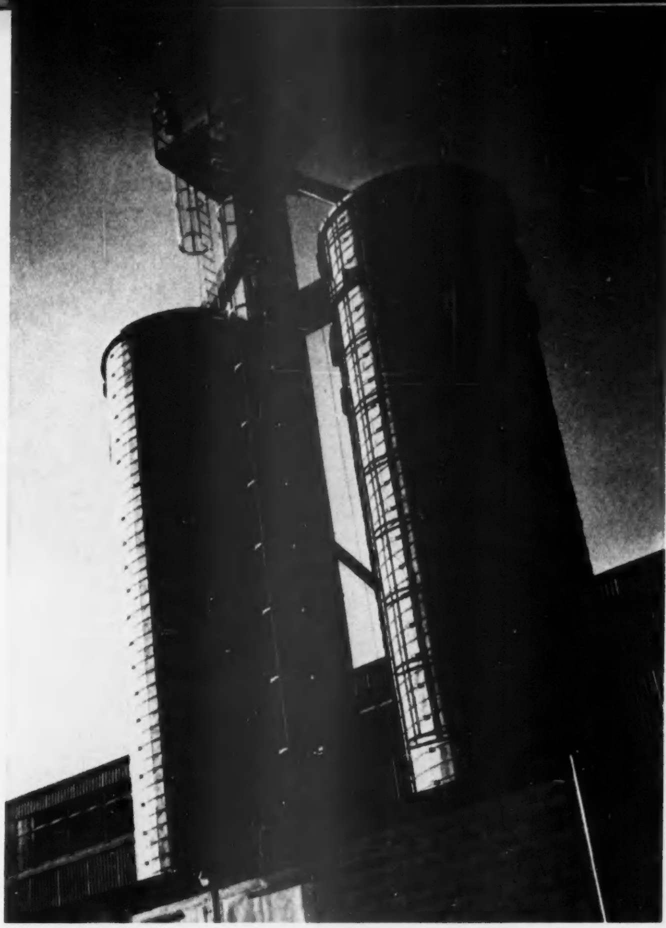
Some 33 acres surround the building that has a manufacturing area of 128,939 square feet.

Every conceivable type of materials-handling equipment is used to handle and process the magnets. Blanketing the two-acre plant are more than 1½ miles of conventional conveyors, plus belt and vibrator types, all synchronized with bucket elevators, chutes, tote trays, monorails, electric hoists, and fork lift trucks to gear a once highly specialized job-shop operation into a production-line setup. In several areas the work station itself is built in as an integral part of the conveyor system, or a conveyor is utilized as a workbench so that work-loaded tote trays don't have to be lifted or removed while the work is being processed.

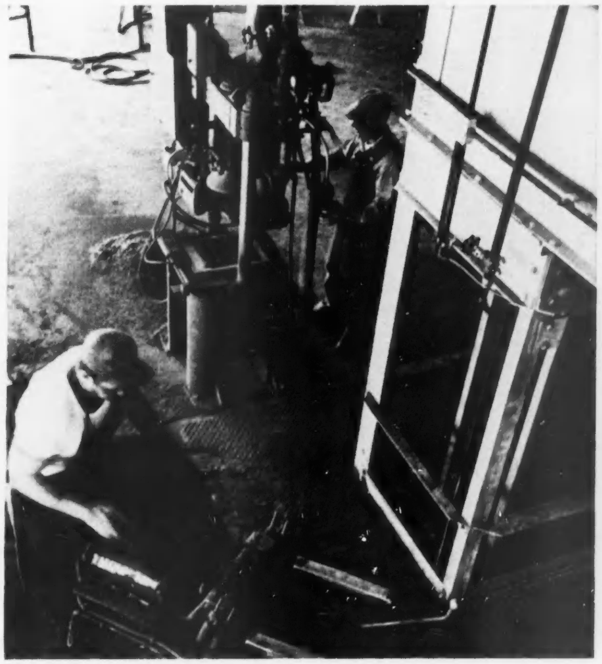
Permanent magnets are manufactured by two methods: casting and sintering. Casting accounts for the majority of the magnets produced in volume, while tiny magnets and those requiring more closely controlled dimensional or higher physical properties are produced by sintering.

On the next four pages you'll see how magnets are produced by the casting method in one of the most modern, fully integrated foundry and manufacturing operations in the country.

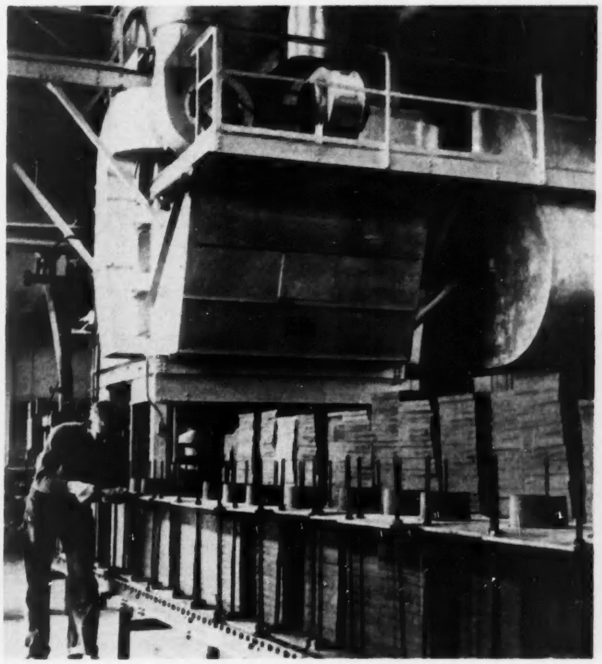
Photographs by George Burns



1 Each silo holds 250 tons of dry sand used in making magnet cores. In each are 30 tons of "live" sand immediately available. Remainder is in storage.



2 From silos, sand drops to mezzanine floor where it is mulled, then dropped to core-making area. Cores are formed, then . . .



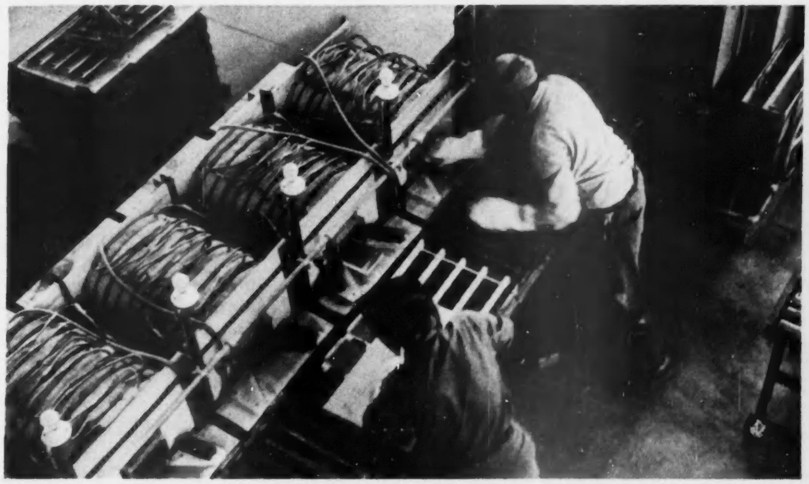
3 . . . baked in electrically heated forced-air tower oven, then stacked 15 high on conveyors, ready for pouring.

4 As metal ingredients for magnets are melted down in electric furnaces, stacked cores are conveyed to pouring position. Test bars from each heat are immediately analyzed by a direct-reading spectrometer and by the metallographic laboratory.

5 In a 96-foot hooded and vented tunnel, the poured molds cool for eight hours.

6 Vibrating "shakeout" knocks off sand. Castings are raked into tote boxes.

7 After magnets are cleaned and rough ground, they are loaded into "boats" . . .



8 . . . for heat treating in a roller-hearth furnace (*upper right*). After heat treating, the boats are pushed into magnetizing solenoids (*above*) where they cool.

9 After cooling, the magnets are dumped by the boatload, then conveyed to . . .

10 . . . one of six aging furnaces to stay for about six hours. Then . . .

11 . . . magnets are cleaned, demagnetized (*above*), and sent in tote boxes to . . .

12 . . . finish grinder (ground on both ends), then ejected for final . . .

13 . . . inspection and testing, such as for strength (*above*). Note tote box on conveyor, convenient to operator.

14 Magnets are usually demagnetized before shipping; otherwise they're hard to handle. Tote tray goes direct to . . .

15 . . . shipping area where magnets are counted and packed. The conveyor does triple duty: conveying, workbench, and weighing. The finished product may be used to . . .

16 . . . separate steel sheets for transfer to stamping operation. Ω

National Society of Professional Engineers

By PAUL H. ROBBINS, P.E.

Acquainting the public and users of engineering services with the value of engineering as a profession is but one of the aims of the National Society of Professional Engineers. Liaison with legislators and government agencies, practices followed in employing engineers, income and economic status of the profession's members, orientation and assimilation of young men entering the profession, co-ordination of civilian and military demands on engineering, and ways and means that the engineering profession can service the nation—these are some of the other activities that all engineers not only have a stake in but are also vitally concerned with.

NSPE Organized

Because of the magnitude of these activities it was believed that an organization of professional engineers should devote its entire efforts to their study and promotion. Accordingly, at the invitation of Dr. D. B. Steinman, representatives of the Connecticut, New York, New Jersey, and Pennsylvania Societies of Professional Engineers met at Columbia University Club in May, 1934, to form the National Society of Professional Engineers.

In September of that year representatives of the same societies adopted a constitution and elected Dr. Steinman as the first President of the national organization. The other officers were: T. W. Batten, First Vice President; Hugh A. Kelly, Second Vice President; Willard S. Conlon, Treasurer; T. Keith Legare, Executive Secretary.

As the new organization reviewed the problems confronting them, they recognized that the implementation of programs in their fields would require effective action at the local, state, and national levels of operation. And so a pattern developed that contains local chapters—whose representatives govern state society activities—and state societies—whose representatives form the governing board of the national organization.

Membership Requirements

It was further believed that the effective resolution of the particular concerns of the engineering profession could be accomplished only if it had the support of individual members of the profession. Thus, individual membership was established as a basic requirement of the Society—the engineer who joins the NSPE automatically becomes a member of all three levels of the organization.

This decision necessitated establishing criteria for membership. All qualified engineers, it was believed, would soon be registered by the registration boards in the various states, accomplishing a complete review of each person's qualifications at that time. For this reason the founders thought it unnecessary for the Society to do any further reviewing. And so the essential requirement for membership in NSPE became that of registration as a professional engineer.

In 1948, however, the membership requirements were broadened to include those who meet the requirements of engineers-in-training and certify to the respective state boards their intention to become registered professional engineers as soon as qualified.

Starting in 1934 with slightly more than 2500 members in four state societies, the NSPE has grown to more than 30,000 members in 1954, with 39 affiliated state societies and over 325 local chapters.

Directors and Committees

The Board of Directors of the National Society determines policy and directs national activities. It is composed of representatives from each state having a vote for every 500 members or portion thereof. In addition, the President, Treasurer, and a Vice President from each of six geographical areas of the United States, as well as the two immediate past presidents, are also members of the Board, with one vote each.

State societies usually have a similar pattern of organization—their Board of Directors is composed of the officers and a representative of each of the chapters, with voting power in proportion to the size of the chapter.

The National Society has a number of committees who concentrate their efforts in special fields of professional development. These include Awards, Budget, Chapter activities, Constitution and bylaws, Corporate practice, Education, Employment practices, Engineers in industry, Ethical practices, Interprofessional relations, Intersociety relations, Legislative, Membership, National affairs, National defense, Nominating, Publications, Public relations, Registration, Reserve fund, Resolutions, Salary and fee schedules, and Young engineers.

Publications

The Society issues a number of regular publications, plus special publications released from time to time covering subjects of interest to its members.

Its monthly magazine, *American Engineer*, contains articles by the nation's leaders on subjects related to the profession; news of NSPE and other engineering organizations' activities; stories of general professional interest; and various special features such as committee reports, studies in the engineering field, and reports on national legislation and federal agency decisions.

A monthly legislative bulletin is published and distributed to the members, outlining in detail some of the governmental activities of interest to engineers. A number of policy statements concerning professional practice, as well as

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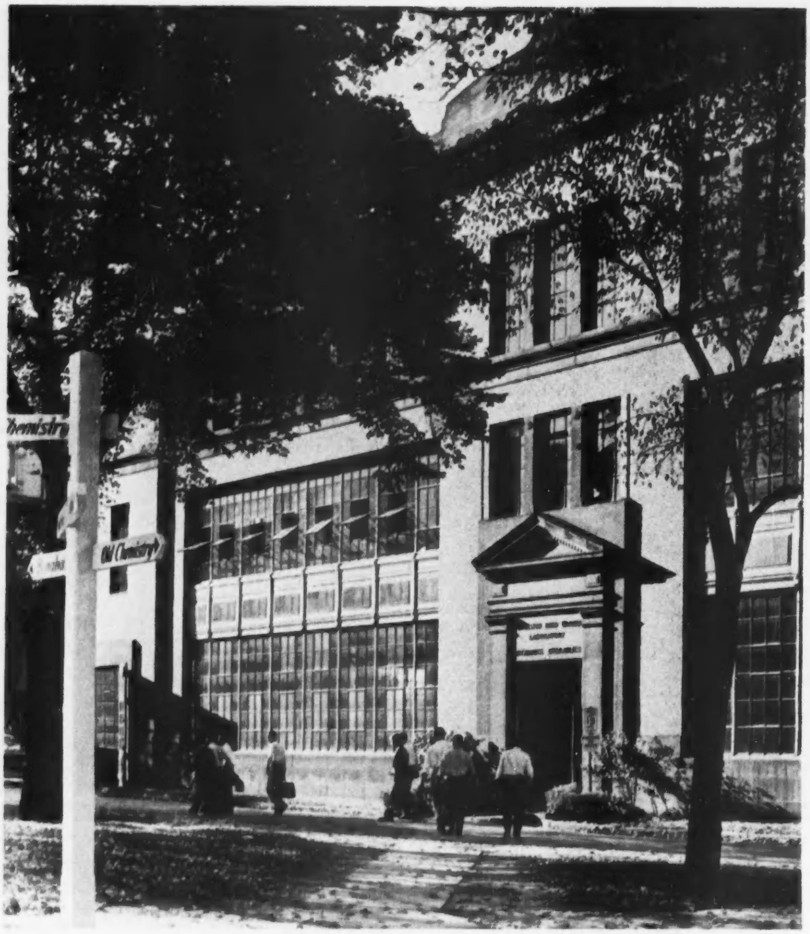
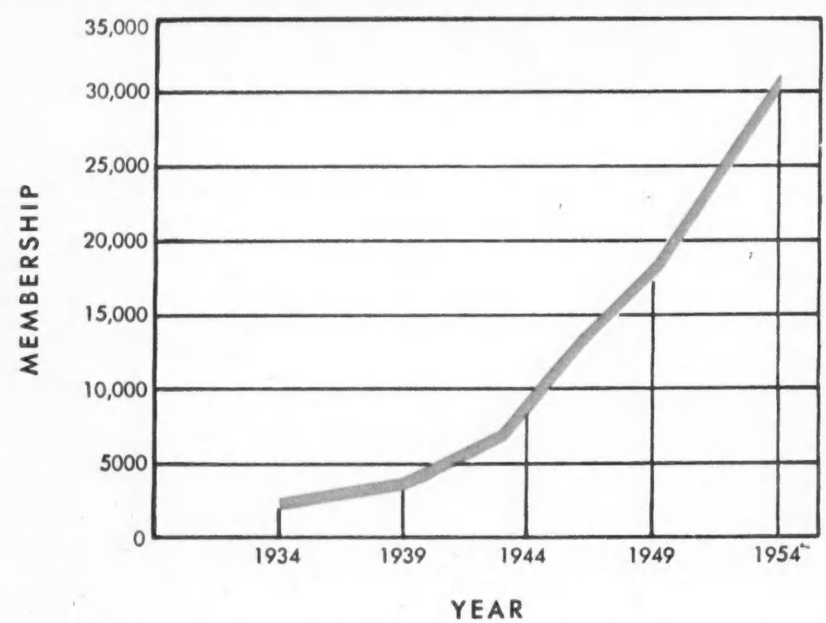
Mr. Robbins is Executive Director of the National Society of Professional Engineers. He has held this position for the past seven years.



DEVELOPING PROFESSIONAL AWARENESS AMONG ENGINEERING STUDENTS IS AN NSPE FUNCTION.



NSPE MEMBERSHIP CURVE SHOWS RAPID GROWTH, ESPECIALLY DURING THE LAST 10 YEARS.

reports, surveys, and publicity material on registration, opportunities for an engineering career, and similar items are also released from time to time.

The Annual Report of the Society summarizes each year's activities and gives a short résumé of the various NSPE programs. A limited supply is available to interested nonmembers, and they may obtain a copy by writing to NSPE headquarters.

The Society's Major Award

The principal award of the Society is presented periodically to an engineer for noted contributions to the national welfare, outstanding public service, and leadership in the professional development of engineering. To date, the award has been given to three individuals—Herbert Hoover in 1949; Dr. Steinman in 1952; and to Charles F. Kettering in 1953.

A committee composed of outstanding leaders in the engineering profession anually reviews recommendations made by the state societies to determine the individual to whom the award will be given. In the form of a bronze plaque, the award contains an etched photograph of the individual to whom it is presented and an appropriate citation of his contributions.

Society Headquarters

The NSPE headquarters office at 1121 15th Street, NW, Washington 5, DC, houses a small staff, supplemented by staff at the state level and at the chapter level in the larger areas. Besides the Executive Director and a Legislative Analyst, there are the editorial and business staff of the magazine, public relations personnel, and a clerical staff engaged in the usual record-keeping and supply activities.

Public Relations . . .

One of NSPE's big activities each year is sponsoring National Engineers' Week—a phase of the Society's general public relations program that endeavors to convey to the public the value of engineering services. Local chapters, state societies, and the national organization co-operate in this annual event. Significantly, it is celebrated during the week coincident with the birthday of George Washington—extensive research has disclosed that he engaged in a variety of engineering activities. Many mayors and state governors proclaim the period as Engineers' Week; hundreds of radio, television, magazine, and news-

LEGISLATIVE ACTIVITIES OF THE NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS CENTER ON A NUMBER OF PROFESSIONAL PROBLEMS.

paper programs acquaint the public with the myriad engineering activities.

As a second phase of their public relations activities, NSPE created the Professional Engineers Conference Board for Industry. Under its auspices a series of Executive Research Reports are compiled continually. The first two reports—"How to Improve Engineering-Management Communications" and "How to Improve the Utilization of Engineering Manpower" — received widespread attention and were reported extensively in the business, trade, and public press.

A survey of professional engineers with respect to their income and a general evaluation of such items as geographical variations, comparisons between branches, type of work and responsibility was recently completed.

Legislative . . .

The Society is concerned with federal legislation governing the employment of engineering personnel. In co-operation with a number of other societies, NSPE was active in having included in the Taft-Hartley Law recognition of the unique conditions under which professional employees work. More recently, the Society has been active in sponsoring an amendment to this Law which would provide greater freedom of association by engineering personnel.

The matter of collective bargaining and professional development has been the subject of extensive study by the Society. A policy was adopted indicating that NSPE believes collective bargaining to be incompatible with professionalism because of the regimentation inherent in it.

Legislative activities of the NSPE have centered on a number of other professional problems: utilization of engineering personnel by the Armed Forces, social security coverage for self-employed engineers, and amendment of the Defense Production Act to provide exemption from salary controls for professional engineers, to name a few.

Educational . . .

In the field of education, NSPE has been active in working with educators and young engineers in developing professional consciousness among engineering students and recent graduates. Attention was also focused on the salary situation of engineering teachers. And to improve the training of young engineers, co-operation with various organizations in the educational field has been a key program of the Society.

. . . and Co-operative Activities

The NSPE co-operates actively with a number of organizations that are mutually concerned with specific problems. The Society has a joint committee with the American Institute of Architects as well as representatives on several Engineers Joint Council committees and one to the American Standards Association. And it is actively concerned and co-operates extensively with the National Council of State Boards of Engineering Examiners.

The Society's activities are perhaps best summarized in the preamble of its constitution. . .

"The National Society of Professional Engineers, recognizing that service to Society, to State, and to Profession is the premise upon which individual opportunity must be built, does hereby dedicate itself as an educational institution to the promotion and the protection of the profession of engineering as a social and an economic influence vital to the affairs of men and of the United States." Ω

AMONG MANY TRANSISTOR APPLICATIONS ARE LOW-VOLTAGE HEARING AID . . . 10-MEGACYCLE AMPLIFIER USING POINT-CONTACT TRIODES . . .

. . . PEN-LIKE PHONOGRAPH PREAMPLIFIER WITH ITS ELECTRON TUBE COUNTERPART . . . RADIO RECEIVER THAT SAVES BATTERY POWER.

Transistor Applications

By DR. J. S. SCHAFFNER

The transistor is slowly changing from a miraculous cure-all into a reliable component with known properties. And as the first transistorized articles appear in the market place, a clearer picture of this new and versatile device begins to emerge.

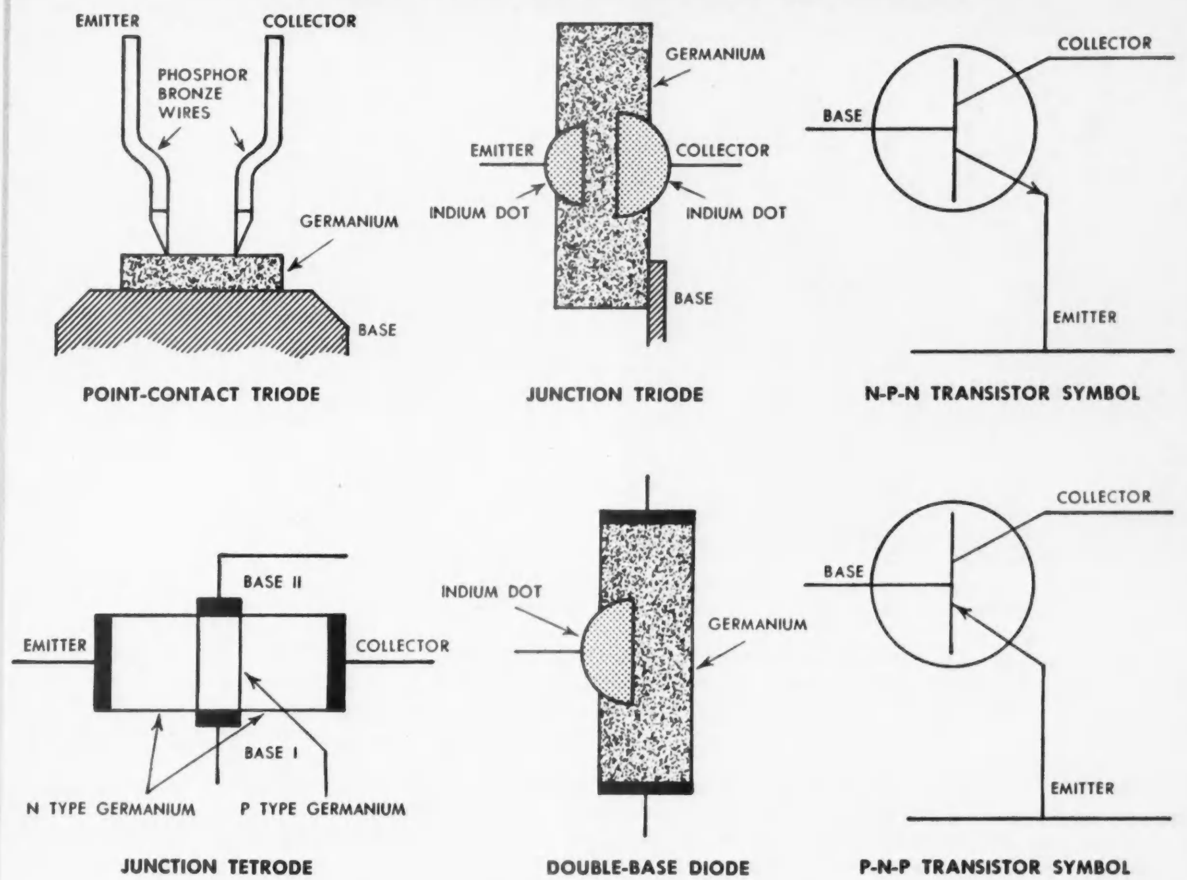
Too, application techniques are becoming more well-known as engineers factor transistors into their design thinking.

To get some conception of the application problems, we first must have an over-all view of the different types of transistors.

In the first place, the term transistor is used today for semiconductor devices capable of power gain. (This excludes germanium diodes because such devices pass current in one direction only and are not capable of amplification.)

The basic elements of semiconductor devices, including diodes and transistors, are "barriers." You can form a barrier in a number of ways: by placing a phosphor bronze wire on a small block of germanium and welding the two together (point contact), or by placing a dot of indium on germanium and heating the indium so that it forms an alloy with some of the germanium (alloy junction).

CROSS SECTIONS OF SEMICONDUCTOR DEVICES



The "classical" transistors were composed of two barriers, closely spaced together. However, a new class of transistors using only one barrier was developed recently. The most promising of these is the double-base diode, a switching device that is the semiconductor counterpart of the thyratron.

Transistors are divided into two classes—the junction and point-contact (or whisker) transistors—according to the type of barrier used (illustration, above).

Point-contact transistors are formed by closely spacing two 0.005-inch-diameter wires on the face of a small rectangular block of germanium. These wires are then attached to the germanium by welding or by pressure and subsequent heating.

Junction transistors are manufactured in a number of ways. Most of the commercially available transistors are made by placing two dots of indium on opposite sides of a thin slab of germanium. The indium is heated and forms an alloy with germanium on the surface of the slab. Wires are then attached to the two indium dots on the germanium, a process originally developed by General Electric.

As we have said, the words "junction" or "point-contact" are added to indicate the type of barriers used in a transistor, and words like "triode" and "tetrode" designate the number of electrodes Typical examples of this nomenclature are: point-contact transistor triode and junction transistor tetrode or, in short, point-contact triode and junction tetrode.

At present only the junction and the point-contact triodes are commercially available, both in a variety of types. They differ considerably in such areas as power gain, maximum power dissipation, and switching time. But the number of types will increase considerably in the future as transistors still in the laboratory stage are released for production.

Junction triodes are available in two different forms—n-p-n and p-n-p transistors. They are almost identical except that the direction of all currents and voltages is reversed. If the n-p-n transistor corresponds to an electron tube with ordinary (negative) electrons as charge carriers, then the p-n-p transistor would correspond to a tube with positive instead of negative electrons.

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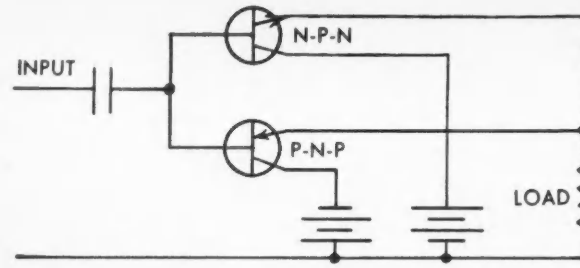
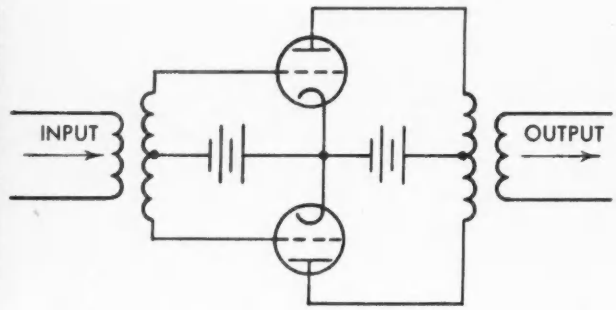
A graduate of the Swiss Institute of Technology and former research assistant professor at the University of Illinois. Dr. Schaffner joined GE in 1951. He is now working on transistor circuits at the Electronics Laboratory, Electronics Park, Syracuse. Dr. Schaffner is one of nine co-authors of the Book, PRINCIPLES OF TRANSISTOR CIRCUITS (*Wiley, 1953*).

BOILING WATER treatment proves that recently designed junction transistors can be operated at ambient temperatures up to 110 C.





PUSH-PULL amplifiers using n-p-n and p-n-p transistors or electron tubes are often used for high-fidelity phonograph equipment.

Obviously, such a tube cannot be built. The availability of p-n-p and n-p-n transistors is, therefore, one of their unique features.

Transistor Circuits

Because transistors are similar to vacuum tubes, you expect circuits using transistors to be similar to circuits using electron tubes. Such is the case. Ways of thinking and methods of analysis can often be transferred directly from one field to the other. One reason is that both vacuum tubes and transistors can be represented with good approximation by active linear networks (equivalent circuits) so that the theory of these networks can be applied to both. But a number of differences do exist, and you can't, as a rule, replace electron tubes by transistors if the rest of the circuit is left unchanged.

Before going into a discussion of specific applications, we must cover a number of problems occurring in transistor circuits.

Temperature . . .

At one time, germanium transistors were rather sensitive to variations in temperature. But now, because of recent improvements (photo, above), junction transistors can be operated at ambient temperatures up to 110 C, and point-contact transistors up to somewhat lower temperatures. It should also be noted that some parameters of transistors will change at temperatures considerably lower than those at which the transistors become inoperative. However, with careful design it is possible to design equipment that will operate uniformly over a temperature range of zero to 100 C.

At the present time, effort is being made to supplement germanium with silicon in semiconductor devices. It is believed that this will eliminate the problem at lower temperatures and permit operation at much higher temperatures.

. . . Noise

The large amount of "noise" generated by transistors was one of the most serious obstacles to their application until a short time ago. Today this problem has been largely eliminated. Noise figures for point-contact triodes have been reduced from 60 to 48 db, while commercially available junction triodes have average noise figures of 20 db. Experimental junction triodes with noise figures as low as 3 db have been built, and you can expect to find available soon junction triodes with noise figures of 5 db. (This is comparable to the noise figure of electron tubes.)

These noise figures are given for a frequency of 1 kc. At higher frequencies they may be substantially lower. A point-contact triode with a noise figure of 48 db at 1 kc will have a noise figure of 18 db at 1 megacycle.

. . . and High Frequency

The high-frequency response of transistors was greatly improved during the last year. Oscillator frequencies up to 300 megacycles (FM radio and VHF television) have been obtained in the laboratory with both point-contact triodes and junction tetrodes. The frequency response of commercially available transistors is, however, considerably poorer—for junction triodes a reduction in power gain is already evident at 455 kc (the frequency used in the intermediate-frequency amplifiers of broadcast receivers). Point-contact triodes have a much better frequency response (photo, top right, page 50). Switching time as low as 0.01 microsecond has been obtained and for one commercially available type of point-contact triode a frequency of 50 megacycles in a given oscillator circuit is guaranteed.

Because electrons move in crystals at low velocities, a comparatively poor high-frequency response results. This means that transit-time effects will become evident at relatively low frequencies. In a high-frequency transistor where transit-time effects must be kept to a minimum, the barriers must be spaced closely together. A typical distance is one-thousandth inch.

Transistors vs Electron Tubes

Today the transistor is competing with the electron tube for the market in electronic equipment. Technically, transistors have a number of important advantages over the electron tubes, but it is hard to say which is the most important because they are all spectacular.

High reliability is the primary advantage of the transistor. No reason is known why a carefully manufactured, hermetically sealed transistor should ever deteriorate in its performance. Even if experiments should show that transistors fail under extreme conditions after a number of years, it would still not be a sudden failure but, rather, a slow deterioration of performance over a period of many months. This could easily be detected by periodic checks.

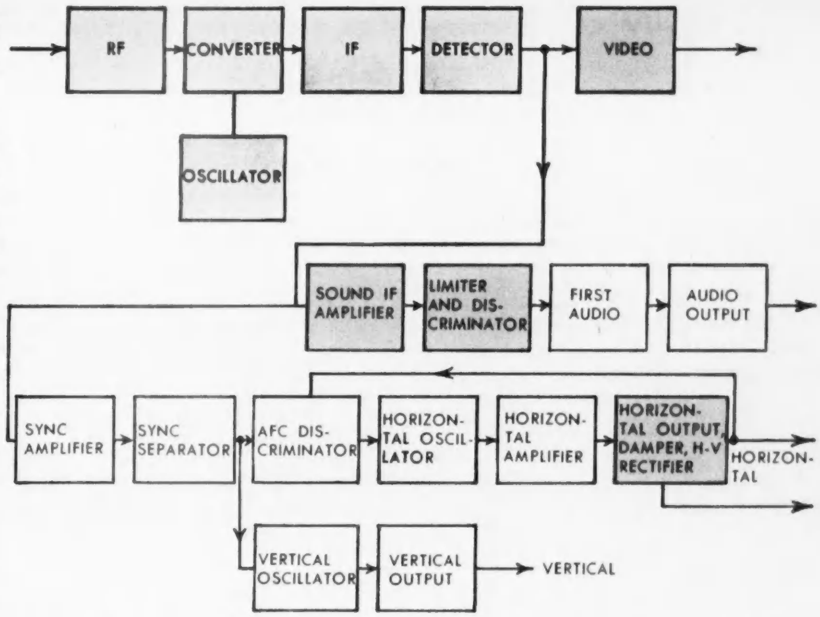
Early transistors were sealed in plastics, but the trend is toward hermetic seals. Today all General Electric junction triodes are hermetically sealed—an absolute necessity to insure high reliability.

(Imperfectly sealed transistors will deteriorate because their surface becomes contaminated. Only minute amounts of impurities are necessary. Ordinary water vapor, perhaps one of the worst offenders, is always present in the atmosphere, and enough can diffuse through plastics to seriously contaminate the transistor.)

The fact that no cathode heaters are needed is another advantage of transistors. This means that they can operate at power levels of a fraction of a milliwatt, and stand-by operation is possible at a fraction of the maximum output power. This is vitally important where power is at a premium, for example, in battery-operated equipment. Furthermore, undesirable feedback and heater hum are eliminated. The absence of the heater also simplifies wiring and results in savings because a smaller power transformer is used.

Other advantages of transistors are: operation from low d-c supply voltages (as low as one volt), small size, and the availability of both n-p-n and p-n-p transistors. This last advantage is quite important. It permits you to design simple circuits with a minimum of components. For example, an n-p-n and a p-n-p transistor in parallel can operate as a push-pull amplifier (illustration, opposite page) without input or output transformer. Such amplifiers, with their high efficiency and low distortion, are often used for high-fidelity record-playing equipment (photo, bottom left, page 50).

Because of the low power dissipated as heat in most transistor circuits, they may be packaged together in a small space without any danger of its overheating—another advantage to designers.



SOME TV RECEIVER CIRCUITS can use commercial transistors (*white areas*), some can use advanced laboratory transistors (*yellow*), while a few cannot now be transistorized (*gray*).

At the present time transistors are manufactured in relatively small numbers by rather expensive pilot-line methods using comparatively little automatic machinery. Under these circumstances, it is not too surprising that they are more expensive than comparable electron tubes. But because transistors have a relatively simple structure, ultimately they will be manufactured at lower prices than electron tubes.

Transistor Applications

Transistors, because of their desirable properties, shortly will replace electron tubes to a large extent in such items as communication equipment, computers, radios, and television receivers.

At present, transistors are limited in power output and frequency response; therefore, they can replace electron tubes only in a limited number of functions. For example, right now it would be impractical to use transistors in a 30-megacycle amplifier for radar applications because the power gain of commercially available transistors is at best very small at this frequency.

Only in a few items—hearing aids, for instance—is it practicable to replace all electron tubes with transistors. Usually only a few electron tubes can be replaced with present transistors so that the equipment is mixed.

As improved types of transistors are put on the market, it will be possible to replace more and more electron tubes in equipment. However, it is not expected that a complete replacement of electron tubes by semiconductor devices will ever be technically possible or economically practical.

But there's another facet to the application story: In addition to replacing electron tubes in existing equipment, they will, of course, be used where electron tubes would not be practicable.

Transistor Amplifiers

The junction triode, commonly used in transistor amplifiers has three electrodes—emitter, base, and collector—connected respectively to the emitter, base, and collector regions. The base region corresponds approximately to the inter-electrode region in an electron tube, and the base electrode to the grid electrode. The emitter corresponds to the cathode, and the collector to the plate.

The junction triode is normally used in low-frequency amplifiers (for audio reproduction at 50 to 15,000 cycles) with the emitter grounded, the base used as input, and the collector as output. The collector, or output current, depends upon the base, or input current, in much the same way as the plate current of an electron tube depends upon the grid voltage. The short-circuit current amplification of the amplifier stage remains nearly constant over a wide range of operating points.

In this it resembles the open-circuit voltage amplification of electron tubes. Typical values for the transistor short-circuit amplification are between 20 and 200. Because the short-circuit current amplification is in the first approximation independent of the operating point, it's advantageous to think of the transistor as a current-amplifying device and to analyze amplifiers in terms of current amplification.

The networks coupling succeeding stages are similar to those used in electron-tube circuitry. In audio amplifiers, transformer or capacitive coupling is used; in d-c amplifiers, direct coupling; and at high frequencies, transformers and resonant circuits.

Hearing Aids

A typical example of an audio amplifier is the transistor hearing aid (photo, top left, page 50), now manufactured and sold by a number of companies.

A comparison of hearing aids using transistors and electron tubes for amplification shows the advantages of transistorized equipment. All transistor advantages, such as high reliability, absence of heater, and low-voltage operation are evident. The improvement is spectacular.

The amplifiers used in hearing aids must amplify the input power by approximately one-billion times and have a power output of a few milliwatts to drive the earphone. Transistor amplifiers with this performance can be built with a d-c supply voltage of 3 volts and a power drain of approximately 15 mw (for an over-all efficiency of 20 percent). Stand-by operation at a much lower level can be achieved if a Class B push-pull output stage is used. A hearing aid of this type can be operated from ordinary penlight cells at a cost of only a few dollars a year. Usually the batteries must be replaced about once a month.

Comparable electron-tube hearing aids need two batteries, one of 22½ volts for plate power, the other of 1½ volts for filament power. The power drain from these batteries is several hundred milliwatts for filament power alone. Batteries must be replaced frequently at a cost of approximately $70 a year.

The circuit of a transistor hearing aid has three stages of amplification. The first two stages are coupled by transformer, the second and third by a capacitance. In the third stage a push-pull combination with one n-p-n and one p-n-p transistor is used to reduce the power necessary for stand-by operation.

Transistor hearing aids have a number of secondary advantages. For instance, they are comparatively free from pick-up and radar interference. There is no question of their superiority over electron-tube hearing aids, even if the transistor types are presently somewhat more expensive.

A similar application is in preamplifiers used for record-playing equipment and microphones. Here transistors offer a considerable saving in size when you compare them to electron-tube preamplifiers.

Broadcast Receivers

Portable radios using transistors can be built today with a performance equal to that of similar electron-tube receivers (photo, bottom right, page 50). Such radios are of the standard superheterodyne type, consisting of a local oscillator, mixer, intermediate-frequency amplifier, detector, and audio amplifier. Automatic gain control is used in the same way as with electron tubes. A radio-frequency amplifier stage can be added to improve the performance. Considerable savings in battery power again can be achieved because the set can be operated from a 6-volt battery.

For home radios operated directly from 60-cycle a-c power, the advantage of high efficiency will largely disappear because power cost is negligible. Similarly, the premium that the public is willing to pay for high reliability in an ordinary home radio is probably small. But the advantages that remain are: no filament current (simplifying the wiring), absence of a socket (transistors can be wired in directly), no warm-up time, small size, and simplification of circuitry because of the use of both n-p-n and p-n-p transistors.

But the really convincing argument would be, of course, the low price of transistors. Because of the sales appeal it may, however, be expected that transistors will appear in a relatively short time even in home radios.

Television Receivers

The advantages of transistors in a home television set are the same as in radio. But because a TV set operates at considerably higher frequencies, it is not always possible to replace all electron tubes with transistors without a serious degradation of the set's performance.

The block diagram (preceding page) shows where transistors can be used in television receivers . . .

- White areas indicate the circuits that can be transistorized using commercially available transistors. These circuits include the synchronizing amplifier, the synchronizing separator, automatic frequency changer (AFC), horizontal oscillator and amplifier, vertical oscillator, vertical output, and audio circuits.
- Yellow areas indicate circuitry that can be transistorized with advanced laboratory transistors but not with commercially available transistors.
- Gray areas designate circuits that cannot be transistorized in the near future.

Digital Computers

The input characteristic of point-contact transistors and double-base diodes has this peculiar property: Over a considerable range the current decreases as the voltage increases. In vacuum tubes this "falling" characteristic is found in secondary emission tetrodes or dynatrons.

Devices using this property are ideally suited for switching circuits, such as the ones used in digital computers and oscillators. A saw-tooth generator, for example, can be obtained by simply connecting a capacitance across the input terminals of the transistor; similarly, a sine-wave oscillator can be obtained by connecting a resonant circuit across the same terminals.

This property is of value to computer designers because transistorized computers can be built into a much smaller space than electron-tube computers. Other applications are in telephone exchanges, in pulse generators, and in frequency multipliers.

As a result of the development of the many types of transistors and their continued improvement, they are replacing electron tubes in a variety of applications. The field of these applications is continually being broadened—contemplation of the great potential field of transistor applications cannot but instill a spirit of enthusiasm. Ω

CARNEGIE INSTITUTE'S D. W. VERPLANCK EXPLAINS A COIL PROBLEM TO YOUNG ENGINEERING PROFESSORS AT AN ANNUAL SEMINAR OF . . .

Educators in Industry's Classroom

By R. H. BUESCHER

Almost everywhere you go you'll find the practicing engineer aware of the differences between the college campus and the industrial world. He realizes only too well how his day-to-day learning differs from that absorbed in the engineering schools. The student works to solve the theoretical problems of next week's quiz; the engineer works to solve the practical problems of industry.

Here in General Electric—as in any industry—we utilize the product of the engineering colleges, namely, technical graduates. After selecting personnel on the basis of their desirable characteristics, we then proceed to augment these with some additional engineering characteristics.

What is the quickest way an effective engineer can be developed from a technical graduate? One way is through our industrially administered training programs. We know that we can teach a young engineer to solve problems quickly and efficiently by letting him do just that—solve problems. And this principle is the basis of our teaching philosophy: *learning by doing.*

Bridging the Gap

A unique and barely tapped solution to the problem of bridging the gap between college and industry is a program of industrial co-operation with colleges —not only with schools in a given area but through direct nationwide contact with educators. By sharing industry's teaching techniques and philosophies in this way, we can ultimately close the gap.

Our latest approach to the problem is the Teaching Methods Seminar held for the past two summers at GE's Schenectady Works. Lasting six days, these Seminars are jointly sponsored by The American Society for Engineering Education (ASEE) and General Electric.

Last year we invited 130 accredited schools to nominate to the Seminar a young professor—around 30 years old—of either electrical or mechanical background. In reply, the colleges nominated 70 professors who would spend a week at Schenectady in June. Twenty more schools hoped to reserve a nomination for this year's Seminar.

After giving careful consideration to the locations and curricula of these schools and to the recommendations of their deans, we invited 26 professors to attend. Coming from Maine to Cali-

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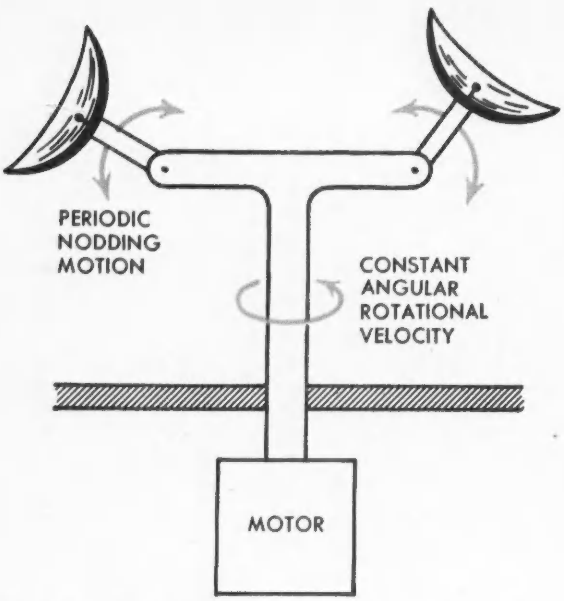
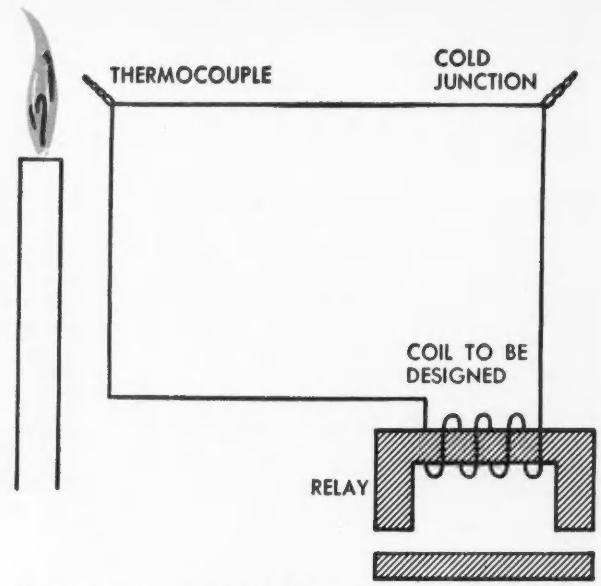
As Supervisor of GE's Technical Courses, Engineering Services Division in Schenectady, Mr. Buescher is responsible for the planning and operation of educational courses for technical graduates. He came to General Electric in 1949.



PROBLEM: ANTENNA DRIVE SYSTEM—Given the physical dimensions, find torques the motor must produce to drive the system.



PROBLEM: FLAME DETECTOR CIRCUIT—Determine the number of turns the coil should have to hold the relay in a closed position.

fornia, their distribution greatly resembled the population distribution of America.

No Holds Barred

What was our purpose in inviting the professors here? We thought they could use some of our own teaching methods to advantage in undergraduate work. We wanted to show them the methods we've used effectively in our Advanced and Creative Engineering Programs. In short, we wanted to help them apply these same principles to their undergraduate teaching.

Because the engineer profits most through his experience, learning by doing is the teacher of many in industry. If you want an engineer to solve problems of an engineering nature, then a good way to teach him is to give him problems to solve—real problems, up-to-date problems, no-holds-barred problems.

Too often when we were students, our college instructors assigned us problems at the end of a chapter that could be worked by equations in that chapter. Rarely were the solutions dependent on the other chapters in the text. And almost never were they dependent on other courses. We were not always shown the relationships of our knowledge in different fields. And as a result, much of our knowledge was forgotten.

Then too, although he should be given problems of a realistic nature, the young engineer in industry is often asked to "see" an unrealistic problem—the solution sometimes requiring six frustrating months of work. At the outset of his career he should be well-equipped to tackle the poorly defined problem that is certain to confront him. He must understand that an engineering problem seldom has one answer—that each solution is dependent on the approximations used to solve it.

Problem Solving

And so we tried to show the professors at the week-long Seminar the teaching method based on our own philosophy: that a student learns best by doing. To teach the method we simply applied the method itself. During the week the professors became students, took an entrance examination, and solved three difficult engineering problems. Each problem was subsequently evaluated and discussed in the classroom (photo, preceding page).

The first problem (illustration, left) concerned an antenna drive system. As the antenna rotates horizontally, its two "dishes" oscillate vertically at a slow rate, scanning an entire hemisphere.

The problem was to find the torques that the motor must produce to drive the system. Finding these torques is a complex problem because the oscillatory motion of the "dishes" changes the moments of inertia of the whole rotational system. Hence, additional pulsating torques are developed. The problem called for such technical material and techniques as the dynamics of rigid bodies and vector algebra. Thus the learning-by-doing process of its solution presented two or more academic topics that have an excellent chance of being retained by the student.

The second engineering problem required solution by a creative approach: designing a device that could replace the common doorbell—not so simple a problem as you might think. The Seminar members presented ideas ranging from simple and ingenious carrier-current devices utilizing the house wiring to radar televiewers for announcing guests. Some of the professors even proposed that an answering scheme be employed, while others gave the caller a choice of ringing the housewife, her husband, or any number of their children.

Problem three differed in that it was an application of the techniques actually used in undergraduate engineering education. Presented by D. W. VerPlanck of the Carnegie Institute of Technology as typical of a problem given in courses at his school, it involved the design of a coil.

As you are probably aware, much information can go into the design of a coil to do a certain job. This particular one was for use in a flame detector circuit (illustration, right) actuated by cur-

EDUCATORS scrutinize the high-pressure end of a large steam turbine on a tour of GE's Turbine Division. The young professors met informally with prominent engineers and mathematicians, and also visited the Research Laboratory at The Knolls, near Schenectady.

rent from a thermocouple. The problem was to determine how many turns the coil should have to hold the relay in a closed position as long as the flame was heating the element. At first glance, the coil could have any number of turns and still produce the same number of ampere turns of flux—provided certain assumptions were made. A closer examination, however, revealed limiting factors—the coil's resistance and the window area of the core.

Informal Get-together

Through the working of these problems the "student" professors were given firsthand opportunity to gage the effectiveness of our teaching technique. What's more, they employed a tool not widely used in engineering colleges, namely, creative analysis.

We feel that an engineer in industry must be creative in both his problem definitions and analytical solutions. This points up again our philosophy of there being no *one* correct answer. For example, an engineer would be greatly hindered in designing an amplifier if his thoughts were limited to electronic means. He could well use amplidynes, amplistats, and mechanical or hydraulic systems to accomplish the same thing in different systems.

The professors, incidentally, turned out to be typical of class members of our own Advanced and Creative Engineering Programs. Their rigorous 14-hour daily schedule left little time for anything but 10 o'clock coffee. In a typical fashion they appeared in the class sessions busily discussing the work they'd done on a problem the night before. And they were candid in their evaluation of the problems, the techniques, and the material presented.

But so far we have talked only about the planned portions of the Seminar, the portions that were formal. Of great value also were the unplanned discussions—conversations that accomplished more than a planned discussion ever could. Besides instilling the members with many of our teaching philosophies, the Seminar furnished additional information that they wanted.

Although many of the professors were engaged in some sort of industrial research, many of them told us they had never worked in an industrial organization. Consequently, they were vitally interested in speaking with representatives of certain technical fields.

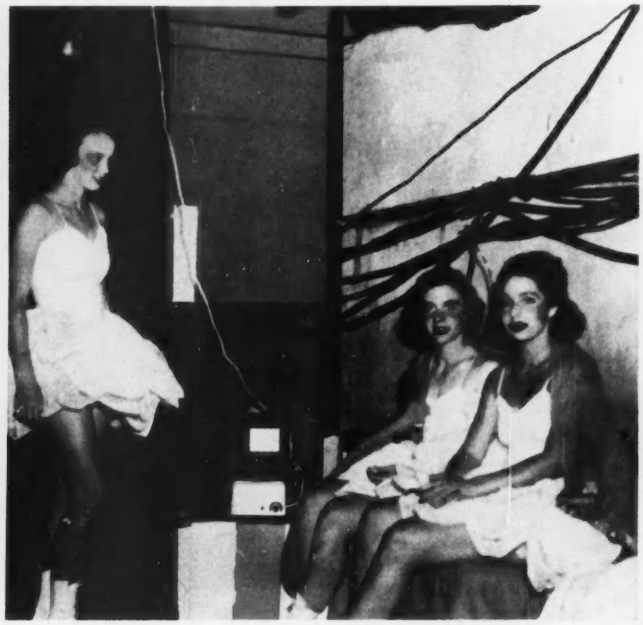
To satisfy their interests, meetings were established between the professors and engineers prominent in several fields. We arranged to have motor experts, control-system experts, turbine experts, and mathematicians gather with our guests to chat informally about their work. In addition, two afternoons of the busy week were devoted to tours of the Turbine Division (photo, above) and the Research Laboratory at The Knolls, near Schenectady.

Mutual Understanding

What did the professors gain by attending the teaching Seminar last summer? Replies received since then indicate that they considered the week well spent. For example, some of the members wrote reports to inform their colleagues of the teaching methods they observed throughout the Seminar. Others undertook to establish regular courses of a similar problem-solving nature at their own institutions. Still others planned to inject into existing courses more of the real problems they found in industry. Many now feel closer to industry and better equipped to answer engineering students when they ask: "Why will I need to know this?"

We in General Electric also gained much from the Seminar. Valuable, indeed, are the closer and improved relationships with these schools. In addition, we were able to absorb some of the colleges' viewpoints. For a problem facing the colleges right now is much like one facing industry: How can an engineer be trained for broad future opportunities when little is known initially about his ultimate position?

Obviously, if industry is to continue to get engineering graduates of high calibre, persons with real teaching ability must be encouraged to teach. And we must do everything we can to keep them motivated along this worth-while course. The Teaching Methods Seminar, we feel, is a step in that direction. Ω



INVENTOR W. K. KEARSLEY INSPECTS A 1938 ELECTRIC BLANKET PROMOTED THAT YEAR BY A SKATING BALLET AND M-G-M STARLET MARIE

History of the

By G. C. CROWLEY

It was hot in the Mohawk River Valley during the summer of 1934. And one of the hottest places was General Electric's huge Schenectady Works.

In Building 5, a non-air-conditioned seven-story structure that was then the home of the Company's Research Laboratory, a couple of scientists were doing something to make sleeping on hot nights more bearable.

Dr. William D. Coolidge, Director of Research, with the help of his associate, William K. Kearsley, had developed a tent-like affair that went over a four-poster bed. Cool or warm air was circulated over the inhabitant of the enclosure. In some remote way this could be looked upon as the forerunner of today's room air conditioners, but in 1934 it didn't prove practical. Blower motors of that era were just too noisy.

Early Experiments

Kearsley tried numerous experiments that consisted mainly of blowing refrigerated air into a sleeping bag made by sewing the edges of two bed sheets together. That didn't prove practical either.

By the time Kearsley concluded these tests, hot weather had passed, and the chilly nights of northern New York State were upon him. His concern now was to keep the sleeper warm.

Radiant heaters placed over the bed was his first attempt. It proved to be a possible but impractical method because the rig required about 1500 watts to produce noticeable warmth. (Present-day infrared heat lamps used around the home are rated 250 watts.)

Kearsley discussed the excessive power requirements with Dr. Coolidge, who suggested that perhaps a more efficient type of heater would be an electrically heated cover that could be placed over the sleeper like a blanket.

This wasn't an entirely alien idea to Kearsley. In the 1900's he lived at a bachelors' boarding house near GE's Harrison Lamp Works. The heat was turned off at midnight, so he built a contraption that closed the window, kindled a fire in the grate, and started a phonograph at the proper time every morning. He also ran a length of resistance wire between two pieces of cloth and made an electric foot warmer for his bed.

Dr. Coolidge and Dr. Willis R. Whitney thought that the foot-warmer construction would be practical for a cover large enough for a bed.

First Heated Blanket

Kearsley's first electrically heated blanket consisted of two pieces of muslin sewn together at two-inch intervals. Nearly 200 feet of stranded 0.003-inch-diameter copper resistance wires with cotton-braid insulation were shuttled into the channels of the blanket. The total resistance was about 1.2 ohms. When connected to the output of a 110/11-volt transformer, the blanket put out 100 watts.

To make the blanket fully automatic it was necessary to devise a control that could automatically regulate the heat of the blanket according to changes in

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After graduating as electrical engineers in 1912, both Mr. Crowley and Mr. Holmes immediately joined General Electric and completed the Test Course. Mr. Crowley is now Manager of the Engineering Section, Automatic Blanket Dept., Asheboro, NC. Mr. Holmes is Supervisor of Production Engineering in the same department.

WILSON. BLANKET HAS EVOLVED FROM TWO LAYERS OF COTTON FLANNEL WITH STITCHED WIRE CHANNELS TO ONE-PIECE WOOL FITTED DESIGN.

Automatic Blanket

and R. G. HOLMES

room temperature. Many thermostatic controls were available, but none could supply an increasingly greater amount of heat as the room became cooler. Kearsley overcame this obstacle by inventing his own room-temperature responsive thermostatic control.

The control consisted of a heating element—connected in series with the thermostat contacts and the primary of the step-down transformer—placed near the bimetal of a thermostatic furnace control. When the thermostat contacts closed, current flowed through the blanket heating element and also through the heating element near the bimetal. This caused the bimetal to cycle the contacts on and off. As the room temperature dropped, the bimetal became less responsive to the adjacent heating element, and the contacts remained closed for a longer time. As the room temperature rose, the bimetal responded more readily to the heating element and remained open longer. By proper selection of resistance for the heating element near the bimetal, Kearsley was able to control the integrated wattage to the blanket from zero to 100 watts over a temperature range of about 20 F.

Dr. Coolidge and Kearsley tried the hand-made automatic blankets for a few nights and were amazed at the comfort they provided.

News of the promising development traveled fast—it was only a few days before Gerard Swope, then president of General Electric, requested an automatic blanket for himself. After only two nights of sleeping under the blanket, Mr. Swope was so enthused that he asked for 12 more automatic blankets to be made and field tested during the winter of 1934-35. He also suggested that proper facilities be organized to take advantage of the market potentialities of the new product.

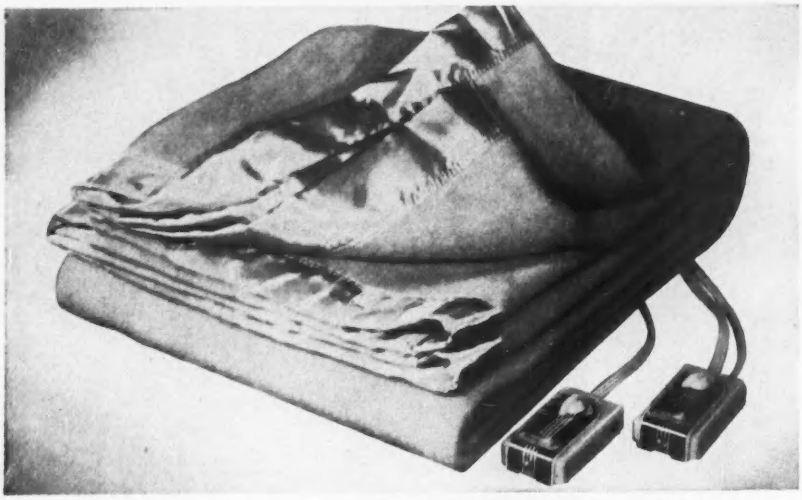
Commercial Production Begins

The demand soon became too great for Kearsley to make so many blankets for field tests. A search was started to find an established division within General Electric that could make additional blankets for field tests and also go into production on commercial automatic blankets. But no division in the Company was manufacturing a similar product. At this time, however, GE's Pioneer Products Division in Bridgeport, Conn., was just being established to develop and manufacture diversified new products. To this new division was assigned the task of developing and manufacturing automatic blankets.

The construction of this blanket was similar to the first one made by Kearsley. Cotton flannel was used with channels stitched two inches apart for the blanket wire. The wire was still stranded from 0.003-inch copper wires but the insulation was changed to rubber. As an additional safety feature, four overheat protective thermostats were located in the blanket to turn the power off in case of an overheat in the blanket. For greater adequacy range the wattage was increased to 180.

About this time it became apparent that additional safety against accidental overheat was necessary, so the number of overheat protective thermostats in the blanket were increased from four to six—50 percent additional protection.

During 1940 and 1941, automatic blankets really began to receive public acceptance. No longer regarded as a novelty, they were now appreciated for the comfort they gave to the sleeper. The only major change was separation



A SERIES OF IMPROVED AUTOMATIC BLANKETS WAS INTRODUCED IN 1945 AND LATER THE . . .

. . . SLEEP-GUARD SYSTEM GAVE GREATER PROTECTION AGAINST OVERHEATING, AND . . .

. . . FITTED DESIGN, FURTHER INSURING SLEEPING COMFORT, WAS MADE AVAILABLE IN 1953.

of the ambient responsive part of the control from the bulky transformer that could then be hidden under the bed.

Tests on Flying Suits . . .

Just when the automatic blanket business got into full swing, World War II broke out. Appliance production, including automatic blankets, was sharply curtailed and finally prohibited. Such an event was foreseen, however, and we obtained a government contract for development and manufacture of electrically heated flying suits. At the time that manufacture of automatic blankets was suspended, the development of an electrically heated flying suit was completed and the factory almost overnight converted to manufacturing electrically heated flying suits.

In developing the various items of heated clothing, we accumulated a vast amount of physiological data on human heat requirements under various climatic conditions. These data were gathered through hundreds of tests using humans as guinea pigs. In the postwar years these data and techniques obtained from physiological tests were especially useful in accurately determining the correct wattage and adequacy range of automatic blankets.

. . . Aid Blanket Development

When the war was over in 1945, Pioneer Products Division had a wealth of valuable information that could be directly applied to automatic blankets. Personnel were well-trained, and factory space was available to immediately shift production to automatic blankets.

The first greatly improved postwar automatic blankets were introduced in 1945. Because of the vast improvement in heater wire construction, the wire in these new blankets had a flex life over 100 times that of the prewar blankets. And the insulation was so greatly improved that 115 volts could be applied directly to the blanket. This eliminated the necessity of the bulky step-down transformer. Six thermostats for overheat protection were used, and their size was reduced by about half.

To more accurately determine the correct wattage for these blankets, a bedroom was constructed in the laboratory so that the temperature could be closely controlled to any specified setting. Surveys disclosed that very few bedroom temperatures go below 40 F. And in this bedroom more than 100 people were tested to determine the wattage in the blanket necessary to maintain comfort at 40 F. Using the same people we conducted tests to find the bedroom temperature that required no heat in the blanket for sleeping comfort.

During these tests the comfort of the sleeper was not measured by his own observations but was accurately determined by equilibrium of body temperature measurements. The technique of making these measurements was developed during the war in testing various items of electrically heated clothing.

When the results of the tests were evaluated, we found that the average wattage necessary to maintain comfort at 40 F was 180 watts; the temperature at which no heat was required was 65 F. This indicated that the control mechanism must supply heat to the blanket lineally from zero watts at 65 F to 180 watts at 40 F. Because of the variance in individual requirements, however, a manual adjustment was built into the control. Its purpose was to supply more or less heat to the blanket by shifting the 25-degree adequacy range of the blanket from a higher to a lower temperature.

Problem of Overheat Protection

This first postwar series of automatic blankets was manufactured from 1945 to 1948. No changes were introduced during that period except to step up the overheat protection by increasing the number of protective thermostats in the blanket from six to eight, and finally to nine. This need for additional protection against overheating brought about the first major design change in the electric blanket since its introduction.

Protection against overheating as a result of misuse is one of the major problems we face in designing electric blankets. Other electric appliances are seldom left closely surrounded by insulating material that can prevent normal heat loss, but an automatic blanket may be folded up and covered with other bedding so as to trap the heat developed and cause a dangerous temperature rise. The folding may completely exclude any of the nine thermostats, so we decided that instead of adding more thermostats, a method to provide complete protection over the entire wire length should be investigated.

One means we considered for eliminating thermostats was an electronic system that measured the resistance of the heater wire itself. This didn't prove completely satisfactory because tests indicated that a small section of the blanket could overheat to a dangerous level while the remainder of the blanket would not rise appreciably in temperature. We decided that a material with a negative-temperature coefficient of resistance was needed. As a first attempt, carbon was impregnated into a thermoplastics and tubed over standard construction heater wire. Over this was spiraled another ribbon of copper wire. Despite the large resistance change of the plastics with temperature, manufacture was difficult because the carbon-impregnated thermoplastics compound was soft and the ribbon tended to cut it.

Control-circuit Design

Then we found that nylon had a very high leakage current at high temperatures, so a sample was made and tested. Because it was tough and withstood an outer wrapping of copper, the nylon proved quite satisfactory. In addition, it had a high melting point that made it desirable from the standpoint of repeated overheating. Tests on the nylon coating showed a large change in impedance with temperature change.

In designing the control circuit for the nylon-coated wire, two fundamental considerations were met: complete failsafe characteristics and positive overheat protection.

Complete failsafe characteristics were obtained in the control by use of a resonant circuit for supplying voltage to the relay coil. An open or short circuit of any component will either immediately turn the control off or will have no adverse effect on overheat protection. In the wire itself any open or short circuit, except for an open circuit in the heater wire, reduces the resonant voltage to turn the control off. An open circuit in the heater wire obviously needs no supplementary overheat protection, because no current will flow through it.

In operation, when an overheat occurs in the blanket, the wire impedance decreases. This impedance appears between the outer conductor (signal wire) and both sides of the line supply and shunts the components of the resonant circuit. The control turns off when the impedance of the blanket wire decreases to approximately 50,000 ohms. This reduces the voltage across these components and, therefore, the potential across the relay coil. The control cannot be energized again until the temperature at the overhead section has been reduced. To turn the blanket off under normal conditions, a momentary Off button shorts the relay coil and opens the control and blanket heater circuit. A resistor in series with the capacitor is used as a current limiter to the blanket heater circuit for an additional failsafe device if the On button of the bedside control is jammed closed. If the switch is kept closed, the relay contacts will close the heater circuit, but on incipient overheat, the relay contacts will open the heater circuit and the resistor connects in series with the low-resistance heater circuit across the line voltage. This effectively drops the voltage to the heater wire and prevents heat dissipation.

This system of control provides much greater protection against overheat than can be obtained by using any number of thermostatic switches. The signal wire system of overheat control is, in effect, the equivalent of an infinite number of thermostats. Overheating along the wire length causes the control to de-energize the heater circuit.

Fitted Design

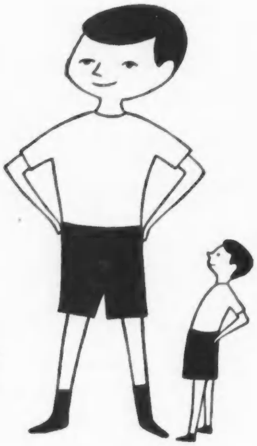
Blankets using this new system of overheat protection are called *Sleep-Guard* blankets. Production was started in 1948 and the design has remained substantially the same. In the early part of 1953 the shape of the blanket shell was changed to a fitted design. The bottom corners of the blanket are notched and stitched together to form an envelope that fits snugly around the bottom of the mattress.

With the introduction of this newest development in the automatic blanket industry, sleeping comfort on cold winter nights is further assured. Ω

CREDITS

Page	Source
Cover, 8, 9, 14, 16, 22, 42–46, 49	George Burns
10, 11, 15 (bottom), 18–19	U.S. Army
12	U.S. Navy
18–19	Western Electric
27, 28 (top)	Schenectady *G-E News*
38 (left)	Robert L. Mize
48 (top)	Grant Anderson
55, 57	John S. McCrindle

It is difficult to write a definition of the American way. But it is easy to find good examples. Here is one:



Giant boy

Scientists now foresee that the already dramatic electrical revolution in this country may be only in its infancy.

The giant now appears to be a boy, with most of his weighty growth still ahead. When such fantastic gains have already been made—in lights, turbines, electronics, TV, radio, electrically powered ships, trains, factories, homes—where can the imagination possibly go from here? What are some of the predictions?

Take a personal thing first. Millions of homes will have heat pumps to heat and cool automatically—using electricity for fuel.

You can expect to cook food someday by electronics—in seconds. Electrical incinerators will consume your waste paper and waste food. Dust will be taken from the air electrically. The day may come when TV screens hang like pictures on the wall, with only a tiny wire to the set.

Nuclear fuels are on the timetable of the scientists. Energy from the atom will eventually be a major source of power, regardless of whether fossil fuels are seriously depleted. By century's end, most new plants generating electricity will operate with atomic (fission) fuel. Aircraft, battleships, and the like will measure fuel consumption in grams.

What would converting sea water to fresh, at low cost, be worth to drought-deviled seaboard cities? This is possible and will be worth billions to the public. Storing heat from the sun is another long-range project of scientists.

As simply as we can say it, we are beginning, not ending, an era of possibilities involving the health, comfort, welfare and defense of the nation.

The year 2000 looks big and distant. Actually it is only 46 years away. By then, any puny prognostications made today will have been rewritten many times. But larger. Electricity has always been a field where each new fact generates many more things new. The years should be interesting to watch.

You can put your confidence in—

GENERAL ELECTRIC