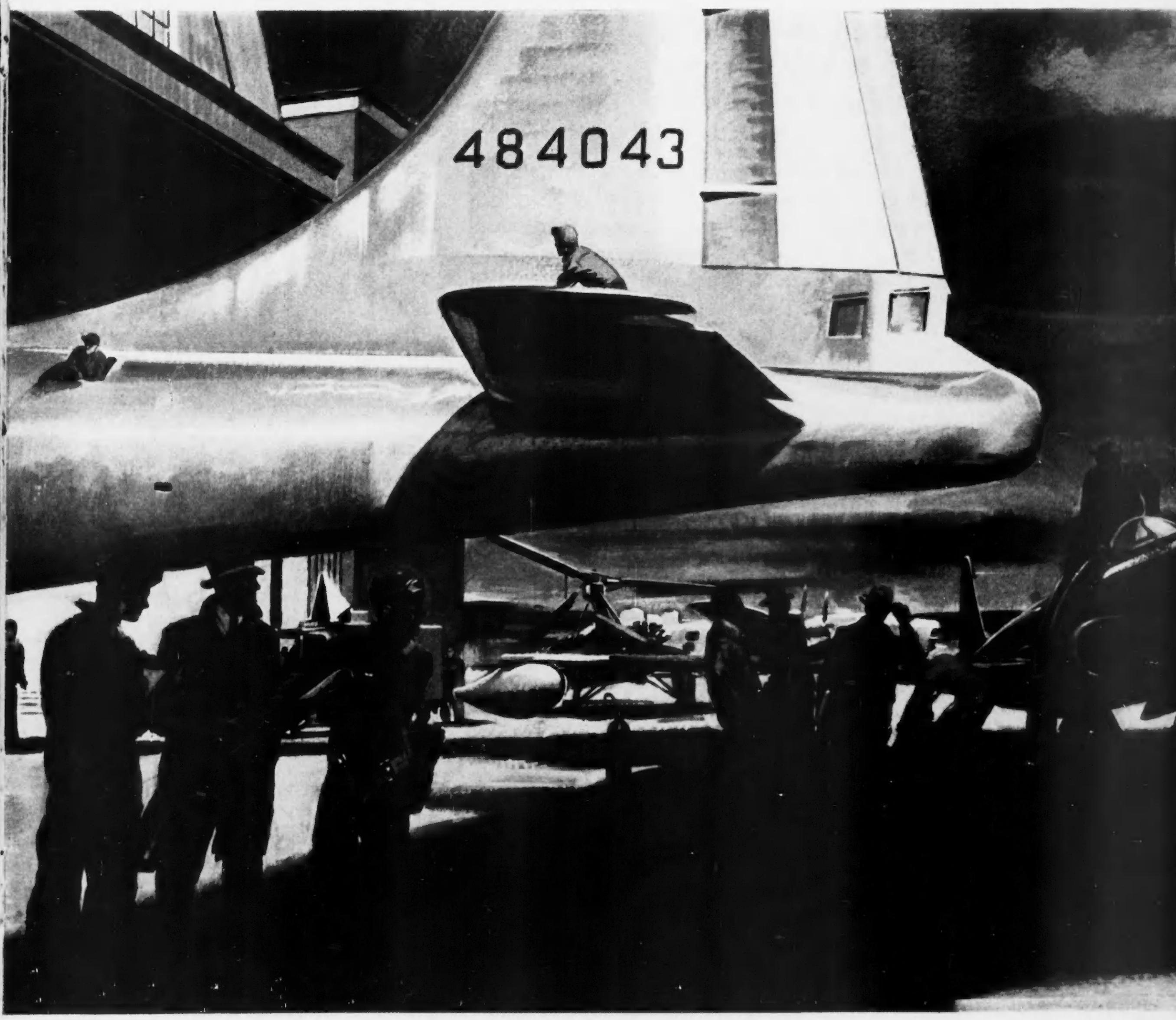
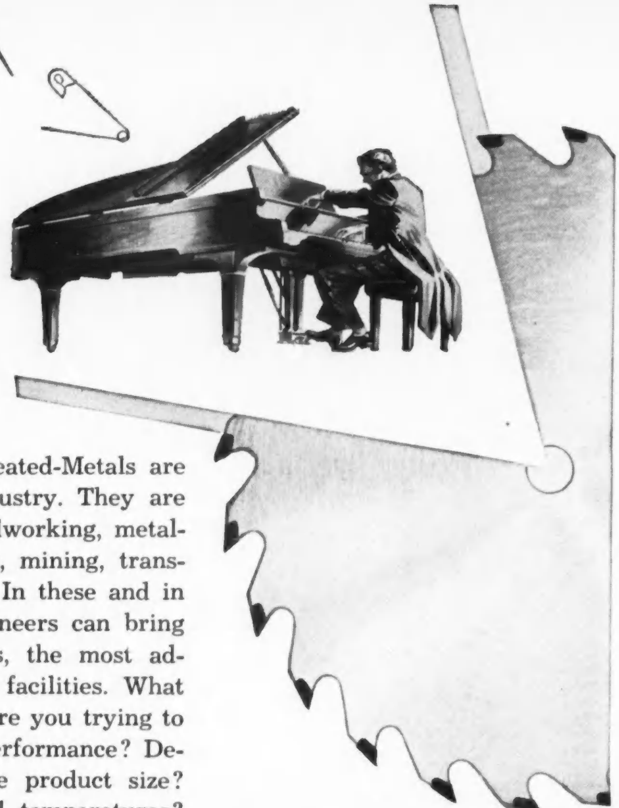
GENERAL ELECTRIC Review



MAY 1954

From pins to pianos



Carboloy Created-Metals are answering many design, production and cost problems

Today, more than ever, Carboloy Created-Metals are being applied across-the-board in industry. They are solving problems in the fields of woodworking, metalworking, ceramics, chemicals, textiles, mining, transportation, electronics, and petroleum. In these and in many other industries, Carboloy engineers can bring to the applications of Created-Metals, the most advanced engineering and development facilities. What engineering problems do *you* have? Are you trying to increase production runs? Improve performance? Decrease costs? Reduce wear? Decrease product size? Eliminate parts? More closely control temperatures? Let Carboloy technicians assist you.

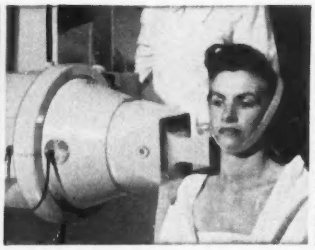
This brochure can help you — send for it, today. Learn how many industries are applying Created-Metals to improve design, increase production, lower costs. Write on your company letterhead for this brochure – "Changing the Shape of the Future with Carboloy Created-Metals." Carboloy Department of General Electric Company, 11201 E. 8 Mile Blvd., Detroit 32, Michigan.

CARBOLOY®
CREATED-METALS

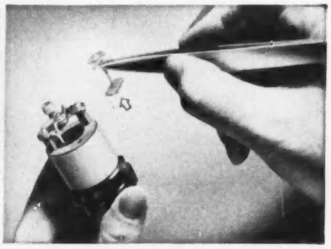
"Carboloy" is the trademark for products of the Carboloy Department of General Electric Company

THERMISTORS help actuate temperature compensation devices in supersonic rockets. Extremely sensitive to thermal changes, Carboloy Thermistors, with their negative temperature coefficient of resistance, are used in thermostats, switches, time-delay devices, and in other controls.

CEMENTED CARBIDES help prepare baby's food – and yours, too. Spray nozzles of cemented carbide, used in homogenizing and dehydrating food products, decreased corrosive-abrasive action; increased nozzle life from 100 hours to 3000 hours.



HEVIMET, in this cancer therapy unit, gives 40% more gamma ray protection than lead. Because it is not only denser than lead, but also 50% heavier, Hevimet also finds important uses wherever maximum weight in minimum space is essential.



PERMANENT MAGNETS can greatly simplify design, as small, powerful Carboloy permanent magnets did in this aircraft fire-detection device. The magnets eliminate need for electronic amplification, operate from minute thermo-couple current.

SETTING THE PACE FOR INDUSTRIAL PROGRESS

MAY 1954 • VOLUME 57 • NUMBER 3

GENERAL ELECTRIC Review

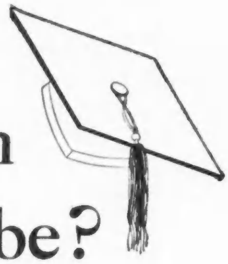
EVERETT S. LEE • EDITOR PAUL R. HEINMILLER • MANAGING EDITOR

COVER—Engineers, pilots, and ground mechanics are an important part of the team at GE's security-wrapped Flight Test Center, near Schenectady, NY. Artist Tran Mawicke caught this scene as fighter plane at right is prepared for a flight test; tail projecting from the hangar belongs to a B29 *Superfortress*. For the Flight Test story, see page 8.

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.

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

How smart can machines be?



Back in the twenties there was a stage play about a factory that made mechanical men, who repaid their creators by trying to wreck civilization. The term "robot" has made people uneasy ever since.

How smart can a machine be? At General Electric we're beginning to find out. For some years now we've been working with machines that come startlingly close to duplicating the thought processes of men.

Can they outsmart men? The reassuring fact is just the opposite: they make men even smarter by taking over routine mental chores and freeing men for the creative thinking only human minds can encompass.

General Electric is using machines with "electronic brains" in engineering, accounting and management to speed our most important product, progress.

A jet engine used to be designed by trial and error. You had to build it first, or a costly model, to find out how it would work. Now, an electronic computer helps solve long and complex jet development problems in advance. In 15 minutes it goes through 8 million mathematical calculations and comes up with an answer that would take a mathematician 7 years. With "think machines," engineers can bring you new and better products quicker.

It used to take seven days to put together the payroll in one of our plants. Now an "electronic brain" gets rid of the drudgery and cuts the time to four hours.

In management, "hunch" is giving way to fact. Electronic data-processing machines can zip through head-spinning statistics on things like market changes, product design factors and income trends to come up with the answers General Electric managers need to make sound decisions, not hopeful guesses. Patterns emerge that make it possible to avoid errors. In time new light may be shed on the reasons for boom and bust. It looks like everyday living might catch up at last with our fantastic progress in science.

Machines that can read, write, do arithmetic, measure, feel, remember, now make it possible to take the load off men's minds, just as machines have eased the burden on our backs.

But these fantastic machines still depend on people to design and build and guide and use them. What they replace is drudgery—not people. Or General Electric wouldn't be so enthusiastic about them. Because it's people, with their hopes, desires and jobs, that we depend on for customers. Machines can't dream.

Don't worry; smart though they are, machines will never be as smart as people. Not while people are smart enough to think them up, smart enough to let them do man's drudging work.

Progress is our most important product

GENERAL ELECTRIC

GERMANIUM PRODUCTS

The complete General Electric line for use in electronic and electrical power circuits requiring

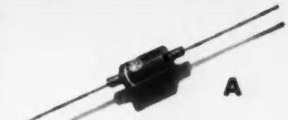
DETECTION . . . RECTIFICATION . . . AMPLIFICATION!

CATEGORY	KEY	RETMA DESIGNATION	G-E TYPE	PEAK INVERSE VOLTAGE	CONTINUOUS OPER. INV. VOLTAGE	MIN. FORWARD CURRENT (MA) AT + 1V	MAX. INV. CURRENT (μa) AT — 50V	AVERAGE RECTIFIED CURRENT (MA)	PEAK RECTIFIED CURRENT (MA)	SURGE CURRENT (AMP)
GENERAL PURPOSE	A	1N48	G5	85	70	4.0	833	50	150	400
		1N51	G5C	50	40	2.5	1667	25	100	300
		1N52	G5D	85	70	4.0	150	50	150	400
		1N63	G5E	125	100	2.5	50	50	150	400
		1N65	G5G	85	70	2.5	200	50	150	400
		1N75	G5M	125	100	2.5	50	50	150	400
TV	A	1N64	G5F	20	Min. dc current in 44 mc rectifier—100 μa					
JAN (Ceramic case)	B	1N69	G5K	75	60	5.0	850	40	125	400
		1N70	G5L	125	100	3.0	300	30	90	350
		1N81	G5P	50	40	3.0	10@—10v	30	90	350
VHF	A		G6	15	Min. Rect. Eff. at 100 mc and 2 v signal—60%					
UHF	A	1N72	G7		+3 db max. noise factor over 1N21B in 500 mc mixer CKT			25	75	
			G7A					25	75	
			G7B	5	75% min. rect. eff. at 100 mc for detector			25	75	
			G7C	5				25	75	
			G7D	5	Tested for sharpness of break E-1 char. for freq. Multiplier			25	75	
			G7E	5				25	75	
			G7F	5	60% min. rect. eff. at 100 mc for detector			25	75	
			G8G	5				25	75	
MATCHED PAIRS Note (1)	A	1N48 (2)	G8	85	70	4.0	833	50	150	.400
		1N52 (2)	G8A	85	70	4.0	150	50	150	.400
		1N63 (2)	G8B	125	100	4.0	50	50	150	.400
		1N75 (2)	G8C	125	100	2.5	50	50	150	.400
QUADS	E	1N73		75		Note (2)	50@—10v	22.5	60	.100
		1N74		75		Note (3)	50@—10v	22.5	60	.100
DIFFUSED JUNCTION RECTIFIER		1N91		100	30			150	470	25
		1N92		200	65			100	310	25
	C-1	1N93		300	100	(ALL RATINGS AT 55° C)		75	250	25
	C-2	1N151		100	30			500	1570	25
		1N152		200	65			500	1570	25
		1N153		300	100			500	1570	25
		1N158		380	185			500	1570	25
TRANSISTORS	D	2N43	PNP Junction Transistor, Current Amplification 0.98, Maximum Power Gain 40 db, Maximum Collector Dissipation 150 mw.							
		2N44	PNP Junction Transistor, Current Amplification 0.95, Maximum Power Gain 39 db, Maximum Collector Dissipation 150 mw.							
		2N45	PNP Junction Transistor, Current Amplification 0.92, Maximum Power Gain 38 db, Maximum Collector Dissipation 150 mw.							

(1) Matched at +1v so that current through higher resistance unit is within 10% of lower resistance unit.

(2) Consists of 4 balanced diodes. With 15 ma forward current, the voltage drop of each diode is 1.3v min. and 1.7v max. All diodes are within 0.1volt of each other, and voltage drop of a pair is 0.03 volts of each other.

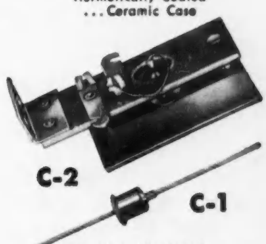
(3) Consists of 4 balanced diodes. With 15 ma forward current, the voltage drop of each diode is 1.2v min. and 1.8v max. All diodes are within 0.2v of each other and voltage drop of a pair is 0.1v of each other.


A

WELDED GERMANIUM DIODES


B

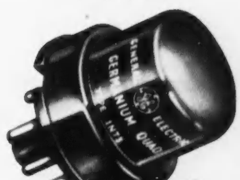
SPECIAL, GAS-TIGHT DIODES
Hermetically Sealed . . . Ceramic Case


C-2 C-1

DIFFUSED JUNCTION GERMANIUM RECTIFIERS


D

JUNCTION TRANSISTORS


E

GERMANIUM QUADS

SEND FOR THIS HANDY REFERENCE MATERIAL

GERMANIUM DIODE HANDBOOK, complete specifications on G-E germanium diode products. Contains diode and rectifier characteristics and applications, curves on resistance, voltage, temperature, efficiency, circuit diagrams covering AM, FM and TV receivers, radar, carrier current. $1.25 post-paid. Send your check or money order today to: *General Electric Company, Section X764, Electronics Park, Syracuse, New York.*

GERMANIUM DIODE INTERCHANGEABILITY CHART IS FREE UPON REQUEST

You can put your confidence in—

GENERAL ELECTRIC

THE ENGINEER—
AND HIS ENGINEERING SOCIETIES

The engineer is a builder. And not only does he build the products of industry, he builds engineering societies—strong, active organizations of great power. In them he hears his associates tell of new advances in engineering, new systems, new products, new horizons. And he is a much better engineer for those associations than he would be without them.

The freedom of telling of our accomplishments has been a key to unlock the door to new vistas. It is the introduction to new ideas, to new accomplishments, to new friendships. To walk and talk with one's fellow engineers is to feel the thrill of the profession, to experience the great motivating power of achievement. Every engineer can have the thrill of this experience.

I well remember many years ago when, as a young engineer, I had the urge to write a paper and submit it to the American Institute of Electrical Engineers of which I was an Associate Member. I had a good friend in Dr. Louis Robinson, and he suggested I write a paper tracing the Btu's from the coal pile to their final appearance in the electric motor, and telling how the temperature was measured at various points in the process. I wrote my paper, sent it in, and received it back marked "Too Commercial." I threw it in the wastebasket and vowed I'd never write for AIEE again.

Time passed. We moved into the work of improving the high-voltage cable insulation, so essential to the transmission of large blocks of power for our cities. Voltages were increasing—they had to be increased to transmit the necessary power. Sixty-six thousand volts were not high enough; we had to go up to 132,000 volts—and oil-filled paper cable insulation came into being.

There was to be an AIEE session in New York, and I was asked to write a paper. The subject was: "Testing High-tension Impregnated Paper-insulated Lead-covered Cable." I wrote it with fear and trembling, remembering my first paper—but it was accepted. My presentation of ten minutes came and went.

And then followed the discussion. Engineer after engineer discussed the paper. We adjourned for lunch and came back after lunch to continue the discussion in formal session. Finally, at about 4 pm, the discussion was stopped to let the 2 pm session begin. Other discussion was to come in by mail. In the AIEE *Transactions* today, vol XLIV, page 104, you will find recorded 13 pages of discussion. There are few papers which are discussed at such length. That meeting started a new era for the dielectricians—an era which still continues today.

Once I heard a reporter on a great New York newspaper say that he had gone into the Engineering Societies Building and listened to the engineers as they gave their papers and that he couldn't understand a word they were saying. It is that sort of thing which gives rise to the idea that the engineer is inarticulate and does not know how to put his story across, or that he is too narrow. Small wonder that the public does not understand him, and that he does not have the recognition he deserves.

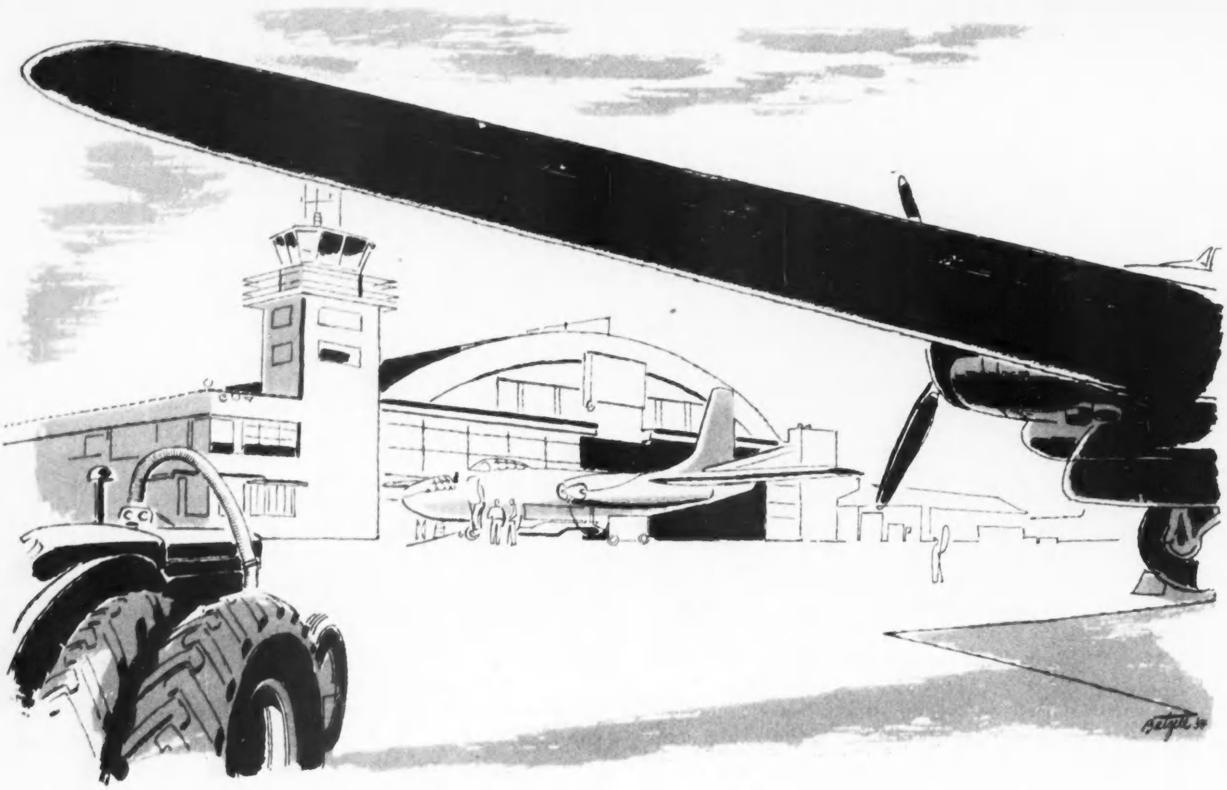
What a picture! How thankful we can be that at least no one questions his engineering nor his engineering accomplishments. The world needs the engineer, and it is to his great and outstanding honor and glory that his engineering has been superlative.

Now I would not demean the activities of the engineer beyond the technical; they are more important than he himself often realizes. In the past these activities have been furthered in some of the technical engineering societies, but it is now more and more evident that increasing legislative problems of fundamental scope require more continuous attention. It is in the professional engineering society, then, that the engineer will have to increase his attention and his ability and his participation.

I have always said that every engineer should belong to at least one of the great technical engineering societies appropriate to his field. Nowadays we have not only the technical engineering society, but also the professional engineering society. These two spell greater responsibility for the engineer, I grant you—but I have learned in life that the reward of work well done is always more work. So it is with the engineer and his engineering societies.

Everett S. Lee

EDITOR



Laboratories in the Sky

***Review* STAFF REPORT**

While a controversy exists over the merits of American- versus Russian-built airplanes, the fact persists that the score in the air war over Korea was a lopsided 14 to 1 in our favor. What is the explanation? Many of our returned airmen say that the Russian-built sweptwing MIG-15's and their pilots were good. But even granting ourselves a slight edge in the aerodynamic and human departments doesn't alter the one-sidedness of the score.

Perhaps the answer lies partly in the myriad electronic devices and control systems with which our planes are laden—and with which the Russian planes are not. This view has some justification when you consider that it takes from 7 to 10 years to develop a new power plant or a new fire-control, bombing, and navigation system. And each year our government spends millions of dollars to develop just such equipment, either through its own agencies or in conjunction with private industry.

General Electric is one company—there are numerous others—that takes an active part in this co-operative development program. It is natural enough. For as long ago as 1918, GE's Dr. Sanford Moss developed the turbosupercharger, making it possible for aircraft to fly in the rarefied air of higher altitudes. But in contrast to Dr. Moss's time—he had to go atop Pike's Peak to find a suitable climate for testing his turbosupercharger—GE now maintains its own modern flight-testing facilities. The operation is known formally as the Flight Test Center of the Aeronautic and Ordnance Systems Division, conveniently shortened to Flight Test. Since 1946 it has been functioning efficiently and quietly at the Schenectady County Airport. Before that, it was carried on first at LaGuardia Field, then at Brownsville, Texas.

Illustrations by E. A. Batzell

Not so long ago, I decided to get an engineer's-eye view of this little-publicized operation to learn something of the men and machines that play such a large part in America's air defense. After the necessary clearances were granted, I set up an appointment with Curtis G. Talbot, Manager of the Flight Test Center.

As I drove north along Route 50 that day, a sign cautioning "Low Flying Planes" indicated I was approaching my goal. About 300 yards farther down the highway, another sign at the head of a narrow side road announced "General Electric Company, Only Authorized Persons Permitted, Apply at Guard Station." I swung onto this road and in less than a minute pulled alongside the building that houses the administrative and engineering offices of Flight Test.

The small two-story building and flight-control tower atop it are joined to one side of the hangar—a huge structure of poured concrete and steel whose outside surface is painted a dull black. Several large military planes stood motionless on the hangar apron in front. After producing identification for the guard and a receptionist, I proceeded up a flight of concrete stairs to Talbot's office.

Talbot, a stocky reddish-haired engineer and licensed commercial pilot in his early 40's—Curtis Garwood Talbot is his full name—is top man at Flight Test. He greeted me informally and remarked in an unhurried midwestern accent that a little publicity would be fine, provided it didn't violate security. A totally relaxed man whose eyes smile as he talks, Talbot sat down in his swivel chair while I took up a seat close by a small conference table.

"It's a lot different here than in a normal laboratory where you plug in a voltmeter and take a reading," he said. "We provide the means for the design engineer to flight-test his equipment. We lug a plane to the proper altitude and environment and check the performance of the device."

He sat back, folding his hands in his lap. They do two general kinds of development testing, he told me. The first is to install developmental prototype systems in planes that, except for a Company-owned B25, are bailed to them by the government. Then when the prototypes are fully developed, the Air Force or Navy furnishes planes whose capabilities more nearly approach those the equipment is designed for. After system installation the planes are taken to military bases and the systems evaluated against competitive equipment. "Whichever they feel is best, they'll buy," Talbot remarked philosophically.

The second type of work they do is installing fully developed prototypes directly in military aircraft and "de-bugging" them for subsequent evaluation. Their activities are, however, quite varied.

"Take the Convair B36 bomber," Talbot said. "It has six piston engines. We thought it would climb a lot better at higher altitude if we added four jet engines. But jet engines are difficult to start at high altitudes. So we had to develop high-altitude starting equipment. We immediately began work using a B29 *Superfort* and found that the jet engines needed several modifications . . . couldn't possibly have done it on the ground." Some of their earlier work involved target aircraft and simulated fighter attack, he went on to say. For this operation they had to mount a camera in the plane to record gun-direction and radar-instrument readings simultaneously.

The soft-spoken manager of Flight Test picked up a pencil and began toying with it. "Right now we're making an advanced model of the automatic approach coupler," he said. "It will enable high-speed military aircraft to make safe landings in bad weather by latching the plane's autopilot to the instrument landing system of an airport." I asked him what the military requirements of such a device are. "Reliability," he declared. "And lightweight. Why, if weight were no problem we could build equipment to do any kind of a job!" He rocked forward in his chair. "This is the aircraft problem—weight! That's why the job can't be done anywhere except in the air!"

A man with prematurely gray hair and the demeanor of a college professor entered. Talbot introduced him as Weldon Orme, supervisor of engineering at Flight Test. He would get me started on my visit, answer any technical questions, and arrange for me to make a test flight, I was told. I thanked Talbot for his co-operation and we moved on to the engineering supervisor's office.

The small room from which Orme directs engineering contained a busy-looking desk, a table, and a filing cabinet. It looked out onto the three runways of the county airport (a fourth is under construction), with Schenectady rising on a hill in the distance. On his desk was a squawk box—part of the intercom system that constantly blared throughout the engineering offices. A speaker and a radio mike on the wall above his table were used to talk with the control tower and the test planes in flight.

Orme offered me a cigarette and we sat down. A native of New Mexico, he is a composed individual who gets right to the point. The function of his groups, he explained, is to bridge the gap between conception of equipment and its successful operation in aircraft. "Vibration in

Curtis Talbot: "This is the aircraft problem—weight!"

flight, for example, is not only harmful to equipment but introduces spurious signals as well," he said placidly. Someone at station five paged Orme over the intercom. He reached over with a long arm and switched to the channel. A low-pitched voice filtered through the background blare.

"Weldon, does the new organizational setup mean we have to change the titles on our reports?"

"Yes." The voice at the other end moaned and Orme smiled faintly. "Say, Allen, come up here when you get a chance, will you? Over." Turning back to me he said, "That was Allen Bell, project engineer of the North American B45 *Tornado*. I'd like you to meet him." Then he continued the conversation. Stress analysis, mechanical design, and metal fabrication—all are important aspects of their business. He cited installation of a radar gunsight into the North American F86E *Sabrejet* as a case in point. "We had to mount it rigidly to the plane, yet keep it relatively free of vibration when the plane's guns were fired. And to further complicate matters, the sight had to be located near the pilot. That meant positioning its mounting structure in the crowded space of the cockpit. . . ." A modified B26 bomber hauled by a rubber-tired tractor came into view on the hangar apron below. Jutting from one wing was a long, slender boom with a fin-like gadget on the end of it. When I asked Orme what the boom is used for, he said it is a vane to detect yaw and pitching of the aircraft in flight. It is being used in the development of a new flight-control system.

The system works similarly to a gun director, only it directs the aircraft at the target instead. Orme explained it in more detail: "The pilot is directed to a target plane by ground radar. As the pilot nears the target, he latches onto it with his own radar system, which then automatically tracks the target and fires the interceptor's missiles. When its missiles are released"—he arced his hands through the air—"it automatically breaks away from the target plane."

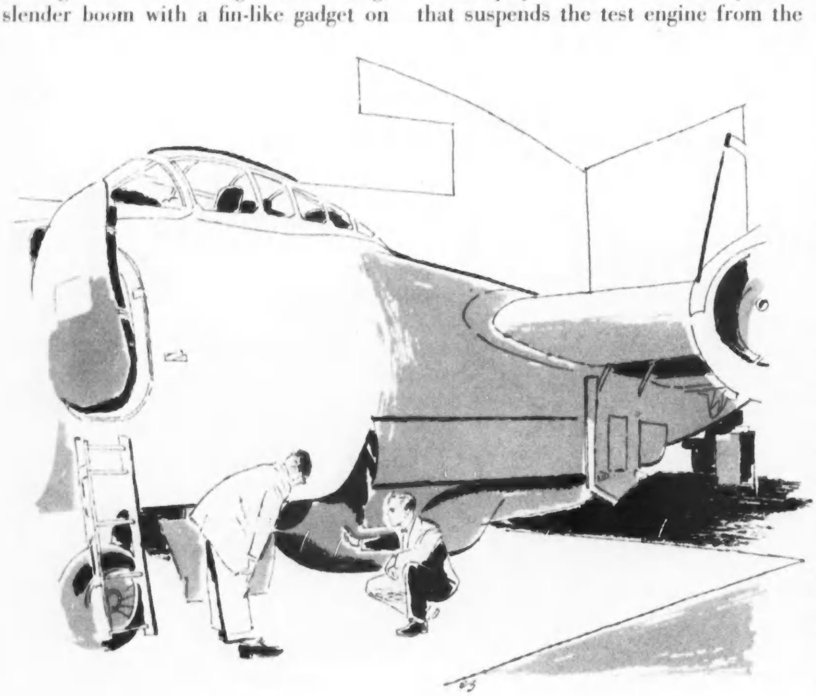
Orme told me that he has been with Flight Test since its inception in 1942. He recalled that the B23, a twin-engined medium bomber, was the first plane modified for test purposes. They have come a long way since then, he related. At present they have six test planes, all in the bomber class except one—the Douglas F3D *Skynight*. Two of the bombers are equipped with test beds for developmental jet engines.

The British conceived the test-bed idea. And in 1944 General Electric borrowed it, converting a couple of B24's (the sturdy *Liberator* bombers of World War II) to develop the J33 turbojet engine. Then in 1946 they got hold of a B29 *Superfort* with a retractable nacelle that suspends the test engine from the bomb bay during flight. They used it to develop the J47 turbojet, and recently, the J73—GE's newest jet engines in mass production. Their B45 *Tornado*, obtained in 1951, was the first jet bomber to be used as a jet-engine test bed.

Allen Bell, the pipe-smoking project engineer of the B45 *Tornado*, sauntered in. He is tall, blond, and in his 30's. After a brief introduction and a word of explanation from Orme, we moved on to his office, a fairly large room where several people were at work. His group, he related, flight-tests the J73 jet engine. Generally, the tests are made on the engine's control system, but occasionally, when there is time, they run performance and endurance tests on the engine itself. Bell, a friendly fellow who speaks in a sometimes inaudible voice, pulled out two chairs from a table in the center of his office and we sat down.

When they receive an engine for test, he continued, they have to instrument it—they build some of their own instruments—to get the right data. It is almost always a matter of recording temperatures, pressures, and flows. They use photopanels and oscillographs to record the data in flight. "The photopanels give you a moving picture of what's happening," he said. A mechanical engineer from the University of Michigan, Bell was a meteorologist during World War II. He still keeps a close watch on the weather with his own charts, although they have other sources of such information at Flight Test. "We don't like to fly in instrument weather," he confided. "Tests aren't long enough to justify it."

Jet-engine compressor stall was a typical problem his group had come up against. In an axial-flow turbojet such as the J73, he explained, the compressor will stall out under certain conditions. "When that happens, you get rough pulsations throughout the plane, and the engine's tailpipe temperature goes up because you're getting too little air and too much fuel into the combustion chambers." So their problem was to determine how much fuel they could inject into an engine without stalling it, under all conditions of airspeed, altitude, and engine speed. To solve the problem they took a J47 turbojet in the air and simulated throttle bursts, increasing fuel-flow until the engine stalled. "We found out how much fuel you could feed it at all speeds so that its control system could be trimmed accordingly." Bell told me the Air Force wanted to bring an engine from low to high speed



Bell pointed out the 22-foot-long bomb bay housing the test engine.

in the shortest time possible. "That's an important selling point with them," he said.

At his suggestion we went down to the hangar floor to have a look at his test plane. Standing in one corner of the huge concrete structure was the Navy's F3D *Skynight*—a lethal-looking twin-jet interceptor capable of 530 mph—with its nose cowling removed. Nearby poised a small cabin plane, its silvery skin contrasting sharply to the nightfighter's bluish-black. But both would have fitted under one wing of the aircraft we headed toward at the other end of the hanger—Allen Bell's plane, a four-engined jet bomber known as the B45 *Tornado.* At Flight Test it is simply called the B45 test bed.

Bell pointed to the plane's 22-foot-long bomb bay housing the partially lowered test engine. During flight the engine is suspended several feet below the plane. "The engineer operating the test engine has to be in interphone contact with the pilot," Bell shouted above the din of roaring engines as a bomber revved up on the hangar apron. "The pilot must know when you're going to make a throttle burst so he can prepare for it—otherwise the ship's nose will lurch upward."

We moved farther along to an open escape hatch near the plane's tail. I followed him up through the small opening and found myself in the aft unpressurized section where the instrument photopanels are located. Bell raised a box-like hood about two feet square, disclosing a cluster of instruments on a vertical panel, with a special camera mounted a short distance away. There were 48 instruments in all, each having its own flood lamp. Farther back in the compartment squatted a large chart recorder that could record 96 consecutive temperatures, Bell told me with some admiration.

Back in the engineering offices he introduced me to Eugene Equi of the aircraft electronics accessories group. Equi, a hard-working individual with a high forehead and a harried expression, is responsible for mechanical installation of equipment in aircraft at Flight Test. A littered desk pushed up against a wall near an entrance served as his bailiwick. He had a stiff back from crawling around inside the F3D *Skynight* the day before, he told me humorously, offering me a chair. That is typically his problem—trying to find space. "In fact," Equi declared, "when there's no room left in the airplane, I'm happy—

Gene Equi: "It's good for 10 G's," he said proudly.

that means my job is well done. It takes quite a bit of ingenuity to get all the units installed so you'll still have room left over for guns and ammunition."

"The problem is further complicated," he went on, "because when you do find space for equipment, there is nothing to tie it to." Besides designing, developing, and supervising installations, Equi has to make the necessary stress analyses and aerodynamic calculations that enable equipment to withstand the severe gravitational forces encountered in high-speed maneuvers, and to keep it free of vibration that might lead to errors in performance. He also acts as engineering consultant on all types of maintenance problems.

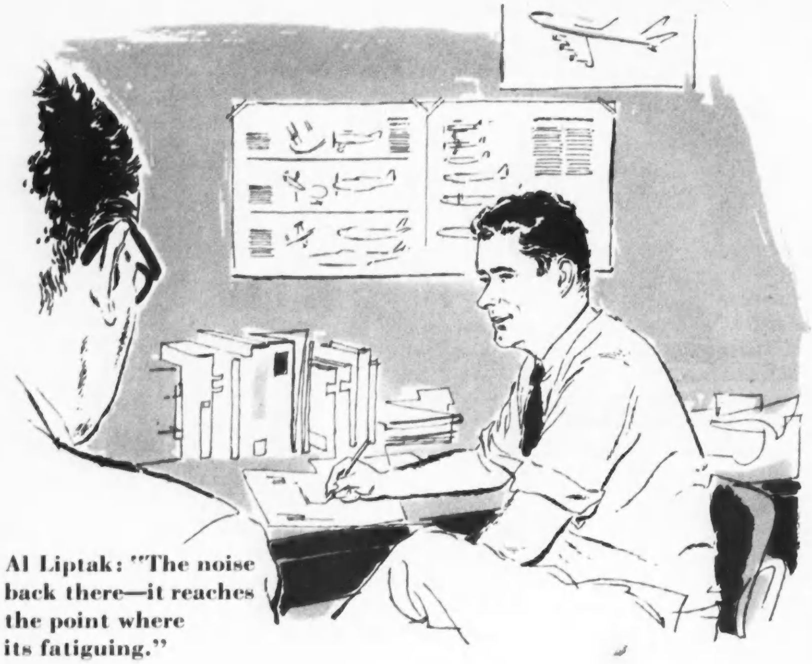
Equi is well-qualified for his job. He has logged 2500 hours of flying time in single- and multi-engine planes, though he does no flying on the job. He has an aircraft mechanic license and a commercial pilot license, as well as both flight and ground instructor ratings, and a degree in aeronautics. His services seemed to be greatly in demand; people constantly paged him over the intercom. Equi, a dynamic individual, would spring from his swivel chair each time, grab up a hand mike from the nearest desk, and say, "Okay, I'll be with you in a few seconds!"

He told me about a radar antenna mounted in the nose of the F3D that he thought would interest me; he termed it "a beautiful installation." On the way down to the hangar he said, "We had to place the radar antenna in the nose in such a way that it wouldn't pick up signals from other equipment. It had to rotate clear of all objects, so we made a mock-up of the antenna and got the smallest man to go in there and move the thing around."

Several aircraft mechanics were working on the partly dismantled nightfighter, but they seemed to pay little attention to us as Equi pointed out the support he'd designed. It was, as he said, a beautiful installation.

Three steel tripods bolted to a slab of armor plate and the bulkhead behind it formed a rigid support for a triangularly shaped radar mount. Clear and simple, it had been a problem in stress analysis. The nine supporting members were so arranged that, whichever way the aircraft was maneuvered, three or more members would counteract the force on the radar antenna. "It's good for 10 G's," Equi said proudly. "Maximum-load deflections are so small it may as well be anchored in concrete!"

He led me around the F3D. Visible through openings in its side were thick bundles of wires. "This airplane is jammed full of equipment," he said. "The B45 over there has space, but not this one—it's a small airplane and there's much more wiring." To find space for wiring, Equi related, they had to utilize the space beneath the fuel tanks. He steered me over to a little brick structure on the far side of the hangar where the planes' electronic equipment was assembled. Inside, wooden benches were laden with electronic components that, Equi explained, were only part of the equipment yet to



Al Liptak: "The noise back there—it reaches the point where its fatiguing."

be placed in the F3D. I commented upon the complexity of the stout bundles of colored wires that interconnected components—there seemed to be more bundles than components. Equi grinned. "You're looking at simple circuits," he said, "only a lot of them." We turned back toward the engineering offices. "Well, if there's anything more I can do for you, please let me know."

Early the next morning I strode up the narrow corridor of the engineering offices on my way to see Al Liptak, project engineer of the B29 *Superfort* and acting project engineer of the aircraft electronics accessories group. At the end, I entered a large room filled with desks and people. Liptak was bent over a desk in the far corner. When I introduced myself he smiled genially and said he'd been expecting me. He is a tall fellow in his mid-30's, with blue eyes, brown wavy hair, and an unusually amiable disposition. The B29 was the first plane to carry a J73 turbojet engine on a test flight, Liptak quickly pointed out. "We designed and built the retractable mechanism, the photopanels, the facilities for instrumentation." He said that the equipment in the B29 is similar to that in the B45 *Tornado*, a slightly smaller plane, but arranged differently. Doodling as he talked, he sketched the two planes in cross section for comparison. All the B29's instrumentation equipment is in a pressurized section aft of the test engine, and four men—three of them engineers—run the test from there. The pilot, copilot, and flight engineer are in the nose of the plane, along with a fourth man who operates some test equipment.

He told me that several months ago they flew to Sacramento, Calif., and stopped off at Los Angeles to take two engineers from North American Aviation for a demonstration flight. "The engineers sat in back with us and observed the in-flight characteristics of the J73 jet engine—they use it in their own planes." Liptak emitted a chuckle of satisfaction. "They said the demonstration was worth several written reports."

I asked him how the tests are run. "Well, we have a plan of test," he replied, and he began sketching again. "For example, we run off throttle position versus engine speed and get a series of curves like this. We've had plans of test over 30 pages long. With the equipment in the B29 we can record over 300 points. I daresay that's the largest capacity of any similar flight-test airplane in the country." A point, he went on to explain, is a pressure or temperature measurement at some place in the engine. In Liptak's group, each engineer is responsible for his particular phase of the test, and each supervises within his own category. "Once in a while we get together for group discussions," Liptak said, "and exchange information with one another. It's education within the group."

Flight tests usually last three or four hours, he explained. "We've covered intermediate altitudes up to 40,000 feet—been up to 45,000 feet—that's our max. I've seen it as cold as −85 F." Liptak's face took on a more serious expression. "By the way, a lot of people think flying is fun, but to us it's just plain old hard work. And when I say hard work, I *mean* it. For one thing, there's a continuous nervous tension. We're under oxygen most of the time, and it's uncomfortable to wear an oxygen mask for long periods. For another, flight costs are high, and we're trying to gain a maximum amount of information in as short a time as possible. The noise back there—it reaches the point where it's fatiguing!" Liptak looked up from his doodling and grinned.

There are two professional pilots at Flight Test, and I met one of them, Ed Richardson, later that day. A big loose-jointed individual with reddish hair that falls down in front of his eyes, Richardson had been a bomber pilot during World War II and a commercial airline pilot for the three years following. Before coming to Flight Test, he got a degree in aeronautical engineering. I asked him how you get to be a flight-test pilot. He shrugged his broad shoulders. "Well," he replied, "you need broad experience as a pilot to be checked out in all the types of aircraft we operate." The checking out procedure, he went on, usually takes place at Wright-Patterson Air Force Base in Ohio. He told me he piloted the B26, the B25, and the B17 at Flight Test. He is now trying to get checked out on the B45 *Tornado*, a four-jet plane. "Gene," he said, referring to the chief pilot, E. M. Beattie, who occupies the same office but was away at the time, "is checked out on a great many planes. He's one of the few pilots in the country with upwards of 700 hours of four-engine-jet flight time."

Between flights, Richardson went on, a flight-test pilot familiarizes himself with the test aircraft. This is necessary because, unlike airline pilots who get to know their plane as they know their own car, flight-test pilots fly only 40 or 50 hours a month—not too much—and that time is divided among four or five aircraft. To be proficient in operating the different flight controls on that many airplanes, he continued, a pilot has to spend a lot of time on the ground studying them. He told me why: "Take the B45, for example. Besides the controls that normally operate the airplane in flight, you've got a bunch of emergency systems. Should something go wrong, you must instinctively know which handle to pull."

Richardson thinks an engineering degree is the coming thing for flight-test pilots. "When we run tests on the autopilot in the B25, I have to operate it from the pilot's position. So naturally I should know something about how an autopilot works. Then I'm asked to criticize it, and comment on any malfunction." He gestured with his hand. "When you do that, you should at least know what an autopilot is." He didn't think that 10 years from now a flight-test pilot would be able to get along without an engineering degree. "Matter of fact," he confided modestly, "I'm going to night school now because I don't understand all these things yet."

"We're going down," Gaynor said to no one in particular.

Liptak called the following day to tell me a B25 test flight was scheduled at four o'clock. And an hour before flight time I arrived at the hangar stock room where a suit of coveralls, a flight jacket, a parachute, earphones, and a throat mike were issued to me. The B25 was already out on the apron, with Ralph Barrett, the plane's crew chief, standing by. I would ride with him in the sedan chair, he informed me, when I reached the plane. Barrett, a wartime B17 pilot with 34 combat missions over Europe, boosted me through a small opening in the B25's underbelly. Inside he raced through an explanation of bail-out procedures and emergency equipment, and then departed.

The B25 gained a lot of fame during World War II as a twin-engine attack bomber, notably for being the first aircraft to bomb Japan. (General Jimmy Doolittle led a group of them from "Shangri-La"—an aircraft carrier in the Pacific.) Known then as Mitchell bombers, they are now widely used as training or transport planes, and affectionately termed *Bravo* 25's. This particular one was once a plush-lined executive transport (not GE's) but for the past two years it has served as a flying laboratory to evaluate flight-control systems. It has a basic autopilot system of its own, called the G-3, into which engineers can readily plug developmental components and observe their effects.

The sedan chair, similar to an auto's rear seat, occupies the place where the top-turret gunner would normally stand —behind the pilot and copilot who operate the plane from under a canopied roof. At the moment a man with a crew hair cut and a corduroy jacket was jiggling the lever projecting from a control unit, about the size and shape of a small shoe box, located in back of the copilot's chair. He did so at the bidding of a second man busily making adjustments on a maze of equipment—part of the plane's flight-control system—in the rear. Mike Marx, the man jiggling the lever, told me he was an engineer from the navigation section of the Aeronautic and Ordnance Systems Division. The lever—about the size of an automatic pencil—is the stick controller of the autopilot. In flight, he explained, the stick with its small box swings around between the pilot and copilot. All the ship's maneuvering—climbing, diving, or turning—is done with the lever, thus saving the pilot a lot of physical exertion. When the stick controller is in a neutral position, the plane holds a preset course. Marx said we would be running a series of in-flight maneuvers that afternoon to see if the autopilot would bring the plane back to a reference altitude.

Ten minutes before scheduled take-off, Ed Richardson, our pilot for the trip, strode up to the B25 in his flight gear. Behind him was Roger Story, a physicist from Liptak's group, who would be copilot. When they were inside, the B25's aggressive crew chief slammed home the hatchcover and helped Richardson into his chute. After some preflight checking with his copilot and crew chief, Richardson started up the engines, let them idle a few minutes, then taxied toward the runway. The time was 3:55. I plugged in my earphones and settled back in the sedan chair. Over the interphone came our instructions from the control tower: We were to head in a general northerly direction and would have good weather all the way. At 4:01 we got an all clear for take-off. Richardson revved the engines to maximum rpm. The crew chief sat down beside me and made fast our safety belt, eyeing the engines intently as he did, while the two engineers from the navigation section hovered over their electronic equipment in the rear. We got our final instructions: "39 Easy, clear to go when ready." Richardson released the brakes. The plane lurched forward, accelerated down the runway, and we were air-borne.

At 4:08 by the plane's clock, we leveled off at 7000 feet and 210 mph. Frank Gaynor, the engineer who would direct the tests, now crawled forward over the sedan chair. Mike Marx would handle the ticklish job of recording data in the rear. Gaynor, a slim fellow with chiseled features and a perpetual smile, slipped on his earphones. Hunching over Richardson's shoulder, he shouted, "Let's try the G-3 at high altitude first!"

"Directional gyro is properly synchronized with compass heading," Marx reported.

"Good," Gaynor replied. The plane went into a moderately steep climb. When we trimmed up for level flight, Gaynor said, "Do you want to engage the autopilot now and try the pitch trim there, Ed—to see if it works?"

Nodding, the pilot engaged the autopilot system and twisted one of three dials on the stick-controller box. Immediately the ship nosed up. He twisted it back and we leveled off. Gaynor suggested he engage the altitude control, and after Marx made several equipment adjustments, the pilot reported that the altitude control seemed to be in working order.

"Good," Gaynor said. "Maybe we should try some banking with the little stick now."

Richardson acknowledged by gently edging the stick controller to the left with his index finger. The plane dipped into a steep banking turn. When he released the stick, the autopilot rolled us out automatically. "Working good," he commented.

"I want to try one to the right this time," Gaynor said.

A while later we were zigzagging up the Sacandaga Valley, the Adirondack foothills below and to either side of us forming a washboard pattern. Gaynor was holding a hurried conversation with the pilot over the interphone. "Want to try some pitch maneuvering now with the little stick, Ed?" The affable pilot nodded and took the plane through a series of bucking maneuvers about an imaginary pitch axis to see if the autopilot would bring us back to level flight. It did, every time. "Reacts pretty slowly, doesn't it?" Gaynor asked.

"No, I would say that was good."

"It's slower coming out of climbs."

"Yes, but it's a lot better than it has been."

"Now, Ed, without using the little stick can you maneuver with the control wheel?"

Richardson grasped the control wheel and swung the ship around manually. Each time he released the wheel the autopilot took over and held us in the maneuver. He said, "Seems to be working fine."

Lake George soon appeared off to the right. We had come out of the Sacandaga Valley at its northern tip, about 75 miles north of Schenectady. Everything had gone along all right. "Okay," Gaynor yelled cheerfully into the interphone. "I think the conventional part of this thing is working." He clapped his hands together in a gesture of finality. "Let's switch to something a little more daring!" The daring he referred to was a developmental altimeter that measures altitude deviation and its rate of change. It would be used in place of the autopilot's conventional pitch gyro reference.

We climbed to 8000 feet and reached an air speed of 205 mph while Gaynor issued some new instructions. When he'd finished, he said to Richardson: "Ed, in this system we don't have any gyro reference at all. If it works, we can throw away the vertical gyro." And to Marx, he shouted, "How about recording an altitude bump here, Mike?"

"Just a minute," a voice muttered over the interphone.

"Why don't you try the settings you think are right, Mike?" Gaynor grinned mischievously. "Engage it and see what happens!"

Marx followed the suggestion. "Okay, I've got the proper settings," he reported. "I'm engaging altitude control now."

"We should be holding altitude now, Ed. Do you want to sort of bump the plane off level flight to see if it has any tendency to drift back?"

Richardson overrode the autopilot with the control column and we plummeted 50 feet. When he let up, the plane started a steep climb up to our reference altitude—overshot it, lost altitude, then climbed again.

"It's going back to altitude now," Marx observed. "Seems to be—."

"Okay, we're leveled off now," Richardson cut in. "We lost about 70 feet. Want me to try it again?" Gaynor told him to go ahead. Once more we swooped earthward. And again we overshot, then undershot, the reference altitude. "We dropped about 60 feet that time; amplitudes of oscillations are becoming less!"

"Well, that's encouraging," Gaynor remarked thoughtfully. "Try it again."

In the next 15 minutes we made nine more tries, Marx meanwhile adjusting the system. Results were better, but still not good enough. The tests were run off swiftly, one after the other, with no pause in between to rest. There was a continual nervous tension, a sense of urgency, throughout the flight. I began to understand why Liptak had said flight testing was hard work.

On the 10th try, Marx set the altitude-rate signal gradient a little higher. This time we got the proper response. The ship climbed rapidly back to its reference altitude and leveled off. Gaynor was jubilant. "Let's record a big altitude bump here!" he shouted.

Richardson again overpowered the autopilot and forced the plane into a dizzying dive.

"We're going down," Gaynor said, to no one in particular.

Tense moments elapsed. Richardson released the control column and suddenly a great force pushed down on us. We began to climb again—right back to our reference altitude. "Very nice," the pilot observed with admiration as we leveled off.

"I'd like to try another recording to make sure I got it!" Marx bellowed over the interphone system.

Richardson accommodated him. Again came the giddy sensation of dropping freely through air, the taut stomach muscles, followed by exultation as we zoomed skyward.

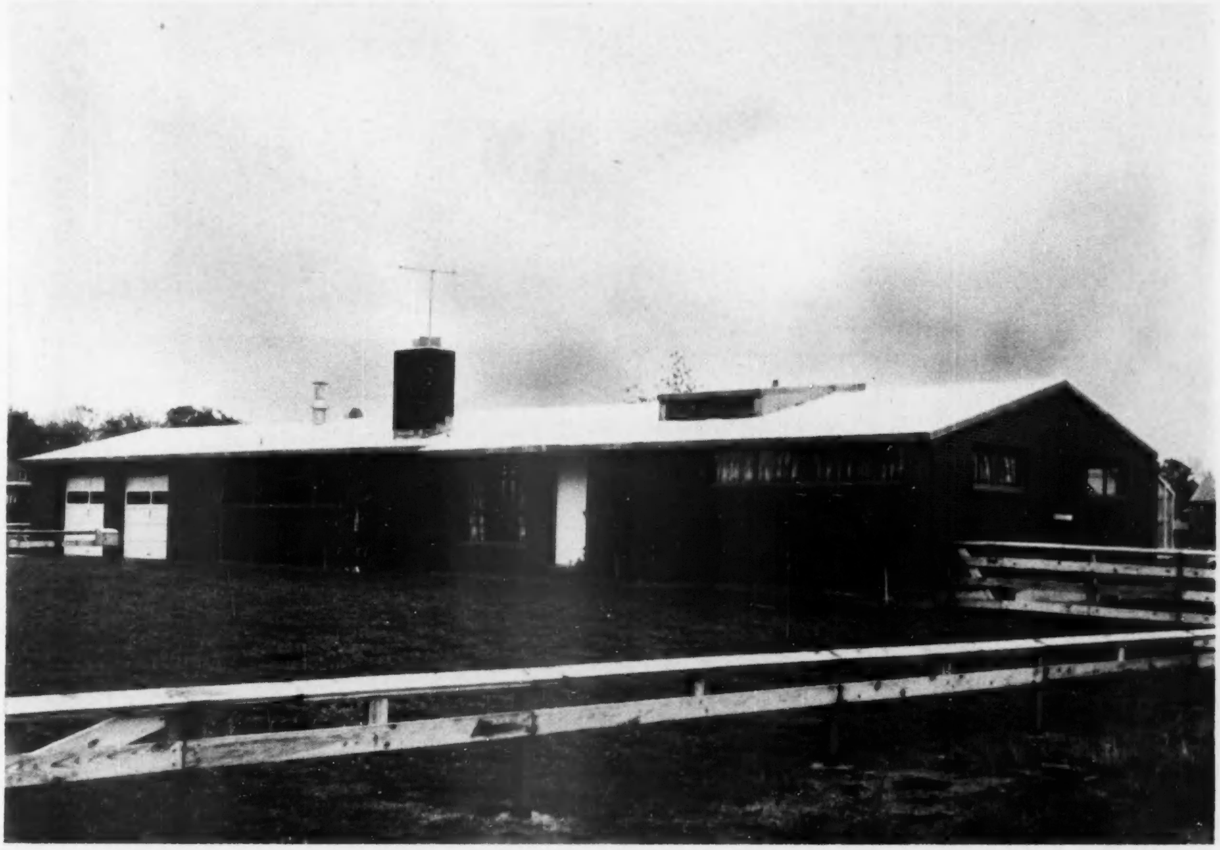
Gaynor voiced his satisfaction. "Seems to bracket right in, doesn't it, Ed?" The pilot nodded. "What do you think, Mike?"

Marx was too enmeshed in his recording job to hear the question. His voice labored, he shouted with vengeance, "Okay, I've got that one!"

A sheepish grin spread on Gaynor's face, now flushed and slightly drawn. Turning to Richardson, he said apologetically, "I suppose we'd better head for home, huh? We can make more runs tomorrow."

We banked left into a setting sun.

—JJR



USE OF Q-FLOOR WIRING IN THE AUTHOR'S HOME DEMONSTRATES THE VERSATILITY OF THIS COMMERCIAL BUILDING PRODUCT.

Q-Floor Wiring for Your New Home

By WILLIAM E. EIPEL

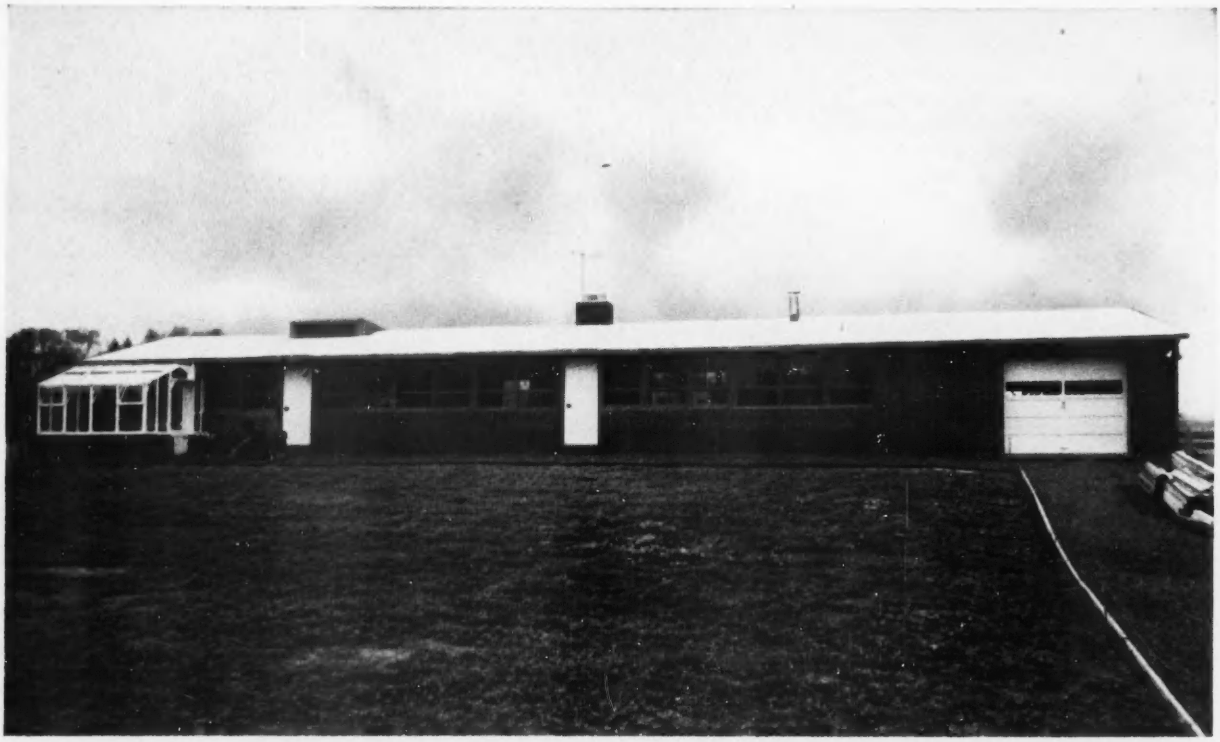
Some friends visiting us asked how I happened to think of using Q-Floor and Q-Floor wiring, both commercial building products, in our new home on Spanish Cove in Larchmont.

The answer is simple: Our firm has specified it often for the buildings we've engineered on the East Coast. For instance, the first job in the New York area was the Federal Telecommunications Laboratory in Nutley, NJ; then in 1951 the Schlumberger Suburban Office Building in Ridgefield, Conn., also used it. Both proved the versatility of this type of flooring, so when I designed our home, these applications naturally came to mind.

Why I used Q-Floor may also be of interest. In the first place, it has high structural strength, and it's also rot- and termite-proof. It's easy to install on commercial jobs, and the same was true for our house—two men put in the entire floor in one workday. But the thing I really liked was that I could run all my heating and electric wiring in the various cells of the Q-Floor. I had no worries about fancy and expensive ductwork for the forced warm-air heating system or about running wires in conduits in a concrete slab.

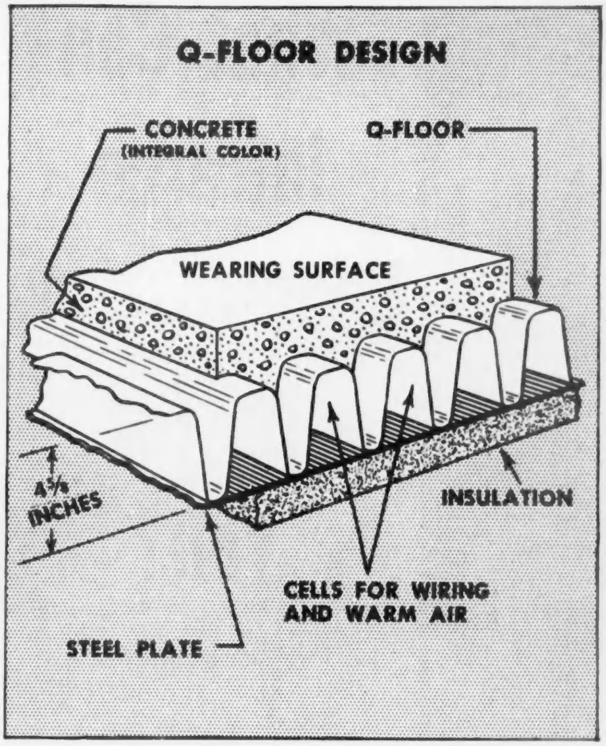
The cells of the Q-Floor act as ducts for the heating system. Running down the center of the house underneath the floor is the major supply duct that is tapped into the cells at specified intervals. The cells are used to conduct the warm air to the outlet grills in the cavity wall at the perimeter of the house; they also serve as cold-air returns. Although 70 feet long, the major supply

Mr. Eipel—a construction engineer—is a partner in Eipel Engineering Co., 101 Park Avenue, New York, NY. Many industrial and commercial buildings on the East Coast have been designed by this firm of consulting engineers. Active in civic affairs, he is a member of the Village of Larchmont Planning Commission and the Traffic and Parking Commission.



BOAT IS HOUSED IN GARAGE; REAR FACES DOCK. MINIMUM HOUSE MAINTENANCE ALLOWS MRS. EIPEL MORE TIME IN GREENHOUSE.

BECAUSE WIRES ARE RUN THROUGH Q-FLOOR CELLS, IT IS POSSIBLE TO BRING UP A FLOOR OUTLET ANYWHERE ABOVE THE WIRE DUCT.



EASY TO INSTALL, Q-FLOOR HAS HIGH STRUCTURAL STRENGTH.

SWITCHES ARE PART OF G-E REMOTE-CONTROL WIRING SYSTEM.

duct was easy to fabricate and install because it was a straight run. The same also held true for the cold-air return duct.

All wiring—a G-E Q-Floor wiring system—is run in a two-inch conduit down the south wall of the house. Floor outlets are brought up along the wall, one on each side of the roof columns (photo, left). Wires also run through the Q-Floor cells to the outlets on the other side of the room—80 convenience outlets are in the house. Because the same ducts are used for wiring runs as for warm air, we used high-temperature wire. Even though outlets are located only at the walls, it's still possible to bring up a floor outlet anywhere above the duct containing the wire, although we haven't done it yet.

General Electric remote-control wiring is used for switch controls throughout. The master switch located in the master bedroom controls a series of different lights, both inside and outside the house.

Although I didn't consider it for this design, the floor could have been a complete radiant system by eliminating the wall warm-air outlets and cold-air returns inasmuch as all the cells were used as carriers of warm air.

After the Q-Floor was laid and the heating, plumbing, and wiring systems installed, two inches of colored concrete—we chose Tuscan Red—was poured over the Q-Floor. For the kitchen area, concrete tile of the same color was used over the concrete.

We have found our house to be practically maintenance free. The only upkeep will be to paint the steel sash on the windows.

Roman tapestry brick used on the exterior walls also forms the interior walls; cavity-wall construction provides insulation as well as space for warm-air ducts. Interior partitions are of brick, too, or are birch-plywood storage walls.

Laminated wood trusses—another commercial-industrial building technique—on seven-foot, four-inch centers support the roof. Over the trusses is 2x4 fir tongue-and-groove. The trusses and the wood ceiling are varnished. With so little upkeep, Mrs. Eipel has more time for her greenhouse.

There is only one difficulty with Q-Floors, but it's a rare one at that. Before the cells were sealed, some mice got in. Tiny feet racing through the cells at night were unsettling. Traps finally got them all. Ω

SOME FACTS ABOUT THIS HOME . . .

Size: 92x25 feet, including garage.

Two bedrooms, two baths.

Situated on one-half acre.

Clerestory windows over both baths.

Garage provides storage for both car and boat. Door at rear faces dock.

House rests on 13 piles. Concrete grade beams span the piles.

Four-foot paved crawl space under the Q-Floor provides access to heating ducts, wiring, and plumbing.

Utility room is off the kitchen. Laundry and food freezer are between the two.

Roof is 2x4 tongue-and-groove fir planking topped by one-inch insulating board and five-ply built-up roof with marble chips.

Cost is less than a brick-veneer house of the same size.

Q-Floor is manufactured by the H. H. Robertson Co., Pittsburgh, Pa.

What Can Infrared Spectroscopy Do for You?

By DONALD L. HARMS

DOUBLE-BEAM INFRARED SPECTROPHOTOMETER, with author at work, automatically refers data to a true zero and produces spectrograms on a transmission vs wave-length chart.

If you're a production engineer, infrared spectroscopy offers an ideal method of process control; it is fast becoming the first choice for matching nonmetallic materials, identifying unknowns, trouble shooting, and similar operations. Accurate quantitative analysis of complex mixtures is one of the most widespread but least publicized uses.

If you're a materials engineer, you may be faced with such routine problems as: What kind of electrical insulation is on this wire? what kind of rubber gasket is this? will it resist swelling after immersion in oil? Perhaps you would like to keep a routine check on the amount of rust inhibitor present in lubricating oil; maybe the labels fell off a number of drums of solvent and you'd like to identify the contents. Rapid and accurate answers to these and many other questions lie in the realm of applied infrared spectroscopy.

If you're a chemist, infrared spectroscopy offers a means of performing a chemical analysis that is rapid, relatively simple, clean, and direct. To an organic chemist it's attractive because the method is generally nondestructive and free from acids, fumes, and odors.

If you're a research physicist, you may be interested in employing infrared in specialized fields that include: development of special filters; reflection studies of inorganics dealing with gem identification; and infrared microscopes and polarized infrared radiation for the study of single crystals, fibers, and similar materials.

Infrared is commonly associated with heating or cooking, but it's that and more. In reality, infrared is that region of the electromagnetic wave spectrum just beyond the red part of the visible spectrum. It extends from 0.78 to about 300 microns (a micron is one millionth of a meter.) The range generally used for infrared chemical spectroscopy runs between 2.5 and 50 microns.

In broad terms, the technique of infrared spectroscopy takes advantage of the fact that molecules have mechanical motion. That is, they vibrate at various frequencies, depending upon three essentially separate characteristics: the atomic masses, the type of chemical bond, and the geometry of the molecule.

Now, if you shine infrared "light" (still a popular term for invisible electromagnetic energy) of successive frequencies on a sample, the light will be absorbed if its frequency is the same as one of the characteristic vibrational frequencies of the sample's molecules. An appropriate comparison would be to consider the spectrometer as a kind of infrared stroboscope to analyze the molecule, just as a stroboscopic light is used to analyze a vibrating mechanical body.

The end result of an infrared investigation is an infrared absorption curve, or spectrogram, with bands or peaks that represent the absorbed energy. Not only are these bands characteristic of the material being irradiated by infrared with respect to their position in the spectrum, but also their intensity is directly proportional to the amount of material causing the absorption. Infrared spectroscopy thus offers an excellent method

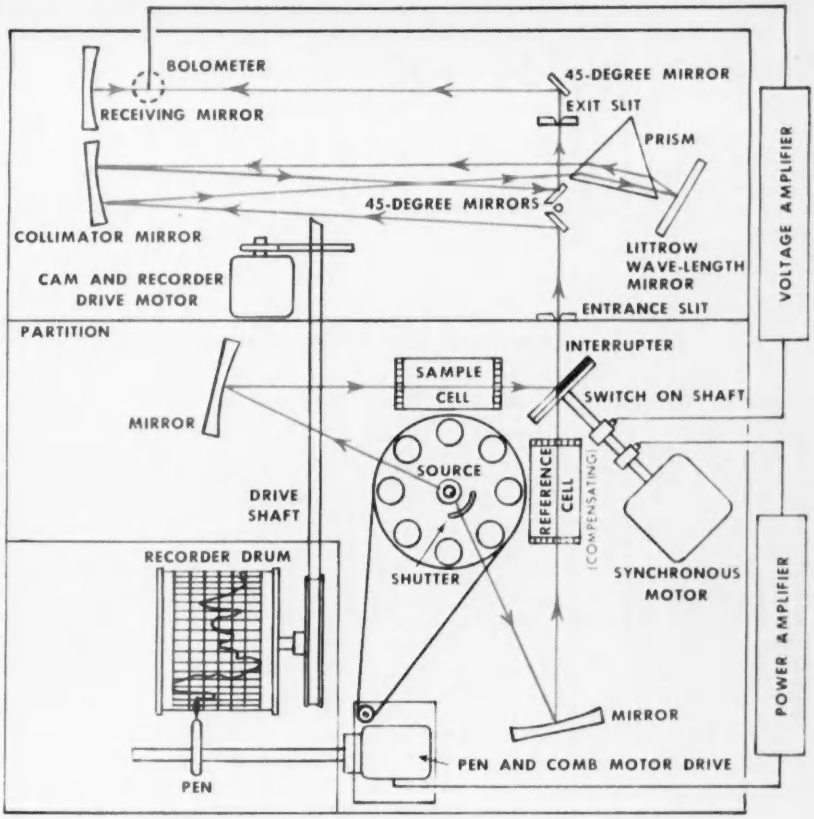
•

When Mr. Harms came to General Electric six years ago, he spent a year on the Company's Chemical and Metallurgical Training Program. He is presently in charge of organic analysis in the Turbine Division's Materials and Processes Laboratory in Schenectady.

of quantitative as well as qualitative analysis. Often, qualitative and quantitative analyses for as many as 10 or 12 constituents can be solved simultaneously.

What about two different compounds having the same spectrum? Without going into detail we can say that the statistical probability of such an occurrence is remote.

Two eminent English chemists, Sutherland and Thompson, stated that the infrared spectrum of a chemical compound is the most characteristic physical property of that compound. This means you have a more specific property than any other physical property of matter commonly used to characterize or identify one compound or material from all others. It's quite easy to find several compounds that for all practical purposes might have the same melting point, boiling point, density, or refractive index; but it's highly unlikely that you'll find two compounds the same in all features of their infrared spectrum.



COURSE OF DOUBLE BEAM in spectrophotometer's optical system is indicated by the green lines. Beam strengths are compared electronically at successive wave lengths.

Infrared—Not a New Theory

It was during the siege of the Great Plague of 1664–66, when the bubonic plague swept all of Europe, that Sir Isaac Newton discovered the spectrum of light. Trinity College, Cambridge, was forced to close because of the ravages of the disease. In this interlude, Newton studied the "spectrum" (he gave it that name) with a prism he made. Newton's contribution was his proof that "the sun's light is a heterogeneous mixture of rays [that are] parted or sorted from one another" in the prism. Then he went from observation to speculation and assumed that all light was of the same nature. This proved to be a disservice to spectroscopy because Newton's great prestige prevented this statement from being investigated until almost the middle of the 19th century.

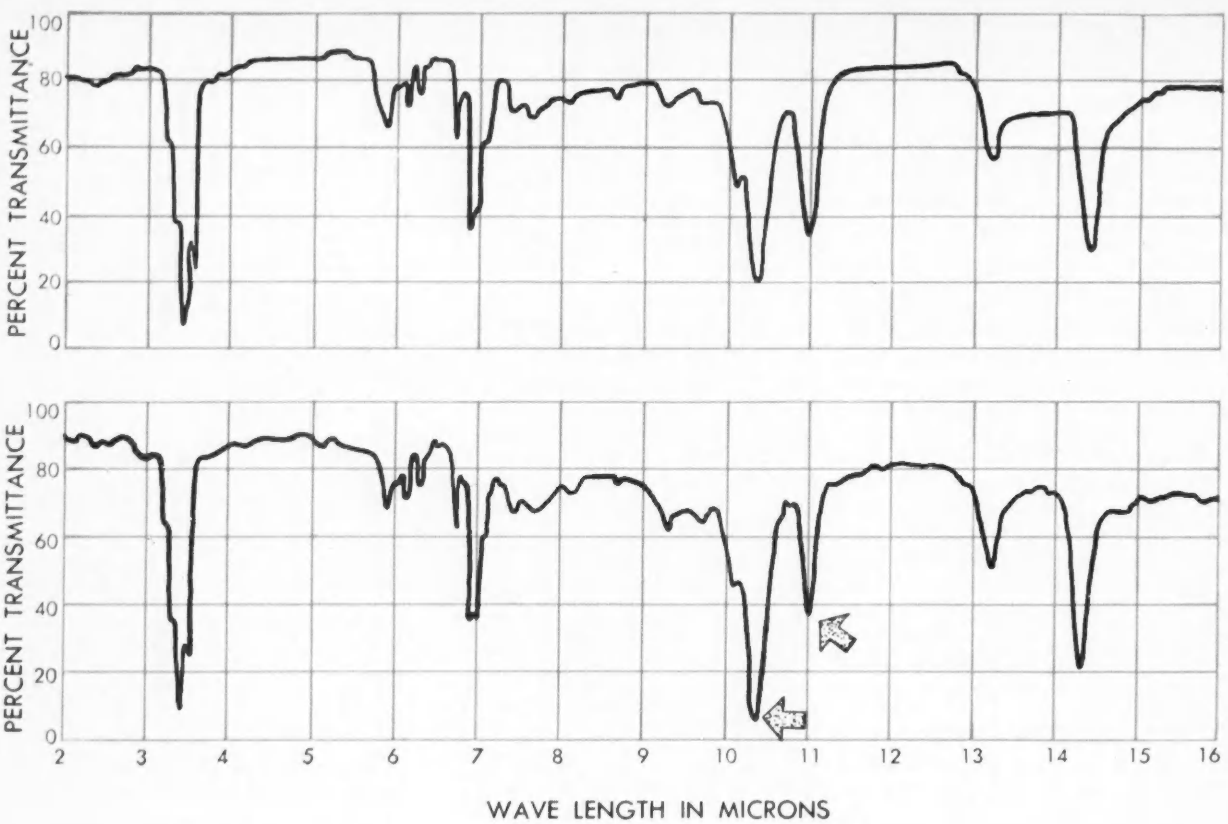
Actually, there was virtually no progress in the study of the spectrum until 1800 when Sir William Herschel accidentally discovered the infrared spectrum. Sir William, British Astronomer Royal, studied the distribution of heat throughout the color spectrum by means of sensitive thermometers. The discovery that the highest temperature was found *beyond* the red visible end of the spectrum was the first knowledge of infrared. Herschel, however, assumed that it was something entirely different from light.

Before the end of the century, James C. Maxwell had shown theoretically, and Heinrich Herz had proved experimentally, the essential identity of light, heat, and other electromagnetic radiation. Infrared, of course, is not synonymous with the common meaning of the word "heat"—for, as Herschel found, there are heat radiations in the visible part of the spectrum.

The real pioneering application of infrared in chemistry was made by William W. Coblentz 50 years ago. As a Cornell graduate student in 1903, he made practical use of infrared in his studies on infrared absorption. Several years later, after he had received an appointment at the Carnegie Institute of Washington, he published accurate infrared spectra of more than 100 pure substances. Although this was accomplished with the most fundamental of instruments, even today, after 48 years of improvement in instrumentation and technique, his work is worthy of study.

Coblentz has an inquisitive mind, and it's amusing to note some of the curious substances he chose to investigate. In a National Bureau of Standards paper published in 1935, he reported the infrared spectra of some membrane from pith of pokeweed, the seed septum of moonwort, a bat's wings, and the wing of a dragon fly. This early work didn't receive much attention, partly because instrumentation left much to be desired and partly because the preparation of a single spectrogram was exceedingly tedious. (If one had the patience and determination to succeed, the results were comparable in resolution with those prepared today on automatic recording instruments in as little as four minutes.)

Between 1930 and 1940, some of the larger chemical laboratories entered the field; but even at the beginning of World War II hardly more than 30 instruments existed in the world, and less than 10 of these were in industrial laboratories. The break came in 1943 when the petroleum industry realized that infrared could provide rapid, accurate analyses of the C_4 hydrocarbon fraction of interest in the production



SPECTRA OF GR-S SYNTHETIC RUBBER (*top*) and "cold rubber" are nearly the same except for the relative intensities of bands at 10.35 and 10.98 microns which are correlated with the respective amounts of two structurally dissimilar molecular forms.

of butadiene for synthetic rubber. In response to this need, commercial infrared spectrometers became available. This availability of instruments, coupled with their new applications, has promoted such a growth that about 1500 instruments exist in the world today—most of them in the United States.

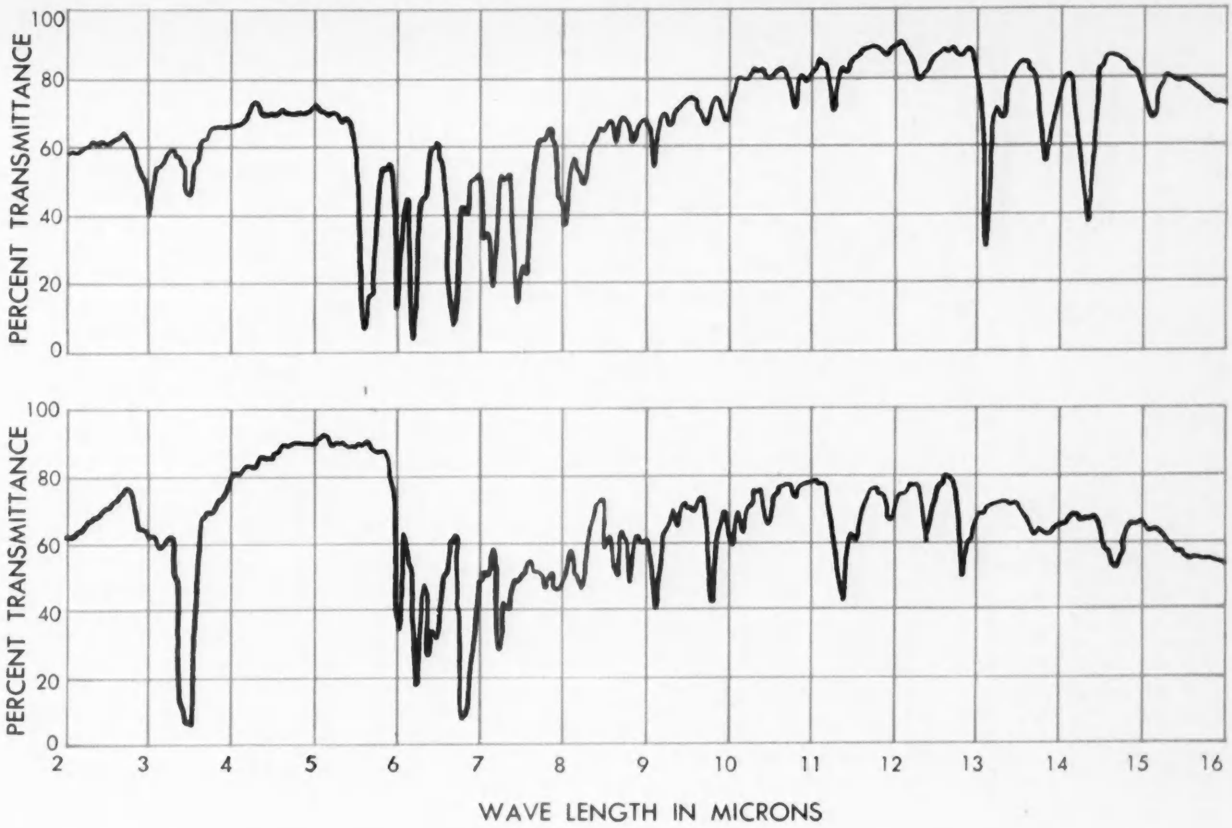
Technique for the Times

Almost all materials composed of molecules of three or more atoms (and some with two) have an infrared spectrum. Within the last two or three years, papers have been published containing excellent infrared spectra of clays, minerals, and rocks. Infrared records of such materials are usually prepared from Nujol (USP mineral oil) dispersions of the very finely ground sample. Liquids and gases are generally the simplest physical states for easy, rapid sampling.

Recently, some of the most impressive contributions to the field of infrared have been ingenious innovations in sampling technique. Although nearly all materials have infrared spectra, usable and reproducible records have frequently been impossible to obtain. One stumbling block to be surmounted lay in the intractable nature of many samples—they resisted the customary sampling techniques. Solids are the chief offenders because many, such as compounded rubber and resins, are opaque to infrared radiation. Some of these cannot be dissolved, ground up, or cut uniformly enough to be examined directly. It is possible, however, to decompose them by strong heating and to identify them by spectra of their decomposition products. Many solid materials that might have been run as Nujol mulls (which at best have the disadvantage of interfering mineral-oil bands) have lately been ground with potassium bromide and compressed in small translucent wafers or pellets. Because potassium bromide is transparent to infrared, an excellent spectrum is usually obtained. This technique, combined with certain instrument modifications, permits the examination of samples as small as five micrograms (five millionths of a gram). This development is already of tremendous aid in cancer research where tiny samples of hormones and other steroids must be identified.

Even in absorption studies, the field is widening to such accessories as a microscope for study of single crystals, fibers, cells, and nerve tissues in polarized infrared light. Another factor has greatly added to the effectiveness of these techniques: the recent development of modern punched-card and automatic machine-sorting methods for indexing and sorting spectra used for qualitative identification work, as well as in correlating spectral character with chemical constitution.

Because of the greater flexibility and broader scope of infrared methods in diversified analytical applications, it can be predicted that infrared's rapid growth will constantly increase. In such closely related fields as Raman and ultraviolet absorption spectroscopy, many of the technique problems that once faced infrared's proponents have not been solved, nor are they likely to be. The reason for this is essentially the inherent



SPECTRA OF PENICILLIN G's potassium salt as KBr pellet (*top*) and terramycin as Nujol mull are as characteristic of themselves as are human fingerprints. An unknown's spectrum is considered identified if shown to be identical with a known compound.

differences in requirements for absence of interfering substances, and these other methods favor samples in the liquid state.

Infrared methods presently afford a more flexible and popular approach to general analytical problems than mass spectrometry. With any gas or volatile material, the mass spectrometer can accomplish about the same thing as the infrared spectrometer, although it operates on an entirely different principle. Aside from the fact that it costs nearly three times as much as infrared equipment, the mass spectrometer is likely to be more time-consuming in operation and subject to greater technical difficulties. In 1952 there were slightly more than 100 commercial mass spectrometers in the United States.

Each of these three other spectroscopic approaches does have superior advantages in limited and specific areas, but if you're looking for a single all-round means for the analysis and control of nonmetallic materials, then the experts generally agree that the infrared spectrometer fits the bill.

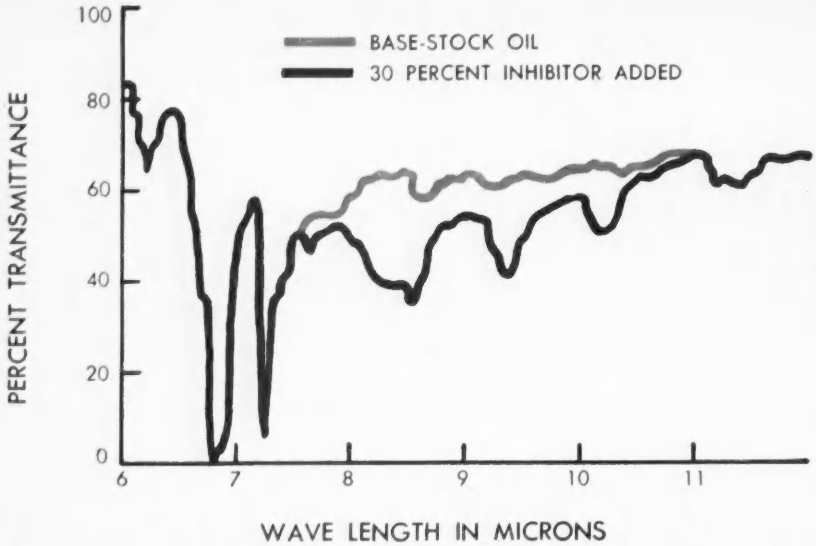
Instrumentation

Essentially there are two types of infrared spectrometers—the single and double beams. The first records spectra on an arbitrary transmission scale so that data must be referred to a zero curve by calculation and point-by-point plotting. The double-beam instrument (photo, page 18) automatically refers data to a true zero and yields spectrograms on a transmission versus wave-length chart.

The components of an infrared spectrometer (illustration, page 19) are quite different in detail from those instruments employed in the visible range, but a close analogy exists. Instead of a light source, such as daylight, a good infrared-radiation source is needed. This usually consists of a silicon-carbide rod (globar) or a Nernst Glower which, when heated by passing current through it, emits the required radiation. This radiation is then passed through the sample.

The requisite scanning of the spectrum is accomplished by rotating a wave-length mirror. The radiation from this mirror (usually the Littrow type) is dispersed by passing through a prism. Aluminized gratings are sometimes used, but prisms are in more common use. Because glass acts as a filter for the wave lengths of infrared beyond about 2.5 microns, the conventional glass prism cannot be used. Instead, various salt crystals are cut and polished to form the prism, and front-surface concave mirrors carry the rays through the instrument. Such prisms are often large and expensive. (One commercial instrument uses a rock-salt prism measuring four inches at the base and three inches in height with a 60-degree angle. Cost: about $1000.)

After passing through an exit slit, monochromatic light from the prism is reflected by the exit mirror to the receiving mirror that focuses it upon the detector. It is interesting to note that modern detectors are nothing but refined thermometers measuring temperature rise of a receiver that is heated by the infrared radiations. For instance, thermopiles, used in some instruments, measure the receiver temperature by



DIFFERENCE IN BAND INTENSITY at about 9.4 microns gives measure of amount of inhibitor present when referred to a series of standard reference spectra.

the thermoelectric effect; a bolometer measures the temperature of a strip receiver as sensed from its electrical resistance; and Golay's detector is a tiny gas thermometer. By using suitable amplifiers, the signal from the detector at any wave length can be translated to mechanical energy which motivates a pen, tracing the absorption curve on a chart.

Applied Infrared

A number of contributions made by infrared spectroscopy have aided in solving problems of international acclaim. The solution of two of these problems has been of tremendous practical importance.

Let's consider the production of a synthetic rubber—the so-called "cold rubber." A copolymer of butadiene and styrene (GR-S), it is manufactured by a new process at comparatively low temperatures. Cold rubber provides superior tread wear, develops less heat when flexed, bounces better, and behaves more like natural rubber than most previous synthetics.

An important factor in the physical behavior of a rubber is the uniformity of its molecules. When the spatial configurations are very nearly alike, as in natural rubber, a much stronger polymer is obtained. The real reason regular GR-S does not come up to par is that its molecules exist in more or less equal portions of two isomeric forms. An isomer is a chemical compound with the same atoms and the same bonds as another compound but differs in spatial arrangement. You recall that the geometry of a molecule is one of the factors influencing absorption. No direct chemical tests could differentiate between the two isomeric compounds in GR-S, but the infrared spectrum provided a sure identification (illustration, page 20). By application of process-control infrared analysis, it was found that lowering the polymerization temperature from 100 to 20 C altered the ratio of one isomer to another (a more desirable isomer) from about 1 to 1 to about 10 to 1—a tremendous amount of progress toward uniformity.

The widespread and rapid advance in the use of the new antibiotics can at least be partially attributed to infrared investigations. Elucidation of the chemical structure of a compound isolated from natural sources is a definite necessity before synthesis can be attemped. Infrared played a large role in deciding the configuration of atomic groups in such new molecules as penicillin, aureomycin, terramycin, and others (illustration, page 21). The first successful attempt to synthesize penicillin G produced about one milligram of sample. One half of this was immediately used for infrared sampling to establish identity with the natural product.

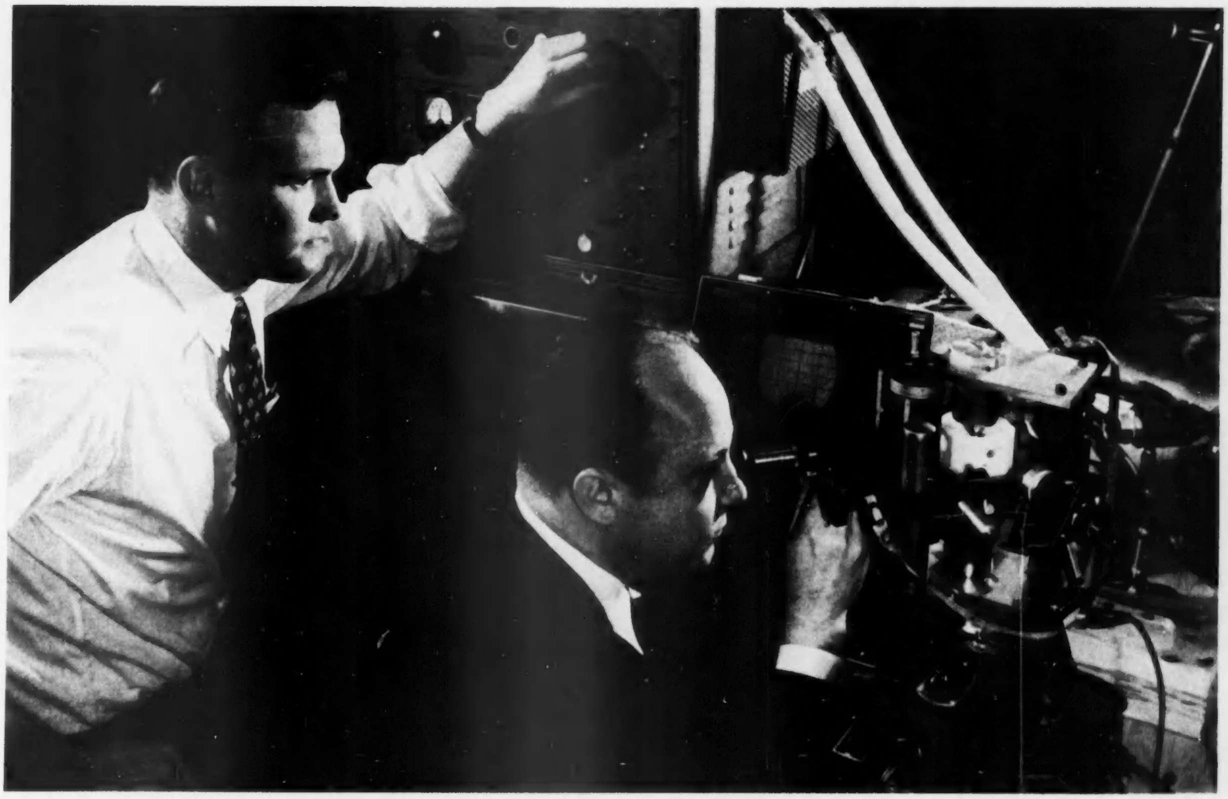
In the early stages of penicillin study, isolation of a pure penicillin sample from the fermentation broth was desired. As purification progressed, samples were submitted for infrared study as well as for bio-assay. When the material reached a stage of about 20 percent purity, certain absorption bands (whose intensities could be correlated with the results of bio-assay) were observed. At that point infrared took over, and the purification chemist advanced rapidly.

A practical example in industry is infrared control analysis of one type of turbine oil. An infrared analysis has been devised to estimate the extent of depletion of corrosion inhibitors present in gas turbine test-stand oils. Certain corrosion inhibitors are designed to cling to metal components of the turbine to protect it from rust during shipment. From the results with infrared (illustration, left), a simple calculation indicates the amount of inhibitor concentrate that should be added to used oils to restore the oil to a proper level of rust protection. The infrared procedure replaces time-consuming and expensive humidity salt-spray and oil-droplet contact-angle tests that are also subject to erratic variations. On a yearly basis, the adoption of the infrared method saved approximately $1200 on costs of analyses alone, to say nothing of improved performances and less waste due to guesswork.

Characterization of an accurate distillation is a problem facing many chemical engineers—a problem ideally suited to infrared analysis. Distillation of an unknown multicomponent mixture may result in more than 100 fractions of which only one or two may be of primary interest. The spectra of selected cuts are obtained, perhaps at the beginning and middle of each plateau—20 to 30 such spectra can be obtained in a day. Inspection of these results permits the analyst to follow the appearance and disappearance of each component and to make rough estimates of cut purity. With this knowledge the cuts of interest can be selected, pooled, and reworked.

As a final example to illustrate the merits of the infrared approach, let's consider wire insulation. Recently, it was desired to determine the composition of a wire enamel. Both the unapplied enamel solution and the finished insulated wire were available for testing. Using conventional chemical methods, a competent chemist required four weeks to deduce the composition of the enamel. Essentially the same operation, although in less detail, was accomplished in two days by an infrared spectroscopist.

The past 10 or 15 years has seen a remarkable swing to instrumentation for the solution of a great many chemical problems. Infrared absorption spectroscopy is now firmly established as an important tool for the analytical chemistry of nonmetallic materials. Ω



RESEARCHERS CROWE *(LEFT)* AND SHARBAUGH STUDY THE CHARACTERISTICS OF AN INSULATING OIL UNDER HIGH-VOLTAGE STRESS.

Liquid Dielectrics

By DR. A. H. SHARBAUGH and DR. R. W. CROWE

Although solid insulators play an all-important role in the electrical industry —that of isolating conductors from one another and from ground while supporting them physically—liquid insulators are equally important in many electrical products. Transformers, circuit breakers, capacitors, and cables are some of the more common devices that utilize liquid dielectrics. In the transformer industry alone, insulating oil by the tens of millions of gallons is used annually.

Through a better understanding of how liquid dielectrics behave in electric fields, engineers have the opportunity to further increase the operating efficiency of their products. For the development of liquids with better electrical properties will yield transformers of greater power capacity per unit volume, capacitors of greater electric capacity per unit volume, and so on.

What electrical properties determine the performance of a liquid dielectric? Primarily they are: 1) ability to resist breakdown under electrical stress, 2) the electric capacitance per unit of volume determined by the dielectric constant, and 3) loss factor—the energy loss per unit volume per cycle. These properties depend on the liquid's operating temperature and frequency as well as on the structure of its constituent molecules.

Let's look first at electrical phenomena in liquids at low voltages, then proceed to the less understood phenomenon of electrical breakdown at much higher voltages. (We'll confine our attention to electrical properties alone—not the physical ones such as heat transfer and mechanical forces.)

•

Both authors are Research Associates in the Physical Chemistry Section of the General Electric Research Laboratory at The Knolls, Schenectady. They are currently studying the fundamentals of electrical breakdown of insulation. Dr. Sharbaugh joined the Company in 1942, Dr. Crowe in 1951.

Dielectric Constant

In deciding what liquids may be classed as insulators, you can arbitrarily select those having resistivities greater than a certain value, say, 10-million ohm-centimeters. (An ohm-centimeter is the resistance between opposite faces of one cubic centimeter of the liquid.) On this basis, for example, you would class water as a liquid insulator, although its resistivity is a million times smaller than other commonly used insulating liquids.

Actually, the application dictates the permissible lower limit of resistivity. Thus water, with a high dielectric con-

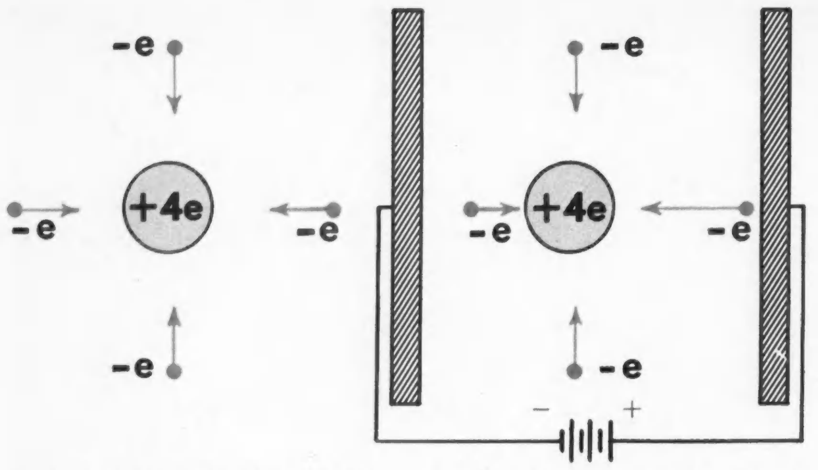


FIG. 1. INDUCED DIPOLES are formed in a neutral atom (*left*) when placed in an electric field (*right*). Arrows indicate the magnitude and direction of polarization.

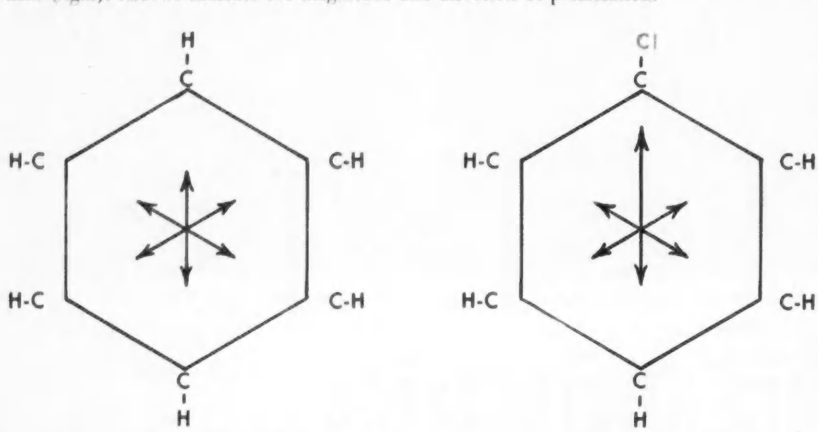


FIG. 2. ELECTRICAL BALANCE of a neutral benzene molecule with six dipoles (*left*) is upset when an atom of hydrogen is interchanged with an atom of chlorine.

stant, can be a perfectly respectable dielectric in some applications and an extremely poor one in others.

What do we mean by a dielectric constant? Perhaps the most familiar property of liquid dielectrics is the capacitance increase observed when an air capacitor is immersed in a liquid. In fact, this ratio of the liquid- to air-filled capacitance is often used to define the dielectric constant of the liquid in question. Explained in this way, its magnitude becomes a property of the liquid, independent of the measuring voltage or geometry of the test capacitor. Extremes of such ratios for liquid dielectrics range from 1.05 for liquid helium to 78 for water; most commonly used liquids have dielectric constants between 2 and 5. On the other hand, the dielectric constants of all gases are very nearly unity. And so, gases do not offer the large capacitances per unit volume that liquids do.

Polarization

The dielectric constant varies with the temperature and molecular structure of a liquid and with the frequency of the applied voltage wave. To understand the reason for this variation and why liquids differ broadly in their dielectric properties, you need to become acquainted with a phenomenon called *polarization*, common to all liquid dielectrics.

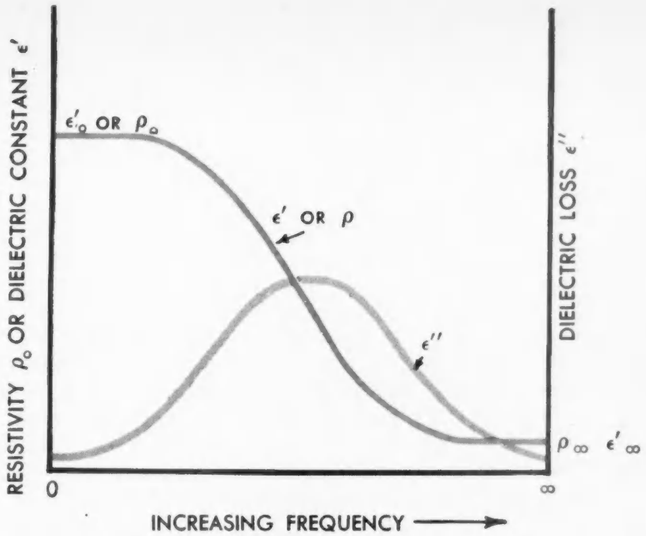
When a unit positive charge $+q$ and a unit negative charge $-q$ coincide in space, their electric fields cancel one another and their net charge is zero. If they are displaced a distance l apart, a resultant field arises. Such a pair of charges now constitutes a dipole, and has a moment μ equal to the product of their displacement and magnitude of either charge, or lq.

For example, an atom (Fig. 1, left) with four electrons symmetrically located about a nucleus of four protons is the equivalent of four dipoles. The moment of each pair, electron and proton, is represented by the length and direction of the arrows. You can see in this instance that all the individual dipoles balance each other and that the atom as a whole is electrically neutral. But place the same atom in an electric field between the plates of a capacitor and see what happens: Now the individual dipoles no longer mutually cancel each other (Fig. 1, right) because the electrons are attracted to the positive plate. Conversely, the positive nucleus is slightly displaced toward the negative plate. The resultant dipoles are called induced dipoles because they exist only by virtue of the externally applied field.

You may remember from your studies of chemistry that different kinds of atoms have different amounts of attraction for electrons, called *valence*. Thus, when a molecule is formed from its constituent atoms, it may not be completely in electrical balance. As an example, take first the molecular structure of benzene (Fig. 2, left), a common dielectric liquid. Here the individual dipoles arising from the different electron affinities of carbon and hydrogen are in complete electrical balance. If, however, a chlorine atom is substituted for one of the hydrogens (Fig. 2, right) there is no longer complete neutralization of the individual dipoles, and the molecule is out of electrical balance. This kind of molecule has a *permanent* dipole moment because it doesn't owe its existence to any external electric field.

The general term polarization refers to the movement of electric charges within a molecule in response to an applied field. You may further classify it according to the kind of body that carries the charge—electronic, atomic, or dipole. Electronic polarization, explained in connection with the atom, involves the relative displacement of electrons with respect to their atomic nucleus. Atomic polarization, on the other hand, is caused by shifts in the equilibrium positions of atoms within the molecule with respect to each other. Dipole polarization (not illustrated) arises when the randomly oriented permanent dipoles of a molecule are oriented by an applied electric field.

At a given frequency and temperature, the value of the dielectric constant will depend on the number of different kinds of polarization that can form. Although all liquids will have electronic and atomic polarizations that contribute to



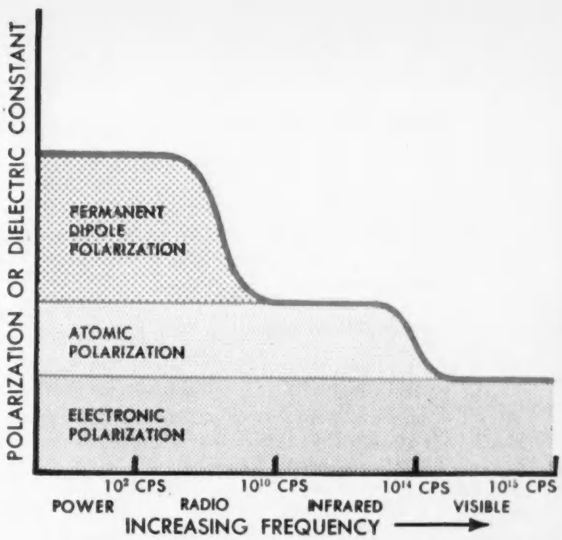


FIG. 3. FREQUENCY DEPENDENCE of the dielectric constant, resistivity, and dielectric loss (*left*) is depicted for one type of polarization. Superimposing curves, shown in green, for the different polarizations result in the composite picture.

their dielectric constants, the amount of dipole polarization will vary greatly according to the magnitude of the dipole moment. If the molecule is electrically symmetrical, it will be zero. The dielectric constant of a liquid may therefore be large or small, according to the arrangement of atoms within its molecules.

Frequency Dependence . . .

If you use a low frequency or d-c voltage to measure the dielectric constant of a liquid having permanent dipoles, all the polarizations will be complete, and you'll obtain the highest possible value of dielectric constant. If, however, you increase the frequency of the applied a-c voltage, the direction of the electric field may be reversed before polarization has time to form. This leads to a decrease of dielectric constant from some steady-state value ϵ'_0 (Fig. 3, left) at low frequencies to another steady-state value ϵ'_∞ at some higher frequency.

The size and weight of the various charge carriers give a clue to the time required for the different types of polarization to form. Electronic polarization (Fig. 3, right), involving the extremely light and small electron, persists from power frequencies through the visible frequencies. Atomic polarization, requiring the movement of the heavier atom, usually does not persist beyond the infrared range. Dipole polarization needs even longer times because it requires the movement of entire molecules, and usually it contributes to the dielectric constant only at power and radio frequencies.

One by one the permanent dipole and atomic polarizations cease to contribute to the total dielectric constant as the frequency is increased from d-c or low-power frequencies to the higher visible frequencies. For this reason water has a dielectric constant of 78 at power frequencies (60 cps) and only 2 at visible frequencies (10^{14} through 10^{15} cps).

The heat generated in a liquid dielectric under stress is determined by the combined effect of: 1) a frequency-independent resistivity measured with d-c voltage and 2) a frequency-dependent resistivity that contributes when a-c voltage is applied. Determined principally by the number of free ions in the liquid, the d-c resistivity can be reduced to an extremely small value in the case of organic fluids. For example, carefully purified water has a d-c resistivity of about 10^7 ohm-centimeters. Thus it represents a highly "lossy" liquid dielectric. On the other hand, a hydrocarbon oil—a liquid such as petroleum containing only carbon and hydrogen—may have a d-c resistivity of 10^{15} ohm-centimeters, making it almost a perfect insulator.

Referring back to Fig. 3 (left), you can see how the measured resistivity starts at its d-c value ρ_0 and decreases to some limiting value ρ_∞. The loss factor ϵ'' is a measure of the amount of heat generated per cycle as a result of this resistivity.

. . . and Temperature Effects

Why does the dielectric constant change with temperature? Remember that its value at any particular temperature is determined by the combined contributions of the different kinds of polarization. In the instance of electronic and atomic polarization, the influence of temperature is slight because these polarizations are affected only as the density of the liquid changes. Hence, they become slightly smaller as the liquid's temperature is raised, because the number of contributing atoms per unit volume becomes smaller. Conversely, they become slightly larger as the temperature is lowered.

A much stronger temperature dependence is experienced in dipole polarization: the entire molecule rotates instead of just its charges being displaced. Because a rise in temperature generally lowers viscosity, the molecules experience less molecular friction as they rotate among their neighbors. They undergo an increased motion as the temperature rises. This action promotes a random orientation of the dipoles that opposes the ordering influence of the applied electric field. And so, the net effect of temperature increase on dipole polarization is a lowering of the measured dielectric constant.

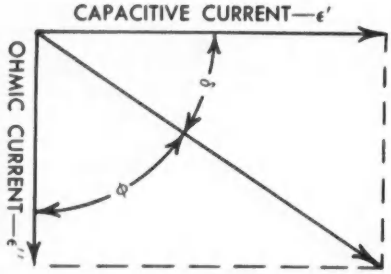
(Because the dielectric "constant" of a liquid may depend strongly on frequency and temperature, you might conclude that the name isn't too descriptive. This is true. However it has gained rather universal acceptance, although various other terms are occasionally found in literature. One that is sometimes used is specific inductive capacity, and another is dielectric coefficient.)

HOW THE LOW-VOLTAGE GOODNESS OF A LIQUID DIELECTRIC IS DETERMINED . . .

That most liquid dielectrics are not perfect insulators has been experimentally proved. But they do have a measurable power loss that's manifest as heat. This fact is taken into account by the equation

$$\epsilon^* = \epsilon' - j\epsilon''$$

where ϵ^* is a liquid's complex dielectric constant, having direction as well as magnitude. Its real component ϵ' is the absolute value of the dielectric constant and gives rise to the current out of phase with the applied voltage. The imaginary component ϵ'', called the loss factor, is a measure of the in-phase current or the heat generated per cycle of applied voltage; j equals $\sqrt{-1}$. This is shown graphically—



A quantity expressing the merit of a liquid dielectric is the loss tangent, defined by the relationship, $\tan \delta = \epsilon''/\epsilon'$. As you can see from the diagram, the complement of the angle δ is ϕ; and the $\cos \phi$ is defined as the dielectric's power factor. For low-loss liquids, δ is almost zero, making ϕ nearly 90 degrees; therefore, $\tan \delta = \cos \phi$. And so, the loss tangent equals the power factor when $\tan \delta$ is less than 0.1.

Liquids having a power factor less than about 0.05 at their operating frequency are usually considered satisfactory for commercial use. To give you an idea of magnitudes, the Table lists values for some commonly used liquid dielectrics, including water.

DIELECTRIC PROPERTIES OF SOME LIQUIDS AT 25 C AND 60 CPS

Liquid	ϵ'	ϵ''	Loss Tangent (Tan δ)	Power Factor (Cos φ)
Pyranol†	5.3	0.005	0.001	0.001
Hydrocarbon oil	2.2	0.002	0.001	0.001
Dibutyl sebacate	4.5	0.040	0.010	0.010
Water	78.0	78,000	1000	1.000

†Reg. Trade-mark of General Electric Company

High-voltage Phenomena

When liquid dielectrics are utilized as insulating material in high-voltage equipment, they are important because of a property differing entirely from that associated with the polarization of molecules. This difference arises from their ability to withstand high electrical stresses for long periods of time. For these purposes, engineers usually prefer liquids that are thermally stable and nonflammable.

If the voltage applied to any dielectric insulator placed between two metal electrodes is increased sufficiently, an electric spark will pass through it. When this occurs the insulator has broken down electrically. And the heat accompanying such a breakdown spark usually results in the accumulation of a large quantity of decomposition products along its path. Because such products weaken the dielectric even more, an initial breakdown often renders a piece of equipment permanently inoperative.

When designing high-voltage equipment using liquid insulation, the engineer wants to know what he can expect of a liquid exposed to high electric fields. Unfortunately, this isn't always predictable. Any property that deals with the violent destruction of matter is often complicated and difficult to reproduce. As a result, the phenomenon of electrical breakdown in liquids is not well understood as yet. Surprisingly enough, the great influence of extraneous factors not associated with the liquid itself makes it difficult to correlate breakdown with any known molecular properties. The engineer, then, is forced to use abnormally large safety factors when designing his equipment.

What Is Electrical Breakdown?

The appearance of an electric spark is certainly evidence of electrical breakdown; but it doesn't tell you why breakdown occurred. Extremely large currents in sparks do, however, suggest this: Electrical breakdown involves the failure of the insulator to retain its initially high electrical resistance. Hence, a general definition of a liquid's breakdown voltage is that amount of voltage required to convert it rapidly from an insulator to a conductor.

How does such a conversion take place? And what does the magnitude of the voltage have to do with electrical breakdown? Perhaps the most widely accepted theory of explaining this phenomenon deals with the electron avalanche.

Consider a system (Fig. 4) composed of a liquid dielectric placed between two parallel-plate metal electrodes. Choose the system so that the electric field will be homogeneous throughout. When you apply a voltage to the electrodes, free electrons emitted by the cathode—or already present in the liquid itself—are accelerated toward the anode. This acceleration will continue until the rate at which electrons lose energy by collision with molecules just equals the rate at which they gain energy from the electric field. Under these conditions the electric current will remain small. If, however, you increase the voltage so that each free electron gains sufficient energy to knock another electron from a molecule of the liquid—called *ionization*—the number of current carriers, and the current, is multiplied by two.

To take it a step further, suppose you increase the voltage until each starting electron can multiply in this manner a number of times as it crosses the gap. Since each new electron produced by collision is also free to undergo the same process, the result is an electron avalanche. Mathematically it works like this: If a single starting electron makes n ionizing collisions while crossing the gap, then 2^n electrons will reach the anode. When n reaches some critical value, the electric current through the liquid will be high enough to lead to a runaway process culminating in the spark. Thus, you can define electric strength as the voltage that will just cause breakdown divided by the distance between electrodes.

Theory and Practice

From what has been said you might expect the electric strength of a liquid to be controlled by its ability to resist the acceleration of electrons to those energies causing ionization. This would be true only under ideal conditions. However, as mentioned earlier, many extraneous factors often overshadow the properties of the liquid itself. Usually they prevent measurement of the liquid's maximum electric strength.

Of these complications, one of the most serious is the shape of electrodes. Seldom do you find smooth, flat electrodes in actual equipment. Irregularities on electrode surfaces—such as sharp edges or points—intensify the electric field in their immediate vicinity. Such a situation often gives rise to localized electric fields far more intense than the uniform field throughout the liquid. And if their intensity is great enough, electron avalanches can be sufficiently large to cause breakdown. You would thus measure an apparent electric strength far below that realized in the uniform field.

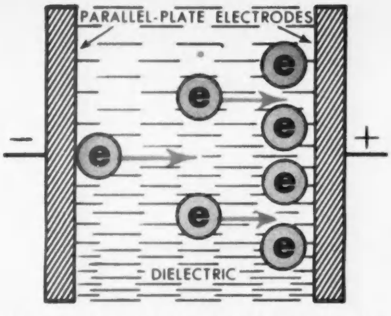


FIG. 4. ELECTRON AVALANCHE begins when a free electron gains enough energy to knock another electron from a molecule.

Often, however, electrode irregularities give rise to electron avalanches of limited magnitude—too small to cause complete breakdown directly. This is so because the field strength throughout most of the liquid is low, and localized avalanches are unable to proceed through the entire gap before they are snuffed out. (The occurrence of ionization leads nonetheless to a gradual decomposition of the liquid and in time may cause its failure. Engineers commonly call prebreakdown avalanches of this kind *corona*—observed electrically as small bursts of current.)

Closely associated with the effect of electrode shape are small particles on the electrode surfaces or suspended in the liquid. Having a dielectric constant higher than the surrounding medium, these particles will tend to move into the regions of highest electric field. Their effect is to create intense localized fields and cause premature breakdown.

But perhaps the most difficult external factor to control in the laboratory is the electrode material itself. Here's why: The electric fields involved in the breakdown of liquids are of the order of one-million volts per centimeter. At these voltages, most metals emit electrons profusely by a process known as *field emission*, or *cold emission*. The electric field at which this emission becomes extensive has a high sensitivity not only to the kind of electrode metal but also to the nature of its surface. For example, if a highly polished electrode is partially covered with an oxide film, its emission characteristics may vary a considerable amount from one part of its surface to another.

Again, if electrons are emitted by this mechanism at a faster rate than they can be swept to the anode by the electric field, there results a large electronic space charge near the cathode. This gives rise to an intense field in the vicinity of the anode. And such behavior invariably results in low values of the apparent electric strength of the liquid.

Thermal Breakdown

Although the distortion caused by intense localized fields may lower the apparent electric strength of a liquid, it doesn't alter the general mechanism by which disruption of the dielectric occurs. For example, another complication that may not be considered external doesn't depend on field distortion at all. If ionic impurities are present in the liquid, the application of an electric stress may cause a large enough current to flow even without ionization to cause a definite increase in temperature. The same thing can happen if the liquid itself possesses a relatively low electrical resistance at low fields.

This rise in temperature is usually observed in liquids that require long-time exposure to high voltage. If it becomes high enough, the liquid may decompose thermally. More often, however, bubbles of once-dissolved gases—or vaporized liquid—that are ejected at the elevated temperatures cause premature failure. This phenomenon is called *thermal breakdown*.

Laboratory Tricks

You might infer from what has been said that any measurement of the electric strength of a liquid has little or no meaning in terms of the liquid's structure and composition. This isn't necessarily true. For if you make a concentrated effort to either fix or remove extraneous factors, it's possible to observe significant differences in the electric strengths of liquid dielectrics. You can do this by carefully purifying and filtering the liquids before testing and by carefully selecting and preparing electrodes.

Hemispherical electrodes are usually used to test liquid dielectrics in the laboratory for a number of reasons. For one, they are relatively easy to fabricate and polish. For another, if their radii of curvature are large compared to the gap spacing between them, a small region in the center of the gap will have a configuration approaching that of two parallel-plane electrodes.

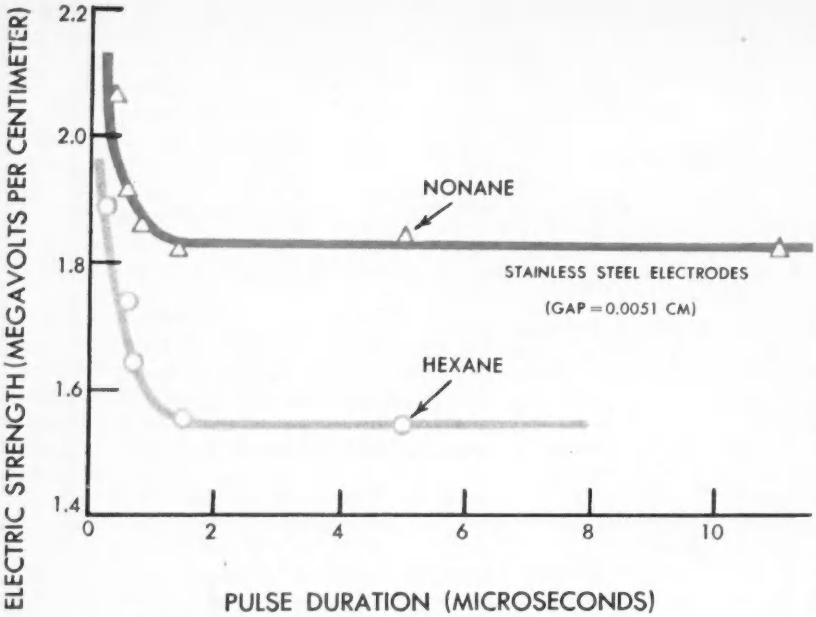


FIG. 5. INVERSE RELATIONSHIP of pulse duration to liquid-hydrocarbon strength ends beyond one microsecond. Beyond 10 microseconds, thermal effects complicate matters.

FIG. 6. ELECTRIC STRENGTH of a liquid hydrocarbon, stressed by high-voltage pulses of short duration, is a function of the liquid's density and molecular structure.

This electrode curvature, reducing the electric field in all other parts of the gap, limits breakdown to the small center region of the electrodes where the field is nearly uniform. And by using rectangular voltage pulses of approximately one microsecond's duration, the danger of interference from thermal breakdown is easily removed. (When pulses of such short duration are applied singly to the breakdown cell, there's not enough time for harmful temperature changes to take place.)

With these techniques it's possible to measure the electric strengths of liquid hydrocarbons within an accuracy of four percent or less. From such measurements (Fig. 5) the electric strength is found to be independent of pulse duration for times greater than one microsecond. Thus the time-independent value of electric strength is the same value you would measure under long-time voltage application—if you could prevent thermal effects. (The latter begin to interfere when pulse duration reaches a value greater than 10 microseconds.)

Field emission effects, on the other hand, can only be fixed but not eliminated. And so, the time-independent value of electric strength represents a combined property of the liquid and the electrode material.

By applying the pulse technique to liquid hydrocarbons of different molecular weight (Fig. 6), it is found that electric strength increases in a linear fashion with the density of the liquid.

The Summing Up

In a general way, some of the more important electrical properties of liquid dielectrics have been presented. And though these properties were divided into two distinct groups—low and high voltage—it doesn't necessarily mean that there is any line sharply dividing dielectrics in usage. For in many applications you'll find liquids with good characteristics at both high and low voltages.

The relationship of a liquid's electric strength to its molecular properties is obviously of value to the engineer in search of a liquid dielectric to fill his specific need. But unfortunately, theories that explain such correlations—or predict the electrical behavior of liquids in high dielectric fields—are presently qualitative at best. Perhaps more information of the type discussed will, in the future, contribute to a better understanding of liquid dielectrics. Ω

Is Your Corporation a Good Neighbor?

By DR. CARTER DAVIDSON

The good-neighbor policy that our national government has advocated in our relations with foreign countries has also been practiced at home for many years by leading American corporations. I know this from personal experience, having lived in several communities where corporations take an active interest in the total life and environment of the people—not merely the employees but all who come within the company's sphere of influence.

And from my experience of living in smaller towns that have no local industry, I know, too, what a difficult time such communities go through to support their community chest agencies, their hospitals, and even their public schools.

The old concept that the corporation is a selfish, selfless, machine or a legal person without a personality has, fortunately for America, been dispelled in our country. An occasional stockholder or even a lawyer will argue that a corporation's only purpose is to produce a profitable product. However, today's enlightened owners, directors, management, and employees believe that, in taking on the personal privileges a corporate organization confers, they must also assume the obligations to society that every person acquires.

General Electric's Vice President Chester Lang recently spoke of the "corporate citizen" and the "corporate alumnus" as having both moral and economic responsibilities. This attitude reflects the modern, distinctly American free enterprise, quite different from European industrialism that resulted in socialism and communism. As Frederick Allen writes in *The Big Change*, this quality of the American economic system has enabled us to evolve past socialism into true economic democracy.

Dr. Davidson is president of Union College in Schenectady. He is also Chairman of the Board of Directors of the Empire State Foundation of Independent Colleges and takes a leading part in community affairs.

Responsibility to Community

A truly American corporation feels a responsibility for the community in which it is located. I am not now thinking of company towns that once disgraced the landscape in some mining areas; out of these have grown model cities such as Longview, Wash., erected by the Long-Bell Lumber Co., and the new steel city growing up along the Delaware River between Philadelphia and Trenton. Perhaps the most famous of these is Hershey, Pa., where schools, clubs, and a famous sports arena were provided by the Hershey Chocolate Corp., through the Hershey Foundation.

The federal government has helped to finance some cities—Oak Ridge, Tenn., and Hanford, Wash. These communities can be overpaternalistic, though most of them have tried to leave major decisions to private citizens.

"...cities' whole standard of living...improved with company help."

I am thinking, rather, of towns and cities that were there long before the industry or corporation arrived, but whose whole standard of living has been improved immeasurably with company help. Rochester, NY—an outstanding city of this class—was given its present cultural distinction through the generosity of George Eastman and the Eastman Kodak Company, Bausch & Lomb Optical Co., and other local firms.

I found the same pattern in smaller cities, such as Kewanee, Ill., where parks and buildings have been the gift of the Boss Mfg. Co., and the Kewanee Boiler Company; or Corning, NY, with its beautiful community center attached to the Corning Glass Museum; or Endicott, NY, with a country club and other facilities provided by International Business Machines Corp.

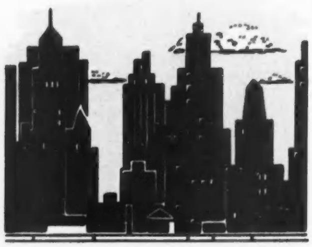
Officers of leading corporations in many cities are on the budget committee of the Community Chest. And when the budget goal is set, they persuade the corporation directors to take responsibility for a reasonable percentage of the total. This percentage may be arrived at by formula of number of employees, total payroll, or company profits.

The growing practice is the establishment of a company foundation into which go up to five percent of the profits before taxes and from which appropriations to the various agencies are made. Because a portion of these funds will be held over from year to year, the ups and downs of company profits are somewhat leveled. Certainly, in an industrial community no drive has a real chance for success unless it is sponsored by the local corporations. In considering sponsorship, officials regard the gifts not merely as acts of charity but also as a partnership with the local citizens.

Decentralization Problems

When a corporation outgrows one city and begins to decentralize its operations, new problems arise. If its executive officers are in Chicago or New York while its plants are in a dozen or more smaller communities, how is the philanthropic, or good-neighbor, program to be planned? Are decisions to be left to local management, or are all questions to be settled at headquarters? There is some danger that central executives, living and working in a huge metropolis or commuting to the suburbs after work, may lose sight of the problems and opportunities in the grassroots where the real work is done.

As a college president, I have been following this development with interest. A home-town industry is naturally tied in with the home-town college. Perhaps some of the officers are alumni; probably some are trustees. Many of the students come from employee families, work in the plant during vacations, and plan to seek permanent employment there after graduation. Members of the faculty may serve as consultants on a "retainer"; some of industry's research problems may be assigned to the college laboratories. Employees and management probably attend adult education courses, lectures, concerts, and other events on the college campus—a community cultural center. What is more natural therefore than that the company should make annual contributions to the college budget or occasional gifts to capital drives? Union College recently benefited from such a hometown gift when the General Electric Educational and Charitable Fund, celebrating the 75th birthday of the Company's establishment, gave the college a substantial sum to strengthen equipment in engineering.



Product Research . . .

The large many-branched corporation also has university affiliations. Perhaps important research in the products manufactured by the company is being carried on at a university; a contribution to such research is not even considered charity but a deductible business expense. Every winter and spring the personnel officers from thousands of corporations visit colleges to recruit scientists, engineers, salesmen, and business administrators from graduating classes. Graduate fellowships in allied fields are supported with company funds, and junior executives are sent to special workshops. Company scholarship funds, such as the Ford Motor Company fund, send children of employees to colleges, and supplement this aid with grants to college budgets. Naturally, most of these company-connected grants go to the larger universities with graduate schools.

Even the corporation without direct college and university affiliations is deeply affected by what happens on the campuses. Women purchase most of the consumer goods, and their standards of selection and level of living are elevated by their college education. The research carried on in the medical schools and the training of competent physicians, surgeons, and nurses have done much to raise the general health level of our people. What is more natural, then, than a gift from the great life-insurance companies or the pharmaceutical houses to support the National Fund for Medical Education?

Intelligent stockholders should be an asset to a good company, and the study of economics and social science should make better stockholders. The free enterprise system will prosper in America only if we make democracy a success. As Thomas Jefferson reminded us, the effectiveness of a democratic society is forever linked with the education of its citizens. Corporations therefore profit from the very presence of colleges and universities in our society because they help to set the tone of our civilization.

In Chicago, Marshall Field & Company and Sears, Roebuck & Co., worked out a plan whereby students could work split shifts in pairs three days a week, and thus earn their entire way through the University of Chicago. In Pittsburgh the great steel companies have joined the Aluminum Co. of America, Koppers Coke, Inc., Westinghouse Electric Corporation, and other local plants to support the University of Pittsburgh in its development of a great medical center and the Carnegie Institute of Technology in its graduate program; they have also united in a physical rebuilding of downtown Pittsburgh's Golden Triangle to create an inspiring new civic center.

. . . and Character Research

In Indiana, the Eli Lilly & Co., manufacturer of pharmaceuticals, has not only been generous to campaigns and charitable agencies in Indianapolis where the plant is located, but has also taken under its wing 10 of the independent and church-supported colleges of Indiana, with almost $4 million in gifts during the last decade. I have been particularly conscious of the good neighborliness of Lilly—through the Lilly Endowment by which company gifts are made. In the past 10 years they have contributed over a million dollars to Union College to support a program of religious education and character research. Certainly this is a field far removed from drug manufacturing, and one not calculated to bring immediate returns. It's an excellent example of contributions in the interest of our wider society—the gift of a good "corporate alumnus."

Standard Oil Co. of Indiana, with plants and distributors in 14 Midwest States, recently announced a gift of $150,000 to the college foundations of those states. These groups of affiliated independent colleges united to provide an avenue through which corporations can give to higher education without the agony of discriminating between Colleges *A* and *B*.

In New York State the 22 such colleges that joined in the Empire State Foundation of Independent Liberal Arts Colleges have already felt the warmth of neighborly gifts from such corporations as International Business Machines Corp., Rome Cable Corp., Carrier Corp., Cluett-Peabody & Co., Inc., American Locomotive Co., General Ice Cream Corp., New York Life Insurance, Union Carbide and Carbon Corp., and others. Bethlehem Steel Corp. contributes a fixed fee for graduates added to their personnel by certain colleges; the E. I. du Pont de Nemours & Co. supports chemistry departments in a selected group of institutions. And each week announcement is made of some new pattern adopted by a corporation for distributing gifts to higher education.

Perhaps the simplest way to discover whether your company is a good neighbor is to look at the condition of the town or city where your plant is located. Then ask if the company contributes anything more than a weekly payroll to the community. Not that the payroll doesn't show a good-neighbor philosophy—sometimes perhaps the best way to improve life in a town is the granting of a wage increase or bonus.

The check list shown here can help you to see your company as the community sees it. After reading the list, what is your answer to the question: Is your company a good neighbor? Ω

HOW DOES YOUR COMPANY RATE?

Does your company place a reasonable percentage of its annual profits in a company foundation chartered to make charitable gifts?

Does a top executive or responsible committee carefully study the agencies, hospitals, colleges, and other organizations within your larger community and recommend gift allocations upon the basis of considered policy? Or does your company merely wait to be asked and then grease the squeakiest wheels?

How much does your company know about its employees' families and its stockholders, their college affiliations, use of hospitals, YM-YWCA, Boy or Girl Scouts, and other connections that may deserve company support?

Does your company demand an immediate concrete return for every gift, or does it recognize that some deserving activities have long-range effects upon the community or our entire society?

Does your company follow through on its gifts to see how the money is used so that a decision can be made to eliminate, continue, or enlarge its contribution next year?

How many of your company family are responsible officers or trustees of agencies being aided?

Is your company making its contribution merely because most of it goes to reduce the corporate income tax, or because it really believes in free-enterprise business supporting the other free enterprises in our democracy?

Are you proud of being a good-neighbor corporate citizen, or do you give reluctantly, under pressure?

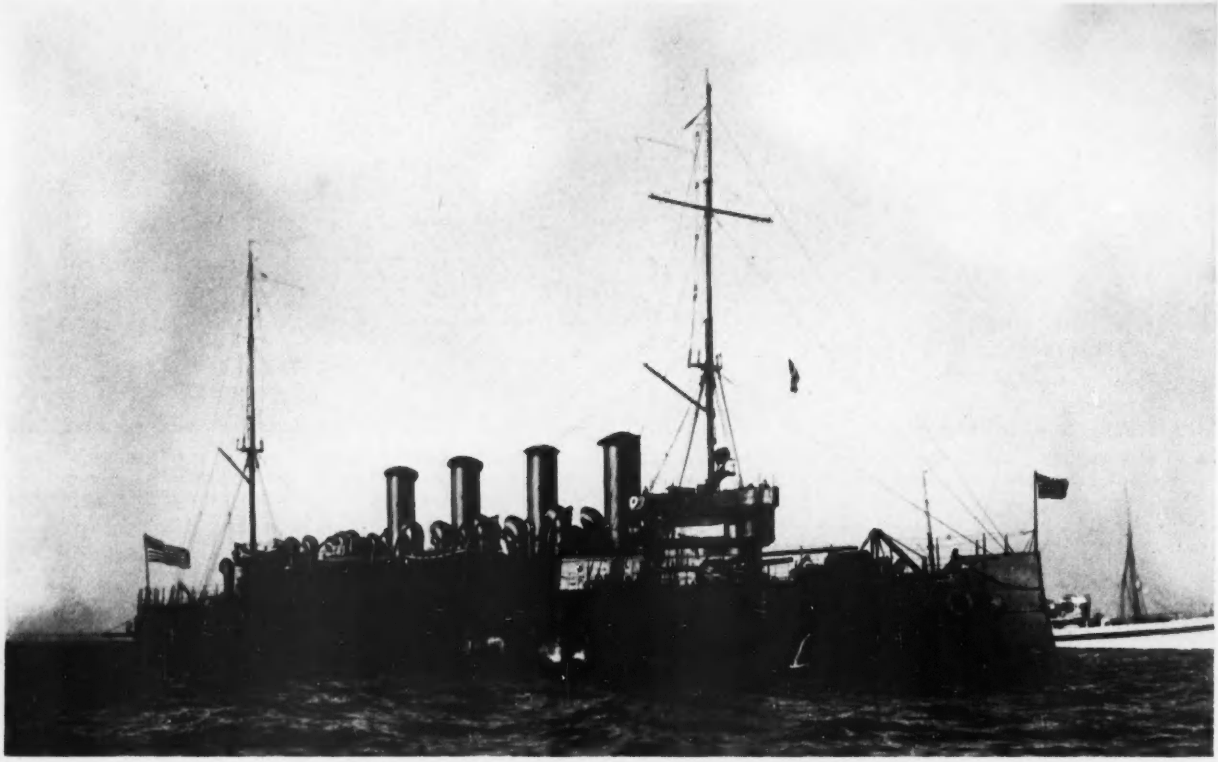
ENGINEERING REPORTS:

MINING output has been increased by amplidyne control engineered into electric shovels and mine hoists, including giant strippers like this. Instant shovel response, plus faster acceleration and deceleration, cuts seconds off each pass, helps increase the daily yardage handled. At all speeds, electrical and mechanical components of your equipment are better protected.

Engineers exploit "short circuits"

ORE-HANDLING, as well as blooming, rolling, pickling and other steel-mill operations, uses the G-E amplidyne. Ore bridge drives provide more accurate bucket control, fast trolley travel.

G-E ENGINEERS L. A. Umansky (left), Mgr. of Engineering, Industrial Engineering Dept., and C. B. Huston, application engineer, discuss an amplidyne application for a new steel-mill drive.



1890 USS *Columbia's* keel was laid in 1890 and the ship commissioned in 1894. Vertical 3-cylinder triple-expansion reciprocating engines powered the 413-foot-long vessel. She carried a complement of 18 officers and 360 enlisted men.

1944 USS *Oregon City* was commissioned in 1946, two years after the keel was laid. Steam turbines of 120,000-shp drive this 673-foot-long ship. The vessel's personnel consists of 129 officers and 1840 enlisted men.

The American Society of Naval Engineers

By CAPTAIN R. B. MADDEN, USN

Naval engineering—and that includes the broad fields of marine engineering, naval architecture, electrical engineering, electronics engineering, and shipbuilding—is among the oldest of the various engineering branches. Although some phases, such as electronics engineering, are relatively new, others date back to the days of Noah. Shipbuilding was one of this country's Colonial industries. Shortly after the United States won its independence, the country's first three warships—*Constitution*, *United States*, and *Constellation*—were designed and constructed under the supervision of naval constructors, as naval engineers were called in those days.

In the 19th century, during the transition period of our Navy from sail power to steam propulsion and from wood ships to iron and steel ships, the profession of naval engineering began to come into its own. Until the turn of the century naval engineering knowledge was largely centered in England and France. But since 1900 the role of American naval engineers has increased to the point that they have become the leaders in their fields.

Naval engineering has broadened considerably with such developments as electronics, electric power, steam turbines, and the use of fuel oil instead of coal. In addition, our warships have improved to the point where they are the finest in the world; since the beginning of World War II, delegation after delegation of foreign warship experts have visited this country for the admitted purpose of determining why our ships are better than theirs.

Educational Contributions

As early as the last half of the 19th century, naval engineers contributed greatly to the advancement of engineering education in the United States; their efforts affected immeasurably the whole course of technological development for many years. By an Act of Congress in 1878, officers of the Engineering Corps of the Navy were assigned to colleges to promote a knowledge of steam engineering and iron-ship building. During the next 20 years 43 naval engineers were detailed to 52 school assignments. Moreover, many of the officers of the Engineering Corps left the service to take up educational work in a civilian capacity. To indicate the important contribution naval engineering made to engineering education, one need cite the names of but a few of these men: Dr. William F. Durand of Cornell and Stanford, Dr. Robert H. Thurston of Stevens Institute and Sibley College (and first president of the American Society of Mechanical Engineers), Dean Mortimer E. Cooley of the University of Michigan, Dr. Albert A. Michelson of the University of Chicago, and Dr. Ira N. Hollis of Harvard and Worcester Polytechnic Institute.

Early Organization

On September 30, 1888, about 20 officers of the Engineering Corps of the Navy met in the Bureau of Steam Engineering. It had been evident that some means for the dissemination of information relative to naval engineering was urgently needed, and the meeting was held to devise ways for the proper presentation and preservation of papers pertaining to debatable subjects in naval engineering. One of the officers present, Past Assistant Engineer A. M. Mattice, proposed that an organization known as the American Society of Naval Engineers be formed for the purpose of promoting naval engineering prestige and efficiency. Under the leadership of Rear Admiral G. W. Baird, the officers present accepted this proposal and decided to issue a quarterly journal to carry out the major purpose of the new society.

Among the individuals most responsible for the development of naval engineering just preceding the formation of ASNE and during the early years of its history, the name of Rear Admiral Benjamin F. Isherwood is outstanding. Admiral Isherwood, the Navy's Engineer-in-Chief during the entire period of the Civil War, is credited with doing more for the advancement of naval engineering since machinery was installed as the propelling power on board naval ships than any other man in this country. His work was the chief impetus for the formation of the Society.

Others who figured prominently in the early years of the ASNE were Chief Engineer Nathan P. Towne, ASNE's first President; Rear Admiral R. S. Griffin, first Secretary and later President of ASNE, World War I Engineer-in-Chief of the Navy, and Chief of the Bureau of Engineering; Walter M. McFarland, later associated with Babcock and Wilcox; Rear Admiral George W. Melville, later President of ASME; Charles H. Manning; Rear Admiral C. W. Dyson, later Secretary and President of ASNE; and Chief Engineer F. G. McKean.

Growth and Membership

By the end of the first three months of the Society's existence, 102 members were on its rolls. During the next year the membership more than doubled, representing the bulk of the officers of the Navy's Engineering Corps.

The importance of membership in the Society became more and more evident as time went on, not only in the Naval service but in civil life too. Early in ASNE's existence only members of the Naval service were admitted as Active Members. However, the important contribution being made to naval engineering by individuals in civil life, both in a civil service capacity and throughout the marine engineering profession, was recognized by the establishment of the

"The wide scope of naval engineering encompasses many fields . . . ."

grade of Associate Member. Then in 1922, when the grade of Civil Member was established, 16 Associate Members qualified by engineering experience became Civil Members. At that time the total membership consisted of 800 Naval Members, 16 Civil Members, and 400 Associate Members.

Since 1923 growth of the Society has been gradual but steady. Today the total membership is more than 2700—Naval Members number half, Civil Members nearly 900, and Associate Members about 450.

Eligibility for the three types of ASNE members varies with the status and engineering experience of the individual. Commissioned, ex-commissioned, warrant and ex-warrant officers of the regular Navy, Coast Guard, and Marine Corps, as well as commissioned and warrant officers of the Naval, Coast Guard, or Marine Corps Reserve, are eligible as Naval Members. Persons in civil life who have had eight years of engineering experience—five of them in responsible charge of important work—are eligible as Civil Members. Persons in civil life who are not eligible for Civil Membership, but who are especially interested in naval or merchant marine matters, can be eligible as Associate Members. And so can commissioned officers of the United States Army or Air Force and of foreign military or naval services.

ASNE Journal

The object of ASNE is the advancement of the art, science, and practice of naval engineering . . .

- By publishing and discussing papers on professional subjects
- By bringing together and publishing the results of experience acquired by engineers in all parts of the world
- By publishing the results of such experimental and other inquiries as may be deemed of value to the advancement of science
- By recording historical events in the lives of engineers.

The decision to publish a quarterly journal made at the organizing meeting in 1888 was to satisfy the impelling demand for bringing within reach of naval engineers valuable technical information and data—possessed by individual officers but not available to the service at large.

The first *Journal* was published in February 1889, and, in addition to notes on recent steam trials and on recent casualties and repairs, its 96 pages contained the following articles:

"Notes on Coals of the Pacific Coast," by Assistant Engineer C. R. Roelker, USN.

"Increase of Horsepower for a Given Speed Due to Foul Condition of Ship's Bottom," by Assistant Engineer W. M. McFarland, USN.

"Data of Some Quadruple Expansion Engines and Their Performances," by Assistant Engineer F. C. Beig, USN.

"Progressive Trials of the Steam Barge of the Commandant of the New York Navy Yard," by Chief Engineer Isherwood, USN.

"Data and Capacity Tests of the High Service Pumping Engines, Washington, DC," by Past Assistant Engineer G. W. Baird, USN.

"Some Problems in Propulsion," by Assistant Engineer W. D. Weaver, USN.

Throughout the Society's 66 years the Journal has been published quarterly without a break. Widely referred to and quoted by other publications in its field, it now finds its way into practically every area of the globe. Further, many of the articles that have been published in the Journal are regarded as valuable reference material by all shipbuilding firms engaged in naval work.

Limited Activites

The ASNE does not hold professional meetings or conventions, relying on the Journal to provide its members with technical knowledge. Instead, it holds an annual business meeting in October in Washington for the presentation of nominations for offices and such other business as may be raised. On January 1 of each year the new officers assume their duties.

In late April or early May the Society holds its annual banquet in Washington. The first banquet, celebrating the 21st anniversary of the Society, was held on May 7, 1909, with 134 members and guests in attendance. Attendance last year was approximately 1700. Each year the banquet attracts top executives and engineers in the shipbuilding and manufacturing industries of this country, as well as leaders in government, besides officers and civilian engineers of the various Armed Services.

ASNE is one of the charter members of the District of Columbia Council of Engineering and Architectural Societies that was organized in 1936.

Role of Naval Engineering

Naval engineers are responsible for the research, design and development, construction, alteration, conversion, maintenance, and repair of naval ships including all their machinery and equipment. The 11 naval shipyards—together they form one of the largest industrial organizations in the country—are manned and managed by naval engineers, as are many naval laboratories. In addition, the private shipbuilding industry and many of the country's large and small manufacturing industries include naval engineers among their executives and engineers. And finally, naval engineers are responsible for the operation of the machinery plants of the United States Fleet's many ships.

The wide scope of naval engineering encompasses many fields other than marine engineering, naval architecture, electrical engineering, or electronics. Numerous members are specialists in such fields as chemical, mechanical, industrial, metallurgical, petroleum, and nuclear engineering. Many officers and civilians who are specialists in aeronautical engineering are also members of ASNE, thus indicating the important relation between the Navy's ships and its aircraft.

Most ASNE members are affiliated with other engineering societies—many elected to high positions. The Society of Naval Architects and Marine Engineers, ASNE's sister society, includes among its officers ASNE members also. At least five presidents of the American Society of Mechanical Engineers have been naval engineers. Other societies have similarly indicated the close relationship between naval and the other engineering fields. Ω

•

Capt. Madden is Assistant Secretary-Treasurer of the American Society of Naval Engineers and Assistant Editor of the Society's JOURNAL.

THREE MEN CONTROL THE FLIGHT OF THE BOEING *STRATOJET* BOMBER AS IT ZIPS THROUGH THE SKY AT 600 MPH, A TRIBUTE TO . . .

AIRCRAFT INSTRUMENTATION— IN STEP WITH THE TIMES

By A. W. EADE and J. J. FRAIZER

Today you commonly read of experimental aircraft flying much faster than 760 mph, the speed of sound at sea level. Because the sonic barrier is no longer insurmountable, engineers have set their sights on the newest obstacle to aeronautical progress—the heat barrier.

Accomplishing all this in the short span of 50 years has called for some highly advanced thinking in terms of air frames and engines. And hand-in-hand with their remarkable development has been the growth of aircraft instrumentation.

For example, only three men control the flight of the B47 *Stratojet*, a 600-mph medium bomber (photo). Its crew receives intelligence from the bomber's complex system of instruments and controls and interprets and acts upon it without hesitation. Such confidence in systems—replacing the human senses in many instances—is an evolution that began with the Wright brothers and is still in progress today.

Early Birds

When the Wright brothers made the first powered flights in 1903 over the wind-swept sand bar of Kitty Hawk, off the North Carolina coast, they went about it in a most scientific manner—with instruments.

Mounted on a wing strut of their hand-built plane was a tachometer to measure propeller revolutions, a vane-like instrument called an anemometer to measure air speed, and a stop watch to measure elapsed time. Of the four flights the brothers made that day, Wilbur Wright clocked the best speed, averaging 12.1 mph, flying 195 feet in 11 seconds.

Following the Wrights came other pioneers who were less interested in instrumentation than the main problem of just lifting their craft safely in the air and keeping it there. These early birds concentrated on developing more adequate control surfaces to give them a greater degree of safety in flying maneuvers. Flights seldom exceeded hops of short duration and were usually made under excellent weather conditions. Hence there wasn't too much need for instruments. And for many years the Wright brothers' instruments plus the magnetic compass were the only ones used in planes.

The first transcontinental flight in 1911 initiated long-distance flying. Better flight controls, navigational aids, and engine instrumentation were now needed. Pilots wished to fly at night

•

Both authors are with General Electric's Meter and Instrument Department, West Lynn, Mass. Mr. Eade joined the Company 12 years ago, taking out four years to earn his engineering degree. He is designing a compass-controlled directional gyro system for military aircraft. Mr. Fraizer came to GE on the Test Course in 1948 and is now designing tachometer indicators.

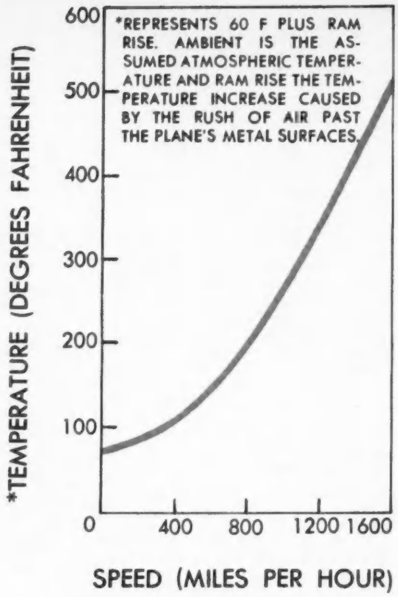
FROM ZERO TO 740 PLANES . . .

GROWTH OF U.S. MILITARY AIRCRAFT DURING WORLD WAR I

Except for a handful of pilots, balloonists, and obsolete planes in the Signal Corps, U.S. air power was practically nonexistent on April 6, 1917, the day we entered the first world conflict of modern history.

But some 19 months later, November 11, 1918, the United States Air Service had based in France approximately 1200 trained pilots and 45 squadrons totalling 740 aircraft. Here's how U.S. air power looked then—

PURSUIT	**20 squadrons of fighter planes, mostly foreign made.**
OBSERVATION	**18 squadrons of fighter planes, including some bomber types.**
DAY BOMBERS	**6 squadrons of medium bombers whose mission was primarily tactical.**
NIGHT BOMBERS	**1 squadron of heavy bombers. Knocking out factories and supply depots well behind enemy lines was their primary mission.**



HEAT BARRIER is more formidable than the sound barrier—redesign of aircraft can't overcome it. Only in the airless reaches of space can missiles escape its effect.

and over designated courses between cities. They wanted to know how much fuel they had in the gas tank, their engine and air speed, rate of climb, altitude, and heading.

Then in 1913 along came Elmer Sperry, a pioneer in the instrument field, who successfully demonstrated the first gyroscopic stabilizer. It represented a great advance in aviation. For a plane equipped with this device would continue in level flight, permitting the pilot more time for navigation and the other duties constantly demanding his attention. (A gyroscope, by the way, is essentially a spinning wheel mounted in universal bearings, or gimbals, so that its axis is free to move in any direction. Once the wheel is set in motion, any effort to divert the spin axis from its fixed position in space is resisted.)

The Twenties

World War I ushered in a new era of flight, not because of any significant technical developments but because of the publicity and glamor it attached to flying. On Armistice Day, 1918, the United States had approximately 1200 trained pilots, 45 airplane squadrons, and an established air service (box). Shortly thereafter regular airmail flights were established and cross-country trips became commonplace.

Night or bad-weather flying, however, remained extremely limited and hazardous. Radio was introduced as an aid, but pilots didn't trust it as a reliable device—they were still prone to fly by visual contact with the ground, using railroad tracks and beacons as navigational aids. As you can imagine, these were inadequate for scheduled airmail flights, and improved instrumentation became imperative.

And so, scientists and engineers throughout the country focused their attention on navigational instruments, particularly gyroscopes. Sperry introduced another instrument, the gyro turn indicator, that aided the pilot in maintaining flight direction and altitude while he took a magnetic-compass reading. The turn-and-bank and rate-of-climb indicators were also introduced, adding to the growing complexity of the plane's instrument panel.

During the early 20's artificial horizons and directional gyros were developed, and airmail flights were possible on a more scheduled basis.

Flying was sufficiently advanced in 1927 to enable Lindbergh to make his famous flight to Paris. The significance of this feat was that it acquainted the public with the possibility of commercial air transportation. And two years later the Army Air Corps further impressed this factor upon the public's mind when it demonstrated the first solo blind flight. (A two-seater open-cockpit plane was used, the rear cockpit covered by a hood.) With the aid of an automatic pilot, developed at about the same time, an airplane could now fly over a designated course without its pilot's having once seen ground.

The Thirties

Pilots soon began to accept instruments for what they were—safe, reliable, accurate devices. This acceptance was a great advance in itself. Radio navigation became a practical reality and instrument flying common.

By 1937, air frames and engines were advanced enough to make feasible the construction of a modern multi-engine passenger plane such as the Douglas DC3. This familiar craft was so well-designed that it is still in use by many airlines today, some 17 years later—an amazing life span in such a fast-moving industry. (The military version of this famous plane is designated the C47; during World War II it was the work-horse of the Air Transport Command.)

Considered a highly intricate airplane in 1937, the DC3 was equipped with about 125 instruments and controls, exclusive of radio and other navigational devices. Miles of wire laced through its fuselage and wing panels. Looking at its instrument panels today, you might wonder if the designer had gone beyond the limits of a person's ability to interpret and react. Yet through the development of check lists and standardized flying techniques, crews learned to fly this plane and the more complicated ones that followed.

By the close of the 30's, transcontinental flights on a scheduled basis were well-established, and men could fly across oceans with relative ease.

World War II

The next war ushered in an even more startling era of flight. Because of the war pressures, instrumentation made about 20 years' progress in four years. Electronics played a major role in this phenomenal growth: During two war years alone—1942 to 1944—the electronics industry increased fourfold.

Aircraft of 1946 were so far advanced over those of 1940 that you can hardly place them in the same category. For example, a plane could now take off, fly a set course, and make an instrument landing in an emergency without a human hand applied to its controls. A turning point and a highly significant step in the instrumentation field was the GE-developed synchronized gun-control system, first used on the B29 *Superfortress.* It heralded the approaching shift from a multitude of individual instruments and controls on the instrument panels toward the development of automatic flight-control systems. These systems were to use fewer panel instruments and more interrelated components located in other sections of the airplane. Whereas all the instruments and controls had been under the crew's immediate supervision, in the future only panel components would function in that manner (box).

Postwar

With the development of new types of propulsion units in the postwar era—gas-turbine, turboprop, ram-jet, and rocket—new and additional measurements were needed. A whole new variety of instruments and controls that presents data to the crew in a form for useful action was and still is undergoing development. Supersonic speeds and increased plane weight greatly influenced flight conditions and created additional problems.

At extremely high altitudes, where the sky is pitch black overhead and the earth a dazzling white blanket below, the human eye fails as a lookout, or spotter. Here, instrumentation in the form of radar and radio is combined to do the job. Where new variable wing structures that can be shifted from normal to swept-wing position during flight are employed, the pilot wants to know their position and whether they are secure. In flights at supersonic speeds, large dynamic oscillations have created new problems of stability.

Then there's the heat barrier. Excess heat is developed in a plane's cockpit or interior by skin friction at supersonic speeds (illustration, opposite page). And even though the stratosphere may be at −65 F, the plane requires some form of interior cooling.

In navigational problems the pilot's need for instrumentation is particularly acute. For if you assume that a gyroscope has a one-degree directional error, then a plane traveling at 700 mph would be approximately 1.23 miles off course in six minutes (not a desirable situation if a pilot were trying to locate an island in the ocean with his fuel tanks nearly empty). Nor can you neglect reliability. Because instruments today are fast becoming components of systems, the failure of one might cause collapse of an entire system. Simplicity, of course, favors reliability and is the ultimate goal. And coincident with this is the desire to decrease the weight of all instrument systems.

Aircraft problems in the postwar era are many and varied.

TO THE AIRCRAFT INSTRUMENTS ENGINEER . . .

INSTRUMENTS are devices located on panels in front of each crew member that indicate various remote measurements by means of pointers and dials.

Example—A position indicator shows the position of the plane's landing wheels.

CONTROLS are devices on or near the instrument panels that are pushed, pulled, turned, cranked, or otherwise moved to perform some function.

Example—A switch turns on landing lights; a knob controls radio equipment.

SYSTEMS automatically combine the functions of several instruments and controls—one lever may signal a whole series of operations. Usually, systems are much heavier than the components they replace because of their great complexity.

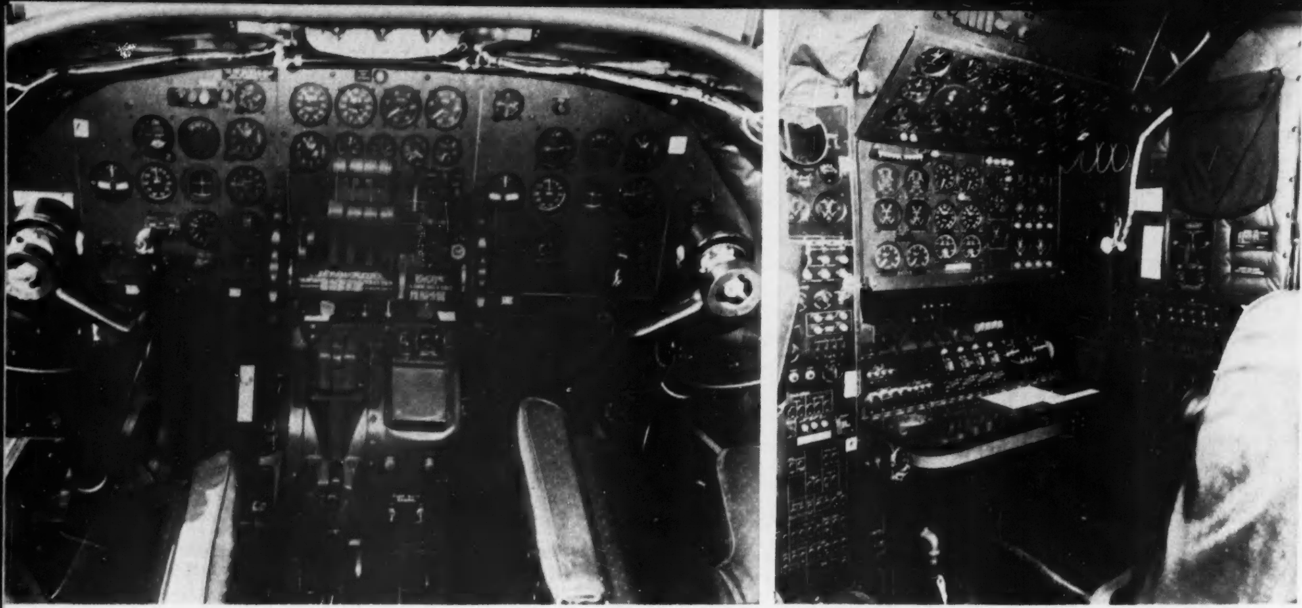
Example—A jet engine control, among other things, provides acceleration proportional to the selector position, computes the maximum rate at which fuel can be supplied without stalling the engine, and limits tailpipe temperature to a predetermined maximum.

The First 50 Years

The growth of instrumentation and the speed of aircraft from 1903 to 1953 are compared in the graph, page 41. The flat portion of the instrument curve reveals the minor role instruments played in the first 20 years. You can attribute this to the primitive nature of the flights and to the attitude of the pilots toward instrumentation in general. Flying was in its infancy during this period, and little of it was done at night or during bad weather.

Instrumentation increased slightly in the 20's because of the interest in longer flights and the faster speeds made feasible by engine improvements. Better instruments and controls were needed as engine and air frame were operated closer to their design limits. Flight attitude and altitude, engine speed, manifold temperature, oil pressure, and fuel quantity were now being measured by instruments.

Note on the graph the significant change in instrumentation about 1933, the year the retractable landing gear was introduced. For then, position indicators became highly desirable to show whether the landing wheels were up or down. Other indicators revealed the position of wing flaps and bomb-bay doors. And it was not long before plane communications systems became necessary, while voltmeters and ammeters were added to



HUMAN ENGINEERING in practice—flight and navigational instruments of modern air transport (*left*), the Lockheed *Super Constellation*, are grouped on a panel immediately in front of the pilot, with duplicates in front of the copilot. Other instruments that aren't absolutely essential to the pilot have been removed to the flight engineer's panel (*right*), whose job continues to grow in complexity.

TABLE I—TIME AND MOTION STUDY OF A B29 COPILOT

The Boeing Aircraft Company undertook a study of the motions of a copilot in a B29 Superfortress making a standard military approach and landing. The approach consisted of four zones, or legs, during which time the copilot had approximately 305 seconds to perform 116 actions. Here's what they found . . .

Zone	Total Time (Seconds)	Motions	Time per Motion
Entry leg	80	21	3.8
Downwind leg	90	50	1.8
Base leg	45	15	3.0
Approach leg	90	30	3.0

TABLE II—TIME TO COLLISION

Consider two planes one mile apart and approaching on a collision course. If you assume both planes are traveling at the same speed, the time to collision will be . . .

Plane Speed (Mph)	Time to Collision (Seconds)
300	6
600	3
900	2
1200	1.5
1500	1.2
2000	0.9

show the status of the electric system.

You'll see that the curve of the instruments and controls begins to drop off about 1950. The reason is the postwar emphasis on simplicity—the use of more control systems. Also, there was concern over the growing cost of airplanes and the loss of performance resulting from their complexity.

On the Human Side . . .

One way to minimize flight hazards at today's high speeds and to increase flight safety in general is to apply human-engineering concepts to instruments and controls. You can define human engineering as the design and positioning of controls and instruments so that humans can use them in the most efficient manner (photos).

The solution to this problem lies in the study of human abilities and limitations. One highly important consideration is the time needed for a trained pilot to see and react to a crisis. For example, when a pilot is flying and sights an obstacle in his path, his eye has to transmit the idea to his brain; his brain must size up the situation and decide upon the correct action, then transmit the message to his hand—to grasp a control, for example, and move it in the proper way. All this takes time no matter how automatic such a reaction may seem (Table I).

The human engineer is concerned with the location and shape of a control. He considers, among other things, how it is set apart from other controls and whether the pilot could grasp the wrong one by mistake. Also, he considers if it is shaped so that there will be no fumbling or slipping as the pilot grasps it.

Prior to World War II these human-engineering concepts were largely neglected; many accidents occurred because an instrument dial was misread or a control mistakenly applied. This lack of standardization from one plane to another often proved hazardous. A pilot flying one type of plane automatically flipped one switch for flaps and another for wheels; in another type of plane, these switches might be reversed, and the pilot might raise the flaps when he meant to retract the wheels.

(In the 22 months from January 1943 to November 1944, the Air Force reported that confusion between landing gear and flap controls caused 457 accidents. For one pilot's viewpoint see "Laboratories In The Sky," page 12.)

Other important items often overlooked in the design of an airplane are visibility, seat design, cabin comfort, and instrument lighting. A good deal of work is under way on instrument lighting to improve the situation, particularly with regard to daytime lighting. Here the pilot may be momentarily blinded when transferring his sight from a relatively dark instrument panel to the extremely bright skies of higher altitudes.

. . . More Automatic Control

Human engineering can certainly help the pilot as flight speed increases. But since his reaction time remains relatively constant, he must rely more and more on automatic controls.

Where airplanes are concerned, automatic control means a plane's ability to land, take off, and maintain a set course —all with a minimum of human guidance. This method of flight has been evolving for some time now. In fact, it had its beginning in 1913 when Sperry first demonstrated the gyrostabilizer.

With each subsequent improvement made on flight-control systems, certain senses of the pilot have been replaced. Automatic pilots, for example, substitute for his sense of stability and hold a plane on a fixed heading at a given altitude. Gyroscopes are the primary detectors for this type of system. Extremely sensitive to changes in position, they will detect even small variations in the plane's course. When a change does occur, the gyros send out error signals in the form of voltages. These operate servomotors that actuate controls to put the plane back on its initial heading.

Radar substituted for the pilot's vision during World War II. It too was a big step in the direction of fully automatic flight. In today's aircraft, radar detects flight obstacles under all conditions of visibility, directs weapons systems, and measures true ground speed and drift.

Automatically actuated controls become even more essential at supersonic speeds. For at 900 mph or more, the time in which a pilot can react to a situation is so limited that automatic controls are absolutely necessary. What will they be at 1600 mph, a speed that experimental military planes have already exceeded (Table II)?

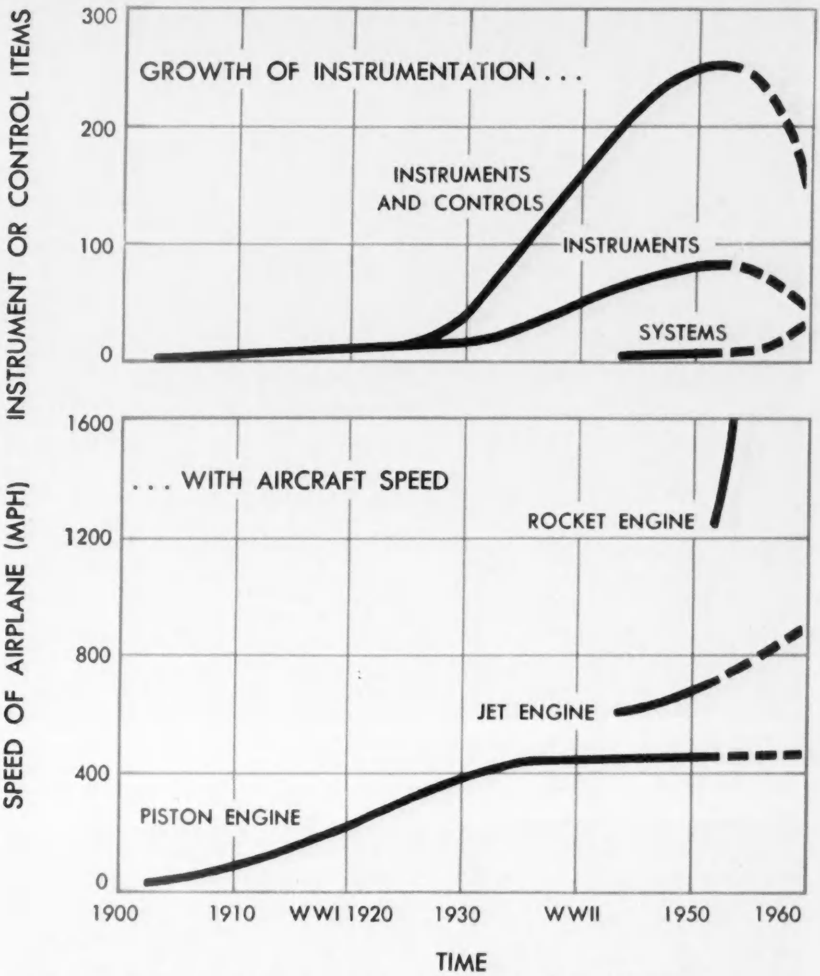
The Future

At the high speeds military planes fly today, the pilot simply doesn't have time to read indicators and co-ordinate information presented to him. To offset this situation, many new flight-control systems are presently undergoing development.

A good example of what is taking place is the automatic jet-engine control system developed by GE for the North American F86D *Sabrejet*. Here seven separate measurements are integrated, allowing the pilot to increase or decrease his thrust by simply moving a throttle; there's no danger of his overspeeding or overheating the engine.

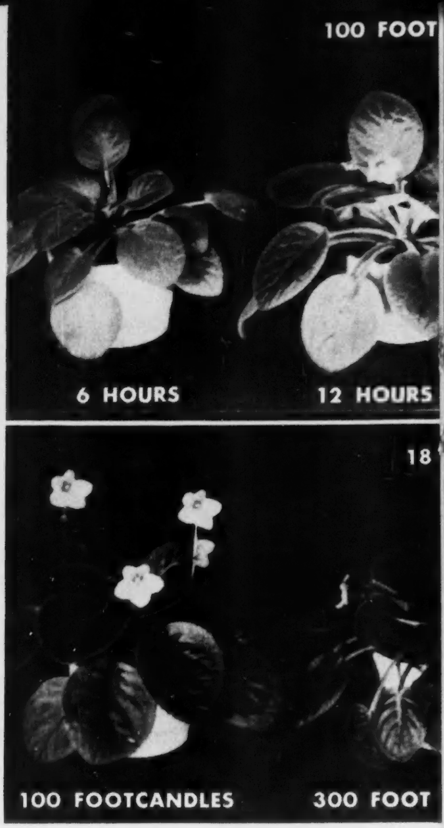
Many proposals have been made to consolidate instruments so that one indicator would serve where formerly three or four were needed. Again, for example, an engine-performance indicator has already been proposed that will replace four separate indicators. This single indicator will at a glance show engine speed and temperature and oil and fuel pressure. The fuel and oil pressure portions of this gage would merely be OFF-ON devices, with a green flag indicating safe, and a red flag unsafe, pressure ranges. On the surface this appears to be a particularly good feature, for airmen often only glance at an accurately marked gage to check the pointer's relative position.

The progress made in the first 50 years of flight has been nothing short of astonishing. And there's reason to expect that it will continue to be even more so in the future. So far as instrumentation is concerned, you can look for a greater consolidation of instruments as the speed of flight moves upward and more use of flight-control systems in place of individual instruments and controls. Everything possible is being done to make the pilot's job easier. And one day, perhaps, he may just go along for the ride. Ω

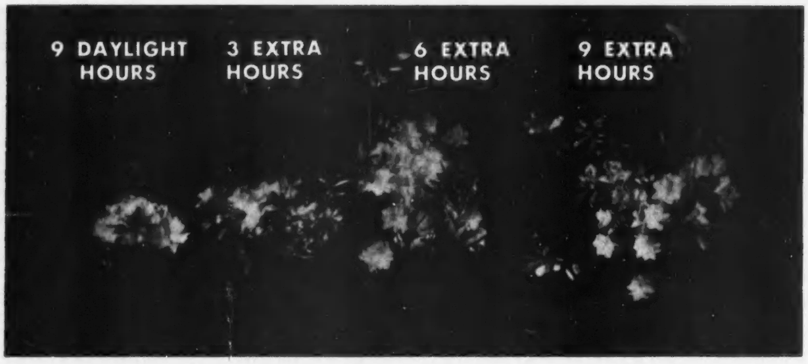


SHARP UPTURN in aircraft instrumentation took place when retractable landing gear was introduced in 1933. The trend to fewer instruments, more control systems, began in 1950.

CHRYSANTHEMUMS Southern California growers control timing of their mums for market by simple lighting systems that encourage nighttime maturing—a good example of photoperiodism technique.



AFRICAN VIOLETS Plants grown in Ohio State University laboratories (*above*)



AZALEAS Grown outdoors in season, these plants wintered in the greenhouse and were forced in the spring. Throughout this cycle, extra photoperiods supplied by filament-lamp radiation of about 30 footcandles increased their luxuriance.

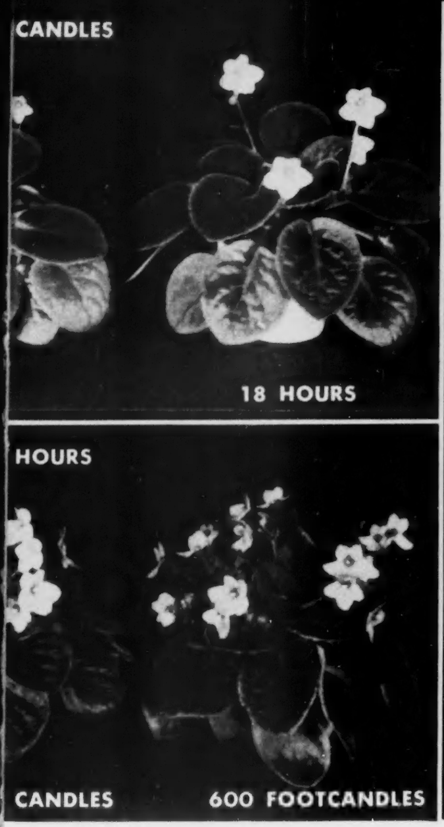
SUGAR BEETS
Where the object is to promote seed, the long-day plant (*right*) shows how this result was achieved while the short-day plant was developing more normal height and foliage.

Light—Its

Light—fundamental to farm production—is becoming the key to farm-crop control. Scientific use of lighting promises more startling benefits for mankind than some other areas of technology that are much more publicized.

Although the relationship of light to life has long been known, only recently have we learned enough about the way light enters the life process to apply it commercially. Just a few applications have begun to multiply the productive capacity on the farms, but what has happened so far has convinced many scientists and businessmen that great things are ahead. Even the farmer is having difficulty maintaining his customary reserve.

Areas of hazard, formerly accepted as unavoidable, are on their way to becoming areas of control. For management of radiant energy in the interests of better crops and favorable market timing has begun.



show the degree of response to various intensities used for each radiation period under artificial lighting. Periods of radiation were continuous for the number of hours indicated. Another lighting installation demonstrates the compact space for a home nursery. Four 8-foot standard cool slimline fluorescent lamps supply the energy to control the blooming and encourage luxuriant blooms.

Influence on Plant and Animal Growth

By J. P. DITCHMAN

Photosynthesis

The process of photosynthesis may be defined as the manufacture of carbohydrates from carbon dioxide and water in the presence of light through the mechanism of chlorophyll. All animals and plants depend on photosynthesis for food. In fact, it is the basic process of food manufacture in nature.

The visible part of the spectrum, the red at 6500 A and the blue at 4500 A in particular, is most effective in this process. Carbon arcs, incandescent lamps, sodium lamps, mercury lamps, fluorescent lamps, and many combinations of these are being used in growth chambers where light, humidity, temperature, and air composition are controlled to grow plants entirely under artificial conditions.

Photosynthesis, the light life of plants, has been called the second most important reaction on earth; it is coupled with the first—the oxidation of carbon. Together, they constitute the process by which a living plant prepares and consumes the food on which its life and growth depend. This chemical process, in which light is the principal energy source, is the basis of all terrestrial life.

The introduction in 1938 of the fluorescent lamp in the United States was significant in agricultural science. The balance of color of early white fluorescent tubes, although initially rather bluish, stimulated considerable experimental application on flowering plants, ornamentals, and some vegetables and seeds. The present plant-growth chambers used by the United States Department of Agriculture (USDA) at Beltsville, Md., and other groups employ artificial light in the proportion of approximately nine fluorescent-lamp lumens to one filament-lamp lumen—a proportion that seems to give plants their best growth response.

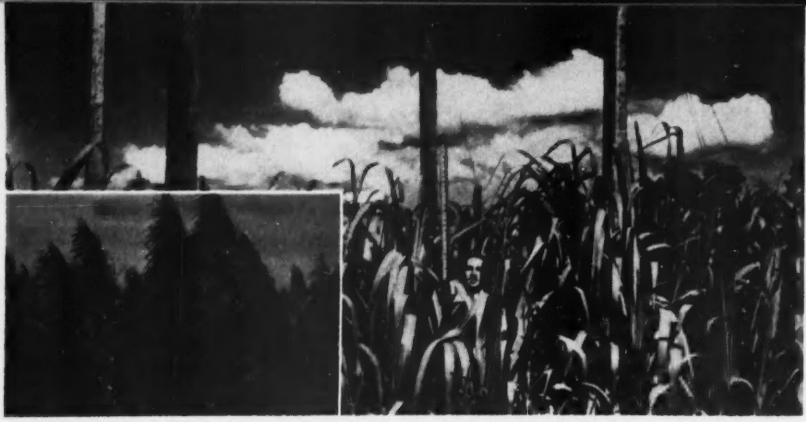
•

Mr. Ditchman, recognized as one of the country's leading farm lighting specialists, joined GE in 1927 and is presently with the Lamp Division, Nela Park, Cleveland. A pioneer in his field, he has touched off national and world interest in nonvisual applications of lighting for plant and animal industry.

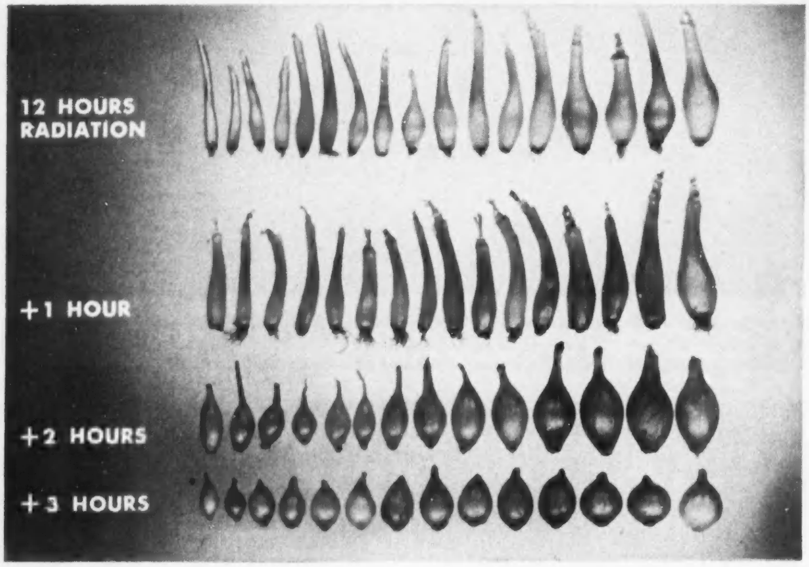
Improved Seed Quality

Vegetable seedsmen are keenly interested in recent USDA and other germination experiments. Vital research of such nature may lead to improved seed quality—a greater percentage containing mature embryos.

Generally, plants in greenhouses get less light but grow under higher temperature conditions than outdoor plants.



SUGAR CANE Lamps atop tall poles in a cane field interrupt nighttime effect. Tests in Puerto Rico show a 25 percent increase in the tonnage of lighted fields vs control plots where cane went to seed (*inset*) without lighting.



ONIONS Growth responses of this savory vegetable suggest advantages of light control for a field crop. Application of extra filament-lamp radiation in natural daylight reduces darkness hours, progressively improves bulb formation.

PLANT STATION In a USDA installation, 106 white slimline fluorescent and 24 100-watt filament lamps are used to produce about 2000 footcandles to ascertain relative growth data on a variety of vegetables.

Although their seeds are usually heavier, the quality may be poorer with a smaller percentage germinating.

In some tests in 1943 on seeds of guayule, or rubber-plant, a low (20) footcandle level was added at the end of the day. This value was chosen to induce a photoperiodic response without appreciably affecting photosynthesis. The Table shows that longer daily periods of illumination sustained the initiation of flowers and the production of seeds—and to some extent lengthened the flowering season. But most important of all, the quality and the quantity of seeds produced was markedly improved. The experimenters reported that while the 24-hour-per-day light treatment produced a relatively large number of seeds, they were of poorer quality with respect to the percentage of heavy seeds. Also of interest is that only one third of the group producing the greatest weight of seeds produced flowers.

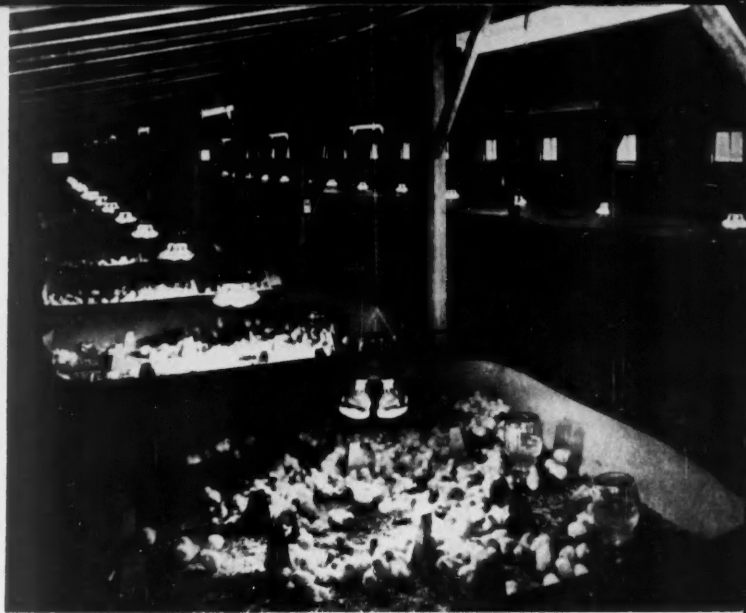
A recent investigation of lettuce seeds revealed new data on the maximum inhibiting effect of infrared rays and the maximum germination stimulus provided by red light. Strangely enough, the two are diametrically opposite in their effect on seeds. Dr. H. A. Borthwick and USDA associates showed previously that the inhibiting effect of infrared rays peaked at 7000 to 8200 A. They also found that red-lighted lettuce seed improved germination to a high point at 6000 to 7000 A. Recent testing disclosed that seeds can be reversed in the germination process, not once, but several times.

Photoperiodic Responses

More familiar to the average person are many other light-response reactions of plants: common house plants bending toward light, potatoes growing elongated shoots in darkened cellars, and leaves and leaf cells orienting under different intensities of light.

By far the most interesting phenomenon is the photoperiodic response of plants. About 30 years ago two USDA scientists, W. W. Garner and H. A. Allard, were assigned the job of getting tobacco plants to flower and produce seeds in the latitude of Washington, DC. They submitted the tobacco to all the then-known factors that govern plant growth. After considerable research, they discovered that the length of darkness and light in each 24 hours regulates the flowering of this variety of tobacco. The tobacco plant requires a fairly short day to produce flowers—

LAMBS Young animals find comfort and freedom in a brooder warmed by 250-watt infrared lamps, promoting frequent feedings and rapid growth.

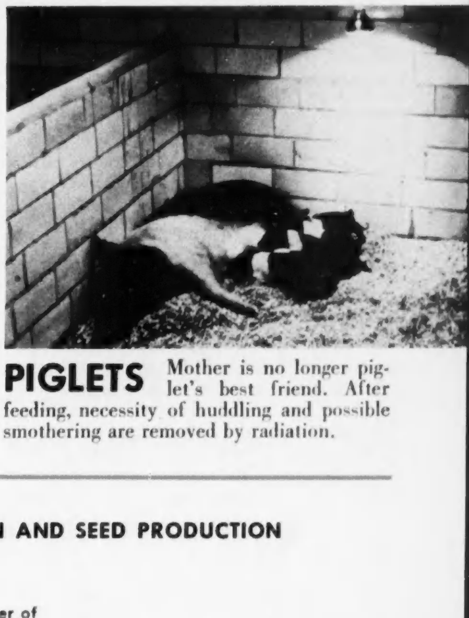


CHICKS Single-lamp homemade brooder for baby lambs is the same type of device as the multiple-lamp unit used in mass-production systems of raising chicks for market—same wattage per lamp.

shorter days than those in the area around Washington. When the plants were removed from the light and placed in the dark from 4 to 9 pm daily, they blossomed and produced seed.

The scientists, in studying a number of other plants, also discovered the fundamental law of nature that tells us why some plants blossom in spring, others in the summer or fall in more or less specific zones, and still others not at all. This knowledge of plants' day-length needs (or more correctly, the night-length needs) has been of great value in adapting the varieties of plants to needs of different sections of the country. Today, plants are classified as short- or long-day plants. A third group—day-neutral, or indeterminate—flower whether the day length is relatively long or short.

Photoperiodism is best exemplified by the many varieties of chrysanthemums. It may surprise you to know that one catalog contains more than 600 varieties, with specific lighting instructions for each. Mums normally bloom in the fall when the day is short. Today the florist controls the blooming time of hothouse chrysanthemums and certain other flowers by regulating the day length in his greenhouses, thus timing his harvest for special high-profit holiday markets. To do this he not only



PIGLETS Mother is no longer piglet's best friend. After feeding, necessity of huddling and possible smothering are removed by radiation.

EFFECT OF PHOTOPERIODIC TREATMENTS ON FLOWER INITIATION AND SEED PRODUCTION OF GUAYULE (RUBBER PLANT)

Treatment	Hours of Light: Natural	Hours of Light: Artificial	Hours of Light: Total per Day	Weight of Seed Produced, September—December (Mg)	Heavy Seed (Percent)	Number of Plants That Flowered November and December	Number of Plants That Flowered January	Number of Flower Primordia January*	Number of Plants Treated
Plant 1	10	0	10	13	0.0	0	0	0	15
Plant 2	10	3	13	287	23.7	6	0	0	15
Plant 3	10	5	15	388	22.1	5	0	0	15
Plant 4	10	14	24	231	7.0	12	0	0	15
Plant 5	14.75–9.5†	0	14.75–9.5	212	16.7	0	0	0	15

* Determined by dissecting branches with aid of microscope.

† Received natural light prevailing from July 1, 1942 to January 15, 1943.

uses time clocks on his lighting system, but he also darkens the plants with lighttight covers if the days are too long and lights the greenhouses when the days are too short. The actual day length varies with every variety.

Light requirements for this process change with each kind of flower, but the variations are slight—0.1 to 50 foot-candles obtained with either filament or fluorescent installations. Experiments showed that the part sensitive to day length is the leaf of the plant. It was also found that all wave lengths in the visible spectrum influence flowering, but a region in the red is especially effective.

The discovery of photoperiodism represented a distinct departure from the once prevalent idea that illumination intensity is the principal factor in determining characteristic growth of flowering and fruiting of plants. This newer concept mainly placed emphasis on the influence of successive rhythmic light and dark periods and the relative length of such periods, rather than on the light intensity alone.

Scientists also found that the formation of bulbs, tubers, thickened roots, production of pigments, and the initiation of dormancy are in a large measure controlled by the daily duration of light or, conversely, the dosage of darkness. Further, many kinds of plants are more sensitive to photoperiodic conditions when grown at certain temperatures than at others. This, of course, explains why plant growth characteristics vary in different latitudes. Some such characteristics are discernible within a distance of a few hundred miles north or south in a given section of the country.

Photoperiodism has significant aspects. For instance, it is possible to grow onions, a very common food, from seed to seed without bulb formation. The sex of hemp plants can be controlled by photoperiodism, thus helping control the amount and quality of the fiber obtained. Tests under way in Puerto Rico and Hawaii to control sugar-cane flowering by dark-period interruptions—towers or poles topped with powerful floodlights are located in the fields—increase the sugar yield per acre.

Animals Stimulated

Equally fascinating is the story of animal research. In 1893, H. Weiske found that light stimulates the metabolism of animal organisms. Both man and animal, with otherwise identical conditions of nourishment, produce more carbonic acid in the light than in the dark. Therefore, it is best to give farm animals—especially draft animals and dairy cows, which demand an active metabolism—all the light they want. To quickly fatten beasts for slaughter, their metabolism can be depressed by shutting out the light, thus provoking the formation of fat and obtaining greater weight with the same feed.

An important but theoretically unexplained difference exists in the composition of morning and evening dairy-cow milk—both in butterfat content and in the amount of milk yield. Also, morning milk has more bacteria than evening milk.

T. H. Bissonnette showed that the winter prime pelt of mink can be induced in the summer in spite of the relatively high temperatures, or hastened in the autumn by reducing the duration of the light periods and intensity to which the animals are exposed daily.

Today, fur-bearing animals can be subjected to light controls on a commercial scale. Tests are also being run on such animals as sheep and goats, which normally have limited breeding seasons. The results are very encouraging to those who wish to extend these seasons simply by controlling light cycles.

Researchers at Cornell University found that the fertility level of cattle can be correlated with the monthly average length of daylight. The response to light varies with the age of the animals involved.

Light Hormone

Fish, fowl, men, and animals all have light-stimuli rhythms and characteristics. Radiation on the skin stimulates individuals and makes them more active. Even though a frog may be in the dark, when its abdomen is stimulated by light, its eyes will react reflexly and accommodate themselves to light. This reflex is not the result of neural action but is due to a substance that rises in the skin under the influence of light and is carried by the blood to the organs. This can be proved by transfusing the blood from a frog kept in a lighted room to one that has been kept in the dark, whereupon the latter's eyes also exhibit accommodating reaction. In his book *Man in Structure and Function*, Fritz Kahn calls this substance a light hormone. It increases the functional capacity of the muscles and sense organs. If a man in a dimly lighted room is shown several gray plates and at the same time light is directed upon his uncovered legs, the plates will appear lighter to him. Similarly, his auditory acuity will also be increased. A person exposed to light hears, sees, and reacts better than one who is in the dark.

In Summation

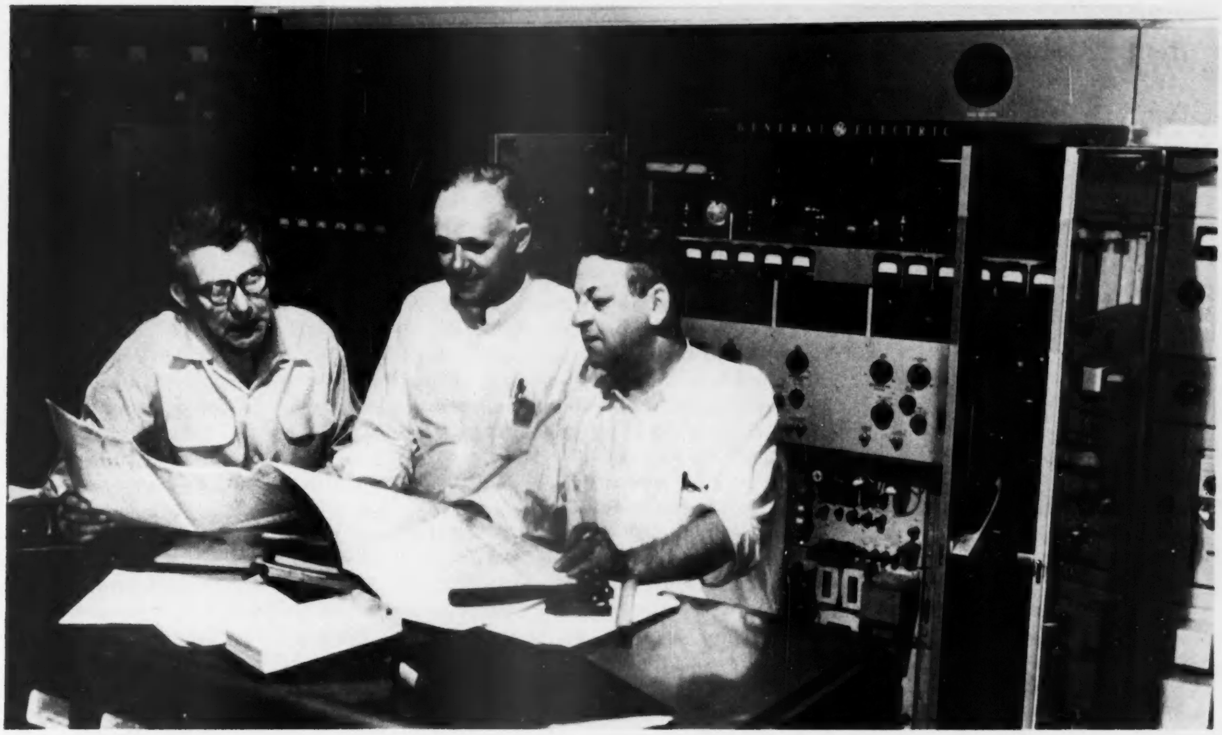
When you realize that almost minute quantities of light may be adequate to affect plants' blooming time, it becomes important to study environments carefully to prevent upsetting the delicate balances. Not so long ago an electric sign upset the dark cycle of poinsettia plants inside a greenhouse. The grower was lucky though; it was discovered in time so that he was able to meet the Christmas trade. However, a mink ranch didn't fare so well; floodlighting in the vicinity completely upset the breeding cycle of the mink resulting in expensive losses.

As our experience broadens, we may well be prepared to extend what we know about familiar problems to the newer, less familiar ones. Most of us naturally think of lighting in terms of human uses. The lightmeter is calibrated for human seeing and film sensitivity. But in dealing with light for plants, animals, insects, fish, fowl, and game, we must think in terms of only the specific energy relevant to each. In a sense, a poultryman must look through the eyes of his chickens. Such completely varied problems in the field must be approached differently—and rarely from the human's viewpoint.

In this vast field, there's much more to find out. Each day we learn how to make more and better food for the undernourished peoples of the world. Our gains in the past two decades have been tremendous. The future holds much promise. Ω

CREDITS

Page	Source
Cover	Tran Mawicke
15–17 (Photos)	National News and Illustration Service, Inc.
21	Charles Pfizer and Co.
29	George Friday
37	U.S. Air Force
42 (top, left)	Southern California Edison Company
44 (lower)	USDA Plant Industry Station, Beltsville, Md.
45 (lower)	Public Service Company of Indiana, Inc.
47, 49	Burns Photography Inc.



PLANNERS: PURCELL, MILLHAM, AND CRUGER CHECK FOR A "PARASITE" AS EARLY-MORNING DEADLINE APPROACHES IN . .

The Switch to 6

***Review* STAFF REPORT**

A few seconds before midnight of Sunday, January 3, 1954, television station WRGB at Schenectady, NY, concluded its day's operation on Channel 4 with the Pepsi-Cola Playhouse, a free-wheeling affair that had robbers, gunmen, a boarding house, and a heroine who finally went back to Muskegon, Mich., or some such. "Miss Darkness" was the title of the play, and because of its apocalyptical tinge, it caused an uneasiness among some of the WRGB engineers.

At 7:01:50 am on Monday, January 4, WRGB began operation for the day on Channel 6 with NBC's "Today" and the nervous casualness of Dave Garroway.

What happened during those 7 hours, 1 minute, and 50 seconds is a story of long-range planning, highly polished engineering teamwork, and a spirited piece of luck.

There is more to changing a modern, complex television station from Channel 4 to Channel 6 than switching a few taps.

A few days before the change-over I met Bill Purcell, Manager of Engineering for WRGB, radio station WGY, and a group of short-wave stations in Schenectady and San Francisco. Purcell is affable, has a longish gray-flecked crew cut, and can explain the technical nature of radio and television in terms that vice presidents can understand. He handcrafted his first wireless set in 1912 from plans in *The American Boy* at a cost of $3 and the forbearance of his parents. From the signals of naval stations in New York, Norfolk, Arlington, and the Canal Zone, Purcell learned code.

In his uncluttered office in WGY I heard about the advance planning for the change-over. "People want to know what's going to happen to Channel 4, and why we can't keep on using it. After all, we've been on it since 1940, and there are about 350,000 sets in our coverage area." He shrugged. "But things haven't been completely right. During the war and the freeze, the Federal Communications Commission—and a lot of us operators—discovered that the early FCC allocation plan had some of the stations too close together. There was interference. For instance, we're too close to Channel 4 in New York and Boston. But if the stations were separated a little more and given more power, more people would get better service.

"In April of 1952 we got the word. The FCC announced its new allocation plan, and we were on the list. Channel 4 was eliminated from this area, and we got Channel 6. Our nearest neighbors will be Portland, Philadelphia, and Montreal.

"Well, the first thing we did was to file an application with the Commission, setting forth what we wanted to do. The main thing was that we wanted to boost our power to the full amount allowable. That meant we had to get a new power amplifier and a higher antenna. The combination means that we'll be able to peek over some of the hills around here

FACILITIES: New 315-foot antenna overshadows old tower and transmitter building.

and get down into the valley towns. Our signal will be better in the fringe area, and we'll pick up a little additional coverage. From the long-range viewpoint, the increase in power and the higher antenna are the most important because they'll benefit our viewers for years to come."

The actual change-over, Purcell went on to say, would involve changing the coils, the complete retuning and alignment of the present transmitter, and the switchover to the new antenna. They would have to do all of it in seven hours.

I asked him what the viewers would think about all this. "They should like it," he replied. "Most people who live in a high-signal area—the area where you don't get 'snow'—probably won't have to do anything except turn their channel selector switch over to 6 and maybe touch up their brightness control. For the people in the outer areas, it will mean that any moderate snow they've been getting will disappear completely. If the snow is severe, it may disappear. But at any rate, there's going to be a gratifying increase in picture quality.

"In all our promotion on the change-over, we've been emphasizing that no TV set will become obsolete. That's entirely true, but even so, some people are going to get hurt in their pocketbooks, and there's nothing much anyone can do about it. It's like this: We have fringe areas where our signal is weak. For instance, north of here it's at Rutland, Vt., 75 airline miles away. There our signal delivers a standard of reception that's below a standard level. But the people have invested a lot of money in expensive antenna arrays to pick up our signal. Some of them cost about as much as the set. Anyway, these antennas are usually tuned to only one channel. Well, you switch channels, and they're no good. Sure, they can be modified, but it's no job for a homeowner. In all cases, we're recommending that the set owner call his serviceman just as quickly as he can. With the weather we've been having it's no time to climb around on a roof and cut elements off your antenna."

We talked for a while longer, and then he made arrangements to pick me up Sunday night to drive out to the transmitter to see the change-over in action.

Plans for the change-over got under way in August when WRGB officials held a meeting for TV distributors in the coverage area. They inspected the WRGB studios, heard talks about the change-over from Purcell and Robert B. Hanna, station manager, and had luncheon at the transmitter site where they were shown the new tower and equipment.

Early in December the news stories began flowing from WRGB to 100 area newspapers, and full- and half-page advertisements were placed in 32 daily and weekly newspapers. The ads were big, uncluttered, and forthright; they stressed that the channel change had nothing to do with color TV or with the "new ultrahigh-frequency stations that are about to start telecasting in this area." (One was already on the air when the ads were run.) There were a few lines stating that the change was being carried out by order of the FCC as part of a long-range plan that will bring better TV reception to all areas of the country. The minor role given this rather important fact might have been due to the good-naturedness of WRGB officials in not wanting to point the finger at the federal government for all the grief that was inevitably to follow. Or it might have been due to an overabundant amount of faith in the passivity of some of its viewers who, when they received nothing on Channel 4 *or* 6, would merely sit back and call their serviceman.

(WRGB officials also got a tip that one overzealous and rather unethical antenna manufacturer had sent a story to area newspapers that all antennas in use would be obsolete and that they would be very glad to furnish new ones. But alert newspaper editors checked the facts and the story died.)

Also, two special programs on WRGB explained the change-over, as did an elaborate story in *Mike and Camera*, a monthly promotional sheet mailed to 20,000 subscribers.

Tidy as all these arrangements were, they didn't eliminate such queries as: "I understand Channel 6 is a UHF channel." "It certainly will be nice when I change to Channel 6 and can get a color picture!" "If all the NBC programs were on Channel 4, what programs will you be carrying on 6?" (This query was probably from someone who once lived in New York City; network programs there are identified with a channel number, a situation that varies considerably in a one-station market where a mixture of networks is presented on the lone channel.)

Purcell picked me up at 11:30 Sunday night and we drove 20 icy miles to the transmitter, deep in the Helderberg mountains south of Schenectady.

"By now I guess our viewers are really confused," he told me after we were under way. "We blacked out for eight minutes tonight about 7:30, so I suppose everyone is figuring they're really in for trouble." He said there had been a power failure at New Salem that had shut down the transmitter, and it hadn't lasted long enough for the station's stand-by diesel-electric generator to take over.

Passing through Altamont, he told me about some of the engineering details of the change-over. The new antenna, he said, was 315 feet high, compared to the 100 feet of the old one. The antenna alone wouldn't do anything to improve reception to the north, but would help a lot to the south and west.

He also mentioned that the new amplifier would boost the station's power up to the full 100 kw allowable by the FCC for VHF stations. "Actually," he said, "the maximum we can push out is 93 kw, because the 100-kw figure is based on the use of a tower that is 1000 feet tall. We're 1020 feet, so we've got to drop our power to 93 kw. Our new amplifier is rated 35 kw, but we get the 93-kw figure because the antenna has a multiplier factor. What they do is take the energy that normally goes straight up and concentrate it toward the horizon where it'll do some good."

Outside of Altamont we climbed a long slick grade to the foothills of the Helderbergs. It was close to midnight, and the countryside was asleep. At the transmitter I knew that 10 highly skilled engineers were poised to begin the change-over as soon as the sign off was completed, black-level readings taken, and the power dumped.

I asked Purcell if there was any significance to the date of January 4 for the change-over. Wouldn't January 6 have been better to focus the event in the viewer's mind? "We were all ready to go the day after Christmas," he told me, "because a Channel 6 in New Haven went off the air then. But we didn't want to make the change during the holiday season because there were too many good programs of importance to our audience. Anyway, a Monday morning means that the servicemen will have a full week to take care of any troubles."

Pretesting on Channel 6 was out of the question because the frequency on the transmitter had to be changed. The amplifier had been checked and all circuits were gone over to be sure they were in order. The engineers had earlier gone through a dry run of the change-over. They had physically measured the spaces into which the new coils and tuning strips would fit to be sure they were large enough. They each had their routines worked out; each man had a series of jobs to do. Two experts from General Electric's Electronics Park in Syracuse were on hand to assist.

About 12:30 we wound up a recently plowed country road and stopped at the foot of a narrow, steep hill. Above I could make out the red warning lights on the tower. Two headlights flashed from the darkness beyond, and a moment later a four-wheel-drive jeep pickup arrived. In the meantime Purcell had pulled his car into a nearby garage. "A car's no good on this hill," he said, as we clambered into the jeep and labored up the incline. "Now you can understand why all our engineers carry snowshoes, shovels, and storm equipment in their cars. It wasn't so many years ago that our men had to get here on showshoes and skis because of the bad conditions."

A few minutes later we were in the transmitter building—a one-story brick structure, 135 feet long and 30 feet wide. It has a workshop, lunch room, store room, general office, transmitter room, furnace and diesel room, and a former FM studio. Heat from the transmitter warms the building.

We removed some of our gear and went into the transmitter room, the largest one in the building. The equipment was in the middle, with plenty of floor space around it. Facing one side was the control console; above the transmitter was a tangle of vent ducts and the large copper tubing that is typical of high-frequency electronics.

The change-over was already well under way; the men worked quietly and without confusion. Purcell introduced me to B. W. Cruger, a stocky, dark-haired man in his late 40's who is directly in charge of WRGB engineering operations. He didn't say much except that things were proceeding rapidly.

All cubicle doors to the transmitter were open and the engineers working singly or in pairs removed the old coils and put in new ones. Purcell picked up one that was lying on top of the control console; it looked like a small copper spring about an inch and a half long and one-half inch in diameter. Then he took me over to the transmitter and pointed out one of the larger ones. It was 8 or 10 inches long, about 5 inches in diameter, and the coils were about the thickness of a forefinger.

Changing the coils was necessary because the frequency had to be changed. Channel 4 operates in the band from 66 to 72 megacycles, while Channel 6 takes in the 6-megacycle spread from 82 to 88. In all, 25 circuits for both visual and audio transmitting had to be changed and tuned.

I asked Purcell how they picked the transmitter site in 1939. "Primarily from topographic maps," he replied. "We purchased the land soon after, and the transmitter building was completed in 1940."

He went on to say that they got a lot more coverage than they ever expected. "We thought our maximum would be Saratoga, about 25 miles north of Schenectady. But we found that these VHF beams bend around the mountains a lot better than anyone expected. Then too, we underestimated the ingenuity of people in putting up expensive antennas to get our signal way outside our normal coverage area. And, of course, the set manufacturers helped too by building sets that were more sensitive."

We walked over to one of the cubicles where two engineers were working. "This change-over isn't too difficult," Purcell said, "and we certainly shouldn't have any trouble in getting on the air by seven. But you can't tell. One station in western New York State never got a picture until two in the afternoon. And if we had been shifted to any of the channels between 7 and 13, we really would have been busy. It would have meant a complete new transmitter."

SYMBOL: Tense, bowed forms of engineers working in cubicles was characteristic scene.

He explained that Channels 2 through 6 are the most efficient because you can get your allowable coverage under the FCC allocation with the least amount of power. Between Channels 6 and 7 there's quite a megacycle jump, with the result that the FCC permits more power so you can get the same coverage as stations in the lower VHF bands. And for UHF stations, it takes still more power. The higher you go in frequency, the less bending there is, and the more shadows.

"Let's eat," Purcell said, and soon after I was in front of some Pennsylvania Dutch griddle cakes, sausages, and coffee. He's a good cook.

About 3 am the physical part of the change-over was completed and the engineers started tuning the equipment by means of oscilloscopes. I learned that there were seven stages to be tuned, and they all had to be done independent of one another. The engineers would open a cubicle, attach the oscilloscope, and watch the green wiggly lines. Then would come the tinkering and adjusting and fussing to get two major peaks on the 'scope about four megacycles apart.

"You can write all the formulas you want and you can make all the measurements, but you still have to monkey around to get the thing lined up properly. It's still the old story of cut and try," Purcell mused.

The work was proceeding smoothly when Josh Billings, the transmitter supervisor, dodged around the corner of the transmitter to where Cruger, Purcell, and I were standing. He didn't wait for a break, but said in a nervous tone,

"In high-signal areas perhaps 3 sets out of 1000 had to be realigned."

"Better take a look at the radiator; there's water all over the floor." We followed him to the other side of the unit. It was 3:17 am.

The radiator was about the size of an office table turned on its side. Mounted near one of the exterior walls, it was used to cool the distilled water that is circulated around the power tubes in the transmitter. We looked; it was easy to see the drops splashing down the tubes that ran into the header. Billings got an emergency light, and we saw the fault—a thin stream about the size of a pencil lead flowing from a soldered joint. This could wash out the entire change-over because you can't operate a transmitter without cooling it.

Cruger mumbled something about why did it have to happen tonight.

The question was, should they try to repair the leak or try to replace the entire radiator with a spare?

"Either way will take time because we'll have to drain the water out," Billings said. "Why not try a temporary clamp so that we can at least get on the air; then fix it permanently after we sign off?"

It sounded easy. Billings soon came hurrying from the workshop with a small clamp of the type you use on your garden hose and a piece of an old inner tube to fit inside. But the job turned out to be difficult because it was close to the floor and other pipes were in the way. It was slow, wet work with a small screw driver, a pair of pliers, and fingers.

He finished, gave a final dig with one of his tools, and said, "Let's give it a try." The circulating pumps were started; the water still dripped. Billings ordered the pumps shut down and checked again. He found the clamp wasn't close enough to the header plate, so he rammed it closer with a screw driver and gave the clamp another twist. The pumps were turned on; the repair held.

It was close to 4 am; nearly 45 minutes had been wasted with the repair. "Let's get back to the transmitter," Cruger said.

I was sitting behind the control console; it was close to 5 am. Tuning was still going on. Purcell came over and sat down. "This is like driving a new car. The operations are all the same as the car you've been driving but the feel is different. Same thing with this transmitter. It'll just take time to get used to it."

R. L. Smith, commonly known as "Smitty," came over. "My legs are going," he said in a discouraging tone. "I thought we'd have the test pattern on by five; if it hadn't been for that leak, we would have."

"This is going to be tighter than I like," Purcell said.

It was 6:26, 34 minutes before air time, when the test pattern went on. Cruger called the WRGB control room in downtown Schenectady and they reported the picture satisfactory. He also called his wife; she said it was fine. Smitty yelled over and said about 20 kw was being put out.

At 6:37 one of the engineers let out a gleeful "Wow!" Purcell and I went over to see; he pointed to a meter. "We had it up to 160 kw which it took without a bump," the engineer said. It was immediately brought back to the more rational output of 20 kw.

During the time that the tuning was going on, there was an increasing amount of energy among the men working in the audio cubicle. They couldn't get rid of a "parasite"—an oscillation that shouldn't be there. It's a disturbance that causes an annoying racket on home receivers.

"Let's clean it up," Cruger called to a couple of his engineers and one of the Electronics Park men. They went to work, but every time the system was put on the air, it tripped out, including the test pattern. The picture would be dumped along with the audio—such as it was—because both were supplied by the same rectifier.

Six forty-seven and the test pattern read: "Sound is not being transmitted."

Five minutes before air time, Purcell got an open line to the studio and Al Zink, the program director. "Al, I don't know if we're going to make it. Keep this line open, and I'll let you know."

The picture and audio tripped once again.

Purcell called over Bob Millham, one of the Electronics Park men. "Level with me. What are our chances?" he said. Millham shrugged. "We can get on, but I don't know how good it'll be or how long we'll stay." Purcell motioned for Cruger to come over. "Let's get on the air. After all, we're a General Electric station with General Electric equipment. Get a picture on the air and get some sound to go with it." He walked away.

At 7:01:50 WRGB went on the air on Channel 6. About 30 seconds later there was a jumble that lasted 20 seconds, then the full picture came on and stayed that way.

"How's the audio doing?" Cruger said. He got a report that it was at less than half power and that the parasite was gone. Purcell said, "Let's make some phone checks." He made three calls. "It's a little low, but not bad. Keep it rolling, and we'll keep working on it."

On "Today" at 7:11:50 Dave Garroway said, "You folks up in Schenectady are watching us on Channel 6, as if you didn't already know."

Reports began filtering in. Fringe area reception was better. A report from Greenfield, Mass., a small community over the mountains from North Adams, said that the picture was coming in "the best ever."

The crew was pleased, and at 7:40 Purcell got behind the grill once again. The menu: grapefruit, eggs, sausages, toast, and coffee.

At 8:15 the jeep took us down the path to the car, and we drove back to Schenectady. Purcell was happy.

He dropped me off at home and said he was going to the office to see what calls were coming in. I went to bed.

Two weeks later I called on Purcell in his office. He looked as if he hadn't been getting much sleep. I asked him how things were going. "I haven't gotten this business put back together yet," he said with a laugh. "I'm still struggling." He leaned back in his chair and lighted a cigaret. "Seriously, though," he said, "the whole thing was a success. A day or so after the change we tended to panic—it was the first time that any of us had been through something like this—but looking back over things, it went off remarkably well."

He told me that in the high-signal area, perhaps 3 sets out of 1000 had to be realigned. And in the fringe areas, funny things were happening. A whole new pattern of "ghosts" showed up, especially in hilly areas and cities with high obstructions. The ghosts—in some cases as many as eight—were exorcised by various methods: new antennas, modification of existing antennas, rotating the antenna, or changing the antenna's location. "In one instance a guy was getting a perfectly lousy picture with the antenna on the roof. So he put it on the ground near an ash pile. Gets the best picture he ever had."

Immense new areas of viewers were opened up, he told me, particularly through Vermont and Massachusetts. Most of Poughkeepsie was getting WRGB better than any New York station, and it was booming into Kingston and the Catskills. "I think we've added close to half a million people to our coverage area."

Purcell said that by two days after the change the picture quality was at a maximum. A defective coupling between the new amplifier and the transmitter had degraded the quality a little.

He said that about a week after the change, two teams of two WRGB engineers each toured the coverage area to check on results. I asked him what the procedure was in each town. "At first we went to some of the key servicemen," he related, "but that way we only got one side—the complaint side. We finally discovered that the bartenders in the small towns actually could give us the most accurate story of what was going on. They seemed to know everything. But we didn't call on too many in one day."

I asked him how many letters and phone calls they had received. He reached around and pulled a big folder of papers from a desk drawer. "These are the gripes—all 125 of them—and we'll answer every one. Eileen," he said, with a nod towards his secretary, "has the letters that compliment us. There are over a hundred."

In regard to phone calls, he said they received about 400 the first day, and about 400 more spread out over the week. "That sounds like a lot until you remember that we may get 400 or 500 calls in an hour or so when a pro-football game is cancelled. With that kind of call the guy usually shouts some abuse at the station and hangs up. Doesn't care about a reply. On the change-over it was different. We got the abuse and then the caller wanted to know how he could get his set back into operation. Some of those calls lasted from 10 minutes to half an hour. We had them transferred to our engineering staff. You often hear that engineers live sort of a sheltered life and don't get to know the public. Well, ours certainly did. They really got an earful.

"People who were affected in the fringe areas resented the fact that they would have to pay anywhere from $18 to $50 for a new antenna. We'd explain that the change-over meant that thousands more people would be able to enjoy TV that never had it before. Their reaction was, 'Nuts to them, all I care about is my set.' So we'd explain that the change was required by the FCC. But they still thought it was some whim of ours to change channels. But in this game you don't spend a quarter of a million dollars on a whim."

Purcell said that what WRGB went through is the same as all the other 26 stations that have changed. "A Detroit station made a move a couple of days after us. I phoned them. They were going through the same thing. The pattern was almost identical."

I had a chance to read the letters that were received. These unedited excerpts are typical:

Saranac Lake, NY

Yesterday morning (Jan. 4th) we came down before seven o'clock we were filled with so much enthusiasm due to your promise of big improvements in the power of your television station, enabling fringe areas, such as ours, to get better reception. We were not disappointed, as we had our first good look at Dave Garroway. The reception was not as good as that from Canada but it was very much improved. However, our joy was short-lived because later in the morning the picture began twirling around with a pattern mixed in it and music playing that was not connected with the picture, then we discovered what happened—it was CBFT Montreal evidently trying out their new station which is also on Channel 6 (formerly No. 2 which in the future will be all French) and it was coming in on the smaller southern end of our antenna. Their signal is a sort of wheel and it was twirling around with your program which became wild and at times was obliterated altogether.

We have a rotating antenna, the best we could buy, cost $162, with installation.

If you had just stayed on Channel 4 and increased the power to benefit fringe areas and we had Canada all English we would have had a nice choice.

It is pretty hard on the people of this area, as there is so little to do when you are beyond the skiing and skating age.

WON'T YOU PLEASE TAKE SOME ACTION? You lose the benefit of your advertising. The General Electric people are so powerful they must be able to do something. We wouldn't want to lose Canada altogether as the reception is better than any other.

PLEASE HELP US. Thank you.

We, along with hundreds of others, have a big investment in our machines (ours $563 with antenna).

P.S. This morning . . . the reception was perfect until noon and then Canada put their signal on and it was all a jumble. People are furious here, calling service men, the radio station etc. Something must be done.

West Hebron, NY

We had a beautiful picture on Channel 4, everything look real, so life like. Now everything on Channel 6 is double, which is trying on the eyes. My father and I went up on the roof and turned the antenna, but it just got worse. We called our serviceman, who lives 6 miles down in Salem, but he said that it would be weeks or months before he could even look at ours, so it was very funny to hear your announcer at 8 pm Tuesday say, all you have to do is call your repair man. In fact, this repair man had had so many calls, that when we called he blew his top.

Kingston, NY

This is probably only one in hundreds of letters of appreciation for the change over from channel 4 to 6 and the ease to us with which it was accomplished.

Instead of a distorted picture we now have a beautiful clear one.

Essex Jct., Vt.

I am writing this letter to you on a chance you may read it. If I sent it to the main office it no doubt would get as far as the 5th Vice Pres. waste basket and I want some of your outfit to know how mad the natives of N. W. Vermont feel about your change over to channel 6. No one up here can pick you up and even in Burlington on the wired in they are getting very poor reception. You have lost a good many thousand fans as we are getting the new channel 6 from Montreal on the back of our channel 4 antennas. Even the bar flies won't drink beer when it is on the house until they ask if the brand was advertised by you. You say why yell it was for free. Sure free at your end but how about the $400.00 I paid for my T.V. set and $150.00 for the antenna. I had to go up 65 ft to get you. That was above my roof of the house and your low down double crossing Co. has finished that and if you think I am going to put another $150.00 into another antenna as they recommend you are as crazy as I think you are.

After I finished, Purcell rocked back in his chair and put his hands behind his head. "I don't know if we'd do it much different the next time. It's always easy to second guess. Maybe we'd put more emphasis on the fact that the change-over was at the request of the FCC. But I do think we underestimated the loyalty of some of our viewers. Sure, relatively few got burned, but they really let us know about it! What did people do before they had TV?" —PRH

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

• Industrial expansion continues to create an unprecedented demand for young men and women qualified to meet engineering, scientific, and technical requirements.

• A new tool is stimulating teen-age interest in the value of studying high school math. Here's how you can use it to help students in your own community.

Today we are in the midst of an exciting technical era. To be engaged in its contributions, one must have a thorough knowledge of mathematics—the basic language of science and engineering. Mathematics is also essential to technicians, apprentices, and skilled factory workers; and it becomes in fact the plus value for understanding many phases of living, as well as an aid to making a living.

To meet industry's expanding production levels will require the combined efforts of more and more engineers, scientists, technicians, and able assistants in almost every field of endeavor. Rewards for all will be great, and so this message must be taken into communities everywhere to extend the horizons of tomorrow's citizens.

Because mathematics is a prime ingredient of living and making a living in a technical age, our efforts must be directed to that area. Recent surveys indicate only 20 percent student participation in high school math classes. Lack of mathematics in a student's curriculum jeopardizes his opportunity to succeed no matter what his chosen career or his entrance into the college of his choice. If he does enter college, it further jeopardizes his rate of achievement because he must spend time on neglected high school math rather than useful electives.

As early as 1928 General Electric began printing educational material for distribution to schools. This program now includes the use of motion pictures, "House of Magic" shows, and summer science and mathematics Fellowships for high school teachers. Later the Company developed its popular comic-book series; its distribution skyrocketed and won wide acclaim from schools everywhere. ("Tomorrow's Engineers Read the Comics," September 1953 REVIEW.)

Then in 1953, recognizing the need for stimulating greater teen-age participation in high school math classes, editors of school publications at GE turned their efforts in a new direction. An article urging young America to "go back to math" was prepared and published in *Scholastic's* magazines. Teachers responded so enthusiastically that the article was expanded into a booklet titled "Why Study Math?" Distribution has exceeded 1½-million copies, and requests are still coming.

"Why Study Math?" is so convincing and in a style so appropriate for teen-agers that I am interested in 40 to use each term with our eighth and ninth graders for guidance.

Math Instructor, Vare Junior High School
Philadelphia, Pa.

I have just had the pleasure of thumbing through "Why Study Math?" You have done an excellent job setting forth the importance of mathematics in modern society.

Director of Admissions, Alfred University
Alfred, NY

Last spring I used most effectively your "Why Study Math?" From a meager enrollment of 50 math pupils, we now have over 125.

Head, Math Dept., Kerman Union High School
Kerman, Calif.

On the following eight pages you'll find a reprint of "Why Study Math?" Why do we of the REVIEW think it worthy of reprinting?

A vital concern of General Electric—and of all industry—is to encourage the study of math. By distributing "Why Study Math?" and reprinting it here, we feel that you as an engineer or scientist will want to assume some of the responsibility for stimulating teen-age interest. One excellent opportunity is through the many spheres of your influence in your own community.

In your guidance activities with youth groups—YMCA, Boys' Club, church and school programs, 4-H Club—perhaps you can be influential in acquainting teen-agers with the value of being well-grounded in the fundamentals of math. Leaders in service clubs, Scouts, technical societies, and American Legion have requested numerous copies of the booklet.

With the increasing popularity of Career Days in the high schools, you may be called upon to speak at such an event. Again this would be an ideal time to emphasize the requirement of math for technical courses.

In your local PTA activities you want to be assured of a broad mathematics program in your school. It should include not only potential engineering students but also those on other levels of interest as well.

Perhaps in your company you assist in college recruiting programs. This offers you an excellent opportunity to counsel students that math is needed.

And you, as a parent, can transfer to your own children your enthusiasm for the necessity of studying math.

These are but a few of the ways to effectively use "Why Study Math?" By utilizing them fully, you can help provide all of tomorrow's graduates with the groundwork for a richer and more rewarding life.

Another of General Electric's publications for student distribution is the four-page booklet titled "Why Study English?" This contains convincing arguments for a thorough understanding of our language and its value to both the practical and social aspects of living. The enthusiastic response for "Why Study English?" has been even greater than that for "Why Study Math?" You'll see it reprinted in a forthcoming issue. —EDITORS

Copies of "Why Study Math?" can be obtained free by writing to:

Public Relations Services Division
Dept 107-2
General Electric Company
Schenectady 5, NY

why study math?

Do you know what's going to become of you when you get out of high school?

If you don't, you'd better start thinking about it. Of course, maybe you *have* thought about it. Maybe you're planning to go to college. But if that's the case, it only changes the question a little: Do you know what's going to become of you when you get out of college?

By this time you're probably thinking: "So what?" The answer to that is this: No matter what you plan to do when you get out of high school or college, you're probably going to need more mathematics.

Yes, let's face it. Unless you're an exception, you need more math. No matter whether you plan to go on to college or not, no matter what you plan to do after college. chances are you won't have enough math. For many of the fellows and girls who went through school ahead of you found out they didn't have enough math. So they had to make it up to take the courses they wanted or to get the jobs they wanted.

It's a lot harder to catch up on mathematics later on. The time to think about it is now, while you're still in junior or senior high school. If you start early enough, math shouldn't be much trouble at all. Trouble is, the fellows and girls in high school don't realize how important it is to get a good groundwork in math. So we're going to try to explain it to you. First we're going to try to show you how important math is and why you're going to need it, no matter what you do after you finish school, and then we're going to try to show you that math isn't such a tough subject after all.

Why Math Is Important

Mathematics is going to be important to you no matter who you are or what you expect to become after school.

Some people don't need much; they can get along with nothing more than arithmetic. Others need more math—maybe algebra, or geometry, or both. Still others need a lot of math—things like trigonometry or calculus. Let's take a few cases. Let's start at the top and work back; let's start with the people who need a lot of math.

The world today is pretty complicated. It's changed a lot in the past 40 years. Forty years ago there weren't very many scientists and engineers; the world was only just beginning to

realize how important science and engineering are. The automobile was just getting started. Airplanes were a novelty. Radio and television hadn't been born yet. Most homes had no electricity; they got their light from oil or gas, they cooked on a wood, coal, or gas stove, they kept their food in an icebox, and they washed their clothes in a wash tub with a hand scrubbing board.

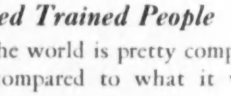
So they didn't need very many technical people in those days. Over a third of all the people who worked were unskilled; they needed very little education—they worked mostly with their muscles, not their brains. Today, although there are still more unskilled workers than any other occupation, *their total number has dropped from 13,400,000 to 11,500,000, while the total number of people working has increased from 37,300,000 to 55,800,000!*

Meanwhile the number of skilled and semiskilled workers went up over the same period. The skilled workers jumped from 4,364,000 to 7,632,000, and the semiskilled workers doubled, jumping from 5,500,000 to 11,000,000.

Back in 1910 there were only 60,000 engineers in the whole United States. Only one out of every 621 people working was an engineer. That wasn't very many. But by 1950 the number of engineers had increased to 400,000—one out of every 139 persons working was an engineer.

We Need Trained People

Yes, the world is pretty complicated today, compared to what it was 40



years ago. And it's getting more complicated all the time. This means that we have to have more and more specially trained people. We need them not only to work out the really tough problems of science like learning how to harness the power locked up in the atom—we need them not only to produce new and wonderful materials like plastics, to find new ways to conquer disease, to design the machines of industry and the labor-saving gadgets of the home—we need them more and more for the ordinary things of every day life.

It takes special training nowadays to be a good carpenter, or a plumber, or an automobile mechanic. But those are simple compared to electronics. We used to think a radio serviceman had to have a pretty special kind of training, but it's much tougher for a TV serviceman today.

Right now some of you who read this are probably thinking: "That's all right for technical people, but I want to be an artist, a druggist, or a nurse," or "I want to go in business for myself. What on earth good will math do me?" All right, let's see.

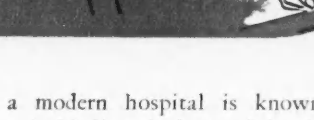
Most artists today go in for what artists call *applied* art. They want to use their ability to draw and paint in advertising, or interior decorating, or something that will pay them good money. But the people in business who hire the artists for that kind of work say that simple artistic ability is not enough any more. There are lots of fellows and girls with artistic ability, but not enough of them know anything about physics, or mechanical things—or mathematics.

To be a druggist you have to be a chemist. That means you have to study chemistry. And don't let anybody tell you that you can learn chemistry without knowing something about algebra.

How about a nurse? One of the required subjects in a course of nursing in a modern hospital is known as Materia Medica. And one of the things you'll learn in Materia Medica is how to figure out doses and solutions of medicines and similar things. Algebra is important in doing the figuring. Too many nurses flunk out of the course nowadays because their math is weak.

It's the same thing with a trade. Whether you want to be a draftsman, a machinist, a molder, or a patternmaker, you'll find out that you need algebra and geometry, plus other things like trigonometry.

Even if you want to go in business for yourself, you'll still need math. For business today, whether it's running the little gas station at the corner or the big factory down by the river,



takes good management and good management takes mathematics.

But most important of all needs for mathematics are the needs of those who are going to keep up the wonderful progress we're making these days in science and engineering. There's a great demand for such technically trained people. They're needed in the offices and factories that turn out the things we need in peacetime and develop new ones for tomorrow. And our military forces need them, too—badly.

War Is Complicated

For war is a very complicated business, also. It isn't like the old days, when big armies met in battle and

slugged it out hand-to-hand. Nowadays a war is fought with airplanes and battleships and tanks and radar and atom bombs. We fight our wars as much with machines as we do with men, and we need men with special training to run the machines. We need them to pilot the planes, to operate the radar, to control the gun turrets on bombers and battleships with such accuracy that even the rotation of the earth is sometimes taken into account.

The people who run our business and military affairs know how badly we need people with special technical training, and they're doing everything they can to persuade more people to get that training. For there just aren't enough trained people to go around. The jobs are there, waiting for them when they get out of high school or college, but not enough fellows and girls are studying the right things.

Trouble is, they don't start early enough. This means that, if you want to be an engineer or a scientist or almost anything at all these days out of the ordinary, you've got to start thinking of it now, while there's still a chance to study those subjects you need to start with. And the most important of these rock-bottom subjects is mathematics.

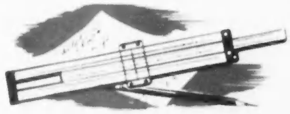
But the fellows and girls in high school aren't getting enough math. The United States Office of Education says that only 20 percent of all high-school students are taking math. Why so few?

There are probably a number of reasons. Maybe you, like many others, don't think you're going to need math in the work you're going to do. And it's true that there are plenty of jobs open where you don't need anything but just plain arithmetic. An athlete, for example, or a farmhand, or a sales clerk, or the operator of a telephone switchboard. There's still a big need for people who are skillful with their hands or who have strong muscles.

What About Computers?

Maybe you've read about those wonderful computers or calculating machines that are being built today—machines that work by electronics to do all sorts of complicated problems in mathematics at terrific speeds. Maybe you think we should let those machines do our math problems. If you do, you haven't got the right story about the computers.

The point is that a computer is no better than the human mind that designed it or the human mind that runs it. It has to have a mathematician to run it. The only difference between the man and the computer is that the machine works faster. Somebody has to



analyze the problem, "set it up," and feed it into the machine before the machine can solve it. (We'll tell you more about this business of analyzing later on.) Computers are a big help—but don't think we can leave it to machines to do all our math for us.

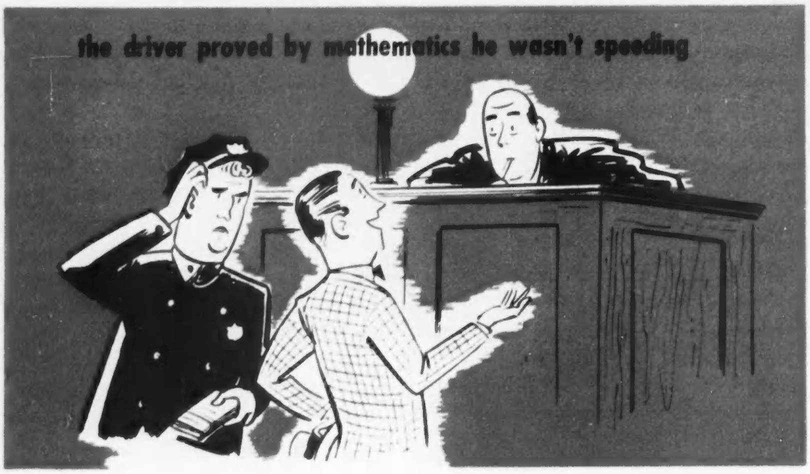
There's still another angle you shouldn't forget. True, you can get along these days without much more than simple arithmetic if you're not particularly ambitious, but there are lots of times that more math would be a big help to you in your everyday affairs.

A famous British mathematician says that we live surrounded by figures—cooking recipes, railway timetables, unemployment insurance, fines, taxes, war debts, schedules of working hours, speed limits, bowling averages, betting odds, calories, automobile and truck weights, temperatures, rainfall, hours of sunshine, miles per gallon, electricity and gas meter readings, bank interest, parcel post and freight rates, radio wavelengths, automobile and bicycle tire pressures, and many more. And we need to know how to use our figures. Let's take a very simple example.

Suppose you have to drive somebody to the station to catch a train. The station is two miles away, and you have four minutes to get there before the train leaves. You start out in the car, and you drive the first mile at 15 miles an hour. Then all of a sudden you realize you'd better speed up if you want to make it. How fast do you have to drive that second mile in order to get there before the train leaves?

Don't spend too much time figuring it out, for there's a catch in it. No matter how fast you go, you can't make it. You used up your whole four minutes driving that first mile. But the point is that it takes algebra to solve a simple problem like this. Anybody who's had elementary algebra should know right away that he should drive faster than 15 miles an hour to make the train.

There are lots more cases in everyday life where simple arithmetic is not enough, and more math would be a



great help. A little application of the principles of geometry, for example, would help you in parking the family car. If you play baseball and want to hit a home run, you might wonder which is more important, a heavier bat or hitting the ball harder. There's a mathematical formula in physics which tells you that it's more important to hit the ball harder.

When you get married and set up housekeeping, there will be lots of times when you could use a little more math to help you solve every day problems. You may want to figure out whether it's worth while to turn down the thermostat at night when you go to bed, so the furnace won't use so much fuel. But you'd probably have to use some advanced math like the calculus in order to find out whether you'd really save fuel or not.

Who Sits Where?

Take a simple little thing like figuring out who sits where at a dinner party. You're going to have six people at the table. Believe it or not, there are 720 different seating arrangements for six people! Figuring out things like that is easy—if you have enough math.

Take the case of the fellow in Milwaukee not so long ago who was picked up by a motorcycle cop for speeding. The cop didn't check the speed on his speedometer; he was stationed at a street corner and he guessed the speed. They went before the judge in police court and the driver of the car got the cop to admit that the car had stopped for a traffic light just before the arrest was made. The driver then proved to the judge *by mathematics* that no car in existence could have picked up speed fast enough to be exceeding the speed limit where the cop was stationed. And the judge let him off.

But there's still one more reason why you should study more math now, while you still can get the groundwork. Even if you aren't going to need more than arithmetic in your job when you get out of school, even if you decide you can get along with just arithmetic in solving your everyday problems, you still may be the kind of person who needs to know something about advanced math to get the most out of life.

Now some people are satisfied to go on living from day to day, having a good time but not caring much about anything else. But there are lots of people who aren't content to live that kind of life. They're interested in life, and other people, and what makes the wheels go around—what makes it rain or snow, what the stars are, or what

makes radio and TV work. Such people are just plain curious about things. They like to learn as much as they can, because they're interested in everything that goes on.

Trouble is, if you're that kind of person, you almost have to learn something about the more advanced branches of math if you want to understand the things you get curious about. Algebra and geometry are so important to an all-round education that it's hard to get through high school without taking those subjects. And many colleges make you study more than that just for a general all-round education.

If you want to learn something about astronomy and how it's possible to measure the distances to the sun or the moon or the stars, you've got to know something about trigonometry. If you want to understand the laws which govern the workings of the universe which includes our earth, the sun, and all the stars, you have to understand the calculus.

Suppose you're interested in economics. That's the study of such things as inflation and banking, whether we're going to have enough food or gadgets or machines to go round, and what we're going to use for money. The fellows who study economics are great ones to use statistics, and in order to make their statistics easy to understand, they make graphs or curves of them. This comes under the subject of analytical geometry—a handy subject to know if you're interested in economics.

A Brick Problem

Before we finish thinking about the importance of knowing more mathematics than just simple arithmetic, let's take one more example of the use of math to solve a simple problem. The problem is the sort of thing that might come up in one way or another to bother anybody nowadays. Although it might be about anything from shoes to automobiles, let's use bricks for example. This is our brick problem:

A brick weighs 10 pounds plus a half a brick. How much do two bricks weigh?

Now actually there are three ways to solve that problem. The hardest way is the way a fellow would do it if he didn't know any more math than simple arithmetic. We could call this the guessing method. By this method, you'd say that one brick must weigh more than 10 pounds—perhaps 12 pounds. But we were told that a brick weighs 10 pounds plus a half a brick, and if one brick weighs 12 pounds, a half a brick weighs 6 pounds, and 10 pounds plus 6 pounds is 16 pounds, not 12.

So we try again. If we try 15 pounds next, we find it still doesn't work, for then 10 pounds plus a half a brick ($7\frac{1}{2}$ pounds) would be $17\frac{1}{2}$ pounds. Not until we try 20 pounds do we find that it works, for then 10 pounds plus a half a brick equals 20 pounds. This makes two bricks weigh 40 pounds, which is the right answer.

An easier way to solve the problem is to do it with algebra. If we let x equal the weight of one brick, then we can set up a simple equation and solve it out like this:

$$x = 10 + \tfrac{1}{2}x$$
$$x - \tfrac{1}{2}x = 10$$
$$\tfrac{1}{2}x = 10$$
$$x = 20$$
$$2x = 40$$

In other words, two bricks weigh 40 pounds, which is the same answer we got by the guessing method.

There's still a third way to do it. It's the easiest one of all. To anyone well grounded in math, particularly algebra, this problem is so simple that he sees the essentials right away; he can figure it out in his head. He may be unconsciously doing it by algebra, but if you were to ask him how he did it, chances are he wouldn't say he used algebra at all but just common sense or logic.

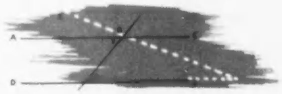
And that's the beautiful part of a good groundwork in math. It helps you to think things out logically. For mathematics is just an application of the principles of logic.

What Is Math, Anyway?

And this brings up a question that ought to be answered right now: What is mathematics, anyway? A lot of people have a completely wrong idea about the answer. Some folks think of math as something that's terribly hard to learn, something mysterious, something that only "brains" and geniuses can get good marks in. Well, if that's the way you feel about math, you're wrong.

When you come right down to it, all—or nearly all—of mathematics, no matter how advanced, no matter how strange it may seem, is just the four simple parts of arithmetic: addition, subtraction, multiplication, and division. The more advanced branches of mathematics teach you how to use these four parts of arithmetic to solve harder problems, and they teach you how to do those four things *fast*.

For we use the simple kinds of math as stepping stones to reach the more complicated kinds. Once we learn addition, subtraction, multiplication, and division, it's easy to learn algebra. Once we learn algebra, it's easy to learn geometry. Logarithms are just a kind of short cut to help solve problems in arithmetic. Algebra's another short cut.



Geometry, however, isn't really mathematics at all. It's the logical study of the shapes and sizes of things. We just use math in figuring out the measurements and capacities of geometrical figures—how big they are or how much you can put into them.

Trigonometry is the next stepping stone after geometry. It uses some of the things we learned in geometry as tools for measuring distances. With trigonometry we can do surveying—or we can measure the distance from the earth to the moon, the sun, or even some of the stars. But when you solve a problem in trig, you still use arithmetic: addition, subtraction, multiplication, and division.

The calculus is a very wonderful branch of math. While geometry and trigonometry are used to figure out problems about things that are standing still, so to speak, the calculus is used to solve problems about things that are always changing, like the speed of a bomb dropping out of an airplane. Yet the calculus is just a more elaborate method of using addition, subtraction, multiplication, and division.

One kind of math that often scares those who don't know much or anything about it is the use of formulas and symbols. They look strange to us, and because we don't know what they

mean, they may scare us a little. But there's really nothing to be scared of, for such things are just a kind of shorthand which mathematicians, scientists, and engineers use. They use them as a simple way of writing complicated ideas or methods of solving problems.

Serve the Pi

Probably the best known of these is the Greek letter pi. If you've studied geometry, you know it's the number of times that the diameter of a circle can be divided into its circumference—about 3 1/7 times, roughly speaking. The actual figure is a very complicated number, for when you divide the circumference of a circle by its diameter it never comes out exactly; the answer keeps running on and on to more and more decimal places.* So, because it's impossible to write it down exactly, we use a symbol for it. Although this symbol, pi, has many other uses in mathematics, most people know, when they see it, that it means the number of times the diameter of a circle can be divided into its circumference.

It's the same way with other symbols. Every one of them is just a kind of shorthand for something longer and more complicated. When you get a mark of A— or maybe F—on an examination paper or your report card, it tells you how well you did. If it weren't for the symbol, somebody might have to write a lot of words like: "This is a very good paper," or "This student didn't pass."

That's the way it is with all the signs and symbols of math. Every one of them means something long or complicated, and it saves time and space to use the symbol.

Don't think that the mathematicians and engineers and scientists can understand all the symbols. Some of the signs, of course, like pi, are pretty well known. But many of them are used only by people in special kinds of work, and people in other kinds of work may not know any more about what the signs mean than you do.

Formulas are used in the same way. People who study physics have proved

hitting harder is more important than a heavier bat

by experiments that, if you're trying to knock a home run, it's more important to hit harder than it is to use a heavier bat. They've figured out just what difference it makes when you use something heavier to hit with, and how much difference it makes when you hit harder.

When you hit with something twice as heavy, it does twice as much good. But when you hit twice as hard, it does four times as much good. When you hit with something three times as heavy, it does three times as much good. But when you hit three times as hard, it does nine times as much good.

It wouldn't be easy to remember how much difference it makes, depending on whether you hit harder (increase the velocity, that is) or use something heavier, if it weren't for this simple little formula:

$$E = \frac{MV^2}{2}$$

The formula may look strange to you, but don't let it scare you just because of that. It's just a combination of signs arranged in the form of an equation in algebra. Each of the signs has a pretty simple meaning. If you know the meanings, you can read them just as you read a sentence in English.

Translated into English, that formula says:

Energy (E) equals half the product of the mass (M) times the square of the velocity (V).

You can translate it still more if you want to. But the point is, that compact little formula is a very quick and convenient way of saying a much more complicated thing. And if it weren't for algebra, we wouldn't be able to say it so quickly or so simply.

So it amounts to this: if you know what the signs mean, and you have studied algebra, you can understand what most of those strange formulas mean. And when you understand that, you'll realize all of a sudden that most of the strangeness of higher mathematics or subjects like physics, or chemistry, or electrical engineering, is caused by the strange symbols and formulas that are used. If you learn what the symbols and formulas mean, those things won't seem anywhere near so strange. You'll find they don't scare you anywhere near as much.

So Far, So Good

Now that we've gotten this far, let's stop a moment and get our bearings. If you've understood what's been said, you know these things:

1. The world today is complicated.
2. That means we need lots more people with special training.
3. That means we'll all need more math.
4. Mathematics can help us even if we don't need it in our jobs.
5. All math is based on simple arithmetic.
6. Most all math is just special ways

* *Here's pi to ten places: 3.1415926535. Although mathematicians have figured out its value to over 1000 decimal places, no more than ten decimal places are ever needed for the most precise work.*

of using arithmetic or of doing arithmetic fast.

7. Much of the strangeness of math is caused by the symbols and formulas, and they're just a convenient sign language.

Before we finish thinking about what math is and how we use it, let's think about one more thing that we learn when we learn math: analysis. When we have a problem, or something happens, and we have to figure out what to do, that's called analysis.

Your arithmetic, your algebra, your geometry, trigonometry, calculus, and other branches of math are the tools you use to solve problems. But you can't use the tools unless you analyze your problem first to see what you've got, what you need to do, and how you should do it. Analysis tells you which tools to use, and how to use them, in solving your problem.

Analysis is the most important part of mathematics. Anybody can learn to use the tools, but unless he learns analysis, he'll never be able to solve problems, even the simplest ones.

If we want to know what percent 48 is of 60, it's analysis that tells us to divide 48 by 60 to get the answer (80%). In solving that problem of the brick that weighed 10 pounds plus a half a brick, it was analysis which made us decide whether to use the guessing method or algebra. And if we were really good at analysis, we solved it while we were analyzing it.

For that's where analysis gets particularly worth while—when we have such a good grounding in math that we

learn to be really sharp in analyzing our problems. And when you remember that analysis is just intelligent, logical thinking, why then you'll begin to see one of the most important things about learning a lot of math. That is: the more math you get, the better you'll be able to think.

Professor Bailey of the University of Michigan said something about that in an article he wrote not long ago. He said that education is mainly along three lines: (1) learning facts; (2) learning to get along with other people; and (3) learning to think better. The first two are not very hard—even a dog can do them. A dog, for example, learns such facts as where his home is, who his master is, and when he gets fed. He also learns to get along with people—if he's had any training, that is.

Can a Dog Think?

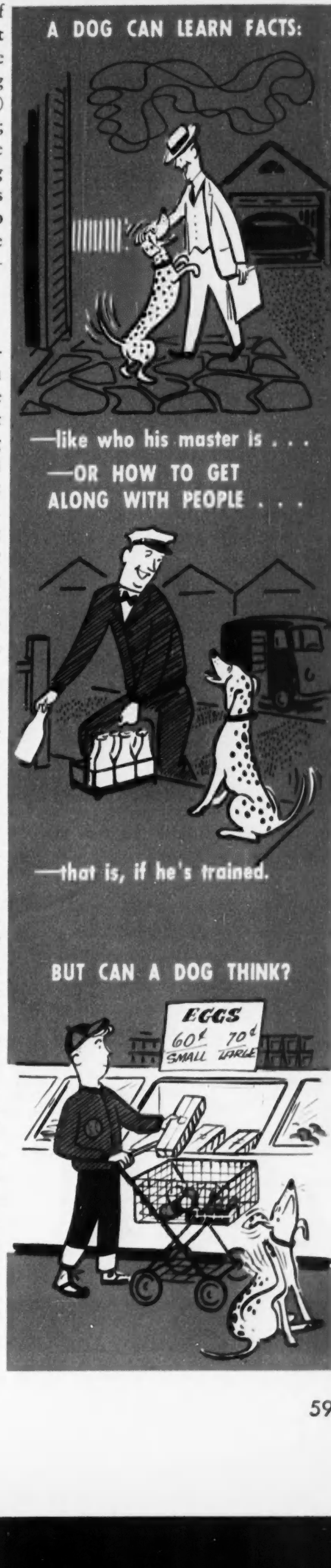
But when it comes to the job of learning to think better, that's too much to expect of a dog. Many people believe that a dog can't even think in the first place—that thinking is something that's done only by human beings. All human beings think, but some do a lot more of it, or do it better, than others.

Professor Bailey wondered what it was that made some people think better than others. He said the first thing necessary to be a thinker was to be born that way, like Benjamin Franklin or Thomas A. Edison. *They* didn't have to be taught to think.

But that doesn't mean people can't be taught to think—or think better. Professor Bailey gave the names of some great examples of well-educated people—Elihu Thomson, Steinmetz, Langmuir, Coolidge. Their education, far from interfering with their ability to think must have been a great help to their thinking ability.

Then Professor Bailey asks what studies in school help most to develop the habit of thinking. And the first of these, he says, is arithmetic. In the study of arithmetic the student is made to think logically and accurately—probably for the first time! And its pretty well agreed that the more math you get, the more logically you think.

So it's to your advantage to study as much math as you can, while you still have the chance. And the best time to get a good groundwork in math is while you're still in junior and senior high school. You'll find it much easier to get through college if you get a good grounding in math now. It will help you to get a better job afterwards, too. Most important of all, it will help you to think better and to get the most out of life.



WILL YOU CHOOSE ONE OF THESE OCCUPATIONS FOR A CAREER?

THESE OCCUPATIONS NEED LOTS OF MATH

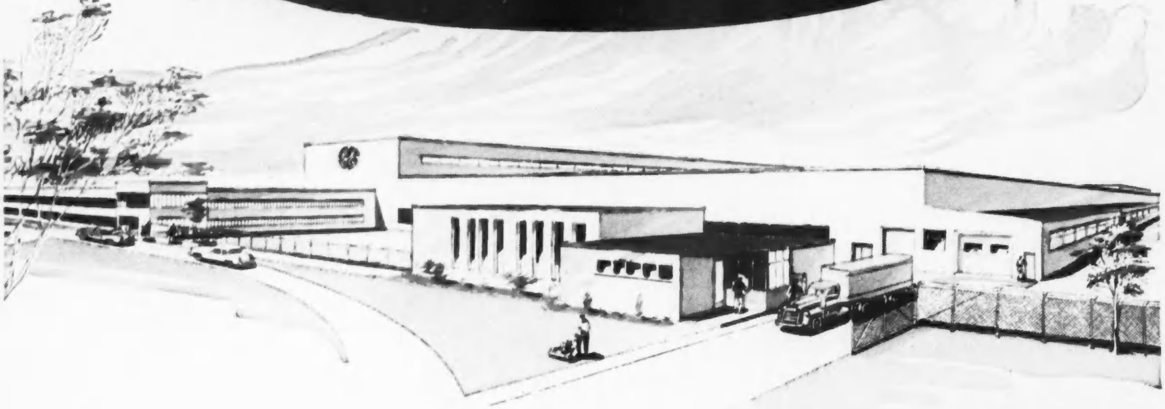
Architect
Aeronautical Engineer
Agricultural Engineer
Astronomer
Ceramic Engineer
Chemical Engineer
Chemist
Civil Engineer
Electrical Engineer
Geologist
Marine Engineer
Mechanical Engineer
Metallurgist
Mining Engineer
Petroleum Engineer
Physicist
Pulp & Paper Engineer
Research Scientist
Sanitary Engineer
Surveyor
Textile Engineer

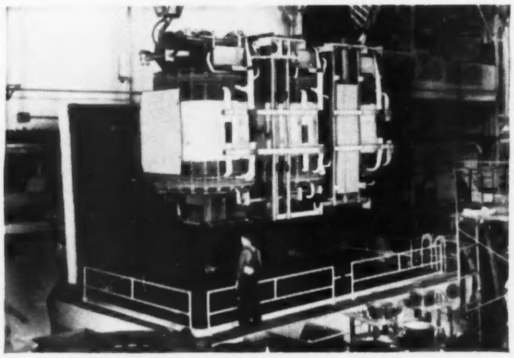
THESE OCCUPATIONS NEED QUITE A LOT OF MATH

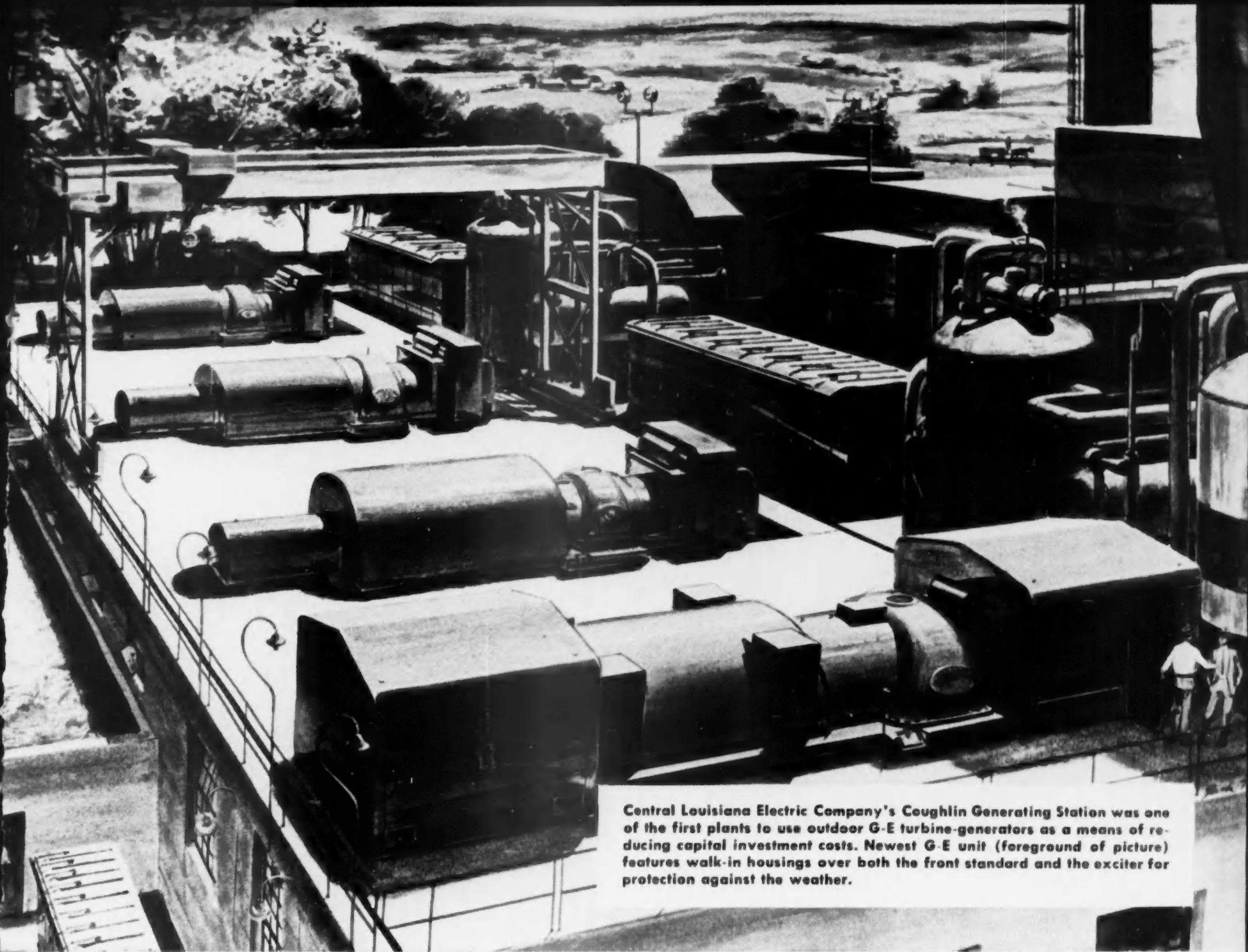
Accountant
Airplane Pilot
Artist
Auditor
Carpenter
Dentist
Dietician
Doctor
Draftsman
Electrician
Housewife
Machinist
Mechanic
Merchant
Molder
Musician
Nurse
Painter
Plumber
Statesman
Stonemason
Teacher
Writer

THESE OCCUPATIONS NEED ARITHMETIC ONLY

Athlete
Athletic Coach
Baseball Player
Farmer
Fireman
Football Player
Gas Station Attendant
Photographer
Policeman
Sales Clerk
Soda Clerk
Stenographer
Telephone Operator

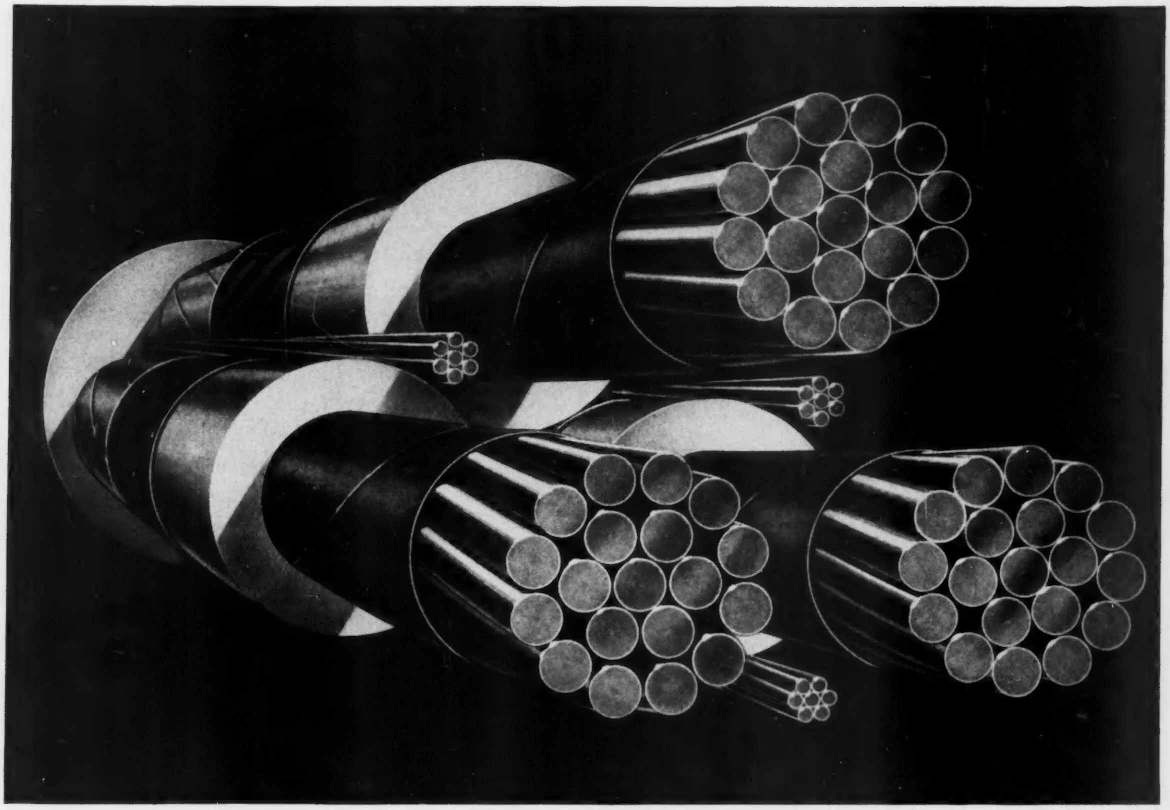






Central Louisiana Electric Company's Coughlin Generating Station was one of the first plants to use outdoor G-E turbine-generators as a means of reducing capital investment costs. Newest G-E unit (foreground of picture) features walk-in housings over both the front standard and the exciter for protection against the weather.

Consulting Engineers: Sargent & Lundy




GENERAL