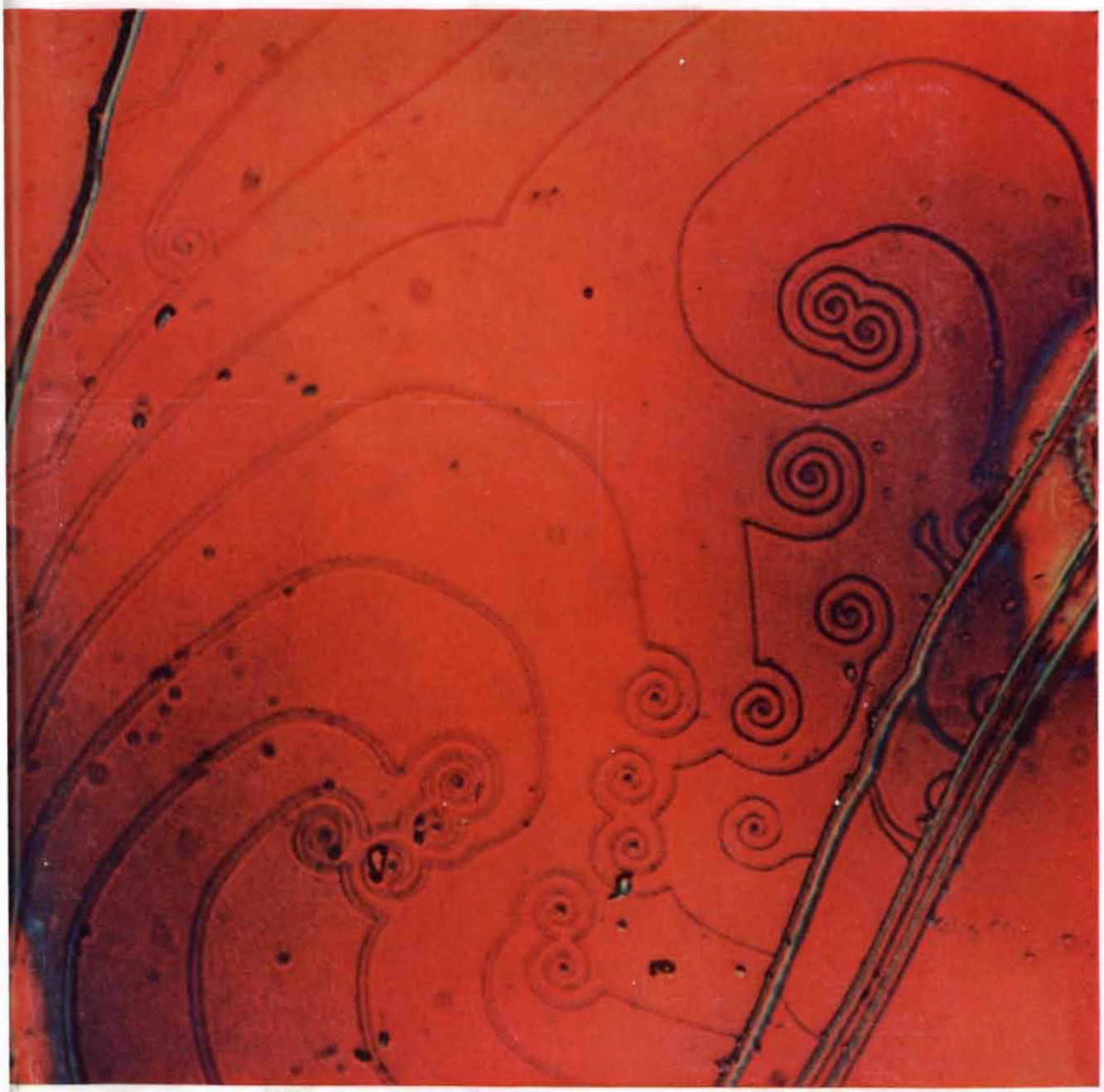
SCIENTIFIC AMERICAN

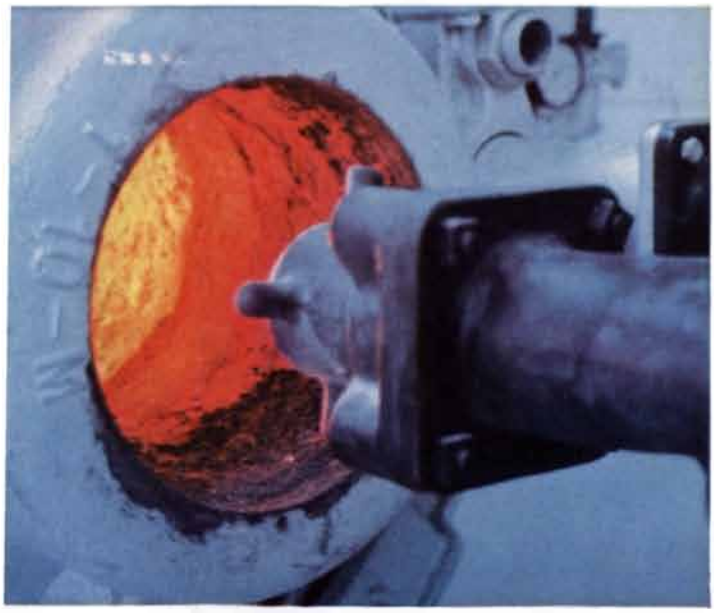


DISLOCATIONS IN A CRYSTAL

FIFTY CENTS

October 1961

THE COMFORT AND LOW COST of this urethane foam mattress were both made possible by M&T Catalyst T-9, one of many stannous and organotin catalysts developed by M&T for use in the new "one-shot" foam process. Tin chemicals have proved to be unusually versatile as catalysts and stabilizers, and biocidally active organotins are finding rapidly widening application as bacteriostats, fungicides, algicides, textile purifiers and as repellents for rodents and marine growth.



HIGH TEMPERATURES ARE ROUTINE as zirconium, antimony and tin opacifiers are evaluated in M&T's newly expanded Ceramics Research Center. Plant conditions are simulated in the firing of glazes and enamels to determine optimum formulations. The Ceramics laboratories are just one of the many specialized research and development facilities working for M&T customers.

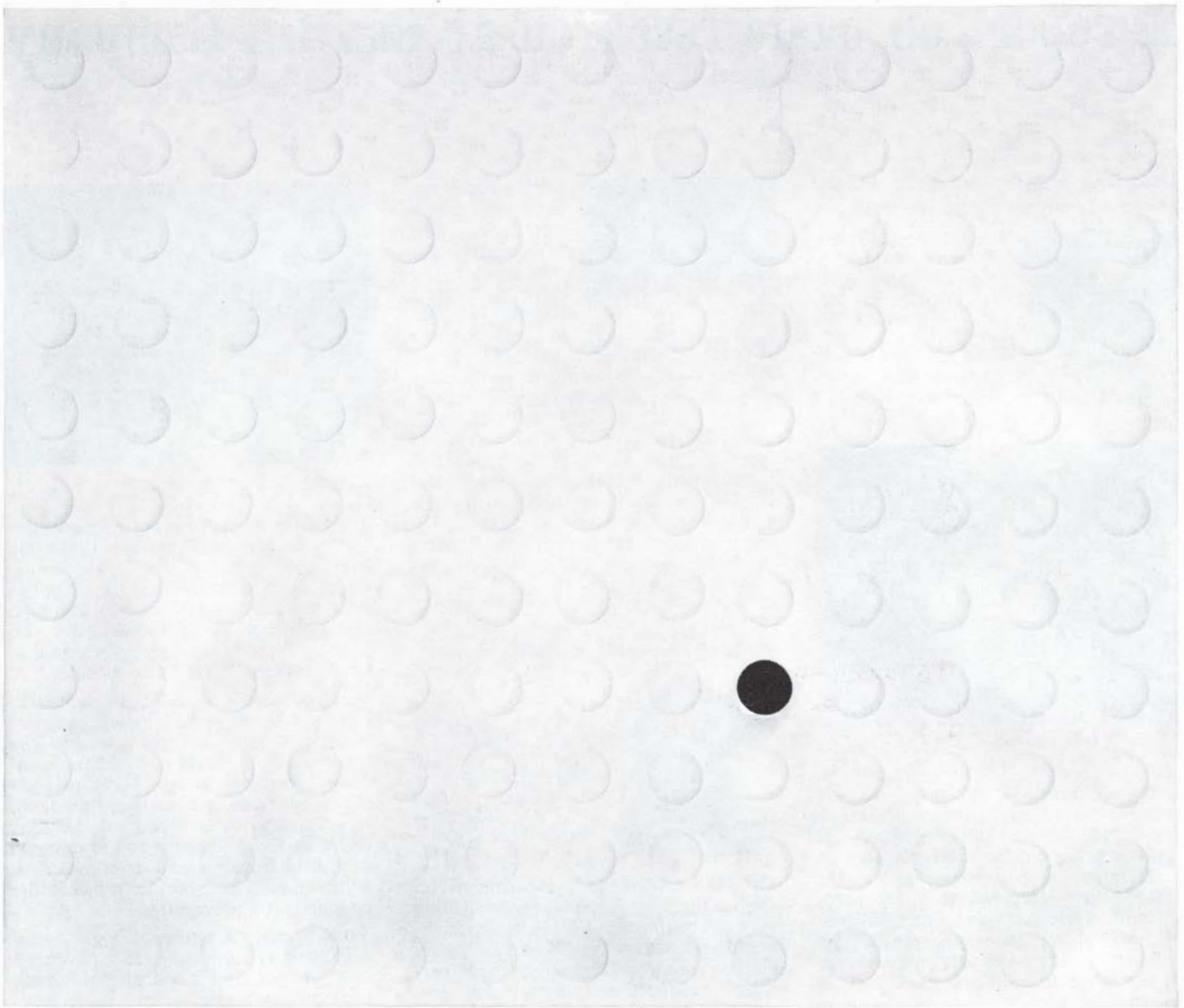
BUILT-IN FIRE PROTECTION is provided for plastics and organic coatings by specially processed Thermoguard® grades of M&T Antimony Oxide. Antimony-based M&T Flame Retarder which has only one-fifth the tinting strength of Sb_2O_3 is also available for use in translucent plastics, or in deeply colored plastics where the high white-tinting strength of antimony oxide is highly undesirable.

Work in inorganic tin chemicals led to organic tin chemicals. These in turn led to other organometallics until M&T now operates a versatile plant that produces the largest variety of organotins and organometallics in the country. From this modern M&T plant come stabilizers, catalysts and biocides on which entirely new products and new manufacturing methods have been based.

M&T Chemicals

Sn Sb P
Si Ti Zr
organometallics and inorganics

METAL & THERMIT CORPORATION GENERAL OFFICES: RAHWAY, NEW JERSEY IN CANADA: M&T PRODUCTS OF CANADA LTD., REXDALE, ONT.



Is your computer tape truly clean?

(If so, you must be using Ampex)

Ampex is the first truly *clean* computer tape! It's produced in a controlled atmosphere, under the most rigid precautions. Every roll must pass intensive electrical and physical tests before packing.

Then, when Ampex engineers are almost sure it's perfect, they take another step to insure it's truly *clean*. They "bathe" it in a special chemical bath that removes all extraneous matter that might cause even a "temporary dropout."

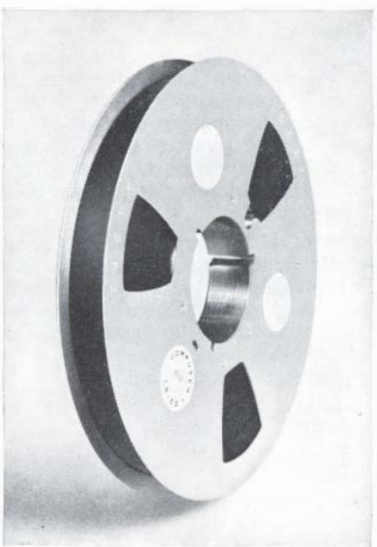
But that's not all. Every inch of Ampex Computer Tape is digitally checked to make sure every reel is completely error-free before it leaves the plant. What's more, it's tested on systems compatible with those it will be used on.

Another thing about truly clean Ampex tape is that it keeps your system cleaner, too! The exclusive Ferro-Sheen process insures a smooth, clean surface that reduces headwear and oxide build-up . . . so you have less costly downtime for cleaning! Ampex performs better and runs cleaner than any other tape!

Some people say we take excessive precautions in making sure our tapes are truly clean and error-free. But this is the kind of deliberate excess that makes products superior enough to be called Ampex, a name that's known for perfection!

To test Ampex superiority, compare our computer tape, at 556 BPI, against any other tape made. See for yourself what Ampex can do!

Incidentally, as you may have guessed, it just naturally follows that our Instrumentation Tapes are the finest available!

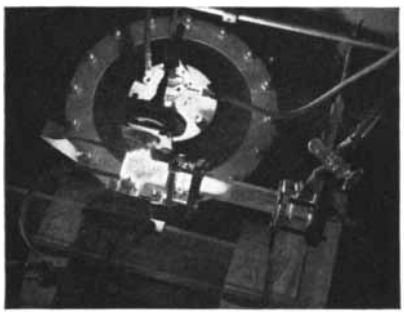


AMPEX MAGNETIC TAPE PRODUCTS
Opelika, Alabama

A report on basic research at Sun Oil Company

Utilizing shock waves to study gases at extreme temperatures

Dr. James L. Lauer, Research Associate
Temple Univ., A.B., M.A., Chemistry, Univ. of Pennsylvania, Ph.D., Physics, 1948, ACS, APS, Combustion Inst., SAS, Sigma Xi



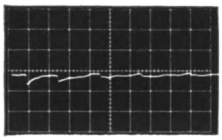
Photograph of shock tube showing propagation of a luminous front.

Using equipment similar in type to that sometimes associated with atomic fusion research, Dr. Lauer, Sun Oil physicist, is exploring the composition of gases at temperatures above 1500 degrees F. He obtains these temperatures at low pressures for micro-seconds by using hydromagnetic shock wave apparatus of his own design. Pressures and temperatures in the wake of a shock wave can be varied over a wide range by changing condenser discharge voltages, relative gas pressures, distances, and other parameters. Analyses are carried out spectroscopically and by other rapid instrumental methods. Accurate rates of composition change and identification of intermediates, e.g., free radicals, are the principal objectives.

"There is enough chemical kinetics at high temperatures to be profitably studied to keep a scientist busy for years," reports an associate. "The analysis of the fluid mechanics involved, and study of the interactions of charged particles in magnetic and electrical fields should result in important contributions to basic science."

Some of Dr. Lauer's studies to date include the formation of nitric acid from air, acetylene from natural gas, and better understanding of the ignition and combustion of hydrocarbon gases.* The use of shock wave techniques shortens week-long experiments to minutes.

**Presented before the Division of Fuel Chemistry, American Chemical Society, St. Louis meeting, March, 1961.*



Oscilloscope trace shows the travel of shock waves in hydromagnetic shock tube: The first deflection (approx. 1 millisec.) indicates the initial shock wave as it passes the pressure detector approximately half way down the shock tube. The second and succeeding deflections (approx. 2½, 4½, 6½, 9 millisec. resp.) show the shock wave after reflections from the end of the shock tube. The increase in time between alternate deflections (shock wave traveling in same direction on alternate deflections), indicates velocity attenuation, and decrease in strength of the shock between successive deflections.

Taking Combustion Apart

Dr. Paul E. Oberdorfer, Section Chief
Ohio State Univ., B.S. Ohio State Univ., Ph. D., Chemistry, 1954 ACS, SAE, API, Combustion Inst.

Dr. Paul Oberdorfer's experiments on the burning of vaporized fuels are yielding very interesting results. He used a high-compression diesel engine driven by an electric motor as a reactor.* This permitted unique time, pressure and temperature relationships. Thus he was able to simulate the first stages of combustion without having the products destroyed by the high temperatures of subsequent stages. One interesting early stage phenomenon is the "cool flame" in which a low intensity flame is generated with only a 100-200 degree F. temperature rise.

The future significance of this line of experimentation lies in two areas. First, there are the possibilities of producing petro-chemicals directly from hydrocarbon gases. Second, it may be possible to improve the combustion characteristics of fuels by having a better understanding of the physics and chemistry in the intermediate steps of the burning process.

**Published in INDUSTRIAL & ENGINEERING CHEMISTRY, January, 1961.*

Research and Development at Sun Oil Company

Sun management believes nothing is more important to the success of an R&D program than the climate in which it operates.

Sun R & D Laboratories.

To assure an intellectual climate conducive to research they are supporting the R&D program by employing leading scientists and providing the facilities necessary to make it one of the high quality programs of the industry. To begin with, R&D is fully represented in top management by a vice president.

Sun encourages its R&D personnel to have the broadest possible exchange of ideas with other areas of research. The company is a member of academic industrial liaison programs. Technical society membership and meeting attendance is encouraged and supported. Leading scientists from universities are engaged as visiting lecturers and as consultants. When desirable, specific projects are conducted by universities.

Sun's research interests are very broad with basic and applied research in chemistry, physics, and chemical engineering. Projects are underway in electrochemistry, new organic and organo-metallic chemistry, polymerization, the surface chemistry of catalysts, films and lubricants, and oxidation.

The R&D organization permits each scientist to know what his associates are working on . . . resulting in a stimulating cross-fertilization of ideas.

The research facilities include the latest in laboratory equipment and apparatus especially designed for the work at hand. Further expansion is now underway.

SUN OIL COMPANY
1608 Walnut Street Philadelphia 3, Pa.

SUNOCO

PROMOTING PROGRESS THROUGH RESEARCH

Established 1845 **SCIENTIFIC AMERICAN** October 1961 Volume 205 Number 4

ARTICLES

DEPARTMENTS

PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK 17, N.Y. SECOND-CLASS POSTAGE PAID AT NEW YORK, N.Y., AND AT ADDITIONAL MAILING OFFICES. SUBSCRIPTION RATE: $6 PER YEAR.

THE COVER

The photomicrograph on the cover shows spiral growth figures on a crystal of silicon carbide. The spirals originate in the vicinity of screw dislocations, and their presence provides one means of observing directly the location and behavior of these tiny imperfections in the regular structure of a crystal lattice (*see page 107*). The cover picture was made with a visible-light microscope using vertical illumination; the magnification is 1,650 diameters. The brightly colored splotches and streaks at the sides of the picture show the presence of impurities or oxidized areas on the surface of the crystal. During the past decade a number of techniques have been developed that make possible similarly detailed studies of dislocations.

THE ILLUSTRATIONS

Cover photograph by F. Hubbard Horn, General Electric Research Laboratory

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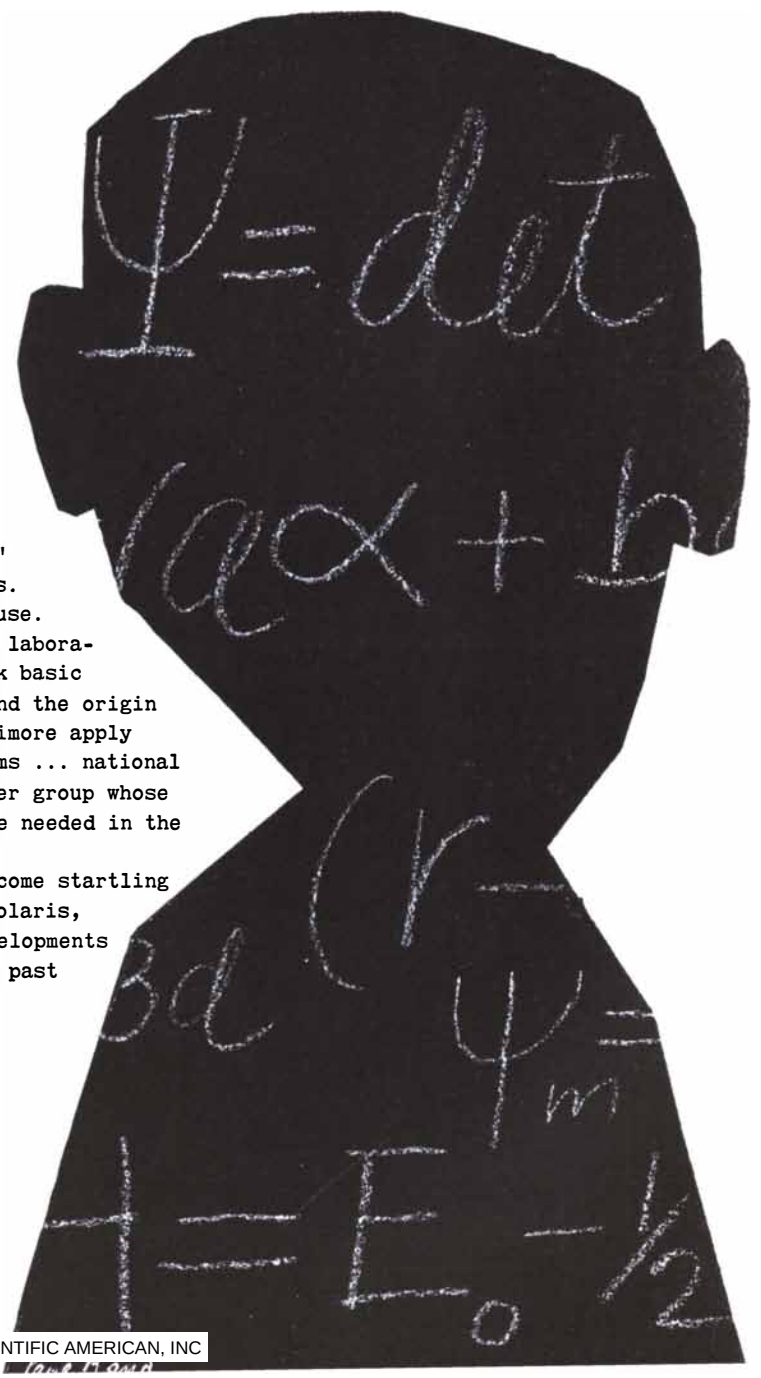
Westinghouse
puts the future
in your hands

Men who do nothing but Think



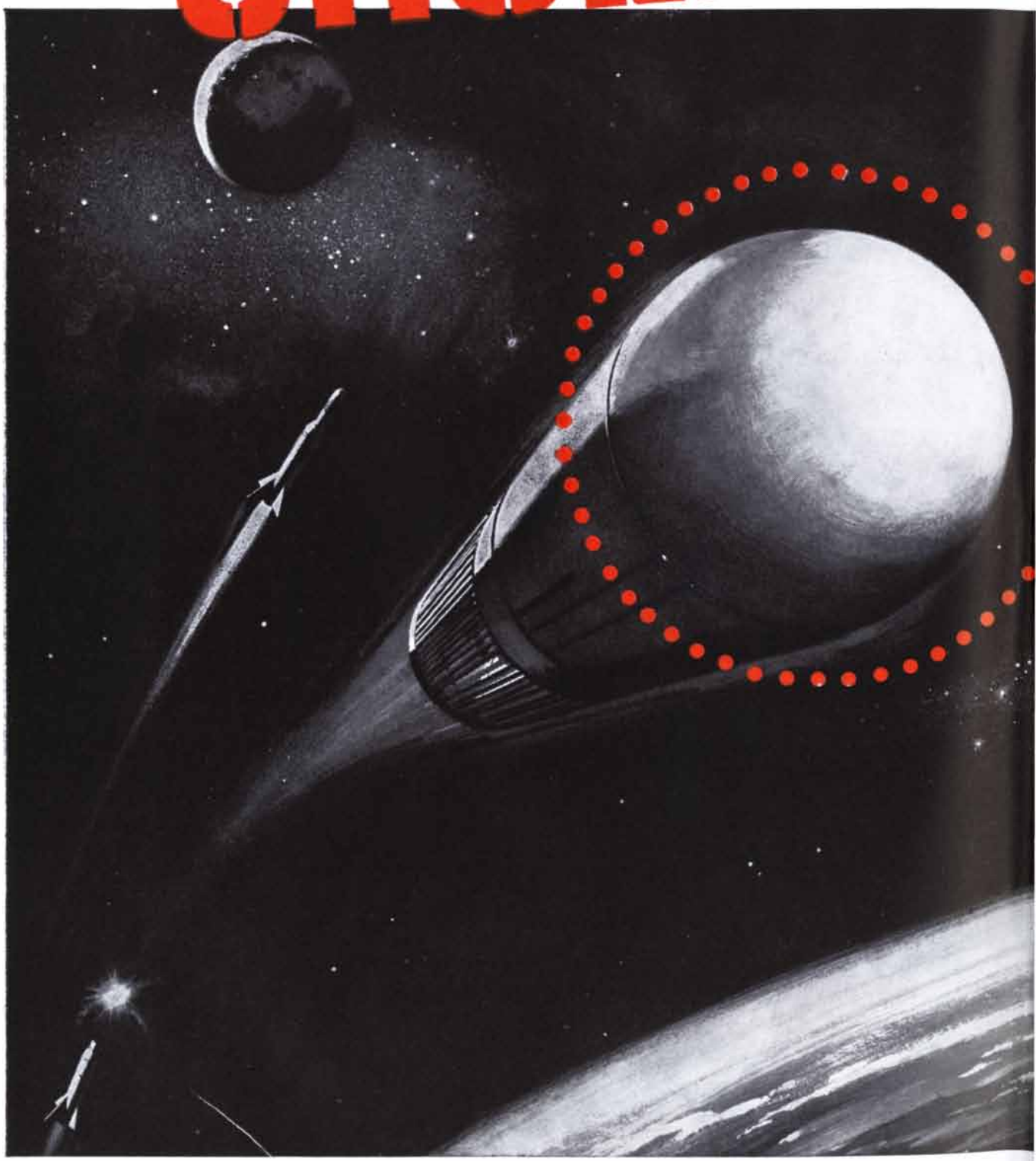
A phenomenon of modern America is the so-called "think company." It owns no factories, manufactures no products and makes no shipments, but just "thinks" about problems, and comes up with brilliant solutions.

We have a number of "think companies" at Westinghouse. One of them is a group of scientists in the research laboratories near Pittsburgh who do almost nothing but seek basic knowledge, like the production of light by solids, and the origin of magnetism. Other Westinghouse scientists in Baltimore apply basic knowledge to that most demanding of all problems ... national defense. And at Cheswick, Pa., there is still another group whose principal job is to think about what products will be needed in the American home 10 or 15 years from now.

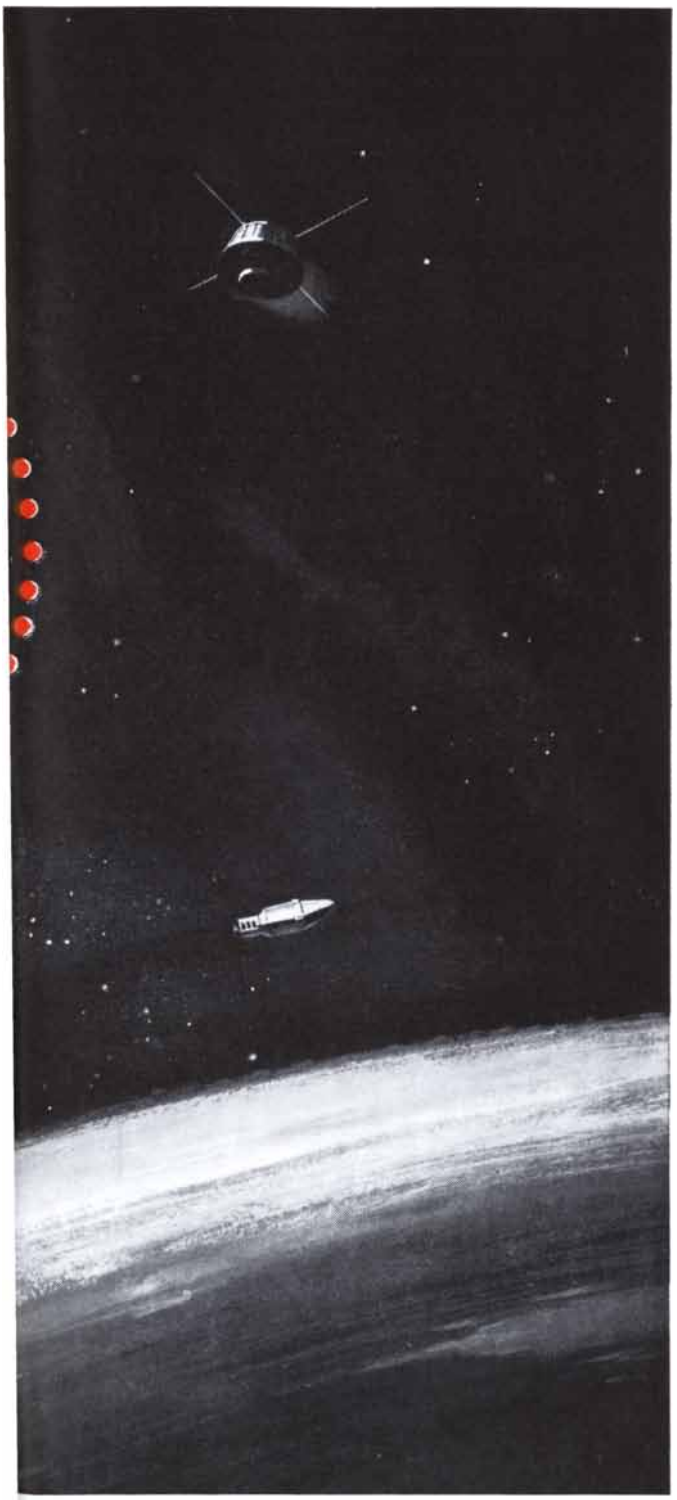
Out of this kind of thinking at Westinghouse have come startling advances in atomic power, the launching system for Polaris, thermoelectric generators and other Westinghouse developments

The achievements of Westinghouse scientists in the past are the best guarantee of new ones in the future. You can be sure ... if it's **Westinghouse**

URGENT:



STOP THAT MISSILE–
AND THE NEXT ONE TOO!



In probing uncharted areas of electronics to solve the critical anti-missile problem, our scientists and engineers have developed advanced early warning systems of vital significance to national security.

For example, our work on ballistic missile defense systems has led to the development of a unique method for performing a great many dissimilar radar functions simultaneously and from one antenna. This technique —known as multifunction phased array radar—allows one advanced radar to replace many conventional radars. It permits long-range detection and selective tracking and targeting of numbers of small high-speed objects, including satellites, other space vehicles, missiles and warheads.

Since tracking beams can be positioned in a *fraction of a microsecond,* it is possible to track a great many targets while continuously searching for additional missile threats. And because phased array radar beams are electronically steered, the antennas do not rotate; and there is no chance for mechanical failure.

Major advances such as phased array radar are typical of the work being done by the scientists and engineers of the entire General Telephone & Electronics corporate family. The vast communications and electronics capabilities of GT&E, directed through Sylvania Electronic Systems, can research, design, produce, install and service complete systems. These include the entire range from detection and tracking, electronic warfare, intelligence and reconnaissance through communications, data processing and display.

That is why we say—the many worlds of defense electronics meet at Sylvania Electronic Systems, division of Sylvania Electric Products Inc., 40 Sylvan Road, Waltham 54, Massachusetts.

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Total Communications from a single source through

SYLVANIA ELECTRONIC SYSTEMS

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Electronic Giants no bigger than your thumbnail... now through electron-beam welding

High-energy density electron-beam welding techniques, recently developed by the Zeiss Foundation of West Germany and the Hamilton-Standard Division of United Aircraft, markedly improved packaging density and production methods in the field of microelectronics.

In microcircuitry, for example, packaged circuits no bigger than a thumbnail can now be reliably produced. Electron-beam equipment now welds microelectronic components into circuits with pinpoint precision, making intra- and inter-circuit connection, and hermetically encapsulating the completed micromodule.

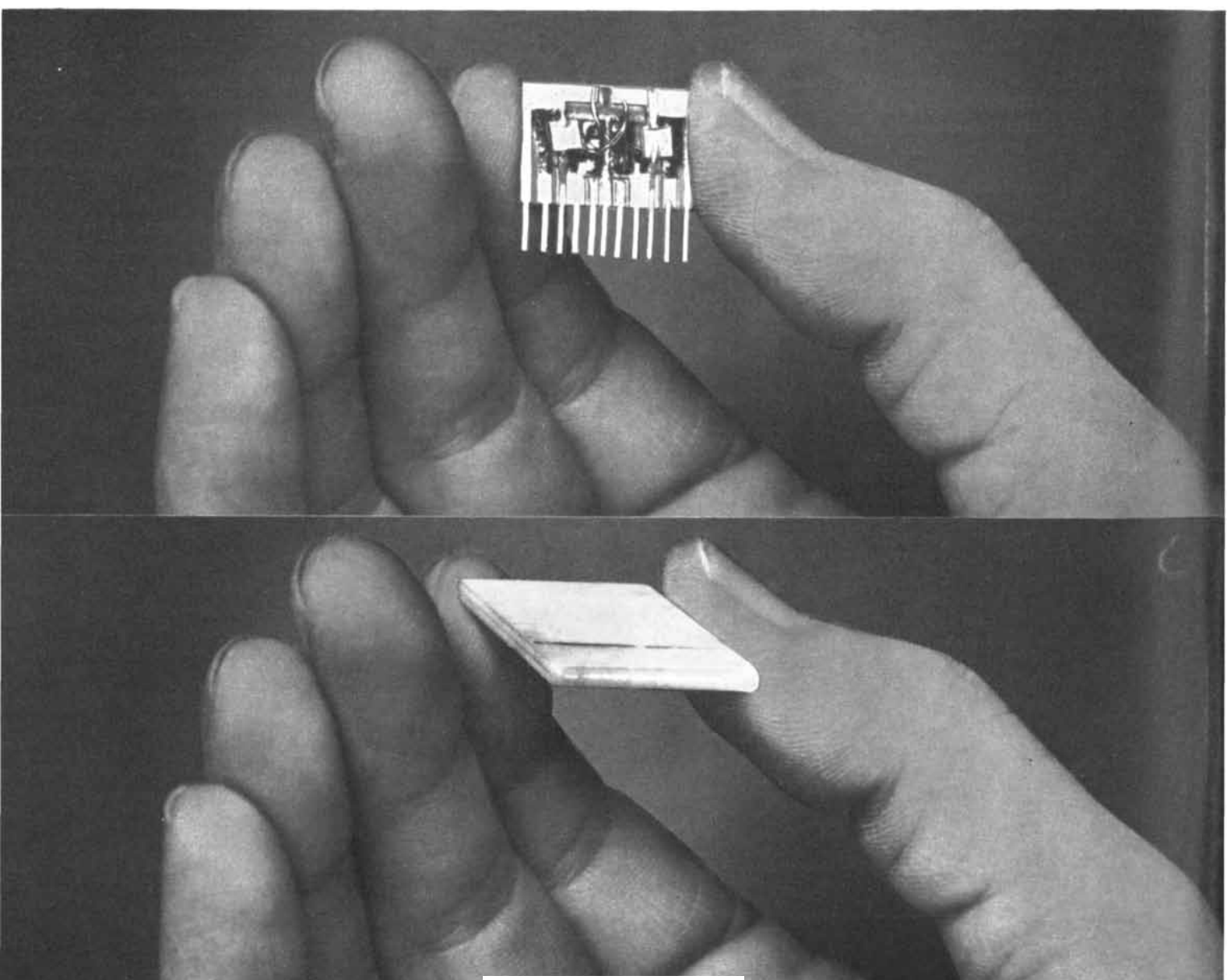
Only electron-beam welding, performed in a high vacuum, can offer these significant advantages for the field of microelectronics: virtual elimination of contamination; a close control of penetration; low thermal distortion; and close dimensional control. The upper illustration shows weldments of 0.002″ thick copper leads to 0.002″ thick nickel-plated ceramic substrate. In the field of thin films difficult welds are possible with this revolutionary new equipment such as 0.002″ gold tabs to chromium-gold films 3000-A° thick.

Another important use of electron-beam equipment is the welding of ceramics used in vacuum tubes which require extremely high temperature performance. For these procedures, tight ceramic-to-ceramic bonds are necessary — bonds available only through high-energy density electron-beam welding. The lower illustration is a 12 X magnification of two aluminum oxide ceramic wafers ½″ x ¾″ x .010″ thick edge-welded by deflecting the high energy density beam of a Hamilton-Zeiss electron beam welder across the edge surface.

Hamilton-Standard, with over twenty years of metallurgical experience and meeting rigid government specifications, has exhaustively tested the welds produced with Hamilton-Zeiss equipment. The data, which are available for your inspection, demonstrate conclusively that the Hamilton-Zeiss method produces welds in miniature workpieces that are as strong as the original materials themselves. Such results are possible only by the use of high energy density and precision focusing by the Zeiss magnetic lens system which are exclusive features of the Hamilton-Zeiss equipment. Find out what this revolutionary equipment can mean in your business. For full information call Hamilton-Electrona, Inc., exclusive marketing agent for Hamilton-Zeiss equipment in the United States and Canada.

HAMILTON-ELECTRONA, INC.

TIME-LIFE BUILDING, ROCKEFELLER CENTER, NEW YORK 20, N. Y.



SCOTCH® BRAND MAGNETIC INSTRUMENTATION TAPES OFFER A RIGHT TAPE FOR EVERY APPLICATION

Knowledgeable tape users realize that magnetic tapes are not all alike—that it takes specific constructions to meet the needs of specific applications. And they've learned to rely on "SCOTCH" BRAND to supply the one right tape for each application. Not only does "SCOTCH" BRAND offer a complete line, it offers that something extra that makes all the difference in performance—the uniformity and reliability that result from 3M's experience, technical skill, and continuing research. Make the "SCOTCH" BRAND label your guide in buying instrumentation tapes. Your 3M Representative is close at hand in all major cities—a convenient source of supply and information. For details, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.

The wide "SCOTCH" BRAND line provides many tapes, including these broad classifications:

SANDWICH TAPES 488 and 489—exclusive with "SCOTCH" BRAND, offering 30 times the wear of standard tapes, drastic reductions in head wear, elimination of oxide rub-off. In standard or extra-play lengths.

HIGH RESOLUTION TAPES 458 and 459—offering superior resolution in high frequencies, greater pulse density in digital recording. In standard and extra-play lengths.

HEAVY DUTY TAPES 498 and 499—offering exceptional life, good resolution, high resistance to temperature and humidity, reduction in the build-up of static charge. In standard and extra-play lengths.

HIGH OUTPUT TAPE 428—offering top output in low frequencies. Performs well even in temperature extremes.

STANDARD TAPES 403 and 408—offering the good all-round performance at low relative cost which has made them the standards of the instrumentation field.

MINNESOTA MINING AND MANUFACTURING COMPANY
...WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

"SCOTCH" BRAND MAGNETIC TAPES *FOR INSTRUMENTATION*

"SCOTCH" and the Plaid Design are registered trademarks of 3M Company, St. Paul 6, Minnesota. Export: 99 Park Avenue, New York, N.Y. In Canada: London, Ontario.

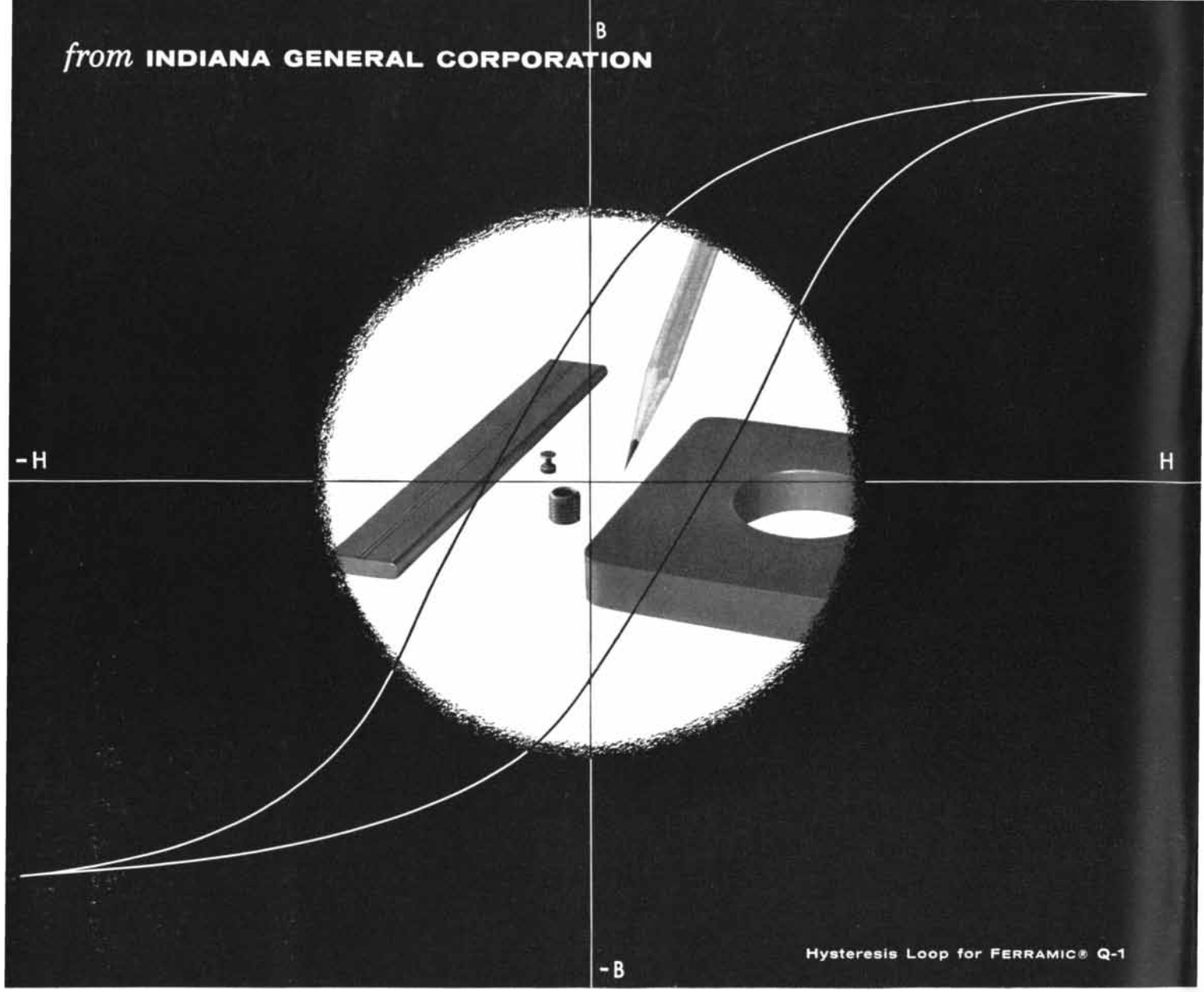
GUIDANCE COMPUTER for NASA'S CENTAUR

Sometime this year, CENTAUR will be spaceborne. Already, the projected uses of CENTAUR bear fascinating implications for the future . . . placing a satellite in an orbit so exacting that it will remain in one spot over the earth's surface . . . soft landings on lunar and planetary bodies . . . timed launchings of several satellites from a single vehicle. Several major guidance functions will be performed in CENTAUR by a compact digital computer system from Librascope. It weighs 62 pounds, occupies little more than ¾ cubic foot. A note to Librascope outlining your control problems will bring a prompt answer from the country's most versatile manufacturer of computer control systems.

GP GENERAL PRECISION

computer control systems
that pace man's expanding mind

LIBRASCOPE DIVISION | GENERAL PRECISION INC., GLENDALE 1, CALIFORNIA



CREATIVE MAGNETICS

TO SHARPEN ELECTRONIC FIDELITY

Here are three examples of how Indiana General ferrites, technical ceramics and permanent magnets are helping manufacturers improve the eyes, ears and voices of entertainment instruments.

Our General Ceramics Division's research in ferrite materials for radio resulted in FERRAMIC® Q-1. This material made possible the first practical ferrite radio antennas, and is the standard of the industry today. Superiority is due to properties like a Q factor as high as 370, a typical temperature co-efficient of permeability of .04%/°C max., and unequaled resistance to changes in permeability and Q factor due to aging.

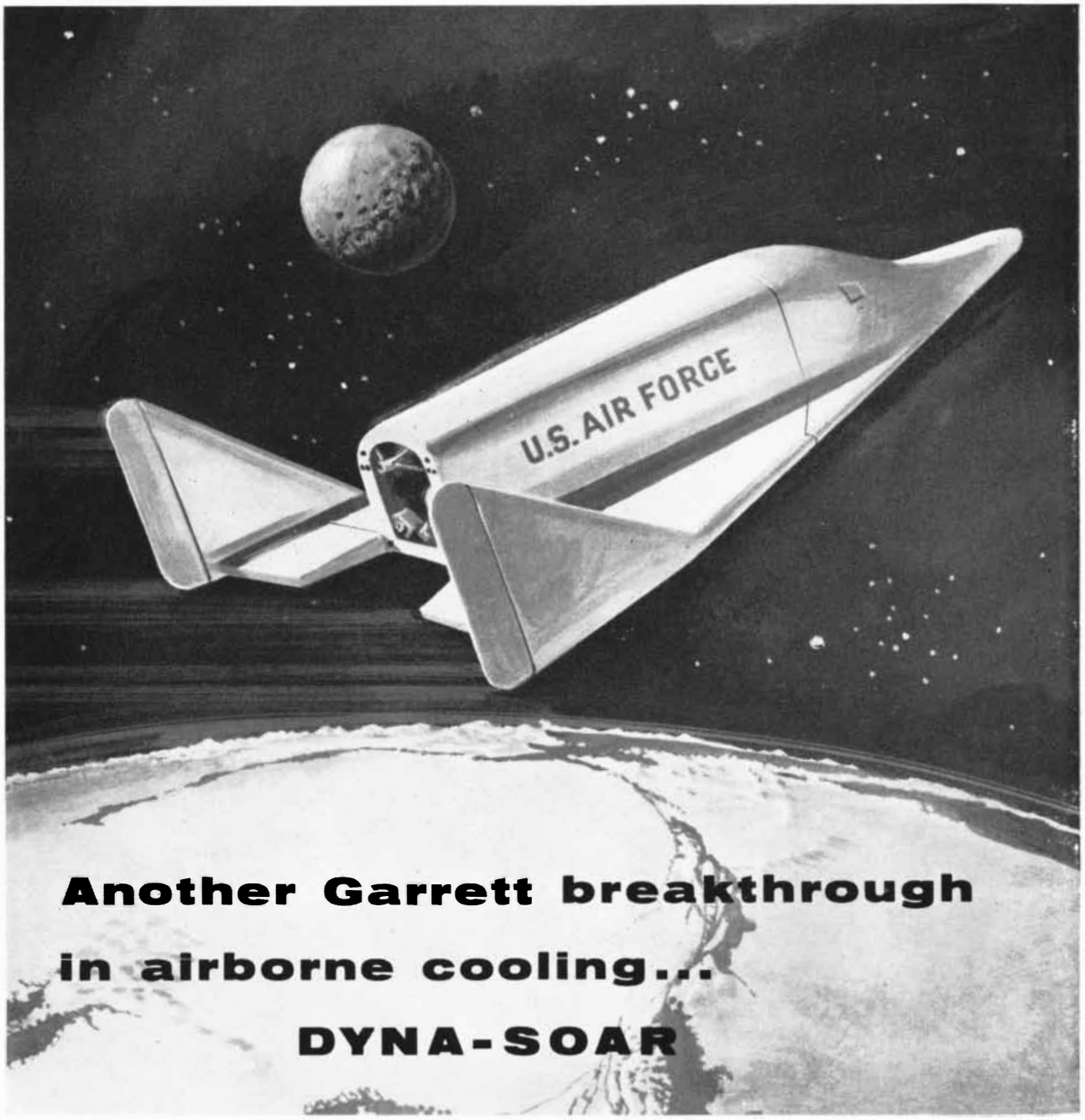
The miniature FERRAMIC bobbin and threaded cup core combination is another General Ceramics "first." It is ideal for IF transformers and all miniature inductors requiring high Q (as high as 70 at 200 mc for Q-3 material), high permeability and an adjustable tuning feature which keeps Q variance at a minimum. General Ceramics has also pioneered improvements in low-loss power ferrite materials for flyback transformers used in television receivers.

Permanent magnet materials introduced by our Indiana Steel Products Division have brought major television and radio design improvements. INDOX V ceramic speaker magnets with a guaranteed minimum energy product of 3.25 million BH max. have enabled manufacturers to cut magnet costs by 13%, speaker weight by 25%, speaker length by 46%.

The above is just a sampling of the advanced materials and designs Indiana General offers in the field of entertainment electronics. Our design engineers welcome the opportunity to work directly with you on your development program. Write us outlining your requirements.

INDIANA GENERAL CORPORATION VALPARAISO, INDIANA

Permanent Magnets • Ferrites • Technical Ceramics • Memory Products • Magnetic Separation and Handling Equipment



Boeing Dyna-Soar Manned Space Glider

Garrett is now developing Dyna-Soar's thermal control system — again demonstrating its 20-year leadership in the pioneering of airborne cooling methods by its AiResearch Manufacturing Divisions.

An important contribution to the rapid over-all development of the Boeing Dyna-Soar manned space glider, the compact, lightweight system will cool the pilot and his equipment, economically utilizing the cryogenic hydrogen fuel of the accessory power system.

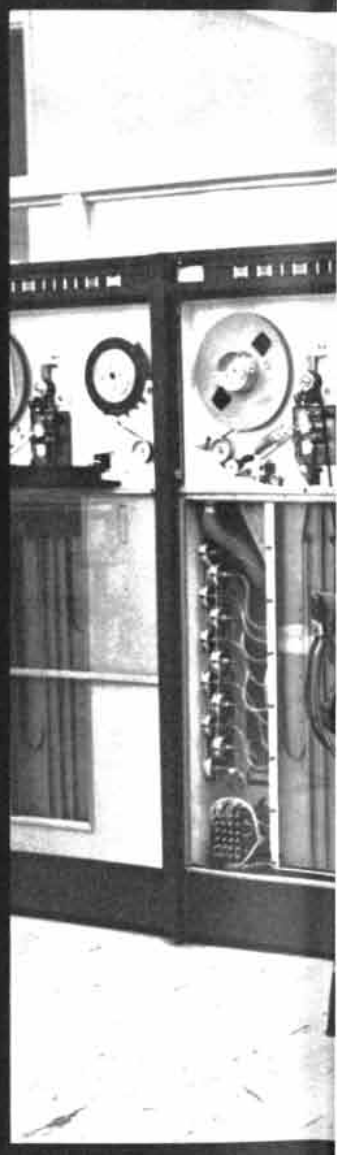
The development of this hydrogen system exemplifies Garrett's continuing advancements in airborne cooling, including air cycle and Freon refrigeration systems, zero gravity gas and liquid systems, and new developments in space radiators and other systems using exotic liquids and metals... all leading to the development of more advanced thermal control techniques for spacecraft.

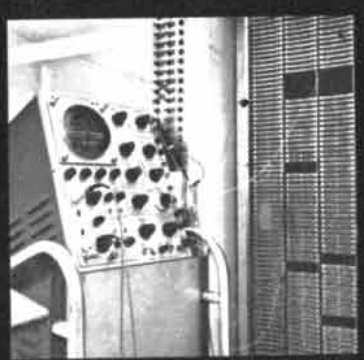
THE GARRETT CORPORATION

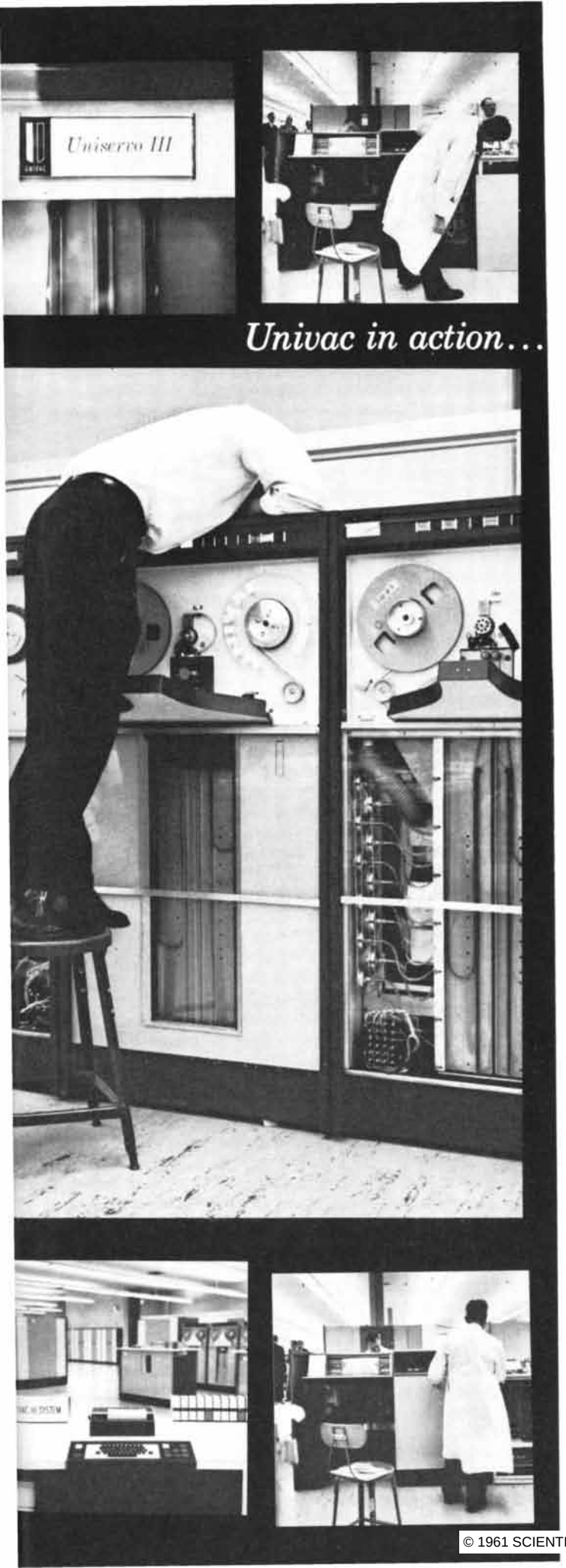
AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS







Countdown on Univac III—the world's most powerful large-scale business computer

This is UNIVAC® III. In November 1961, this new computer completes systems test and goes "on the air" as an operating system—ahead of schedule. *Ahead of schedule* because of automated development techniques* perfected by Univac.

UNIVAC III provides more output at lower unit cost than any other system available today. Renting from $18,000 to $22,000 a month, it delivers more power than computers in the $30,000 to $40,000 class!

Its central processor contains enough main memory storage for a program of up to 32,768 commands. And it takes only 4 microseconds—one million times faster than you can read this sentence—to complete a computer cycle. Add time? 8 microseconds.

Need mass storage for large-scale batch data processing? Up to 32 new Uniservo III tape units can be used to meet your requirements. A new character packing technique permits you to store 48 million digits on a single reel of tape—over a billion and a half digits in all.

Looking for speed? This new Uniservo III tape can be read and written at the rate of 200,000 digits per second. Fully modular, UNIVAC III can handle four of these tapes concurrently—*800,000 digits per second.*

Want easier operation? With UNIVAC III, there's a minimum of operator intervention, a minimum of tape change-over. For example, you can read, write, and compute concurrently with up to 8 different input-output operations. A unique multiple program-interrupt feature assures their compatibility.

UNIVAC III also provides "open-end design." Its 8 general-purpose, bi-directional channels can accommodate any new or improved peripheral equipment, on-line or off. They won't compete with the computer.

You get simplified programming, too. A variety of automatic coding techniques is available to suit your needs.

A continuation in design concept of the incomparable LARC computer, UNIVAC III brings you economy and flexibility, accurate performance and high computing speeds. Because of this advanced logical design, UNIVAC III memory can be made to handle bigger jobs if your future needs require it. You just add the necessary memory module.

Only with UNIVAC III will you find all these advantages combined in a single system. Why not call your Univac representative for full details?

*UNIVAC I was used to design, test and prepare all diagnostic programs as well as for backboard wiring layouts during development of UNIVAC III. Software and hardware were produced simultaneously . . . a major factor in the accelerated schedule of this powerful new computer.

UNIVAC

DIVISION OF SPERRY RAND CORPORATION

LETTERS

Sirs:

I read with interest the article "The Social Life of Baboons," by S. L. Washburn and Irven DeVore, in the June issue of SCIENTIFIC AMERICAN.

I have spent a number of years hunting this fascinating animal in the heavily populated area due north of the Kavirondo Gulf of Lake Victoria in Kenya, where baboons have become a significant problem to the local peasant farmers, taking grain and livestock in ever increasing quantities to meet the needs of their expanding troops. At the same time the human population grows at an alarming pace and the extent of arable land decreases annually because it is overworked and poorly maintained. The two species find themselves in direct competition.

As an antisocial counterpoint to the theme of this fine article I recall one enormous old male I hunted for months and never did get. He no longer lived with the troop but batched it alone and did very well for himself. In the game of hunting and being hunted he was far superior to any animal, including man, I have ever encountered. As I depleted a number of the troops by fair percentages, he is not being idly praised. There were also a number of leopards in this area, and they are particularly fond of baboon. This is one animal that the baboon cannot escape by tree-climbing.

I did not observe the following point to verify it. However, the locals told me that this particular chap, when corn came into season, would bind a rope or vine about his middle and as he raided a field or storage bin would insert corn under the belt and make a far larger haul than he could with his two hands—particularly as he would usually have to leave in a rather big hurry.

I did see him on one occasion ambush two women on their way to market with baskets of grain on their heads. He confronted them in the path making terrifying noises and gestures at them. This immediately had what appeared to be the desired effect on the two women; they panicked and fled, leaving their produce scattered along the path. The old gent ate well that day.

CHARLES P. SKODA

Headquarters
First Cavalry
New York, N.Y.

Sirs:

I read with great interest your article on the calculus of finite differences ["Mathematical Games," SCIENTIFIC AMERICAN, August]. It occurs to me that one of the most interesting applications of Newton's formula is one I discovered for myself long before I had reached the calculus. This is simply applying the method of finite differences to series of powers. In experimenting with figures, I noticed that if you wrote a series of squares such as 4, 9, 16, 25, 36, 49 and subtracted them from each other as you went along, you got a series that you could similarly subtract once again and come up with a finite difference.

So then I tried cubes and fourth powers and evolved a formula to the effect that if n is the power, you must subtract n times, and your constant difference will be factorial n. I asked my father about this (he was for many years director of the Strawbridge Memorial Observatory at Haverford College and teacher of mathematics). In good Quaker language he said: "Why, John, thee has discovered the calculus of finite differences."

JOHN F. GUMMERE

Headmaster
William Penn Charter
School
Philadelphia, Pa.

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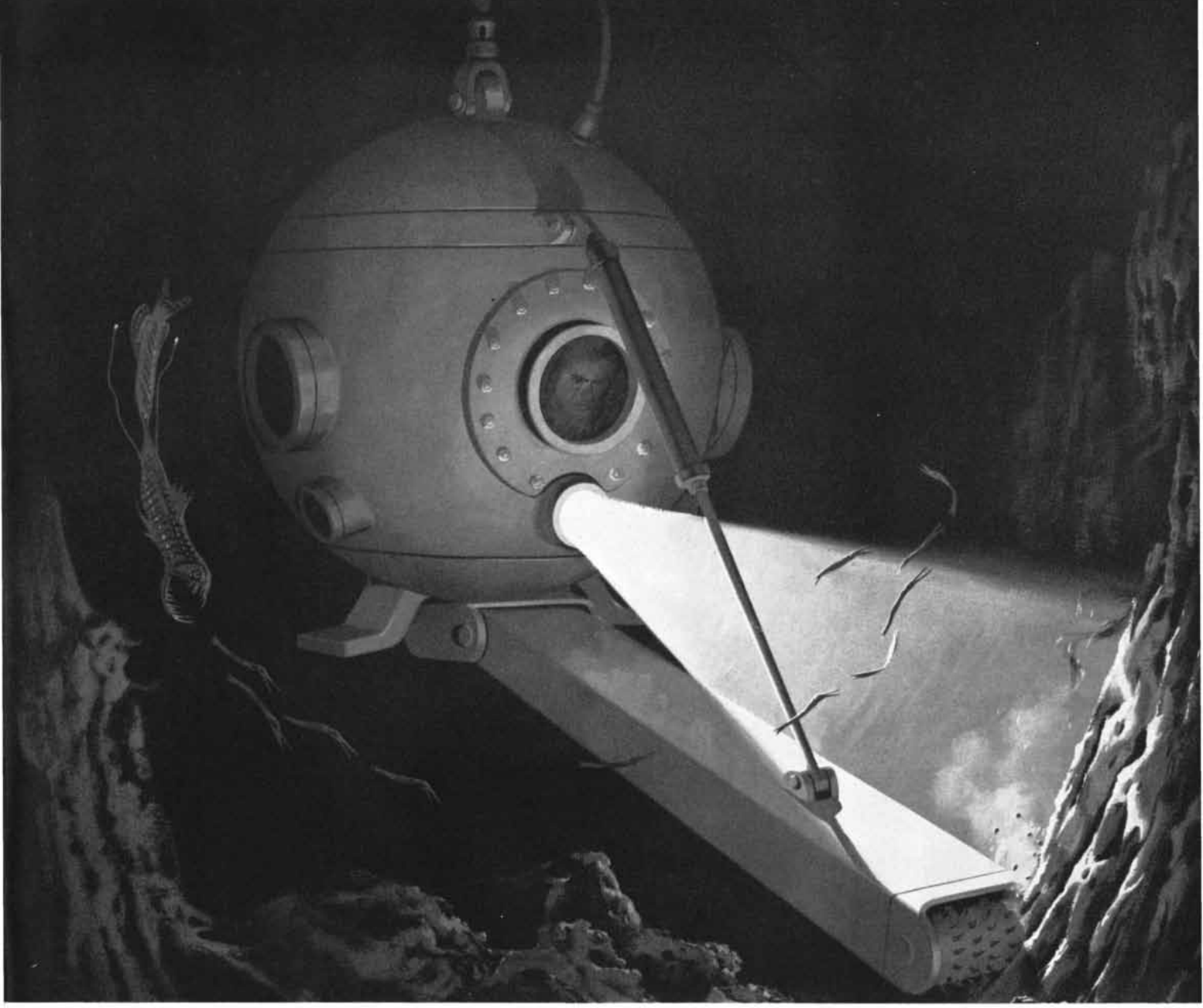

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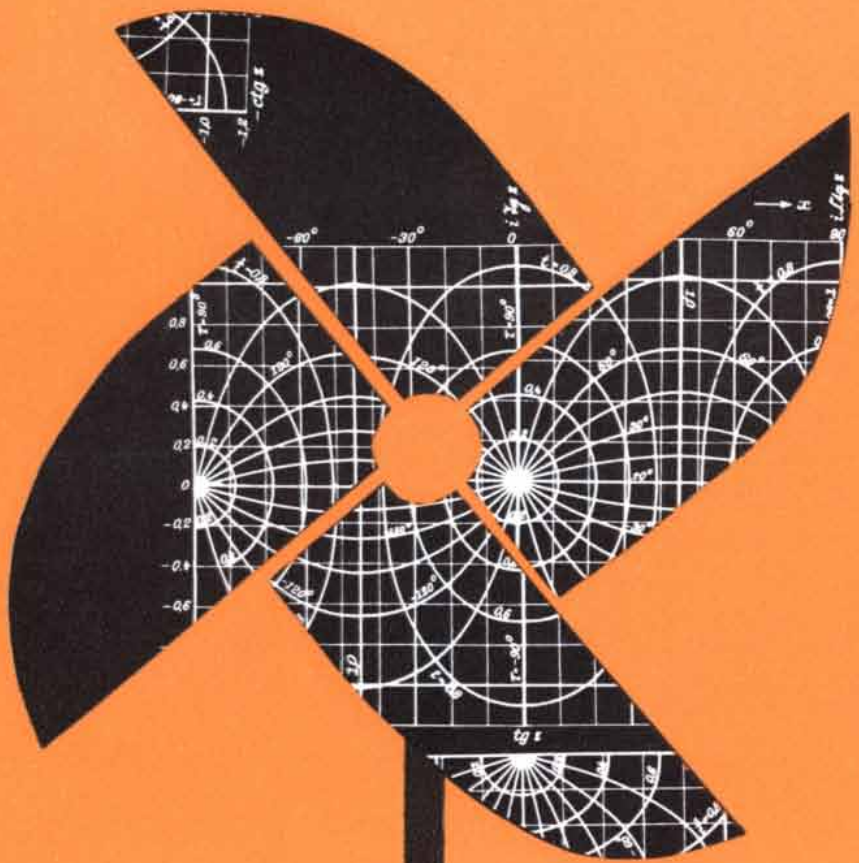

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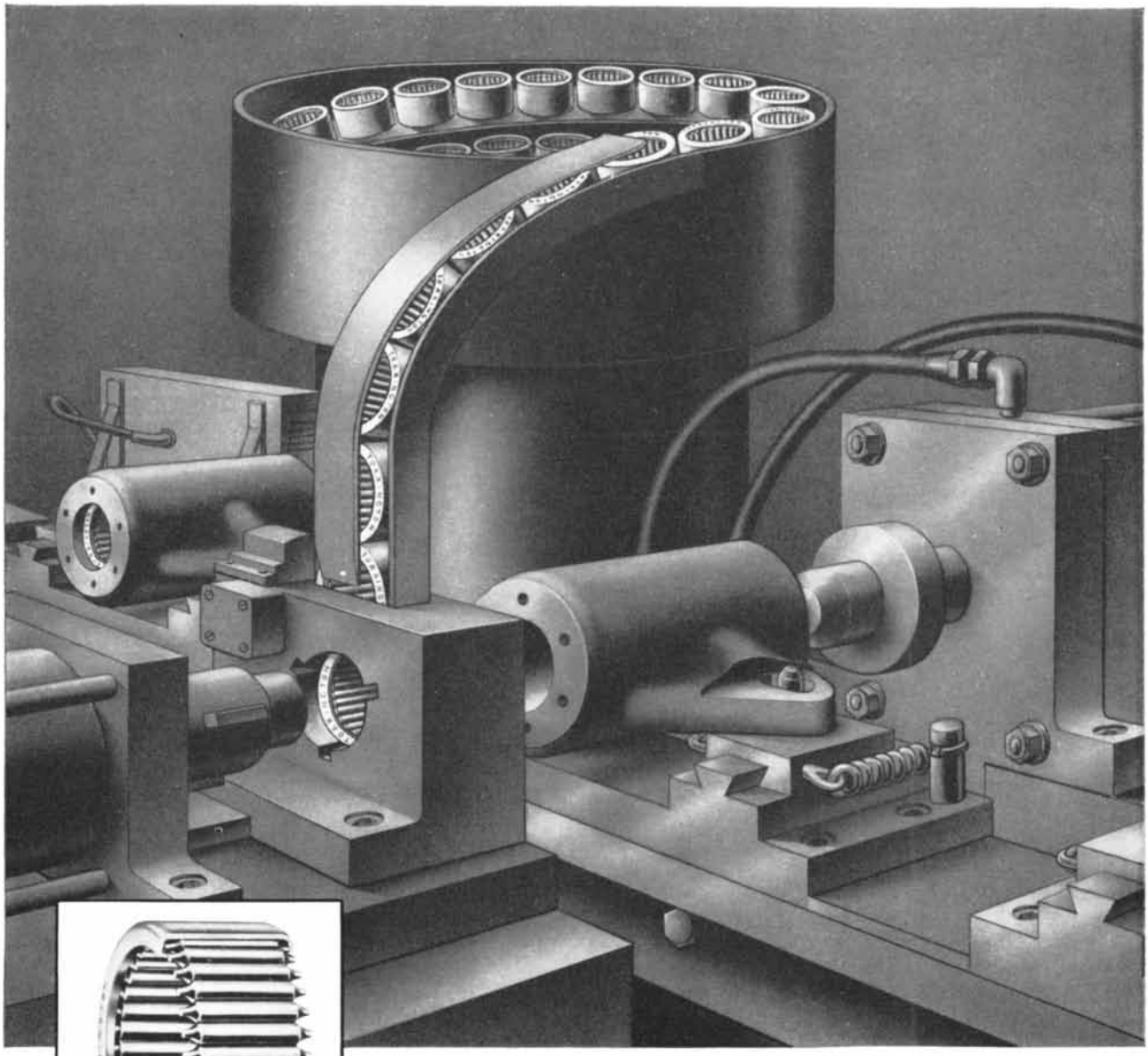

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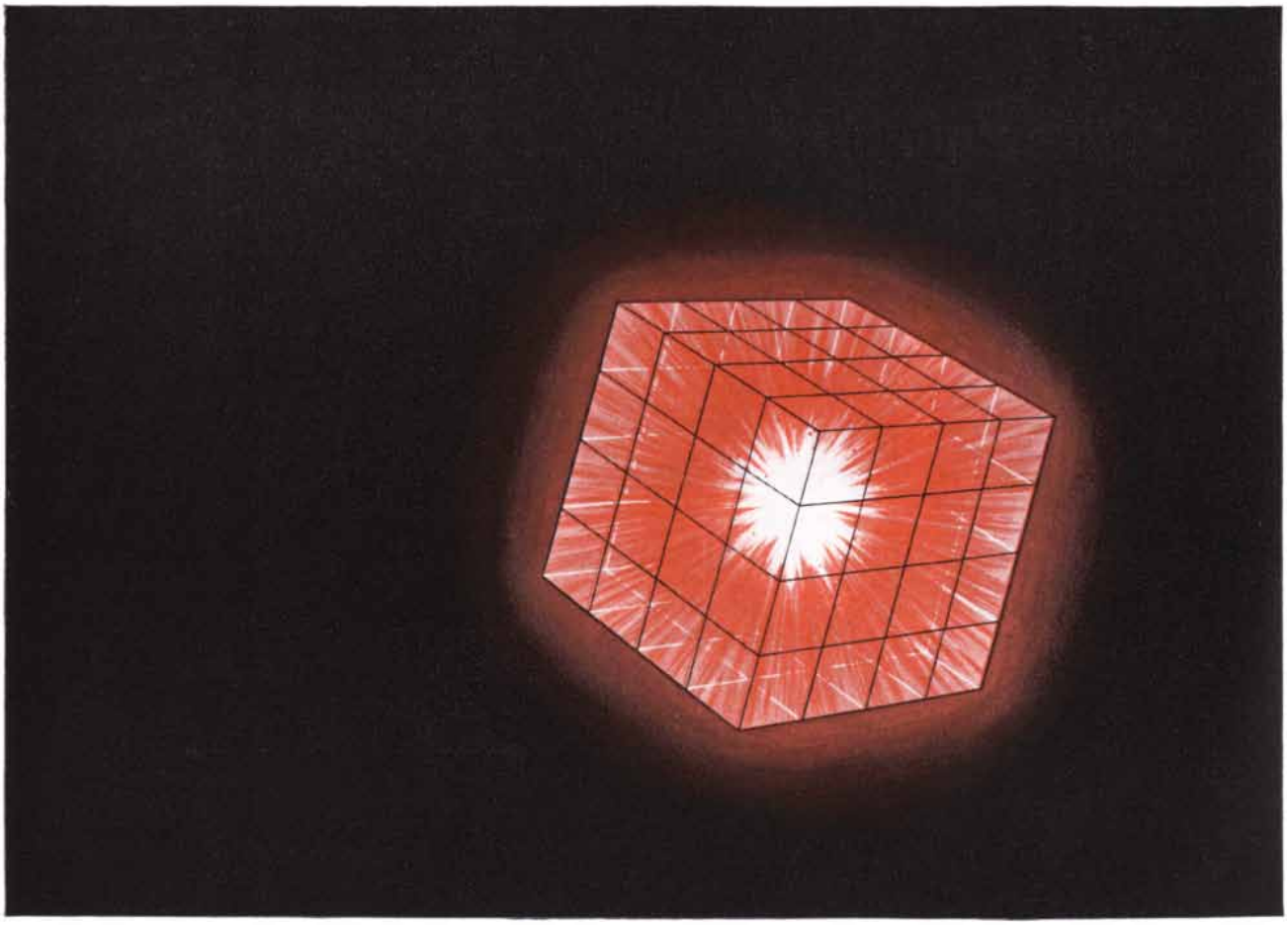

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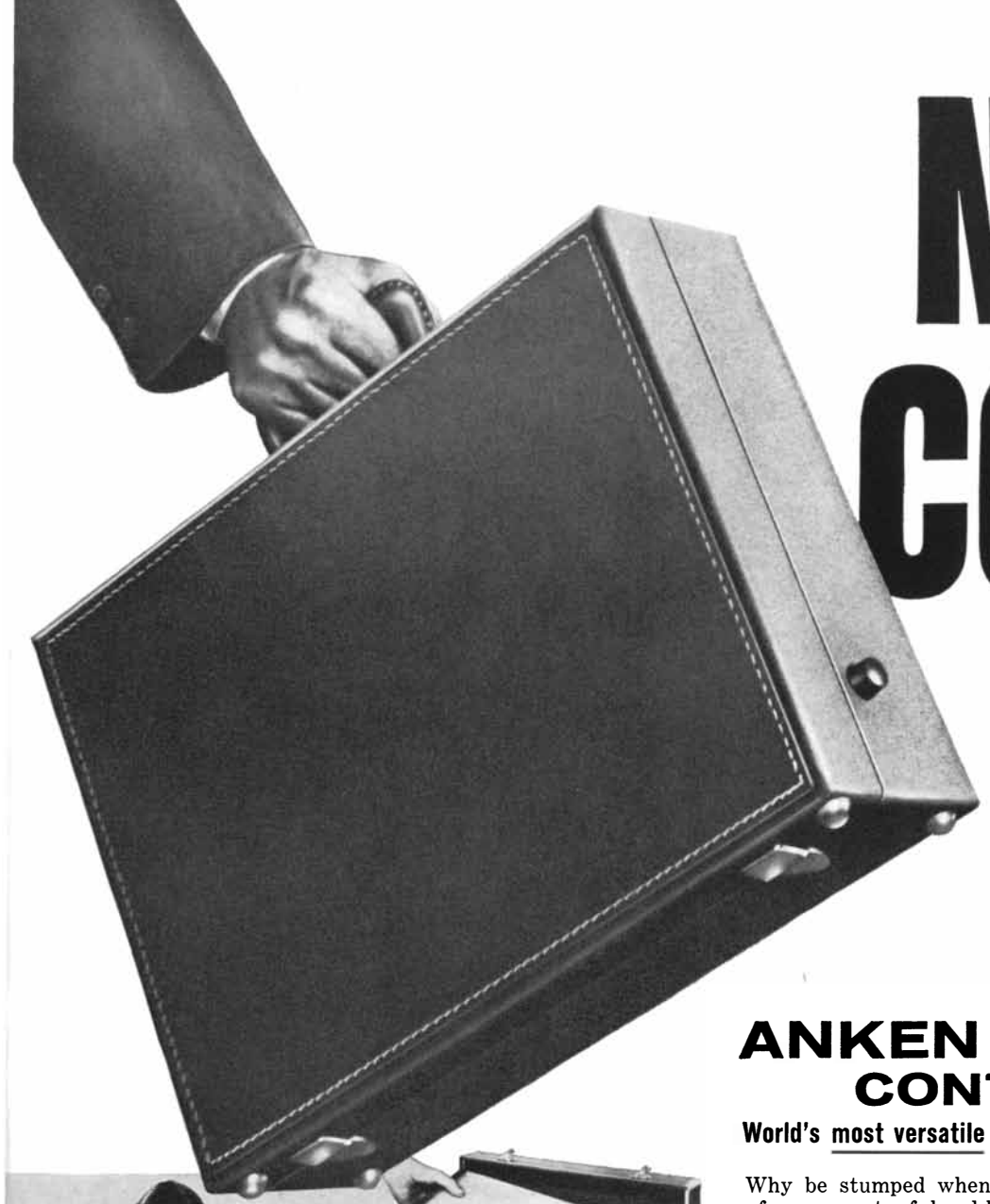

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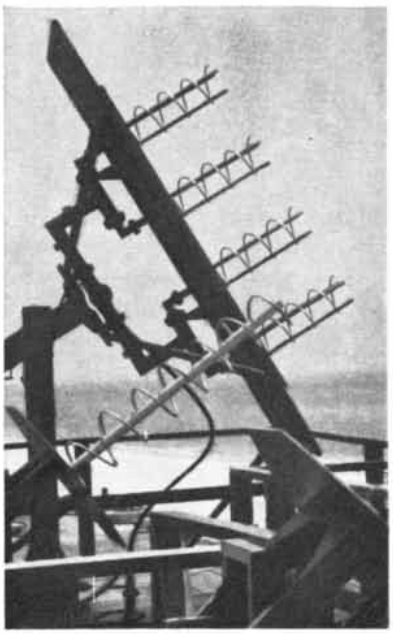

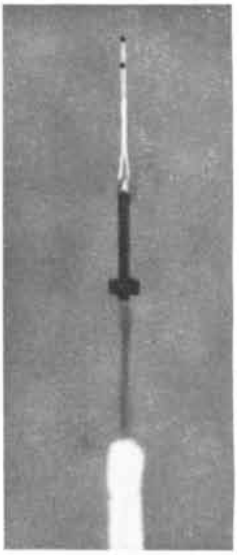

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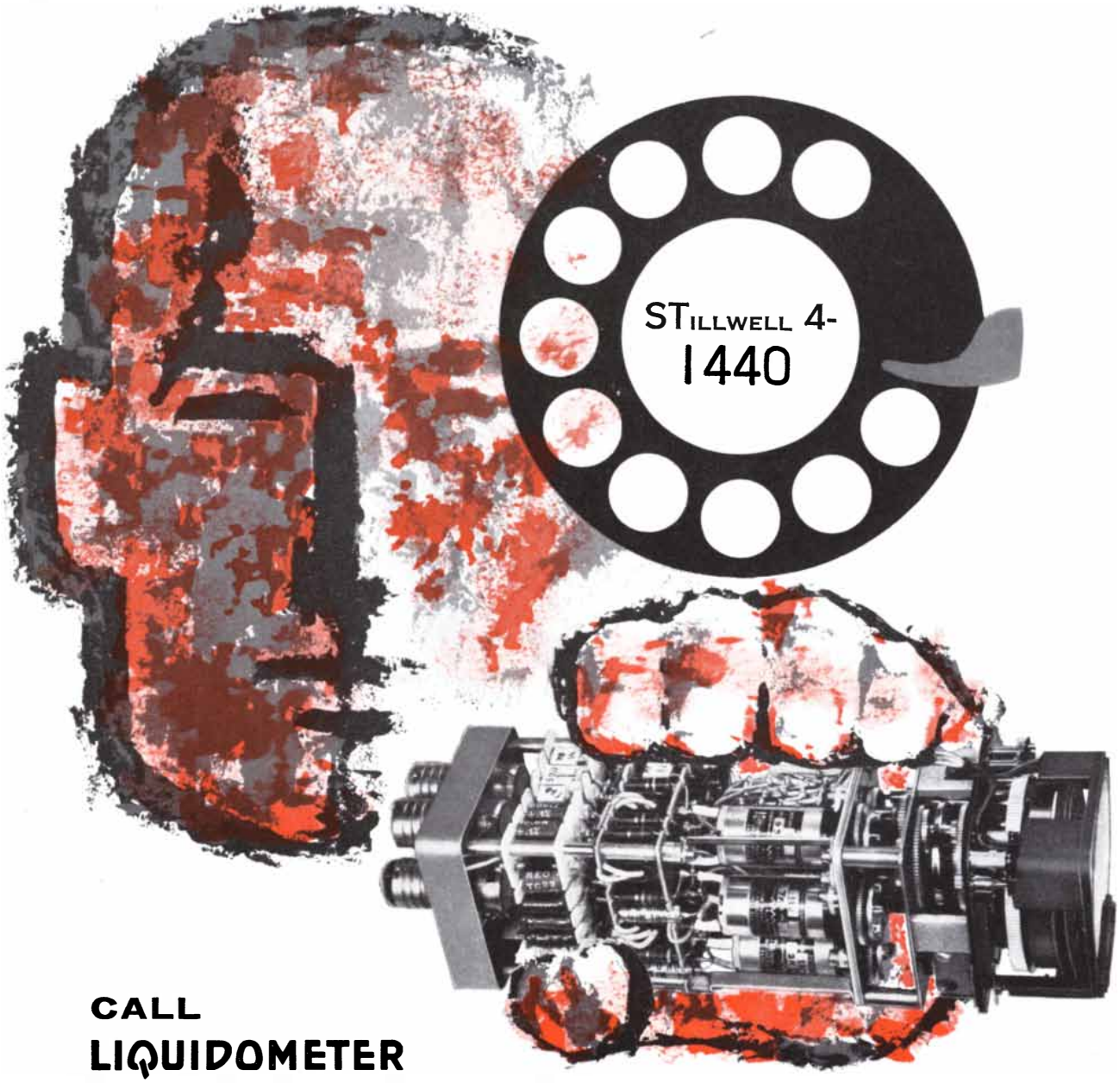

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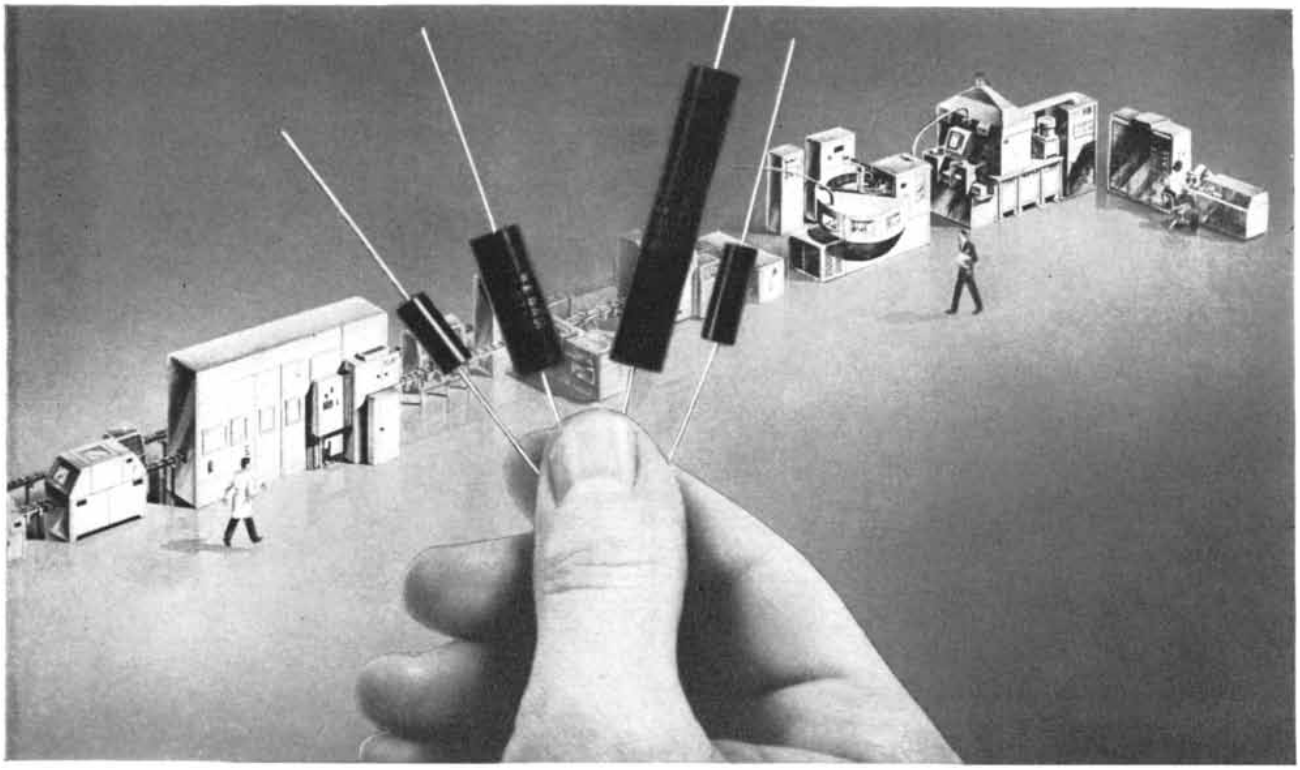

W. E. engineers build computer-controlled line to make precision resistors of high reliability

An outstanding advance in automated manufacture has been achieved by Western Electric engineers . . . a completely computer-controlled production line for making deposited carbon resistors.

The heart of the process is a digital computer that combines, for the first time, statistical quality control with programmed production control.

Western Electric developed the automated line to meet the accelerating demand for deposited carbon resistors in larger numbers and with greatly increased reliability. Our engineers met this challenge with a line that turns out resistors with a failure rate of one per 200 million component hours of usage.

Using the methods of quality control, the computer —a digital model with a 4096-word magnetic drum memory — analyzes data plotted at three critical points in the automated process and applies statistical tests to determine if a trend is developing. The engineers redesigned the computer by adding the input and output circuits required to control the programming, setup and feedback control of individual machines. The computer schedules and programs the work — up to a month's requirements at a time — and arranges it according to four resistor power sizes and an almost infinite number of possible resistance values.

The computer uses statistical quality control to analyze control data, to apply statistical tests to determine if a trend is developing, and to detect and correct any drift away from accepted manufacturing tolerances.

This unusual application of statistical quality control in combination with the rigid inspection procedures makes it almost impossible for an unacceptable resistor to complete its run through the eight fabricating machines and three test points on the line.

In addition to controlling the eleven stations of the line, the computer also estimates the percentage of rejects to be expected in a given run and compensates for them by automatically programming the extra number of resistors to meet production quotas.

This sophisticated use of a computer to control a manufacturing process is another example of how Western Electric engineers are constantly working to make better products faster and with greater accuracy for Bell System communications and defense systems.

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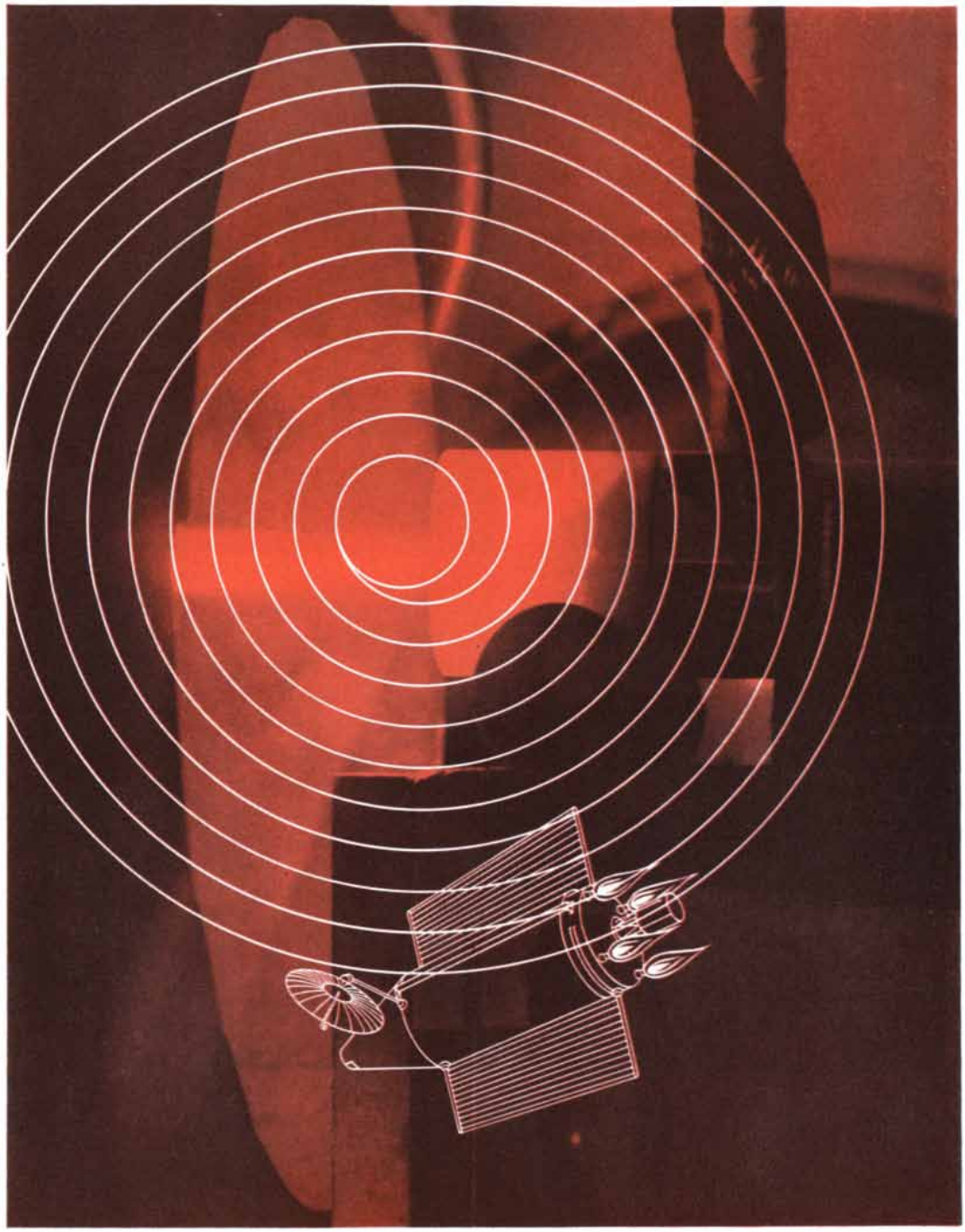

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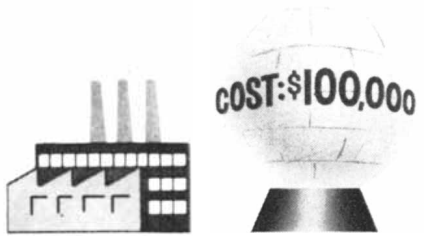

How to get around a natural law to store gases safely

$PV = P'V'$ (temperature constant) expresses the law defining the action of compression. Stored as a gas, 25,000,000 cubic feet of oxygen under 6 atmospheres compression (above left), has the explosive equivalent of 15,000 pounds of TNT.

However, if the temperature of a gas is lowered to a specific point, the gas changes phase and becomes a liquid. As a liquid, the energy of compression is eliminated, and liquid gases can be stored in much smaller vessels . . . safely.

Instead of tying up over a million dollars in storage costs, 25,000,000 cubic feet of oxygen stored as a liquid (above right), now requires a vessel costing only $100,000.

But, many conventional metals—if subjected to cryogenic temperatures—embrittle and even shatter. Disastrous failures of engineering structures have been attributed to this cause.

But now alloys are available that stand up to very low temperatures. These alloys have helped bring about fuel tanks for missiles that can be airlifted all over the world...the use of one ship instead of forty to ship natural gas...the storage of an entire hospital's oxygen supply in a six-foot tank.

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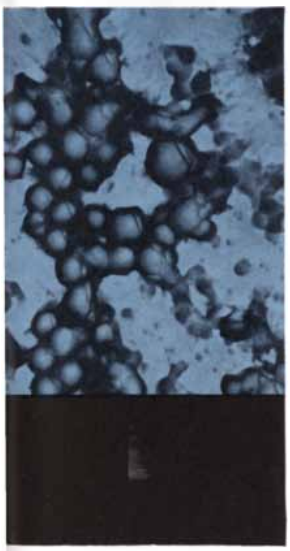
Formulated by Glidden especially for unitized construction, these special single-coat water-reducible coatings cover all nooks and crannies, eliminate "solvent wash-off," avoid unprimed pockets that can rust and weaken load-bearing panels.

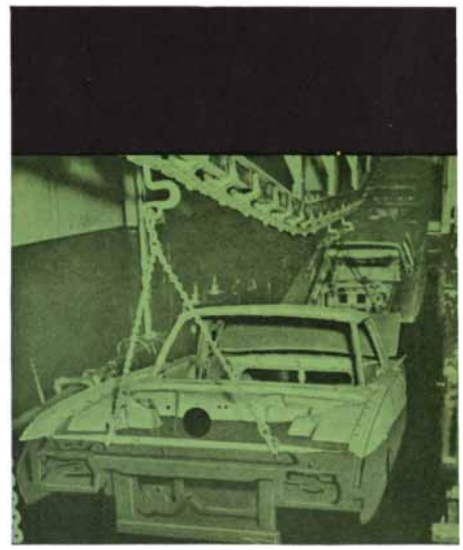
Glidden chemists took new-type water-reducible resins, combined them with pigments, dispersants and emulsifiers, added Glidden experience in finishing application methods... created a new, better, safer priming system for the automobile manufacturer... and helped him give car buyers more for their dollar.



1 Particle size of high solids latex resin emulsion in the Glidden water-reducible primer is kept below 0.3 micron. This assures maximum dispersion of weather-protective resins, producing low-viscosity primers suitable for dipping, flow-coating, and spraying.

2 To make sure that Glidden-developed water-reducible primers would withstand corrosive road chemicals, test panels were exposed for 500 hours to severe 5% solutions in the Glidden lab salt-spray cabinets.

3 To satisfy exacting coating standards, Glidden produces its own resins in latest-type universal reactors. Here, technician checks sample of resin for water-reducible primer... one of more than 100 tests made between initial production and final tank-wagon shipment.



4 Glidden field technicians assist the automobile finishing-line people in adjusting speed of dip-tank travel, and bake-oven temperature to produce ideal preprimer and primer coats.

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SCIENTIFIC AMERICAN

OCTOBER, 1911: "One of the prominent automobiles for 1912 will be equipped with a generator and storage battery normally used for lighting the lamps and igniting the engine, but with the generator so arranged that it may also be used as a motor to 'turn over' the engine, thus obviating the necessity of cranking by hand. When the operator pushes the clutch pedal, a gear wheel on the electric motor will engage with teeth on the flywheel, and the motor will be operated by current from the storage battery, to turn the flywheel and start the engine. When the engine starts, the motor becomes a dynamo and generates current to be used for charging the storage battery and for ignition purposes."

"The total number of ships of the all-big-gun type now built, building or provided for in the current year is exactly 100. Great Britain leads with 32 (which includes two cruisers building at the cost of Australia and New Zealand), followed by Germany with 21 and the United States with 12. Japan, having this year placed orders for no fewer than five ships of the type (one building in England and four to be laid down in Japan), has increased her total to seven. Russia, France, Italy and Austria have four ships apiece, none being yet completed, and the first-named power proposes as soon as possible to raise her total to 12. Brazil and Spain each possess three 'Dreadnoughts,' only two of the Brazilian being finished; and the list is completed by the Argentine Republic, with two ships on the stocks; Turkey with two ordered in England; and Chile with two that are shortly to be placed out to contract."

"The character of the bids that are being asked for work on the Panama Canal indicates how nearly this great work is approaching its final stage. Proposals have been asked for materials for the heavy chain fenders for preventing ships from running into the lock gates with which all the locks will be provided. Ships will not be allowed to navigate the locks under their own steam; but should they escape from the control of the towing locomotives they will be prevented from running into the gates by massive chains stretched across the lock and controlled by powerful hydraulic cylinders, which will exert a resistance represented by 750 pounds to the square inch on the pistons. A 10,000-ton ship running at four knots an hour, striking the fender chain, would be stopped in a distance of 72 feet 6 inches."

Scientific American.

OCTOBER, 1861: "The steamship *Great Eastern*, with a large number of passengers, left Liverpool for New York on Tuesday, Sept. 10, and continued on her course for two days, when she encountered a terrific gale, and the beating of the waves against the broad rudder soon broke her rudder post, when she fell off into the trough of the sea and rolled frightfully, tossing her passengers from side to side and breaking the limbs of a considerable number. It is a fact worthy to be widely circulated that the ship was saved by the timely skill and ingenuity of an American engineer—Hamilton E. Towle of Boston. It will be recollected that in consequence of the breaking of the rudder shaft the ship became wholly unmanageable and was thus left to the mercy of the restless sea. While the *Great Eastern* was lying disabled in the trough of the sea, the angle through which she rolled was carefully measured by Mr. Towle, till it reached 35° each way, making an oscillation through 70°. It was five o'clock in the evening of Saturday when Mr. Towle commenced his operations, the awful scenes aboard the wallowing ship having continued for more than two days and nights. Mr. Towle devised an ingenious arrangement, which was adopted by the officers in command, and the vessel was soon put on her way back to the port of Cork, Ireland, where she arrived off Queenstown on Tuesday afternoon, the 17th of September, at four o'clock."

"Count Rumford was an American savant but a Tory. He left $5,000 in trust for the encouragement of scientific discovery in his native country. The interest of this sum was to be applied every second year as a premium for the most useful and important discovery in light and heat. This premium was to be bestowed in a gold and silver medal, called the 'Rumford Medal,' and the

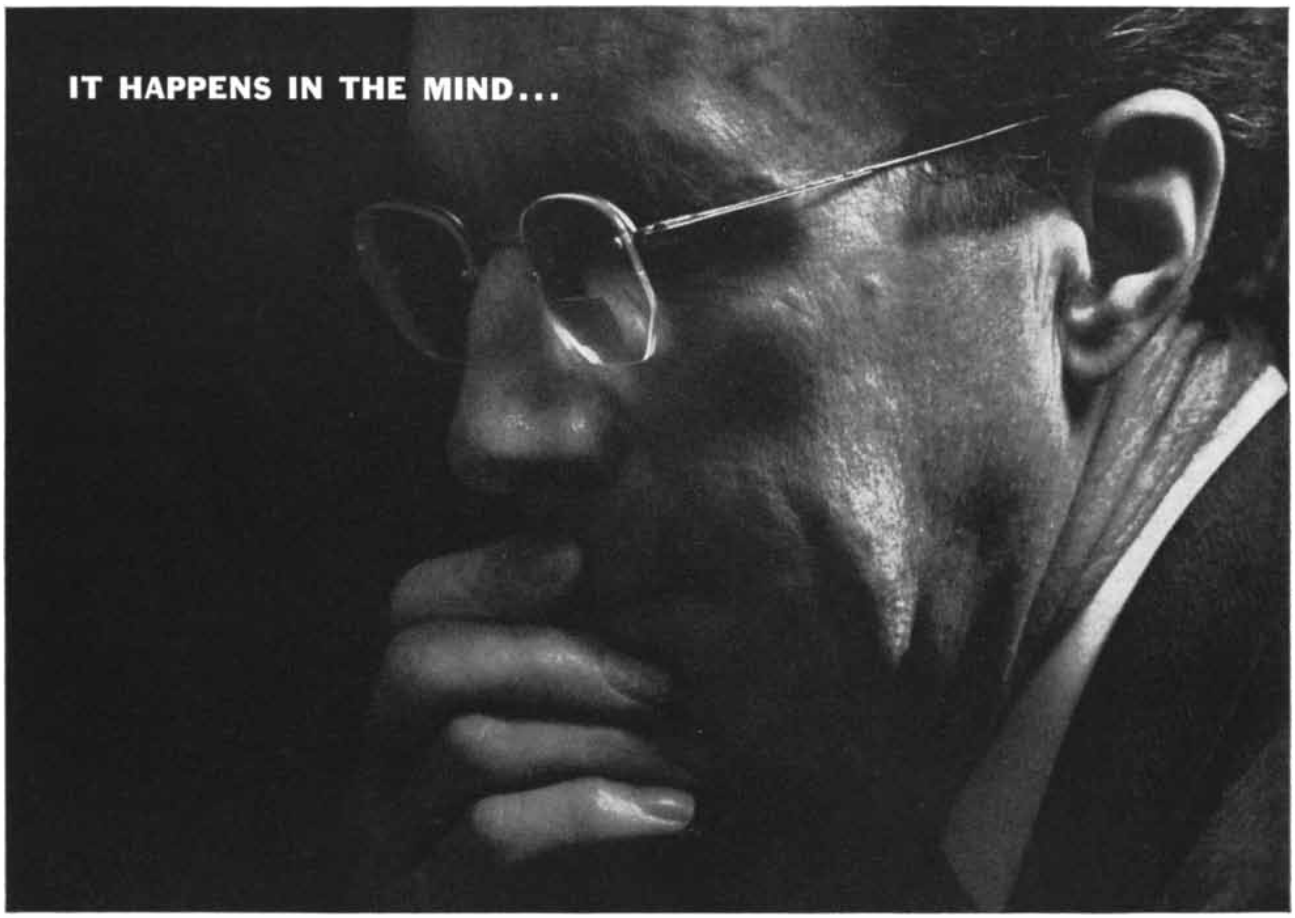
American Academy of Arts and Sciences was appointed trustee of the Count's will in 1796. We do not know what has been done with the interest of the donation. At 7 per cent per annum the sum, at simple interest, should now amount to $45,500."

"For several years a Pneumatic Dispatch Company has been in operation in London, pipes of a few inches in diameter being laid through which small parcels were sent to various parts of the city. The company, finding the system to work well, have decided to enlarge the tubes to a hight of two feet nine inches and to a width of two feet six inches, and ultimately extend their system throughout the whole metropolis. Trucks six or seven feet long are sent through these tubes with loads of one or two tuns. But the most interesting incident is that *two gentlemen have already ridden through the tube on one of the trucks,* thus perhaps inaugurating a new system of passenger traffic."

"Since the charges, so extensively circulated against a portion of our Army clothing contractors, of making the soldiers' uniform of shoddy, the word has become a synonym for everything that is false. The article has an actual existence, and several persons are engaged in its manufacture. There are now no less than six shoddy mills in full operation in this State. It is said that they are doing a large and handsomely paying business. Woollen rags are $5 and $10 per tun for making shoddy cloth. Fine black scraps are worth $100 to $150 per tun. The shoddy manufacturer passes them through a rag machine, which tears the rag to wool and cleans it of dust. When reduced to soft wool, the shoddy is saturated with oil or milk and mixed with new wool in as large proportion as possible. Shoddy in the cloth of a coat will soon rub out of the cloth and accumulate between it and the lining."

"Amid our national troubles the public seem to have forgotten the expedition of Dr. Hays and his companions to the Arctic regions in search of more definite information regarding the open polar sea of Dr. Kane. Since the fall of 1860, when the explorers were at Uppernavic, nothing has been heard of them. In the dismal regions of perpetual snow these heroic Americans are struggling to extend geographical science amid the icebergs of the north, altogether unconscious of the more painful struggles between man and man now taking place in their native land."

At Bell Telephone Laboratories, mathematician Sidney Darlington has contributed notably in developing the art of circuit analysis.



. . . It is essentially a thing of the mind for it works through concepts, symbols and relationships . . . it helps man to analyze and synthesize the complex phenomena of the universe and himself . . . it works in many ways to advance electrical communications:

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At Bell Telephone Laboratories mathematics works powerfully to solve problems involving complex data. For example, engineers must design and synthesize complex systems to process specific signals in precisely controlled ways. At the same time the technology provides a wide choice of circuits and components. Mathematical circuit analysis reveals the circuits which can do the job most efficiently and economically.

Intriguingly, too, the mathematical approach leads to basically new knowledge. For example, it led to the invention of the electric wave filter . . . disclosed a kind of wave transmission which may some day carry huge amounts of information in waveguide systems . . . foretold the feasibility of modern quality control . . . led to a scientific technique for determining how many circuits must be provided for good service without having costly equipment lie idle.

In the continuing creation of new devices, technologies and systems, Bell Laboratories utilizes whatever serves best—mathematical analysis, laboratory experimentation, simulation with electronic computers. Together they assure the economical advancement of all Bell System communications services.

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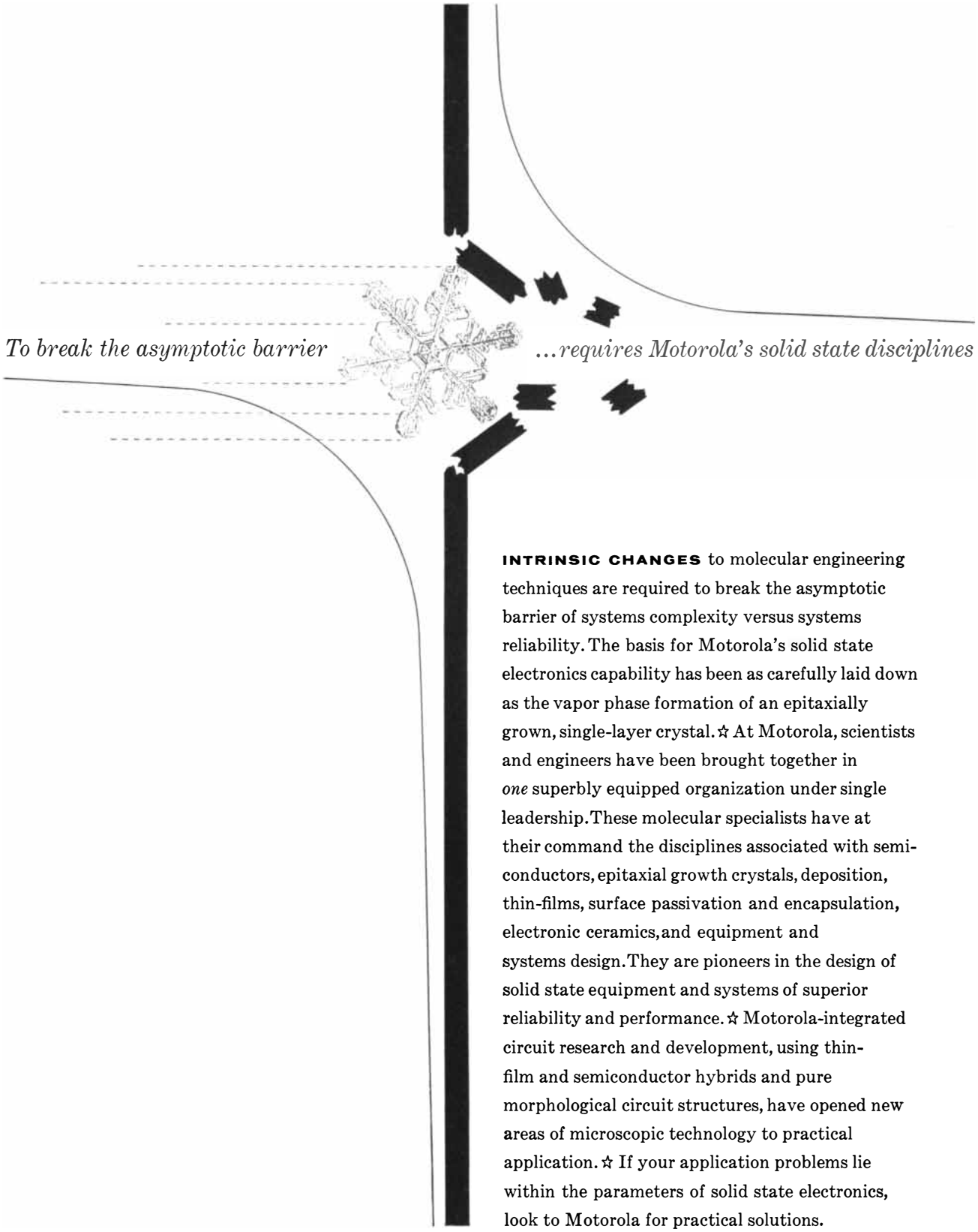

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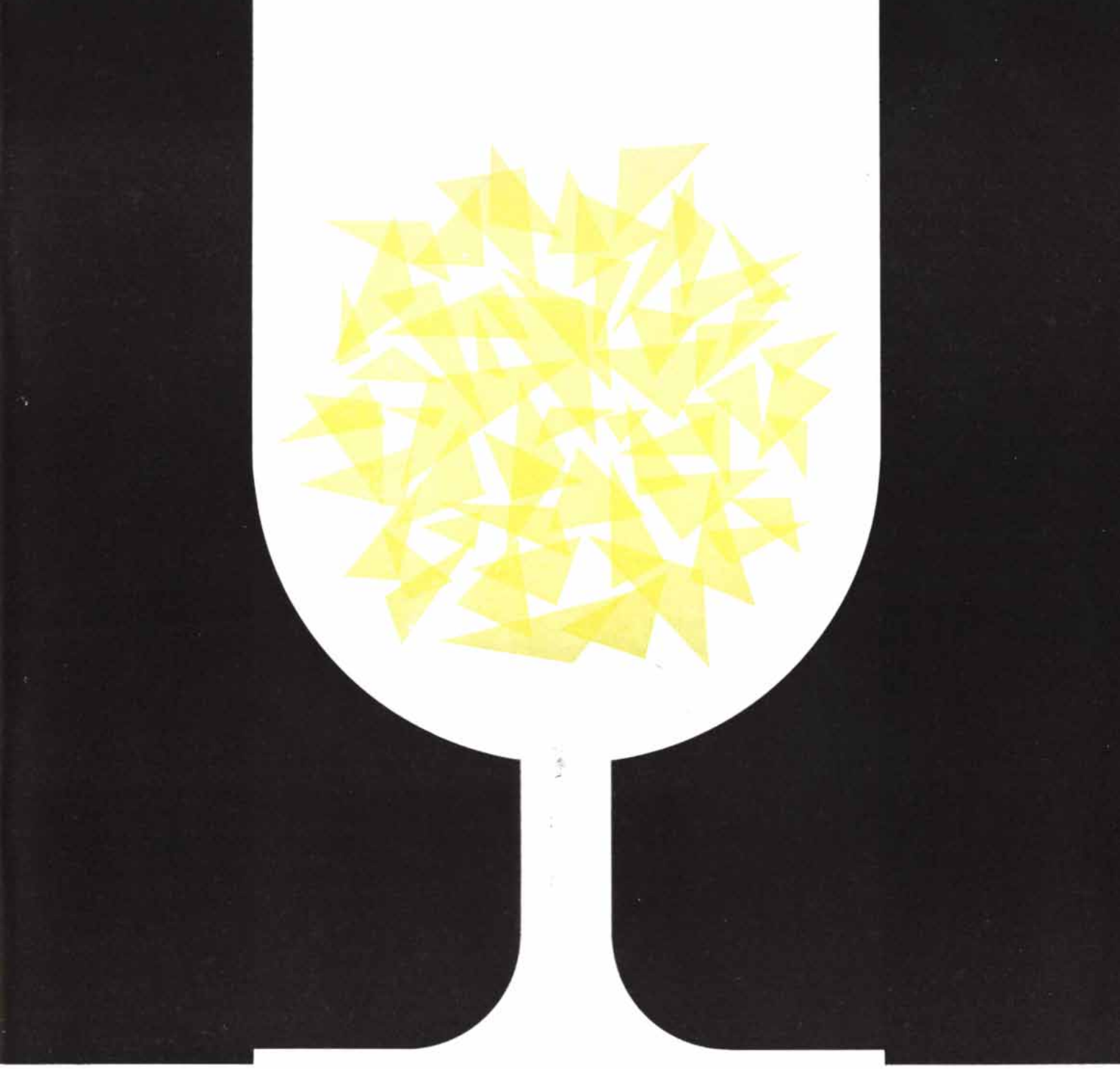

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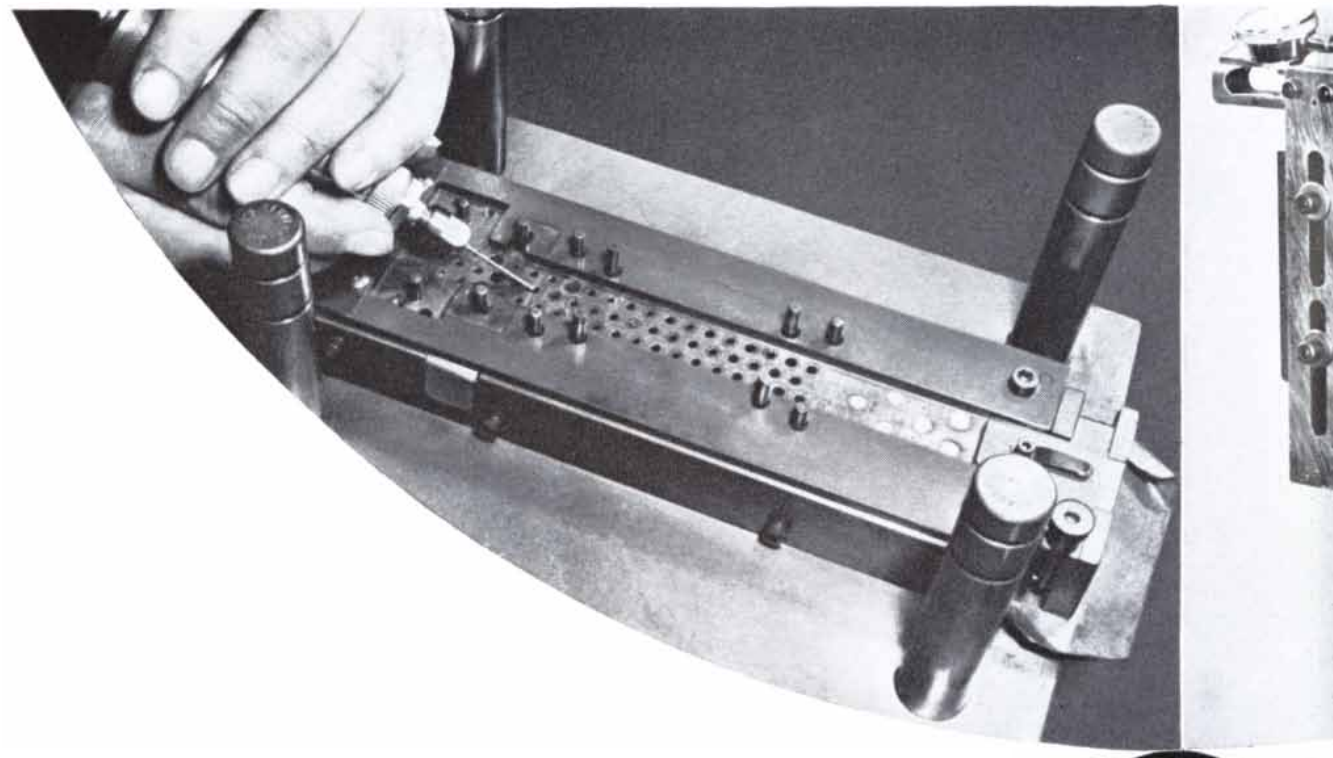
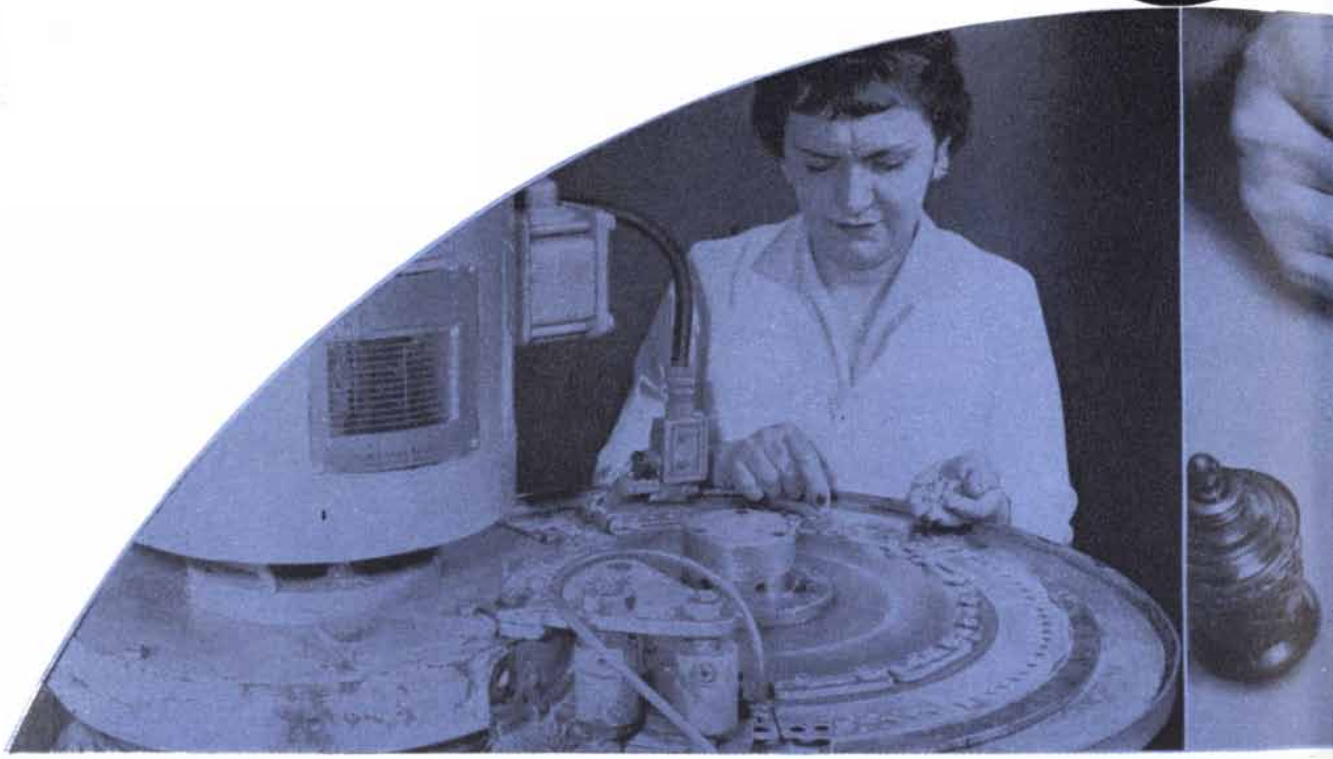


Grinding Ceramic Wafers *(below) for nuvistor tubes. Two diamond wheels finish 2000 wafers per hour for Electron Tube Division of RCA. Wheels remove 0.003" stock from each surface simultaneously. Previous method using abrasive belts ground only one surface at a time, resulting in nonuniform results and stoppages. Expected life of wheels: 5,000,000 wafers.*

Servicing High-Speed Carbide Dies *(above). Jacoby Bender Inc. makes expansion watch bands. Their dies are for precious and semiprecious metals, as well as stainless steel. Finished products must have flawless finish. Small diamond quills from size .020" to ¼" diameter are used to build and service carbide dies. Grinders also cut decorative relief in some dies.*



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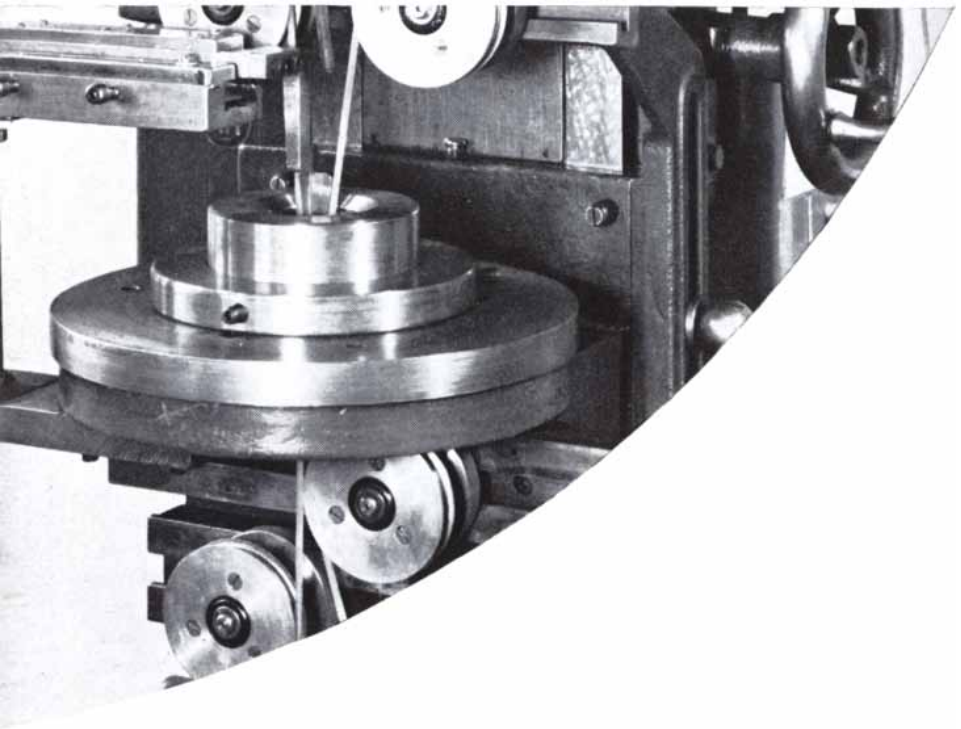
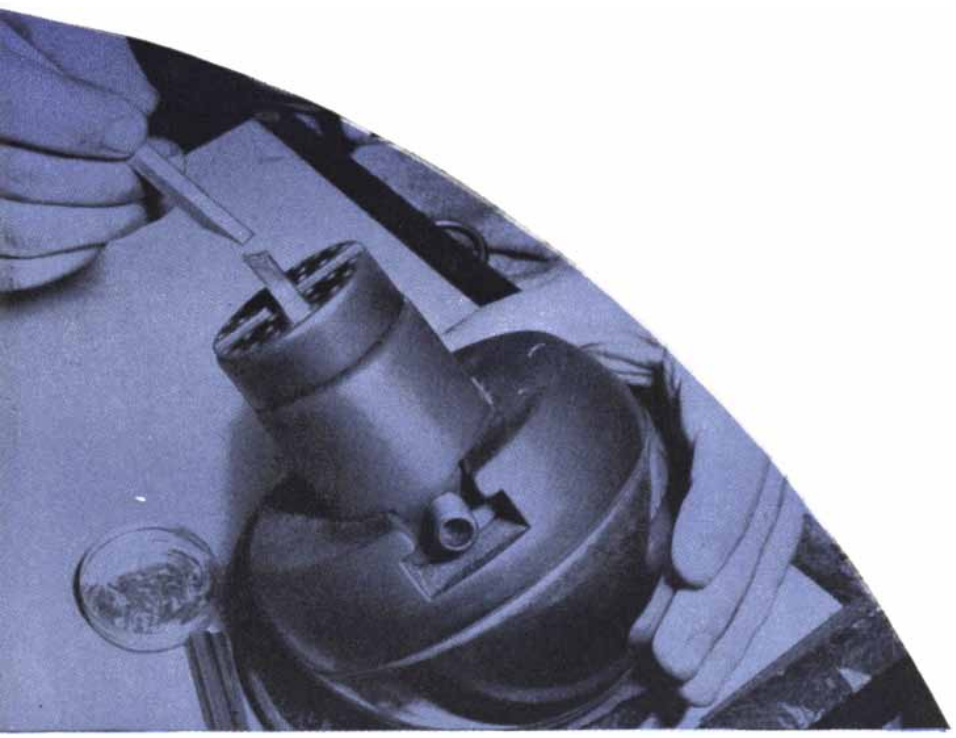


Polishing Drawing Dies *(above) for Chase Brass & Copper. Die-polishing job that once required 2 to 6 hours' handwork is now finished in 15 minutes with diamond belt polisher. Accuracies and surface finishes are also greatly improved. Belts are impregnated with 100, 200 or 300 mesh natural diamond grit. Up to 200 dies have been serviced by a single belt.*

Putting Mirror Finish *(below) on hardened steel part for a forming die at Jacoby Bender. The natural diamond micron powder is applied with a wooden lap. The diamond paste speeds up the polishing operation, and has less tendency to distort the true form of the tool-steel than methods previously used.*



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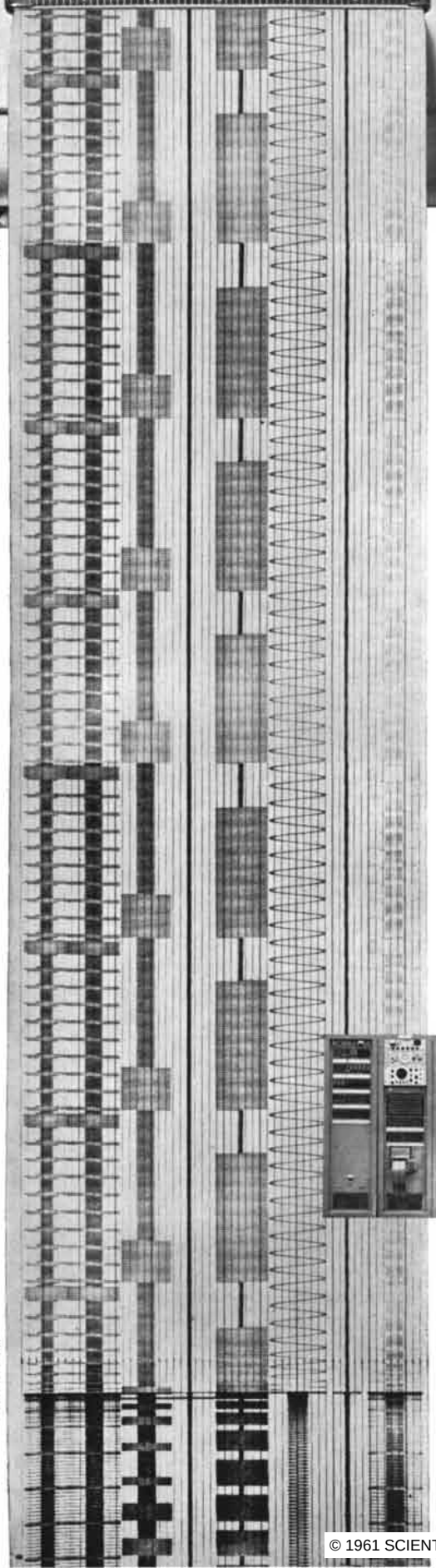
THE AUTHORS

WALSH McDERMOTT ("Air Pollution and Public Health") is Livingston Farrand Professor of Public Health and Preventive Medicine at the Cornell University Medical College. He received a B.A. from Princeton University in 1930 and an M.D. degree from Columbia University in 1934. Tuberculosis interrupted his residency at New York Hospital for a year, and he found that almost the only position available to him at the time was in a newly created syphilis clinic at Cornell. His subsequent work with microbial diseases and the various antimicrobial drugs introduced to combat them gradually led McDermott into the field of public health. For the past 16 years McDermott has been editor of *The American Review of Respiratory Diseases;* for approximately the same length of time he has served as an associate editor of the Cecil-Loeb *Textbook of Medicine*, and more recently, with Paul B. Beeson, as coeditor. For the past year he has also been chairman of the President's Science Advisory Committee Panel on Development Assistance.

ROY A. KELLER ("Gas Chromatography") is assistant professor of chemistry at the University of Arizona. Born in Davenport, Iowa, in 1928, he received a B.Sc. from Arizona in 1950 and an M.S. in chemistry in 1952. Keller then went to the University of Utah, where he studied under the direction of Henry Eyring. It was Eyring who first suggested that Keller do research in chromatography. Keller obtained his Ph.D. from Utah in 1956 and joined the faculty of Arizona later that year.

LAWRENCE W. SWAN ("The Ecology of the High Himalayas") is associate professor of biology at San Francisco State College. He was born in 1922 in Darjeeling, India, where he attended Mount Hermon School until 1937. Swan came to the U.S. the following year to study at the University of Wisconsin, acquiring a Ph.B. in zoology there in 1942. From 1942 to 1946 he served in the Army as a research officer at the Climatic Research Laboratory in Lawrence, Mass. He took two degrees in biology at Stanford University, an M.A. in 1947 and a Ph.D. in 1952. After a year as an instructor at the University of Santa Clara, he joined the faculty of San Francisco State College in 1954. An honorary research associate of the

Visicorder and record shown approx. ½ actual size.



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California Academy of Sciences, Swan has participated in several expeditions to study ecology at high altitudes. In 1946 and 1949 he visited volcanoes in Mexico; in 1954 he accompanied the American Himalayan Expedition to Makalu, a peak of 27,790 feet in eastern Nepal; and last year he accompanied the Himalayan Scientific and Mountaineering Expedition led by Sir Edmund Hillary.

JOHN R. PIERCE ("Communication Satellites") is executive director of research in the communications principles division of the Bell Telephone Laboratories. Born in Des Moines, Iowa, in 1910, Pierce took three degrees at the California Institute of Technology, receiving a Ph.D. in electrical engineering in 1936. Since joining Bell Laboratories in 1936 he has done research on microwaves, high-current electron guns, satellite communication and psychophysical phenomena.

W. C. DASH and A. G. TWEET ("Observing Dislocations in Crystals") are both members of the General Physics Research Department of the General Electric Research Laboratory in Schenectady, N.Y. Dash took a B.S. in engineering physics at Lehigh University in 1946 and a Ph.D. in physics at Cornell University in 1952. He then joined the General Electric Research Laboratory, where he began investigating the optical, electrical and structural properties of semiconductors. In the course of his work he developed a technique for the direct observation of dislocations in silicon crystals by infrared microscopy. This technique, which is discussed in the present article, subsequently led to an understanding of the mechanisms that introduce dislocations into growing crystals, and ultimately to a method of growing dislocation-free crystals of germanium and silicon. Tweet did undergraduate work in physics at Harvard University, receiving his B.A. in 1948, and graduate work at the University of Wisconsin, where he obtained his Ph.D. in 1953. He immediately joined the General Electric Research Laboratory to work on semiconductors and has devoted most of his effort to studying the effects of crystalline imperfections on the electrical properties of semiconductors. This fall he is also teaching a graduate course on semiconductors at Rensselaer Polytechnic Institute.

F. CLARK HOWELL ("Isimila: A Paleolithic Site in Africa") is associate professor of paleoanthropology at the

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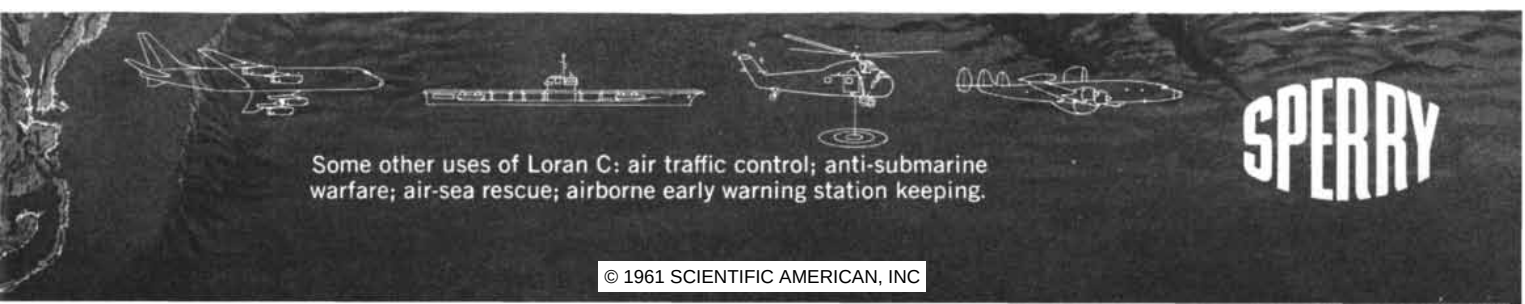

University of Chicago. Born in 1925, he was graduated from high school during World War II and served with the Navy in the Pacific. At the end of the war Howell went to Chicago, where he took three degrees, receiving his Ph.D. in 1953. From 1953 to 1955 he taught human anatomy at the Washington University School of Medicine. Howell's interest in primate evolution, especially in human evolution, has led him to do research and field work in Africa, Europe and Israel. He is at present preparing for excavations at Torralba in Spain, and next year he plans a trip to northwest India in search of the remains of Pliocene and early Pleistocene apes and pre-men.

MARK R. ROSENZWEIG ("Auditory Localization") is professor of psychology at the University of California. He received B.A. and M.A. degrees from the University of Rochester in 1943 and 1944 respectively. He spent the next two years in the Navy before continuing his work in the Psycho-acoustic Laboratory at Harvard University, where he acquired a Ph.D. in 1949. Joining the faculty of California as a physiological psychologist in 1950, Rosenzweig continued the research on the physiological mechanisms of auditory localization he had begun earlier at Harvard. His original interest in auditory perception has since led him to study various problems in speech, communication and the psychology of language. At the present time he is investigating the relationships between learning behavior and brain chemistry, a field of research he first entered in 1953.

ARTHUR D. RAFF ("The Magnetism of the Ocean Floor") is a physical oceanographer at the Scripps Institution of Oceanography. His family moved to a farm near Abilene, Kan., from Caracas, Venezuela, in 1928, when Raff was 11 years old. He received a B.A. from Union College in Lincoln, Neb., in 1940 and from 1941 to 1945 he served in the Army. After joining the Scripps Institution in 1946, Raff concentrated chiefly on two research problems. The first was to find a method of receiving and recording on shipboard seismic-refraction signals from the deep ocean. The technique he developed is now generally used for seismic studies by the research ships of both the U.S. and the U.S.S.R. The second problem was to develop a reliable technique for towing a magnetometer from a ship for many months at a time. Using these methods, Raff gathered most of the magnetic data discussed in his article.

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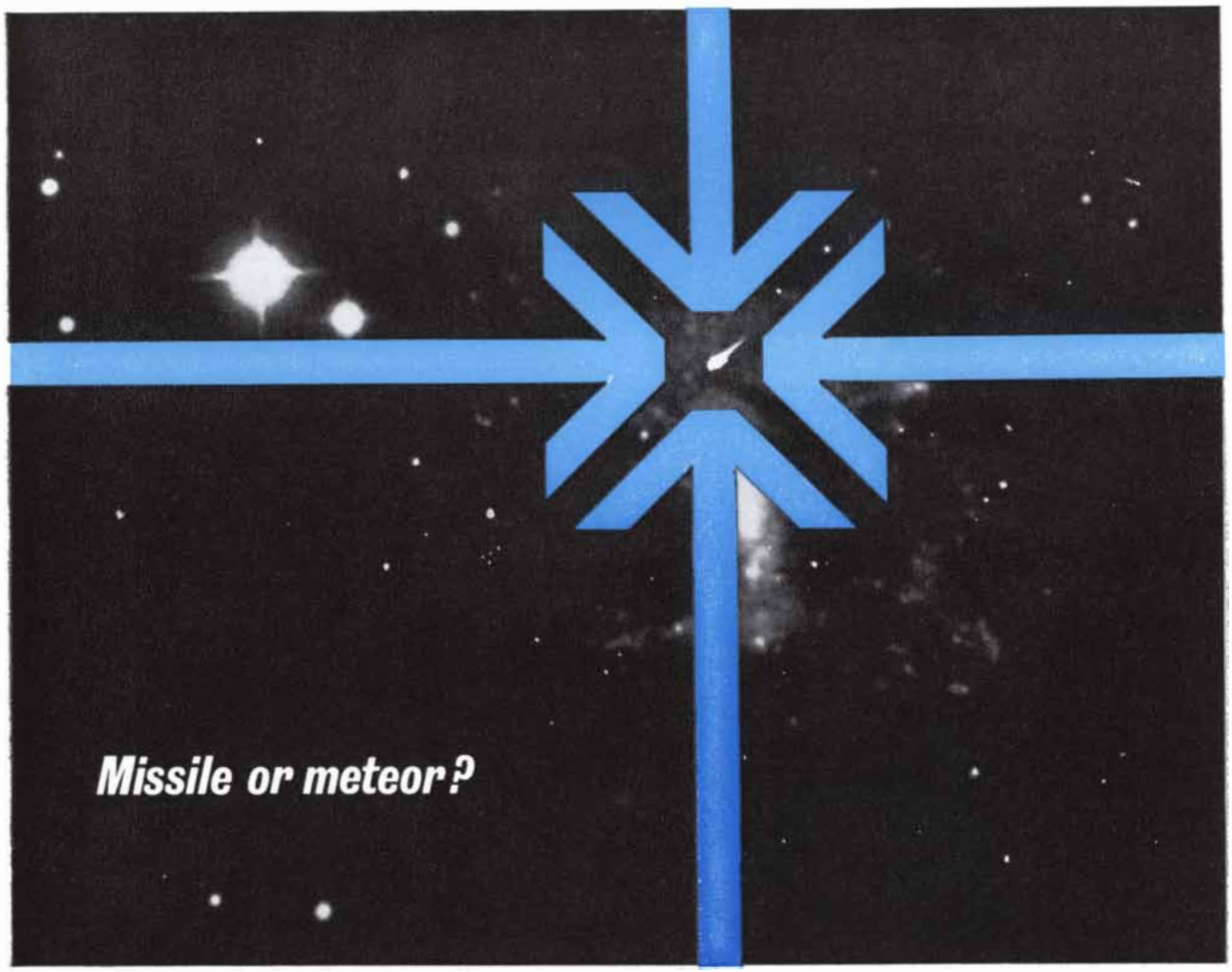

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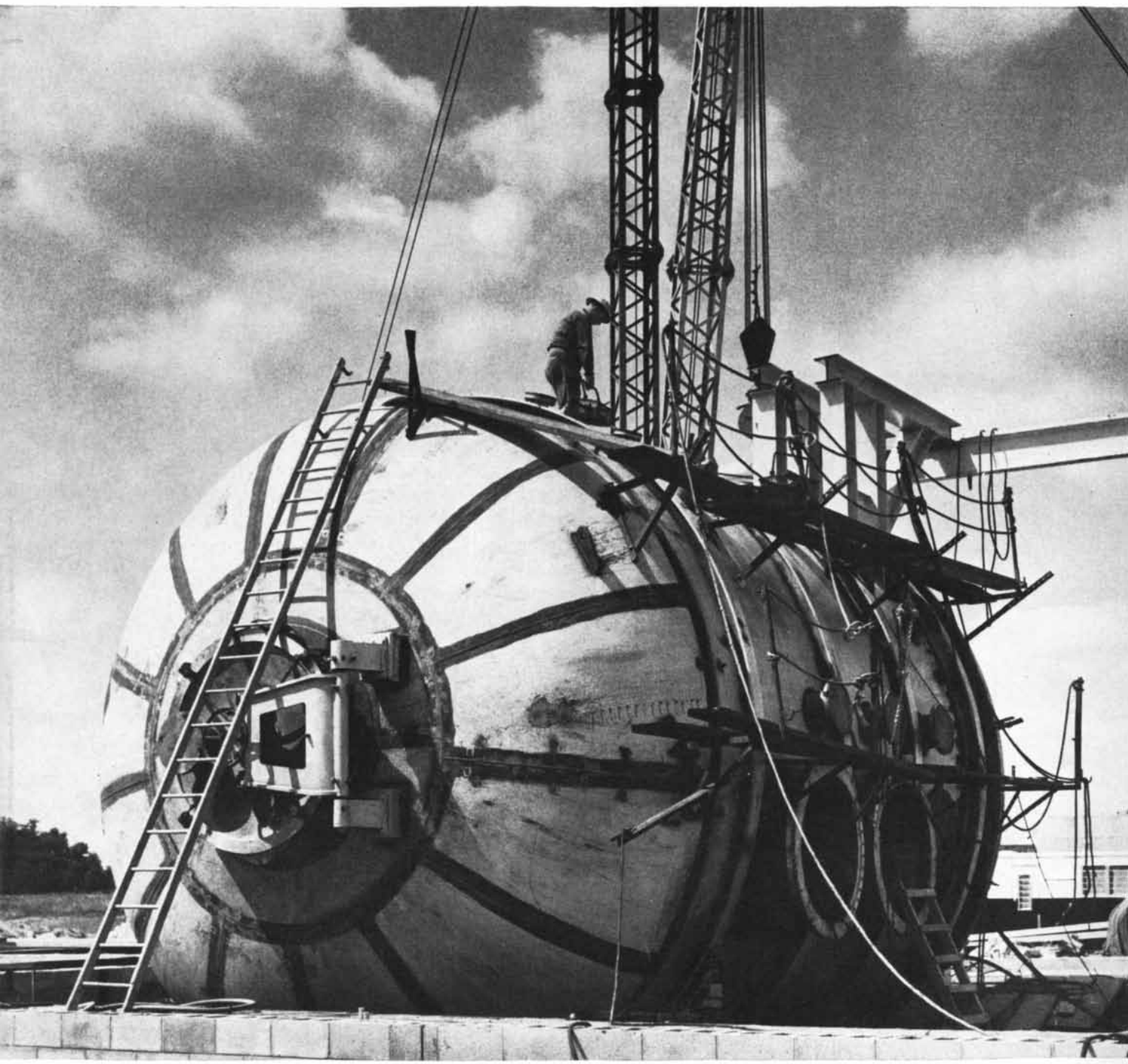

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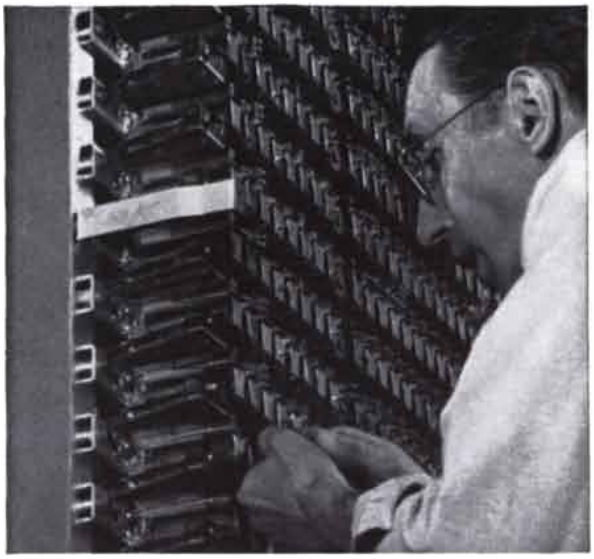

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Charles Judson Herrick... on dogmatism

"Dogmatism has no place in science, and dogmatism about the unknown is especially reprehensible. We live by faith, faith in the order of nature, faith in ourselves, and faith in our fellow men. This faith is our most prevalent motivation, and it is a reliable guide for behavior just in so far as it is founded on knowledge. Where knowledge is lacking we may extrapolate with due regard for the uncertainties arising from the incompleteness of our knowledge. The mystics too often neglect this caution. The naturalists must not, and they find within the bounties of nature ample scope for their best endeavors and for the satisfaction of their highest aspirations.

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—*Evolution of Human Nature,* 1956

Established 1845 SCIENTIFIC AMERICAN October 1961 Volume 205 Number 4

Air Pollution and Public Health

New investigations are confirming the suspicion that over a period of time the accumulated products of combustion have a subtly harmful effect on the health of city dwellers

by Walsh McDermott

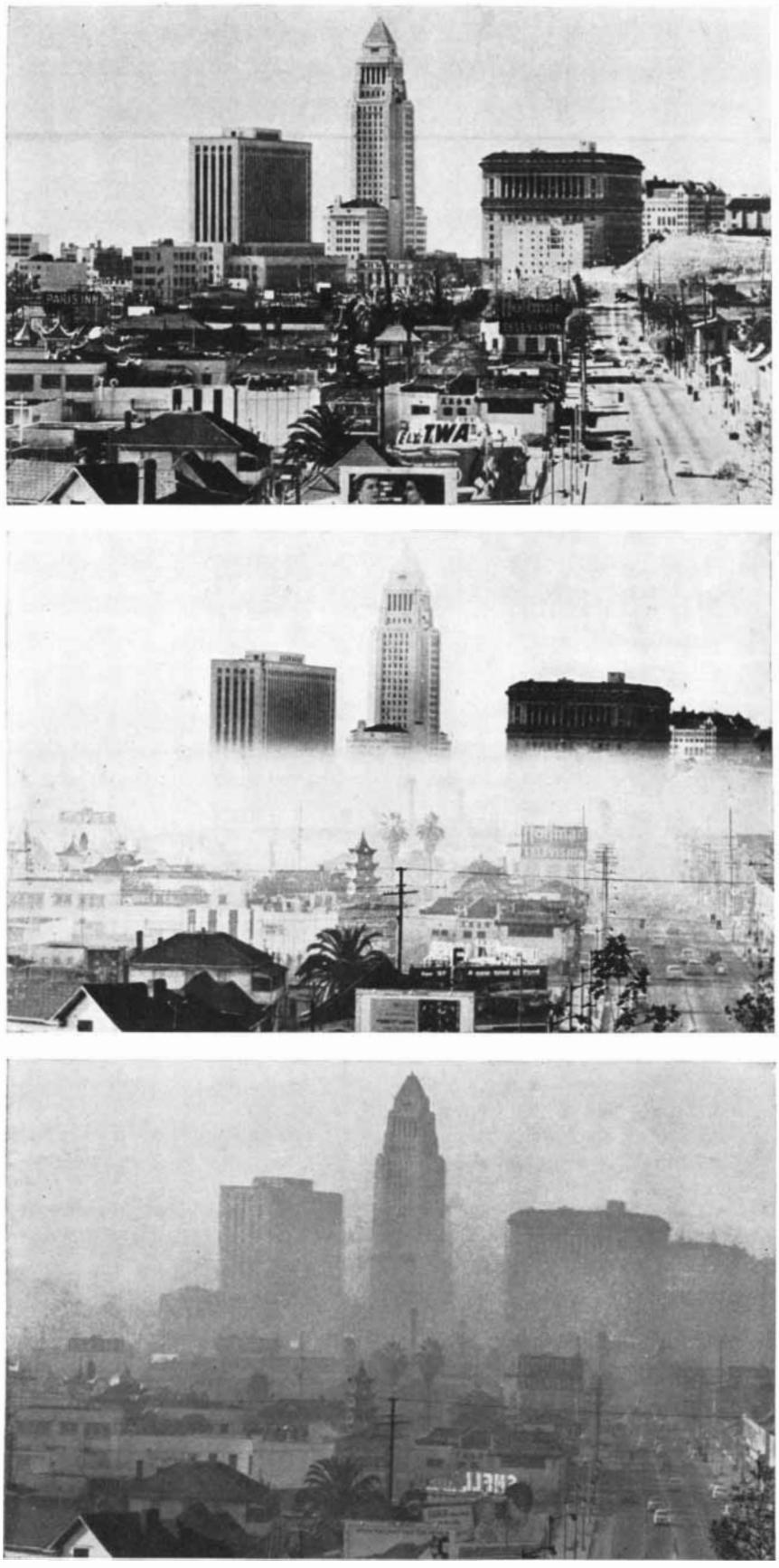
The first sign of a city visible from an airplane on a fine day is the thick brownish haze that envelops it. While still in the air one asks: "How can anyone go on breathing that stuff?" On the ground, however, people do not notice anything unusual. They blame the weather for "just another gray day" and go right on breathing.

Air pollution has nonetheless begun to arouse the concern of the public and of public officials. An increasing number of cities in this country have been recording an increasing frequency of days of severe "smog." The attendant irritation of the eyes and ruination of nylon stockings are taken as evidence that the pollutants cannot be good for the health. In Los Angeles, the most notably afflicted community, the prohibiting of domestic trash-burning has already improved the visibility of the mountains that crowd that city against the sea; local industries have been persuaded and compelled to minimize their contribution to the smog, and the compulsory installation of exhaust-pipe "afterburners" and crankcase "blow-by" scavengers on all automobiles in the state at the end of the year promises to reduce the atmospheric concentration of the substances most positively identified with eye irritation. Other communities are beginning to follow suit, and it appears that the effort to reduce the emissions from automobiles may soon become nationwide. The Secretary of Health, Education and Welfare, Abraham A. Ribicoff, has asked the automotive industry to agree to the installation of pollution-abating devices as standard equipment on all 1964 vehicles and has threatened to ask Congress for a law requiring such installation.

Whether air pollution is to be endured as a nuisance or suppressed by vigorous civic action, it must be reckoned as an unpleasant and expensive consequence of urban and industrial civilization. But is air pollution in fact a menace to public health? The first place to look for damage by unclean air would be the body surfaces exposed to air: the skin, which is hardy and mainly covered by clothing, and the respiratory passages, which are not covered at all. There is evidence that a commonplace disorder of the bronchial tubes and lungs—chronic bronchitis and emphysema—is showing an alarming increase in some places. At the same time, it cannot be said that any particular atmospheric pollutant is the cause of bronchitis-emphysema or other bronchopulmonary disease, in the legal or scientific sense of the term.

If something is happening to the public health from the widespread pollution of the air, it must be happening to large numbers of people. Yet it must be something that goes on undramatically in its individual manifestations; otherwise it would attract public notice as an "epidemic." Fortunately the mysteriously lethal fogs that settled on the Meuse Valley in Belgium in 1930, on Donora, Pa., in 1948 and on London in 1952 remain isolated episodes. On those occasions, strangely, there was no recorded increase in the atmospheric concentration of the usual pollutants; the increase in the death rate involved chiefly the aged and those with a history of pulmonary disorder. But if a substance or mixture of substances present in low concentration can be highly injurious to certain particularly susceptible people after only a few days' exposure, how can one know that two or three decades of exposure to the same low doses will not be injurious to many more people? Such questions are not unknown in public health research. With respect to air pollution the answer is that there is as yet no solid evidence that it is a serious threat to the "healthy" (meaning those without lung damage); there are, however, ominous portents that it may be such a threat.

Most of the pollutants get into the air as a result of burning. Though city dwellers seldom light their own fires nowadays, their daily lives still depend on the process of combustion. The spotless electric stove ultimately derives its heat from the burning of coal, and something has to be burned to make the television set function. In most cities the garbage is burned; sometimes it is burned twice, in the back yard and on the city dump. Automobiles are highly mobile "burners" throughout their active lifetime, and when they are outmoded, they too end up on the pyre. In short,



LOS ANGELES SMOG is the result primarily of hydrocarbons and nitrous oxides from automobile exhaust, chemically changed by exposure to sunlight and trapped by the city's frequent "thermal inversions," which interfere with normal vertical air movements. The top photograph shows downtown Los Angeles on a clear day. The same area is seen (*middle*) as a light smog builds up against the inversion layer and (*bottom*) on a day of heavier smog.

the energy of civilization is supplied by burning, and most of its debris is likewise burned.

The final products of a completed combustion are water and carbon dioxide, which in the amounts involved in urban life would be entirely harmless. In general, however, fuel and debris are only partially burned, and a wide variety of chemical substances are thrown off into the air. Some of this material is visible smoke, made up of particulate matter, including particles that one can see and feel, such as fly ash or soot. Some of the material entering the air is invisible, composed of complex chemicals, and it is these substances that seem to represent the greater menace to health.

Chemical analysis divides the polluted atmospheres of the world's cities into two major types: the London type, composed principally of sulfur compounds from the burning of coal; and the Los Angeles type, composed principally of petroleum products, known loosely as hydrocarbons. Given the commitment to automobile transportation, all the cities in this country suffer to some degree from air pollution by hydrocarbons; where coal is burned for power and domestic space-heating, the air may in addition be polluted with sulfur compounds.

Outside of Los Angeles, however, the term "smog" is usually a misnomer when applied to the prevailing haze; the physics of the true Los Angeles smog is somewhat different from that of the more common London fog. As shown in 1951 by A. J. Haagen-Smit of the California Institute of Technology, the hydrocarbons and nitrous oxides given off by the combustion of petroleum are at first neither visible nor irritating. But when these substances are exposed to sunlight for an hour or so, they undergo important chemical changes, yielding ozone and other reactive compounds. These products of photochemistry are the ones that irritate the eyes. As they undergo further chemical change some of them produce the characteristic haze. In the Los Angeles smog, therefore, it is sunlight acting chemically on petroleum products that obscures the blue sky, whereas in most cities of the country it is a plain London type of fog that traps the pollutants and suspends them in the air. In each case the end result—the irritation of certain cells of the body—is probably much the same.

The automobile owes its supremacy as a source of air pollution to the inefficiency with which it burns its fuel. The U.S. consumer expects his automobile

engine to start instantly in all kinds of weather and accelerate rapidly with no engine knock. To meet these requirements manufacturers build large motors with a high compression ratio that operate best on high-octane gasoline, a fuel that burns with low efficiency except under optimum operating conditions. Hydrocarbons escape both through the exhaust and as vapors from the fuel tank and carburetor vents. Emission through the tail pipe varies considerably, depending somewhat on engine size and faithfulness of upkeep. It is highest during low-speed driving such as occurs twice each day at rush hour on the parkways. On a hot day in traffic the emission from the carburetor and fuel tank approximates that of the tail pipe.

According to Leslie A. Chambers, research director of the Los Angeles Air Pollution Control District, the daily output of every 1,000 operating automobiles in an urban community burdens the air with 3.2 tons of carbon monoxide, 400 to 800 pounds of organic vapors (that is, hydrocarbons) and 100 to 300 pounds of nitrous oxides, plus smaller amounts of sulfur and other chemicals. The hydrocarbons and nitrous oxides are highly important. To what extent the 3.2 tons of carbon monoxide are a menace is not known, but this is beginning to cause concern. In general, except in such closed surroundings as a household garage, the carbon monoxide given off to the air does not usually rise above the 150 parts per million that would represent a hazard. Since carbon monoxide does not change its chemical form in the air, measurement of its presence there provides a good index of the volume of automobile exhaust being poured into the atmosphere at a given moment.

The automobile makes a further contribution to air pollution in the form of highly pulverized rubber and asphalt, generated by abrasion of tires upon streets. This aspect of the situation has not been studied in much detail, but there is reason to believe that contamination from rubber and asphalt is appreciable.

In metropolitan regions all over the country municipal installations, households, industrial plants and automobiles (to list them in ascending order of rank as sources of pollution) give off approximately the same combination and relative volume of chemicals to the air. Whether the contamination becomes a community problem at any one time depends on population density and the weather. The strong breezes that attend the movement of great air masses over the continent regularly bring fresh air into most U.S. cities, and in the absence of breezes the air may be cleaned by updrafts that dilute and carry away both the smoke and the vaporized chemicals. Not infrequently these natural ventilation processes fail, and there may be no movement of air over a particular area for a matter of hours and sometimes days. One mechanism that stops air movement is the "thermal inversion." Ordinarily the air is warmer at the ground and colder above; indeed, the updrafts so essential for air cleansing arise from this temperature gradient. In

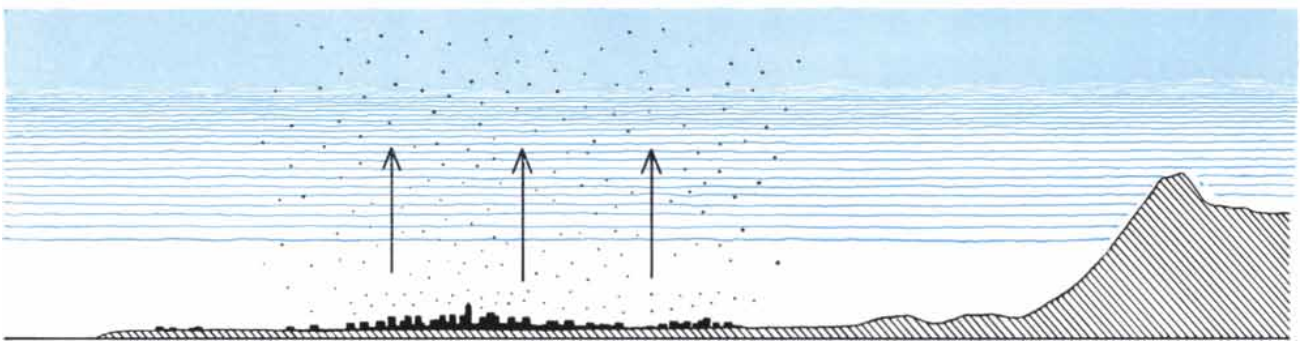
MAN-MADE HAZE lies in a layer over New York City on an otherwise clear day. Skyscrapers protrude above the smog, which is held down by a thermal inversion. A thin haze like this obscures vision only at some distance, and residents may be quite unaware of it.

a thermal inversion a layer of warm air forms at higher altitude and traps a layer of cold air at the ground. When an inversion roofs over the atmosphere of a heavily populated region, the same air must accumulate a much higher concentration of pollutants. This can happen in almost any season of the year to most of the cities in this country; it is the chronic situation in Los Angeles.

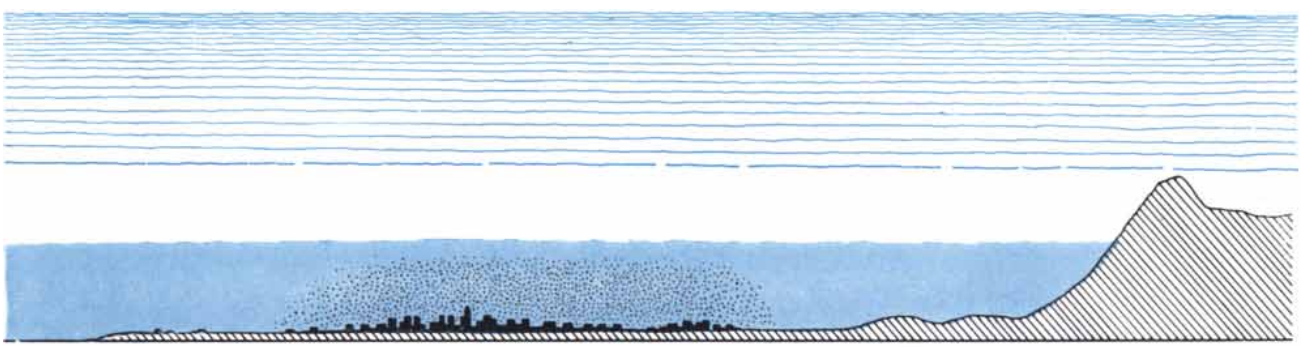
Los Angeles suffers from its smogs not because its natives are unusually careless but because there are so many of them in a place where the cleansing of the air is so frequently interrupted. There six million people with three million cars burn 5.5 million gallons of gasoline each day on a narrow strip of sunny seacoast backed up by mountains. Thermal inversions occur about 100 days each year. The Los Angeles case may seem extreme, and it is the extreme at this moment. But two of the three factors that prevail there—rapid population growth and heavy hydrocarbon emission—are not peculiar to Los Angeles. The third factor—thermal inversion—can come into play elsewhere as well. What has happened to Los Angeles, therefore, is already happening to certain other urban regions and may have considerable future significance for the nation as a whole.

The facts about air pollution are plain enough. But when it comes to assessing the effects of unclean air on the public health, the ground becomes uncertain. What British physicians call chronic bronchitis and its complications is now the leading cause of death in men over 45 in that country and the fourth leading cause of death for the population as a whole. For reasons related to the nature and course of the disease, the corresponding figures for chronic bronchitis-emphysema in the U.S. cannot be stated exactly, but it appears to be on the increase. It is not enough, however, merely to show that the incidence of pulmonary disease has been rising along with pollution. The conscientious investigator must seek out the chain of cause and effect. And the responsible public health official needs better evidence to justify the social cost of control measures.

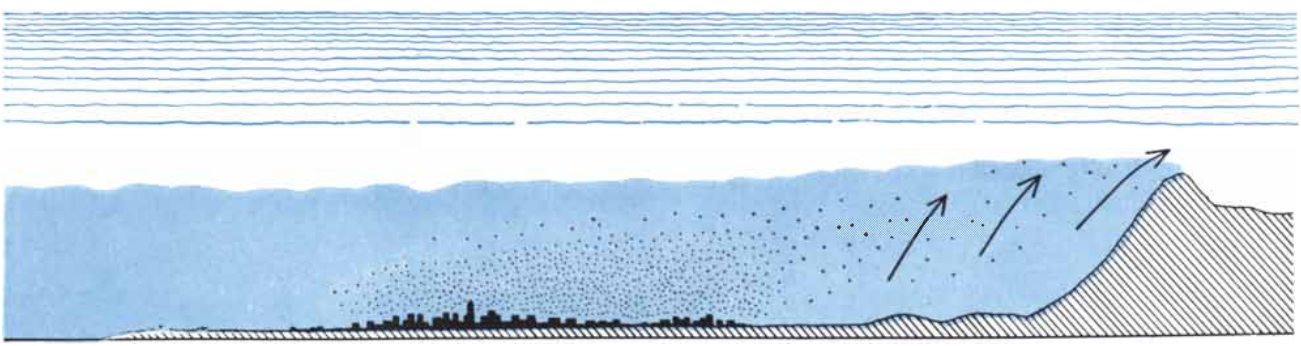
Until recently chronic bronchitis-em-



THERMAL INVERSION, common in Los Angeles, is the main meteorological factor in smog formation. Except in an inversion, air temperature decreases with height (*darker tones indicate cooler air*); the warm surface air rises, carrying pollutants away.



INVERSION SETS IN when cool sea air moves in under warm desert air and is trapped. The normal temperature gradient is reversed in the inversion layer, the base of which (*at the surface in this drawing*) forms a lid over the city, concentrating pollutants.



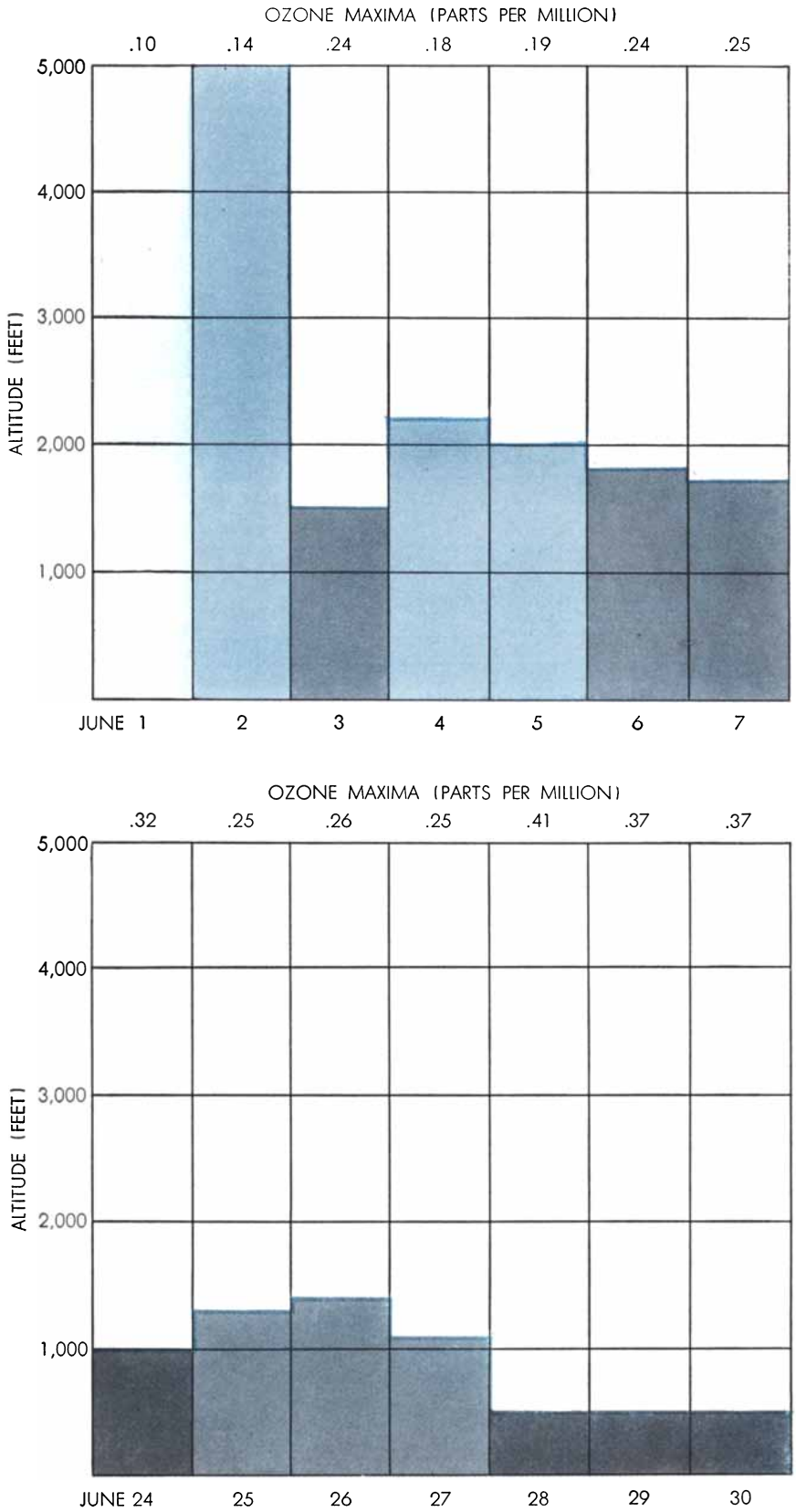
INVERSION PERSISTS until the weather changes, as when the warm air is high enough to permit the cool sea air to escape and carry away the accumulated smog. Thermal inversions occur in Los Angeles about 100 days a year, but they are also common elsewhere.

physema has been considered a rather "dull" disease by medical students and young physicians, and research on the subject has been correspondingly neglected in university circles. The chronic cough and progressive loss of breathing function may be completely incapacitating and lead eventually to failure of the heart. But the course of the disease is usually quite prolonged and undramatic, and not much can be done about it.

The aspect of the disease referred to under the heading of emphysema involves its effect on the millions of tiny air sacs in the lungs, where the transfer of oxygen to the blood takes place. In emphysema several of these tiny sacs merge to form a larger sac, just as small bubbles coalesce into larger bubbles. The single larger sac, of course, offers less surface area for respiratory gas-exchange than the half-dozen or so smaller sacs from which it is formed. This emphysema process occurs throughout both lungs, eventually causing severe impairment of the individual's ability to breathe. The situation is further aggravated by a narrowing of the tiny branches of the bronchial tree through which the air passes on its way to the individual breathing unit. The narrowing may be due to a spasm or it may be permanent. This is the "bronchitis" part of chronic bronchitis-emphysema [*see illustration on page 57*]. Whether the bronchitis represents the cart or the horse is a matter of amiable scientific controversy. In William Osler's day emphysema was attributed to "airway resistance" and as such was regarded as an occupational disease of trombone players—individuals who certainly have to breathe out against resistance!

When the emphysema has become sufficiently advanced throughout the lungs, a heavy load is thrown on the heart, which now must pump the same volume of blood through the far fewer channels available in the greatly reduced air-sac lining of the lung. From this extra work the heart enlarges and eventually fails. Recent research indicates that the cause of the cardiac failure is not quite so simple, but this type of heart disease has been recognized for more than a century as *cor pulmonale*, or pulmonary heart.

Just how the disease gets its start is not known. The process apparently begins one or two decades before symptoms of breathlessness are first noticed. Since the bronchi are in direct communication with the outside air, they are exposed to everything in it. Fortunately



HEIGHT OF INVERSION BASE affects smog density; ordinarily the lower the base, the worse the smog. These charts relate inversion base altitude in the Los Angeles area in the first and last weeks of June, 1961, with smog density as measured by the ozone maximum in the area. The height of the bars indicates the inversion altitude on each day, and the tone of color used for each bar shows the smog density (*darker tones represent higher ozone concentrations*). Actual daily ozone values are given at the top of the charts.

the lining of the bronchi has a considerable capacity for restoration after acute damage, as the convalescent from a bout of influenza is grateful to discover. In some cases, however, presumably as a result of a steady irritation of the bronchi and breathing sacs, minute damage to the tissues becomes irreversible. Once this happens a circular process begins. The slightly damaged bronchopulmonary structures are less able to operate the mechanisms that normally protect the essentially clean lung from the microorganisms in the nose and throat. Both the lung and the bronchi tend to become repeatedly infected. Each infection damages the tissue still further, eventually producing the full bronchitis-emphysema.

A hereditary susceptibility may be involved, and it may be that the disease represents a fundamental aging process. Men are three to five times more frequently affected than women; both the illness rate and the death rate go up sharply after 45, death being caused by heart failure or pneumonia.

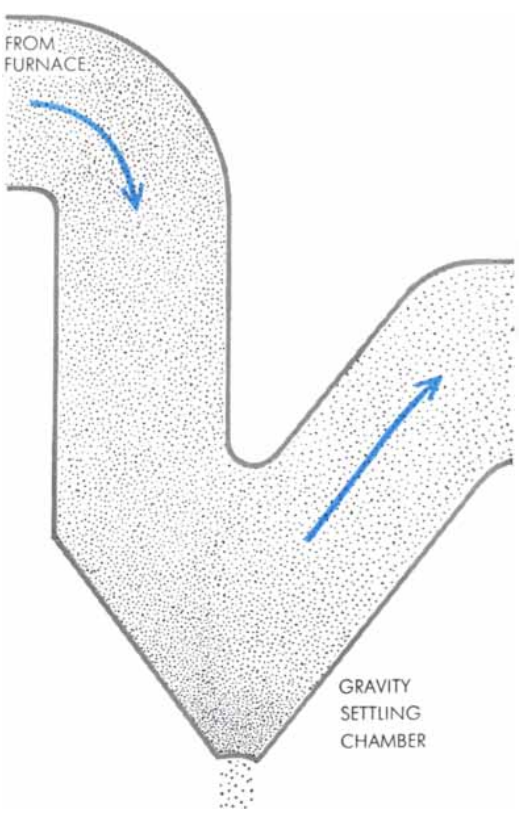
It is not difficult to conceive of a role for air pollution in the disease process. Both the hydrocarbon and the sulfuric compounds are highly irritating, and the bronchi are continuously exposed to them during periods of high pollution. Natural exposure to either type of smog and experimental exposure to low concentrations of smog constituents have produced tissue damage in plants and in cultures of animal cells and scarring of the lungs of laboratory animals. Plant damage in California has occurred in a noticeable swath bordering highways; ozone effects on growing tobacco leaves have been noted in Connecticut. Mary O. Amdur and her colleagues at the Harvard University School of Public Health have shown that inhalation of small amounts of the sulfur components of smog causes interference with the free passage of air in and out of the lungs of guinea pigs and normal humans. Effects of this type, if recurrent, would definitely aggravate bronchitis-emphysema and might actually initiate it. Some authorities suspect that two or more components of smog may act synergistically in the lung to cause damage that might not result from exposure to any one of them. So far, however, there is no direct evidence that continued exposure to urban air can start the disease. On the other hand, once the process does get its start, there is excellent evidence that both kinds of urban smog influence it adversely.

Bronchitis-emphysema is considerably more common among city dwellers than country people. There is some indication, however, that the advantages of country living can be canceled by cigarette smoking, which is, in effect, a portable form of air pollution. In Great Britain it has been shown that the larger the city, the higher the incidence of bronchitis-emphysema. D. D. Reid of the London School of Hygiene and Tropical Medicine was able to find, in careful studies of the absenteeism and permanent disability rates of post-office workers in Greater London, that the workers employed indoors have considerably lower rates than the postmen who worked almost exclusively outdoors. He also showed that the postmen who work in the central and northeastern sections, where air pollution is highest, have a bronchitis rate almost twice that of the men who delivered the mail in the cleaner parts of the city.

Hurley L. Motley and his associates at the University of Southern California School of Medicine have made detailed studies of 100 patients with various grades of chronic bronchitis and emphysema, first when they were breathing ordinary Los Angeles air and then when they were breathing air from which the chemical pollutants had been removed by charcoal filters. They reported that in the purer air the patients showed a striking improvement in lung function, those with the greatest disability showing the most progress. Significantly, several days of breathing pure air were needed before any change became detectable. This suggests that the effect of the contaminants on damaged bronchopulmonary tissues is less transient than those produced by smoking a cigarette, for example.

The aggravation of chronic bronchitis-emphysema by air pollution has been most drastically demonstrated in the few epidemics of acute illness attributed to air pollution. In the cases of the Donora "disaster" and the London episode of 1952 the evidence is decisive. The air at Donora, on a bend of the Monongahela River with high hills on all sides, must take up the smoke and fume of blast furnaces, steel mills, sulfuric acid mills and slag-processing plants. In October, 1948, a thermal inversion occurred over most of the U.S., including the Donora basin. There the usual smog, instead of lifting each day at noon as was its custom, remained unabated. By the third day of constant smog, 5,910 persons were reported ill. More than 60 per cent of the inhabitants 65 and older were affected, and almost half of these were seriously ill. In all, 20 persons died, 17 of the deaths occurring on the third day of unremitting smog. Then a heavy rain fell, the smog disappeared and the epidemic stopped immediately. In London in 1952 there was an "excess" mortality of 4,000 to 5,000 persons during one week. The deaths in both London and Donora occurred almost exclusively among those with previous bronchopulmonary disease. Indeed, the veteran bronchitis patients in the London clinics served almost as the canaries that miners once carried to detect noxious gases: they noted discomfort six to 12 hours before it was evident to others that an episode of smog was at hand.

The smog in these two situations was of the sulfur type, but there is no reason to doubt that a hydrocarbon smog could have the same effect. Perhaps the most significant finding is that no single smog component in either disaster was present in a higher concentration than usual. This may merely reflect faulty analysis of what may have been rapidly changing situations. But the finding points to the ugly conclusion that the same smog breathed by everyone a day or two at a time without immediate or apparent ill effect may be highly injurious to sub-



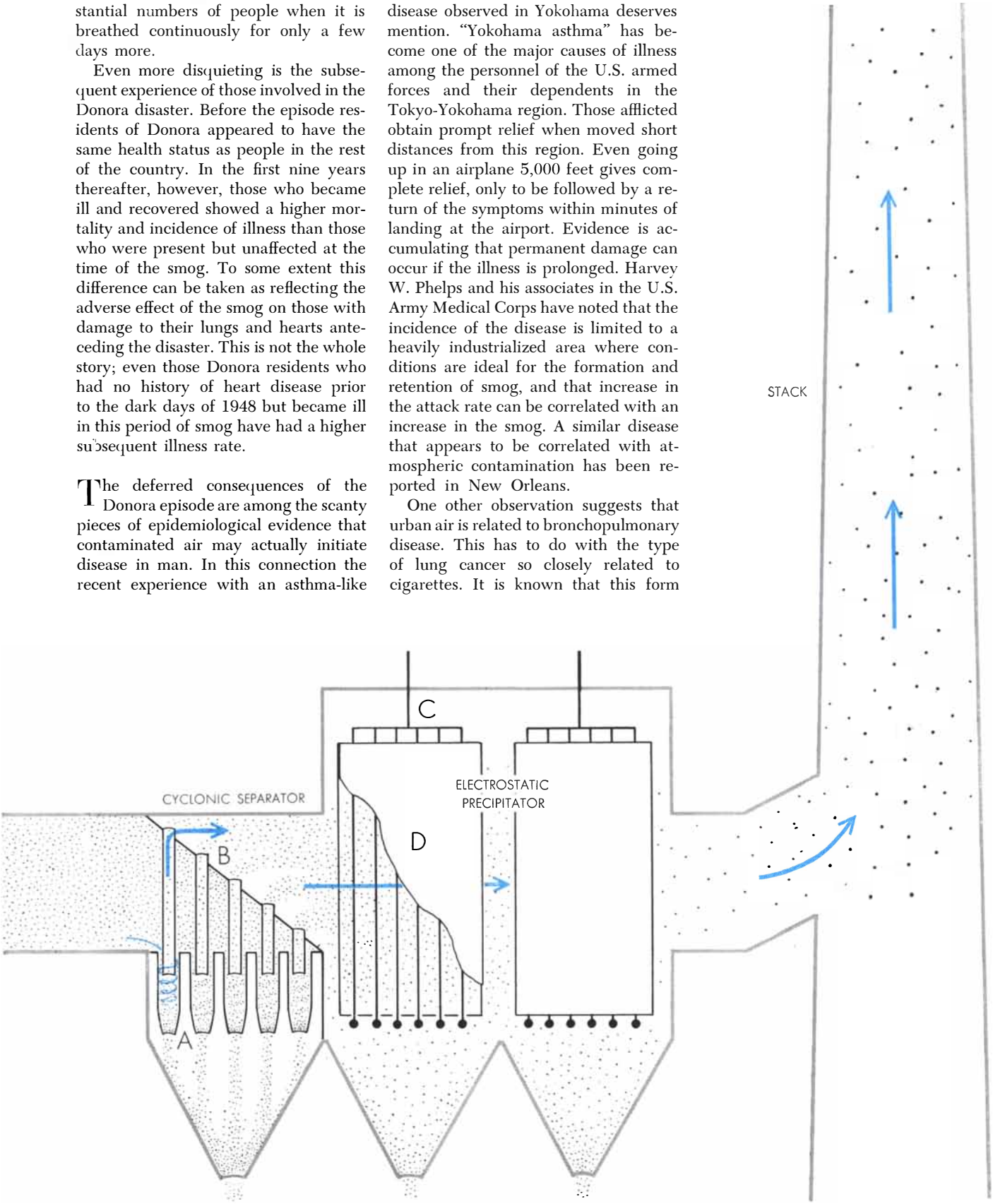
INDUSTRIAL DISCHARGE can be cleaned up appreciably by elaborate installations of the type diagramed here. Exhaust from furnaces enters at the left, where some of the heavy particles settle out because of

stantial numbers of people when it is breathed continuously for only a few days more.

Even more disquieting is the subsequent experience of those involved in the Donora disaster. Before the episode residents of Donora appeared to have the same health status as people in the rest of the country. In the first nine years thereafter, however, those who became ill and recovered showed a higher mortality and incidence of illness than those who were present but unaffected at the time of the smog. To some extent this difference can be taken as reflecting the adverse effect of the smog on those with damage to their lungs and hearts anteceding the disaster. This is not the whole story; even those Donora residents who had no history of heart disease prior to the dark days of 1948 but became ill in this period of smog have had a higher subsequent illness rate.

The deferred consequences of the Donora episode are among the scanty pieces of epidemiological evidence that contaminated air may actually initiate disease in man. In this connection the recent experience with an asthma-like disease observed in Yokohama deserves mention. "Yokohama asthma" has become one of the major causes of illness among the personnel of the U.S. armed forces and their dependents in the Tokyo-Yokohama region. Those afflicted obtain prompt relief when moved short distances from this region. Even going up in an airplane 5,000 feet gives complete relief, only to be followed by a return of the symptoms within minutes of landing at the airport. Evidence is accumulating that permanent damage can occur if the illness is prolonged. Harvey W. Phelps and his associates in the U.S. Army Medical Corps have noted that the incidence of the disease is limited to a heavily industrialized area where conditions are ideal for the formation and retention of smog, and that increase in the attack rate can be correlated with an increase in the smog. A similar disease that appears to be correlated with atmospheric contamination has been reported in New Orleans.

One other observation suggests that urban air is related to bronchopulmonary disease. This has to do with the type of lung cancer so closely related to cigarettes. It is known that this form



gravity. Entering the cyclonic separator, the smoke is forced downward into a series of cylinders (*A*) past vanes that whirl it rapidly; centrifugal force throws some of the suspended particles out to the walls of the cylinders, and the partially cleaned gas moves up through collecting tubes (*B*) and on to the electrostatic precipitator. Here a powerful electric field is established between discharge electrodes (*weighted wires, C*) and collecting electrodes (*plates, D*). The gas passing through the field is ionized; the ions attach themselves to ash particles, which are in turn charged and attracted to the collecting electrode, later to be removed.

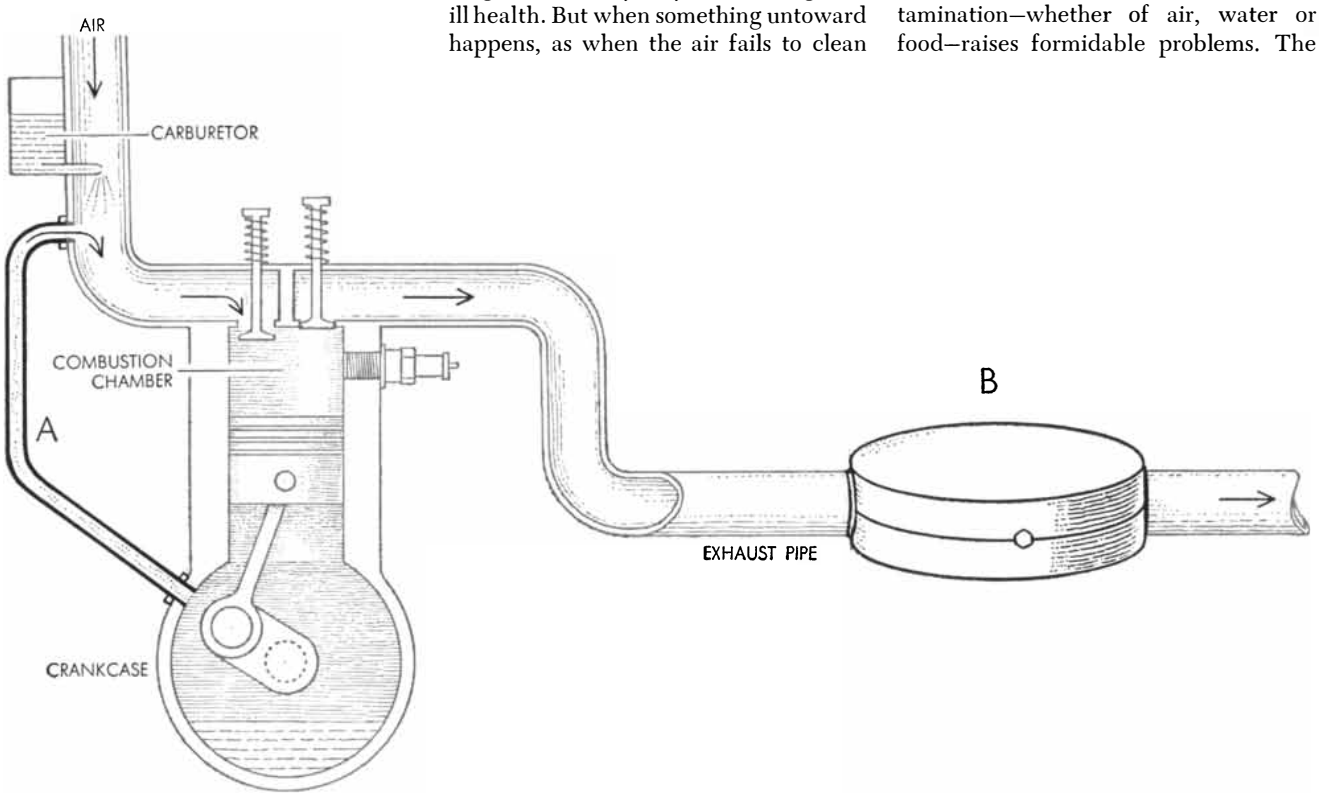
of lung cancer is significantly less frequent in rural areas than in cities. But in the country, where cigarettes are a threat to barns, smoking is a less universal habit. To isolate the effect of urban air on smokers one should have the figures on groups of cigarette smokers who have moved en masse from city to country. Something of the sort is supplied by British emigration to New Zealand. The incidence of lung cancer is reported to be higher among cigarette smokers who lived their first 40 years in Great Britain than among smokers born and brought up in New Zealand. Essentially similar results have been reported for British emigrants to South Africa.

In view of the increasing pollution of the urban atmosphere and with the Donora episode in mind, it would be well to know how large a portion of the population has had a history of bronchitis-emphysema and other forms of pulmonary damage. The figures are scattered and uncertain. In the California State Board of Public Health survey of 1954–1955, bronchitis and asthma were found to be among the 10 most frequently disabling chronic diseases, accounting for 6 per cent of the total days of disability. In 1957, for the country as a whole, emphysema ranked second among the diseases in men for whom disability was allowed under the Social Security Act. During the past decade the California death rate from emphysema has risen 400 per cent, from 1.5 per 100,000 in 1950 to 5.8 per 100,000 in 1957. Presumably some portion of this increase represents better diagnosis reflecting increased medical interest, but it may also be taken as indicating a rising incidence of the disease. Quite aside from any possible role of smog in actual initiation of the disease, the number of people with chronic bronchitis-emphysema is bound to increase. The reason for this is that our population contains a steadily expanding pool of people who have weathered acute bronchopulmonary illnesses. Only 25 years ago almost one of three people with the commonest forms of bacterial pneumonia would succumb to it. Today the fatality rate of the disease would be 1 or 2 per cent.

Large numbers of people are, therefore, alive today in all age groups who would not have been alive in the days before antimicrobial therapy. So long as all goes well, they may show no signs of ill health. But when something untoward happens, as when the air fails to clean itself, they can become seriously ill and may die.

Some idea of the number of people who are in special danger from smog may be had from the recent experience with Asian influenza. This country had its certified epidemic of Asian influenza in the autumn of 1957, "certified" in the sense that the disease was then front-page news. What is not generally known is that more people in the U.S. died as a result of Asian influenza after that epidemic than during it. These deaths were reflected in two peaks of excess mortality: one in the first three months of 1958, the other in the first three months of 1960. Indeed, in the course of the 1960 wave of influenza 26,000 excess deaths were recorded, a larger toll than that of the 1957 epidemic that had been so widely publicized. In large measure these 26,000 excess deaths were those of people with damaged bronchopulmonary structures or chronic heart disease. Speaking broadly, these are the same people who are in danger of serious illness from continued exposure to heavily contaminated air. It is true that they can be protected against the risk of influenza by vaccination. But how can they avoid continued damage from polluted air?

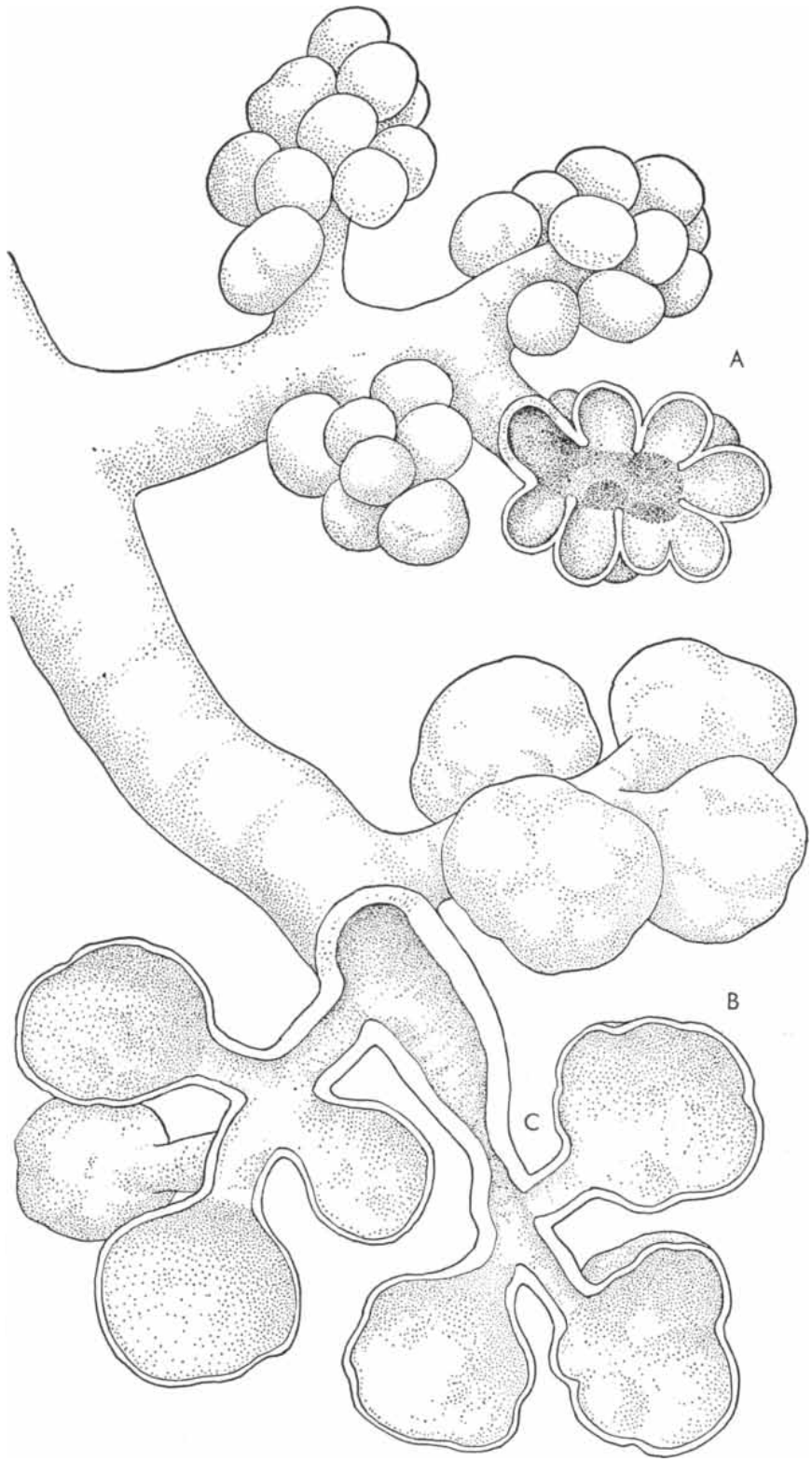
The control of environmental contamination—whether of air, water or food—raises formidable problems. The



AUTOMOBILE EXHAUST is a large contributor to air pollution. Two devices have been developed to cut down this source. One is a "blow-by" pipe (*A*), which takes unburned gases from the crankcase back to the combustion chambers. The other is an "afterburner" (*B*), a special muffler that oxidizes carbon monoxide and unburned fuel in the exhaust gases through a catalytic process.

contamination is not the work of evil men or even slovenly neighbors, as were the contaminations of 50 years ago. Today's contaminations are the impersonal consequences of a highly industrialized society. Corrective measures must inevitably set up tremors across the whole delicate network of that society. Public health officials alone cannot be expected to secure the acquiescence of the host of private and public interests, businessmen, public officials, consumers and taxpayers in the considerable expense and effort that is necessarily involved. What is needed is a citizens' movement in the environmental-pollution field like the conservation movement of Theodore Roosevelt's day. The plant manager is reluctant to raise the factory smokestack 50 feet if nothing is done about the open burning at the city dump, and the city manager faces the same problem in reverse. A citizens' movement is needed, above all, to secure the cooperation of citizens—in minimizing pollution by automobile, for example, by proper engine maintenance. An aroused public opinion has brought the establishment of air-pollution control boards in a number of communities across the country, some of them interstate. In New York and Los Angeles these boards operate laboratories and have access to enforcement powers.

The formulation of effective public policy on the problem of air pollution requires an expanded research effort. For some years the U.S. Public Health Service has conducted a modest program of high quality, covering the sources and control of pollution at its Robert A. Taft Sanitary Engineering Center, in Cincinnati, Ohio, and seeking epidemiological data through community surveys such as are now in progress in New Orleans, La., and Nashville, Tenn. This work has gathered new impetus from the establishment of the Division of Environmental Health as one of the major operating units of the Public Health Service, with its own Environmental Health Center to be set up alongside the Service's other great research institutes. As a result one may now anticipate a quickening of interest in this field among medical scientists in the universities. The literature should soon show the data so much needed on the prevalence of bronchitis-emphysema and pulmonary heart disease. With an adequate estimate of the cost to health of air pollution, the public will be in a better position to assume and allocate the social cost of cleaning up the country's urban atmosphere.



BRONCHITIS-EMPHYSEMA is a chronic lung disease that is apparently aggravated by air pollution. In the normal lung the air passes through the bronchial tubes to enter millions of alveoli (*A*), tiny cells in which the oxygen is transferred to the blood. In a diseased lung the walls of many of the alveoli break down (*B*), causing a reduction in the amount of membrane available to carry out the oxygen transfer. At the same time there is a narrowing of the smallest branches of the bronchial tree (*C*), further restricting air exchange.

GAS CHROMATOGRAPHY

A simple analytical method sharply separates components of complex mixtures. When used to characterize perfumes and flavors, its sensitivity rivals that of the human nose

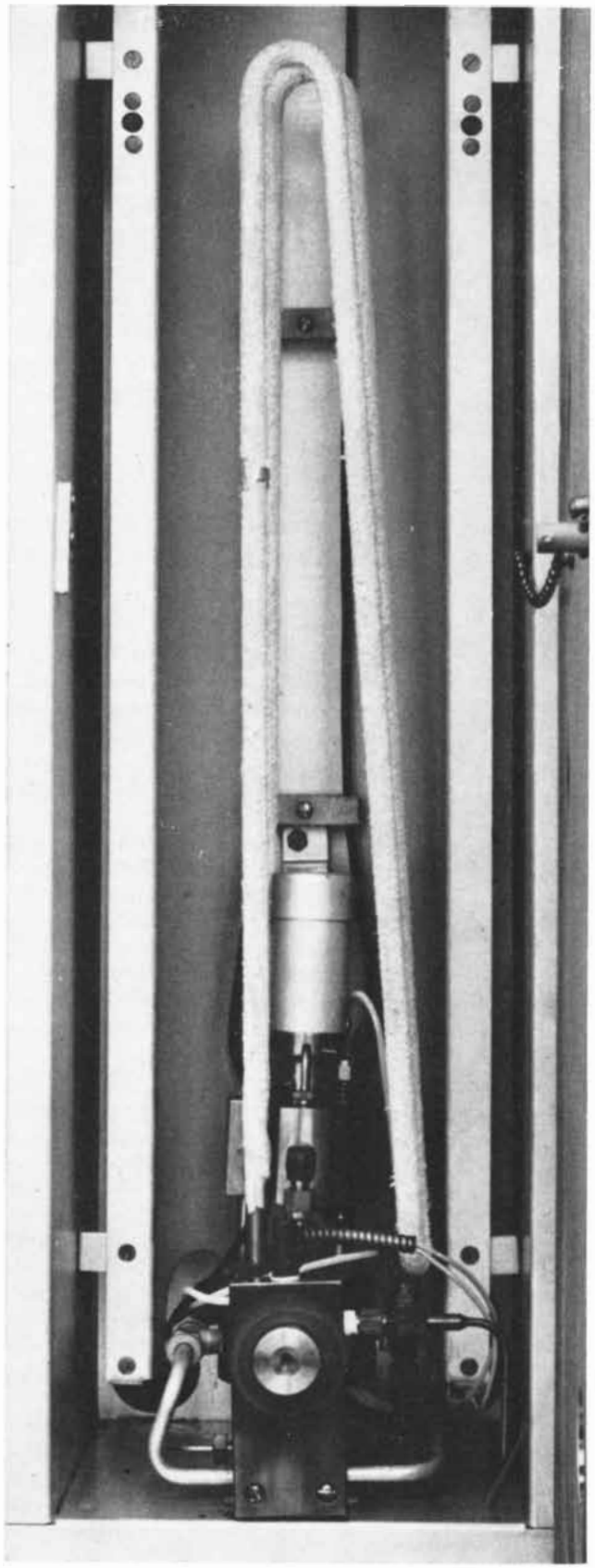
by Roy A. Keller

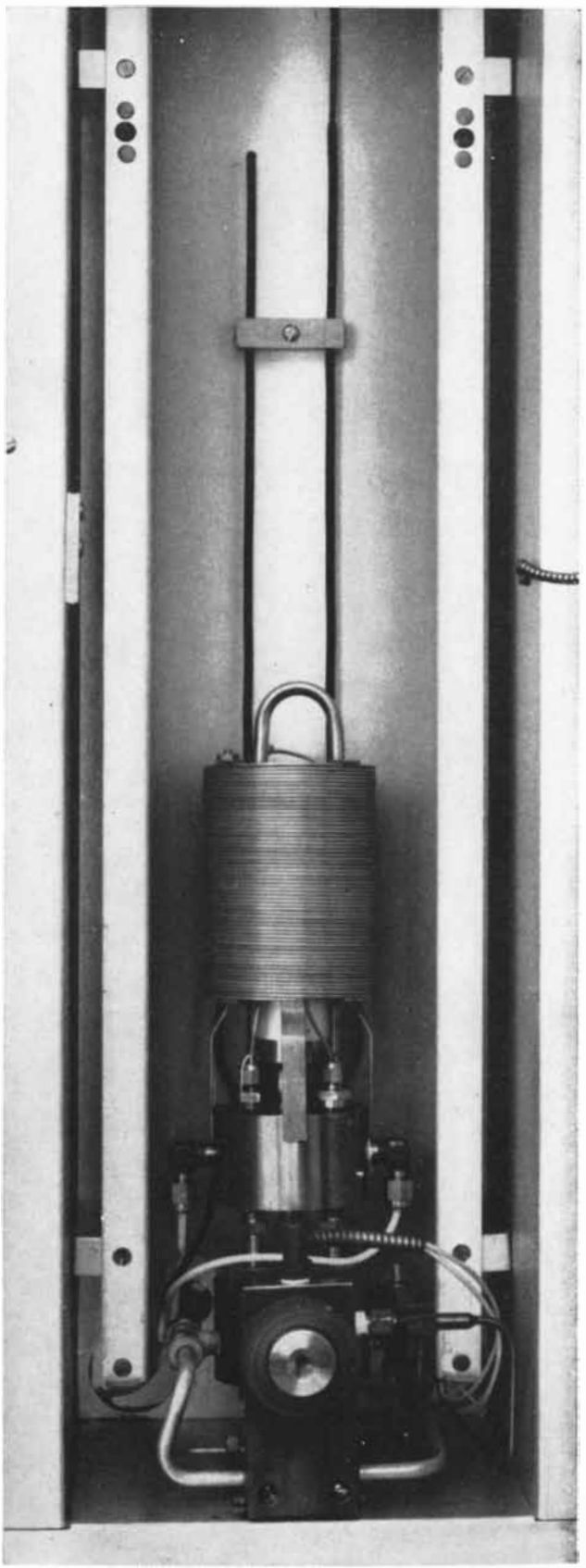
The most pervasive problem in chemistry and biochemistry is that of determining the composition of complex mixtures of matter. The research chemist would like to know at all times exactly what his test tubes and flasks contain; the industrial chemist has an equally urgent need to know the composition of materials flowing through reaction vessels and distillation columns and into product tanks. Within the past 20 to 30 years, in response to this need for fast and accurate analyses, a number of powerful analytical tools have been developed. They include instruments that measure how compounds absorb ultraviolet and infrared radiation, instruments that determine atomic or molecular mass and instruments that determine how the magnetic properties of atomic nuclei are influenced by different molecular configurations.

SAMPLE IS INJECTED into a gas chromatograph by means of a syringe that can deliver liquid samples as small as one hundred-thousandth of a cubic centimeter. Gas samples require a special valve arrangement to meter the sample through a chamber of known volume.

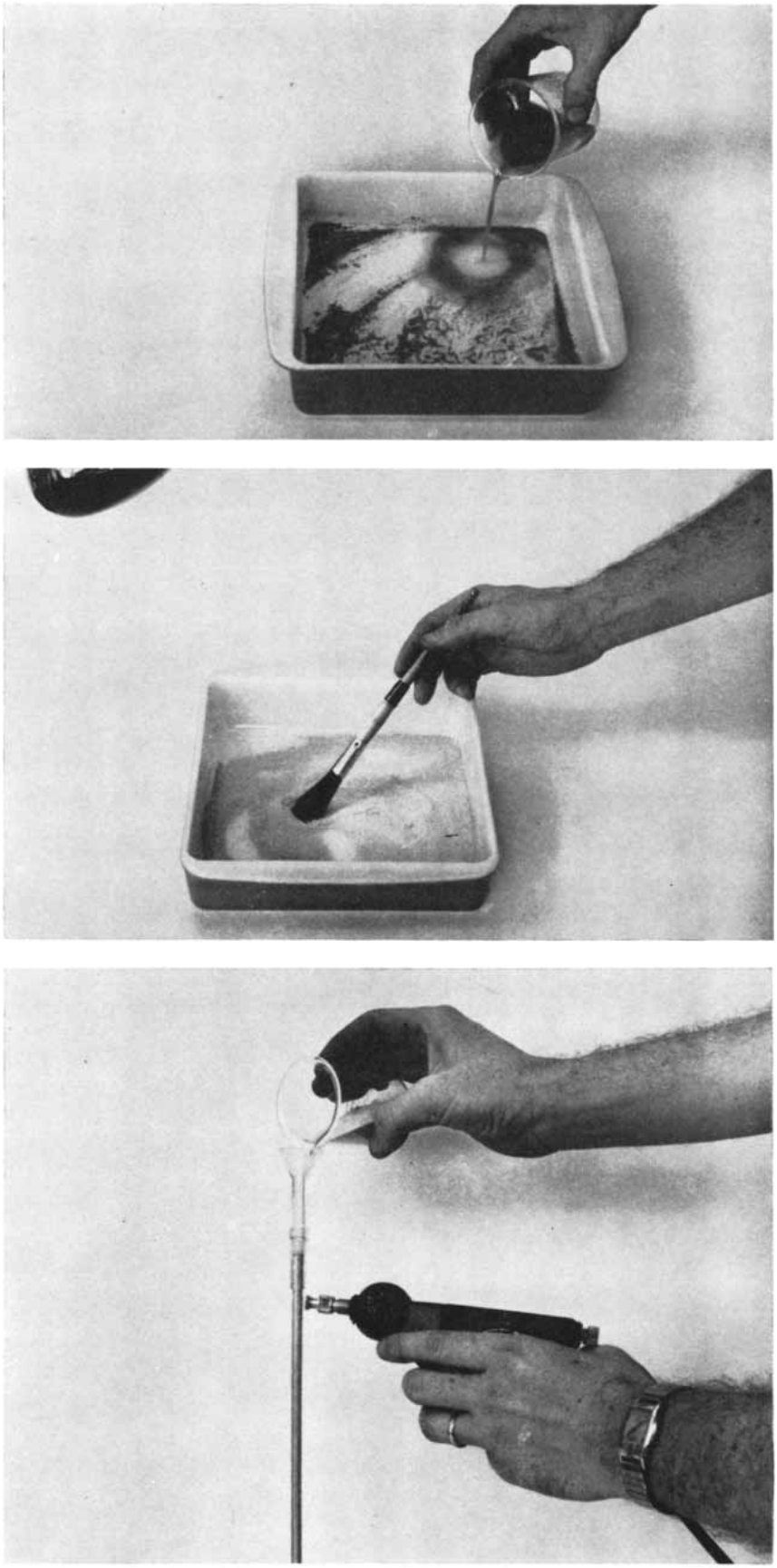
One of the newest and most versatile analytical techniques is gas-liquid chromatography, usually referred to simply as gas chromatography. The name is somewhat misleading; there is nothing chromatic about the method or its results. The name comes from the original method of liquid-solid chromatography described in 1906 by Michael Tswett, a Russian botanist. Tswett found that when a solution of chlorophyll was allowed to filter through a column firmly packed with pulverized calcium carbonate, the various fractions of the chlorophyll mixture separated into distinctively colored bands. He called the result a chromatogram [see "Chromatography," by William H. Stein and Stanford Moore; SCIENTIFIC AMERICAN, March, 1951]. A useful variation of Tswett's original concept is paper chromatography, in which compounds in solution migrate at different speeds across a sheet of porous paper.

In gas chromatography the compounds in a mixture migrate at differing speeds when carried along by an inert gas through a tube that has been packed or treated in a special way. The method was first suggested in 1941 by the British chemists A. T. James and A. J. P. Martin. The method underwent development in many laboratories beginning around 1950, and the first commercial instrument came on the market in 1955. Today some 40 models of gas chromatographs are being built by 20 U.S. and a dozen European manufacturers. The instruments are widely used for analyzing complex organic mixtures such as those commonly found in petroleum products, essential oils, perfumes, flavors and other substances of biological origin. Samples containing as many as 76 dif-





TWO TYPES OF GAS CHROMATOGRAPH differ in the design of the column where fractionation takes place. The instrument at left uses the original type of column, a quarter-inch in diameter and one to several meters long, packed with a pulverized inert substance. The column illustrated is four meters long and is folded twice. Instrument at right uses a capillary column, 150 to 300 feet long, without packing, proposed by Marcel J. E. Golay, a consultant to the Perkin-Elmer Corporation. A nonvolatile liquid carried on the packing, or on the inside wall of the capillary tube, acts as a partitioning agent and promotes fractionation of the sample.



PREPARATION OF CHROMATOGRAPHIC COLUMN begins (*top*) with pulverized diatomaceous earth, to which is added a viscous partitioning liquid dissolved in a volatile carrier. The solvent is evaporated by heat while the coated powder is gently agitated (*middle*). The dried coated powder is packed into a tube with the aid of a vibrator (*bottom*).

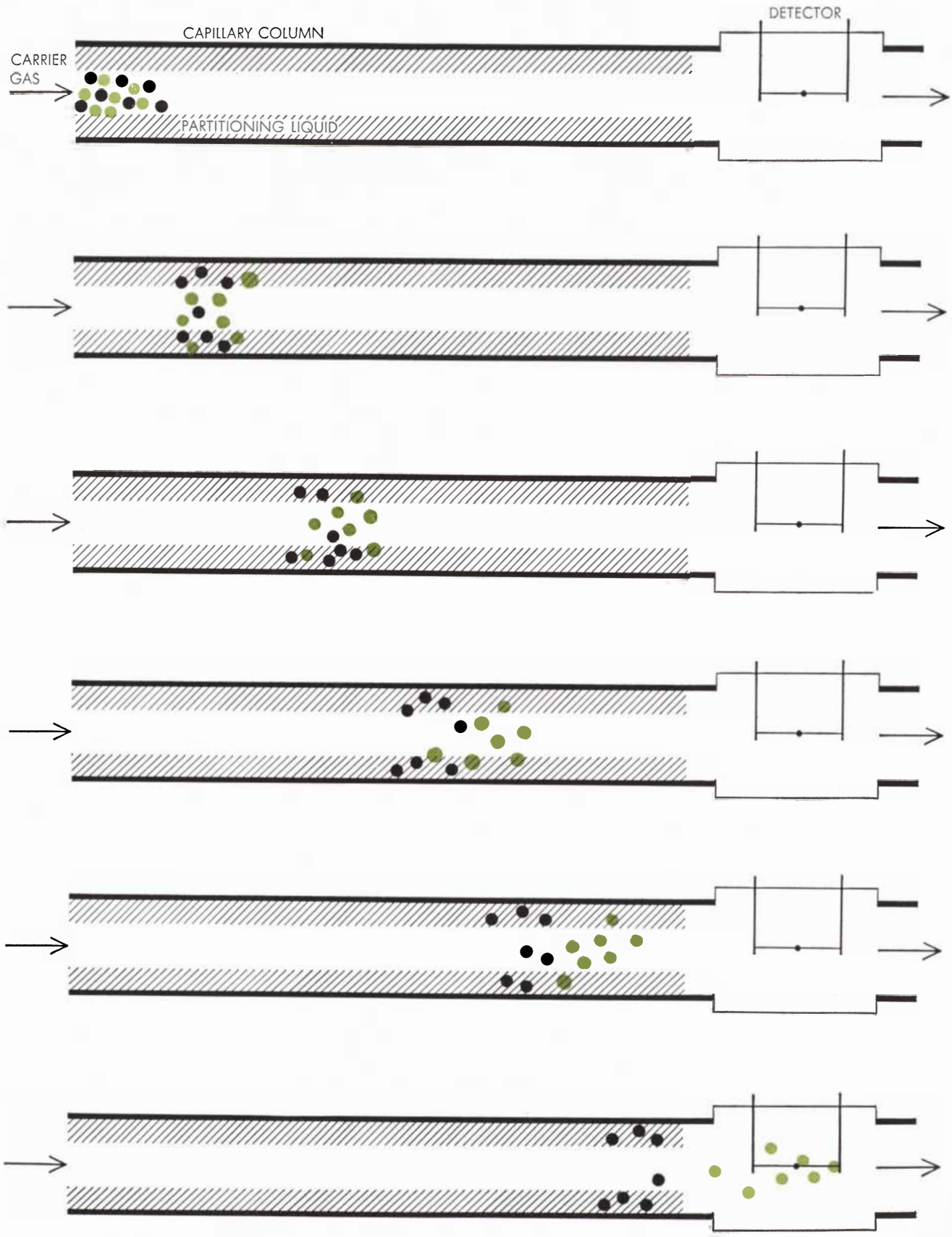
ferent substances have been successfully analyzed in one pass. Analysis time is typically a few minutes and sometimes only a few seconds. Samples usually range in size from a few hundredths to a few thousandths of a gram. Some instruments can handle samples weighing not much more than a millionth of a gram, and in such samples they can detect the presence of substances that weigh no more than a trillionth of a gram—about the weight of a single bacterium.

The fractionating column of a typical gas chromatograph consists of a copper or stainless steel tube about a quarter of an inch in diameter and from one to four meters long, though occasionally much longer tubes are used. The tube is packed with an inert material such as firebrick or diatomaceous earth that has been pulverized and coated with a nonvolatile liquid called a partitioner [*see illustration at left*]. After the tube has been packed it is usually bent into a series of U turns or wound into a helix so that it can be fitted easily into an insulated box, the temperature of which is thermostatically controlled.

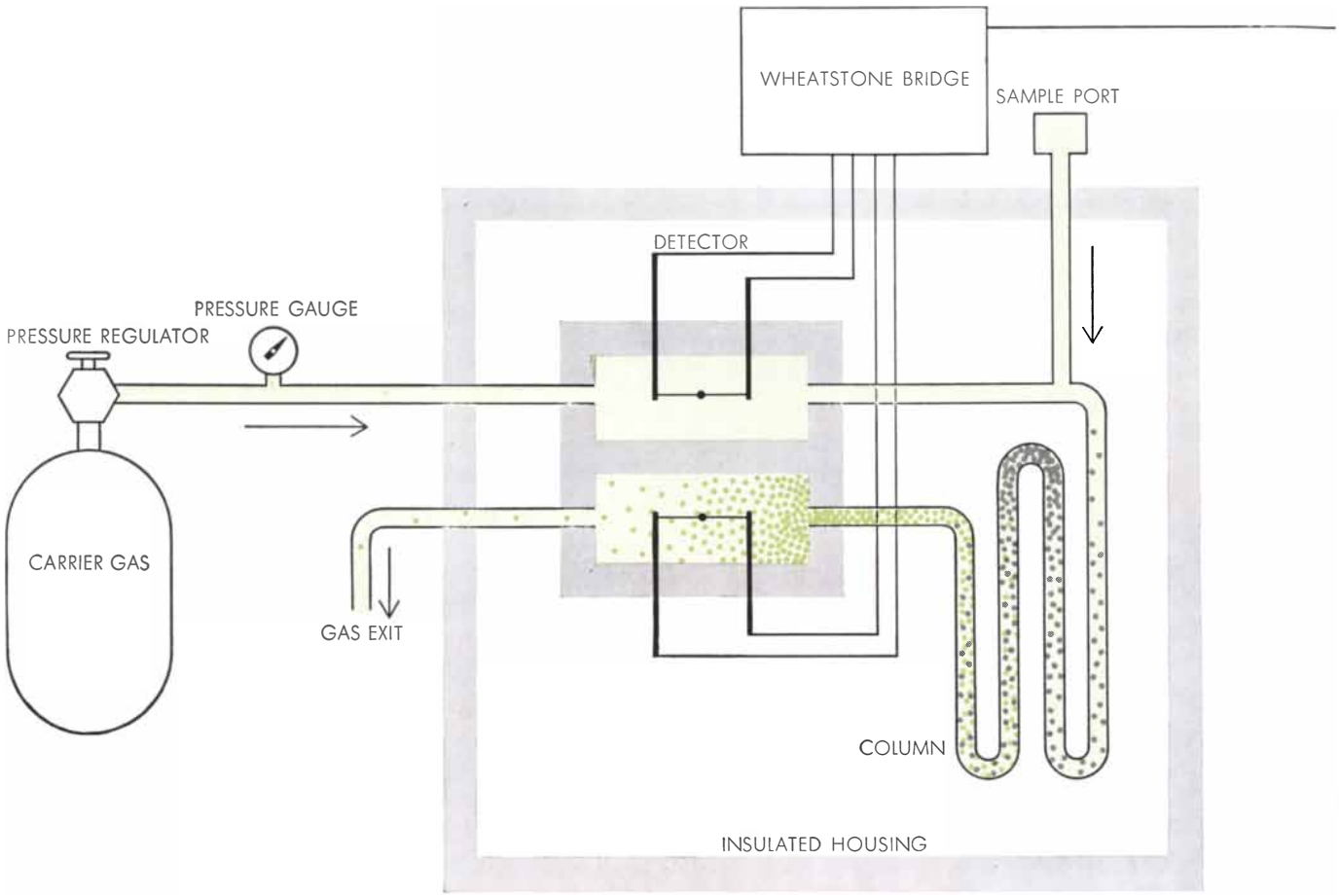
The liquid selected as the partitioner largely determines the performance of the chromatograph. The partitioner must not react with the sample being analyzed and it must not be volatilized by the stream of carrier gas that propels the sample through the column. Above all, the partitioner must show different affinities (to use an old-fashioned term) for each of the substances likely to be found in the sample mixture.

Partitioners that work well with one type of sample may be completely useless for another type. As the sample is moved through the column by the carrier gas, the partitioner must interfere in a selective fashion with the progress of each compound present, slowing up the progress of some and letting others travel through the column more swiftly. At the outlet of the column a detecting device signals the emergence of each different compound by activating a recording pen on a strip chart.

In the search for good partitioners, builders of gas chromatographs have experimented with virtually every viscous fluid, grease and low-melting-point solid in the laboratory, including such substances as silicone rubber, stopcock grease and hydrogenated shark oil. This eclecticism has sometimes had unhappy results when excellent separations were achieved with substances that could never be duplicated, even when re-



CHROMATOGRAPHIC SEPARATION takes place when a sample mixture (*black and colored balls*) is driven by an inert gas through a capillary tube coated with an immobile liquid called a partitioner. In the original form of gas-liquid chromatography the partitioner was deposited on a pulverized packing. The role of the partitioner is to dissolve (and adsorb) various components of the sample in differential fashion. After fractionation the separated components pass through a detector, whose output is recorded on a chart.



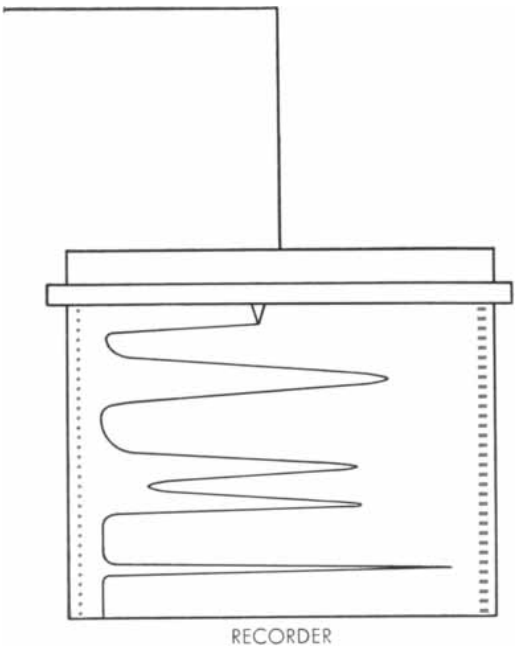
SIMPLICITY OF GAS CHROMATOGRAPH is among the virtues of the instrument. The sample is swept by a carrier gas through a specially treated column in which various components of the sample migrate at different speeds. A detector measures the electrical conductivity of the gas leaving the column as well as that of the carrier gas entering the column. The difference, as determined by

ordered by the same lot or batch number. In order to deposit the viscous partitioner on the pulverized support, the partitioner is usually dissolved in a volatile solvent that can be evaporated, leaving the partitioner behind. Normally the partitioner weighs from about a quarter to a third as much as the pulverized packing in the column. The coated particles should flow freely, and there is some advantage in holding the amount of partitioner to a minimum.

Let us now look more closely at what happens to a collection of molecules injected into the carrier gas moving through the column of a gas chromatograph. Some of the molecules rapidly dissolve in the liquid partitioner, and a dynamic equilibrium is soon established as they pass back and forth between the liquid and vapor filling the interstices of the column packing. At equilibrium the concentration of molecules of each type is a constant ratio in the two phases. Molecules of compound *A*, for example, may partition themselves equally between the liquid and vapor phase; molecules of compound *B*, on the other hand, may be highly soluble in the liquid phase and therefore relatively few of them will be found in the vapor phase once equilibrium is reached. In this case the moving gas will tend to sweep molecules of compound *A* down the tube, leaving those of compound *B* behind in the liquid. Once the molecules of *A* have been carried to a region containing fresh liquid, however, some of them will redissolve until a new equilibrium is reached. By the same token, when fresh gas passes over the liquid containing molecules of *B* in solution, some of the *B* molecules will enter the gas phase in order to establish equilibrium. If we regard the sample as a plug of molecules moving through the column, we can visualize a sort of molecular leapfrog. The volatile molecules are continuously being swept to the head of the plug, where they redissolve; the less volatile molecules fall to the tail of the plug, but they too are continuously being picked up and inched forward by the gas stream pressing from behind. Eventually, if conditions are right, all the molecules of the more volatile components will be carried clear ahead of those of the less volatile and a clean separation will be achieved.

A major problem in the early days of gas chromatography was to find a detector that would respond quickly as the separated compounds emerged in rapid succession from the end of the fractionating column. The job of the detector is not to identify the emerging compound but merely to signal when the output gas is carrying foreign molecules and when it is not. Once this is known it is easy enough to calibrate the output readings by feeding samples of known composition into the instrument.

In their original gas chromatography of fatty acids or amines (which are organic bases) James and Martin passed the output of their column through a solvent that extracted the acids or amines from the effluent gas. The collecting was done in a series of small batches so that the time of emergence from the column could be recorded. Using a color indicator, James and Martin could tell when an acid or an amine emerged from the column. They then titrated each sample to determine how much acid or base was present. The job not only was



a Wheatstone bridge, is recorded on a strip chart. The instrument can be calibrated by analyzing samples of known composition.

laborious but also it lent itself to titratable samples only.

A much simpler and more universal solution to the detection problem was finally found in the thermal-conductivity cell. The cell utilizes the fact that the electrical resistance of a heated wire varies with its temperature. If a gas of constant composition and flow rate is allowed to pass over a heated wire, the wire will be cooled a constant amount and so register a constant resistance. If a gas of different thermal conductivity appears in the stream striking the wire, the wire will change in temperature and in electrical resistance, and this change can be recorded in ink on a strip chart.

At least two other detection devices have been developed for gas chromatography. In both devices a change in gas composition is signaled by a change in the ionization—and hence the electrical conductivity—of the gas stream. In one device the gas stream is ionized (broken up into electrically charged fragments) by being passed through a hydrogen flame; in the other device the stream is ionized by bombardment with radiation from a bit of radioactive material.

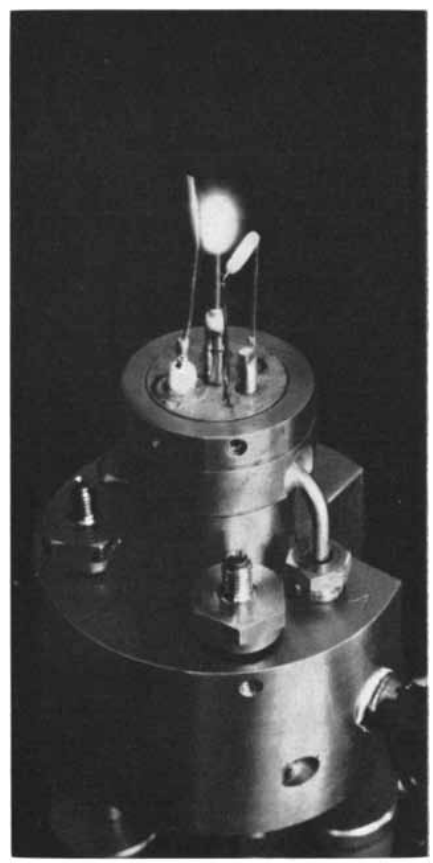
To obtain sharply defined gas-chromatograph records, called fractograms, the instrument designer can vary the pressure and flow rate of the carrier gas, the operating temperature of the column, the structure and particle size of the column packing and, of course, the nature of the liquid partitioner. A considerable body of theory and empirical art has grown up around the solute-solvent interactions that underlie effective partitioning.

For example, if one wishes to separate a hydrocarbon and an alcohol having nearly the same boiling point (*e.g.*, 3-methylpentane and methyl alcohol, both of which boil at about 64 degrees centigrade), it is desirable to use a partitioner that resembles the alcohol in containing hydroxyl (OH) groups in its structure. The hydrogen atom of the hydroxyl group in the alcohol will tend to form a bond with the oxygen atom of the hydroxyl group in the partitioner. The hydrocarbon will not form such a bond and will therefore move through the column faster. A relatively nonvolatile liquid containing hydroxyl groups that can be used for this separation is polyethylene glycol.

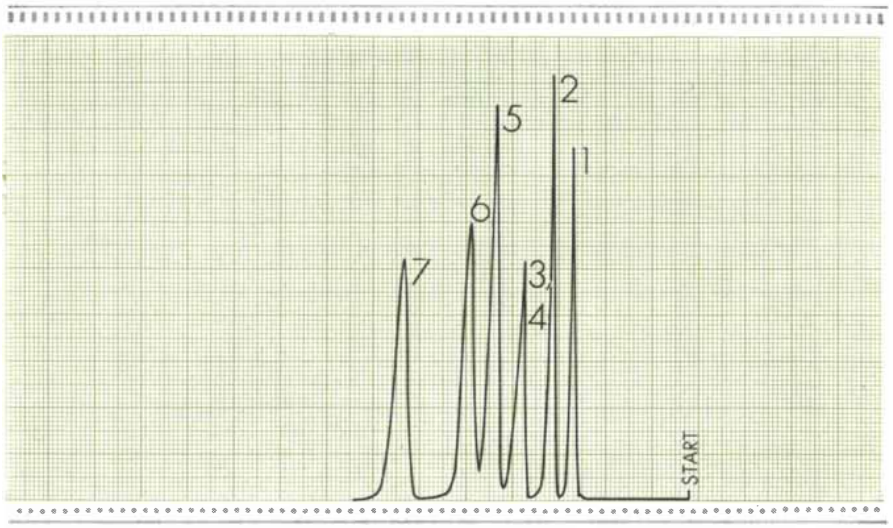
Offhand one might think that a partitioner, to be effective, should show a differential solvent action on each component in a sample mixture. One might then conclude that the solutes would be retained by a partitioner in order of their solubility. In practice, however, this is not always true. The reason is that solubility as conventionally measured with solvents in bulk—say in a laboratory beaker—is quite different from the solubility shown when a solvent is thinly distributed over an enormous surface area, as it is in a chromatographic column. In the latter case a new factor appears: the effect of surface adsorption. A solute is said to be adsorbed if its concentration in the immediate region of the surface exceeds that in the bulk liquid. Adsorption can arise either at the interface between the solid support and the partitioning liquid, or at the interface between liquid and gas, or it can occur in both regions. Sometimes adsorption enhances the desired separation; at other times it interferes with it. For example, when alcohols are chromatographed on a hydrocarbon partitioner, they tend to displace the hydrocarbon and fasten themselves to the support.

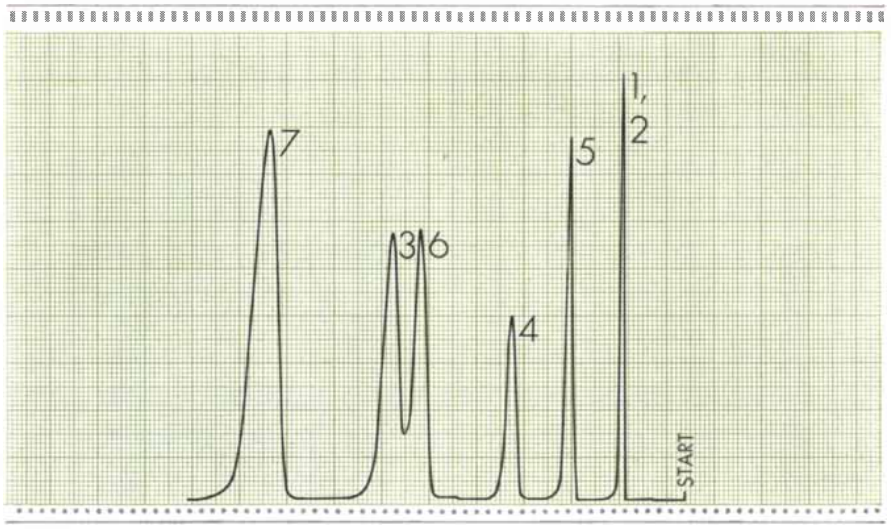
Considerable work has been done on gas chromatographs that achieve separations strictly by differential adsorption on the solid packing, without help from a liquid partitioner. This is called gas-solid chromatography, and for certain sample mixtures in which the molecules have much the same architecture it produces even sharper separations than gas-liquid chromatography.

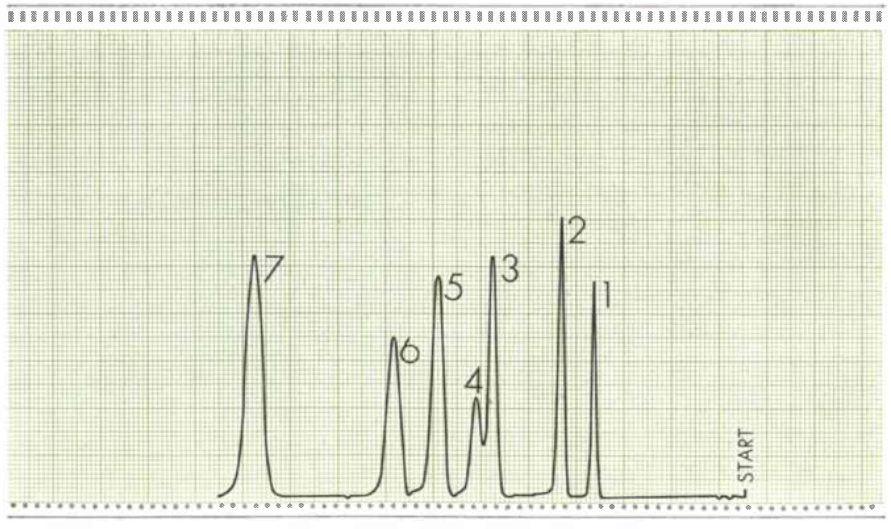
Until recently gas-liquid chromatography was successful only with sample mixtures whose components boiled within about 50 degrees C. of one another. When the boiling range was greater than that, it was usually impossible to choose a column operating temperature that would sharply resolve both the least volatile and most volatile components. If the temperature was held low, the more volatile substances would be resolved, but the less volatile would lag behind and become spread out by diffusion. By raising the temperature the resolution of the less volatile could be sharpened, but the more volatile would then rush through the column and emerge in a poorly resolved bunch. The

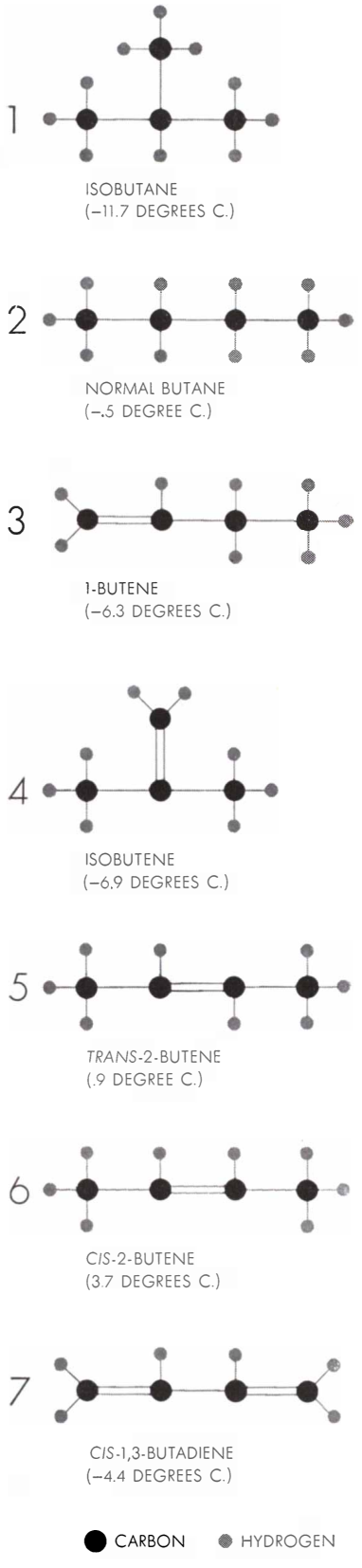


IONIZATION DETECTOR, one of three principal types of detector used in gas chromatography, employs a hydrogen flame to break up chemical compounds into electrically charged fragments (ions). By measuring the electrical conductivity of the ionized gas at the column exit the detector signals the passage of various fractions of the sample. In this photograph the cover of the detector has been removed and the normally colorless flame has been made visible.









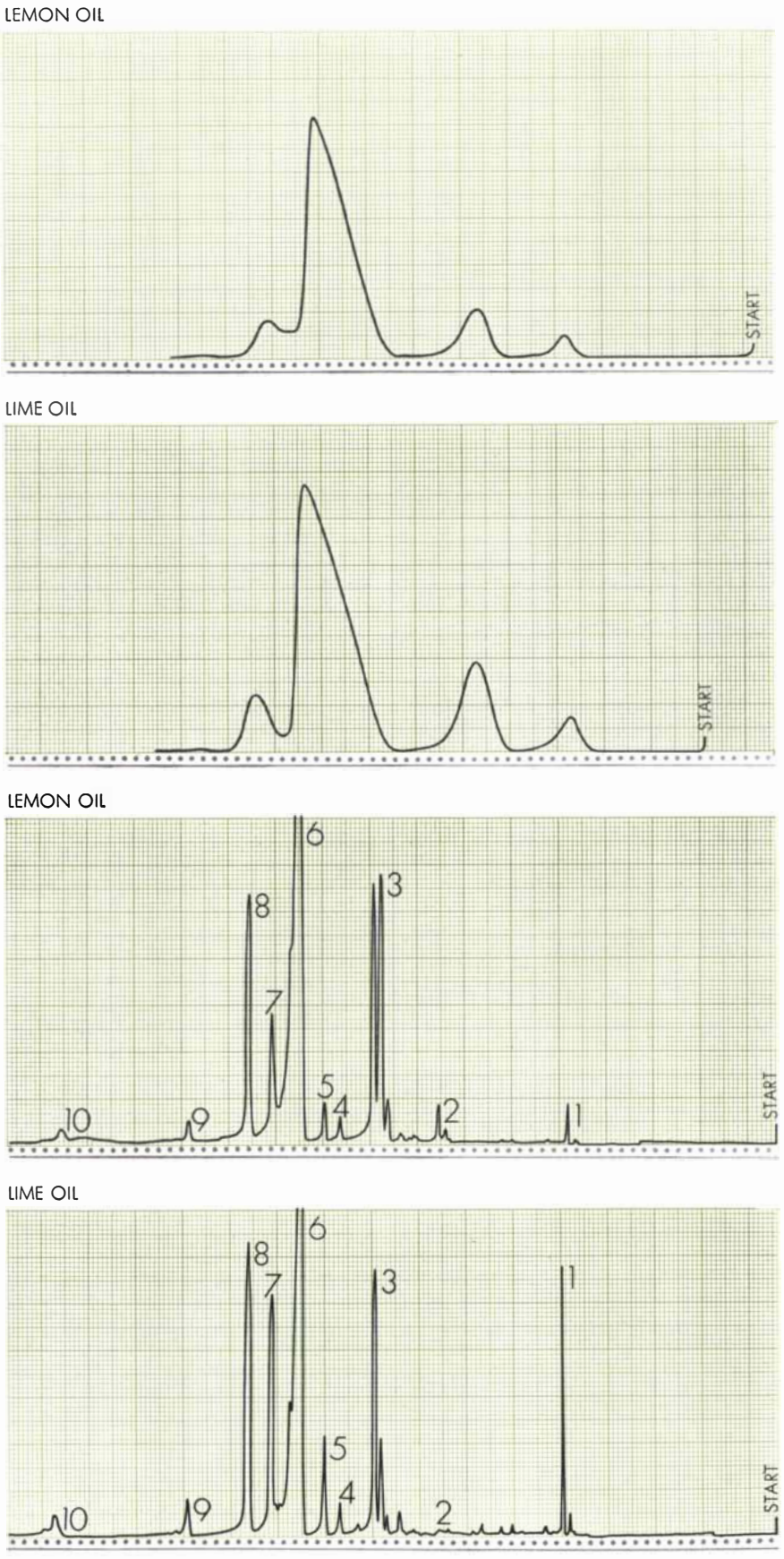
SEPARATION OF FOUR-CARBON HYDROCARBONS, which boil within a narrow range, is a familiar problem in the oil and synthetic rubber industries. The molecular structure and boiling points of the principal four-carbon hydrocarbons appear at right. The fractograms (*left*) show how these compounds are fractionated by different partitioning liquids: dimethylsulfolane (*top*), silver nitrate in diethylene glycol (*middle*) and hexanedione (*bottom*). The upper two fractograms were made on columns four meters long operated at 25 degrees centigrade. Bottom fractogram was made on a column two meters long operated at zero degrees.

answer to this problem has been found in "temperature programing," which simply means starting the separation at a low temperature and raising it in regular steps until the job is done. By this procedure one can fractionate mixtures whose components have a boiling range as broad as 200 degrees C.

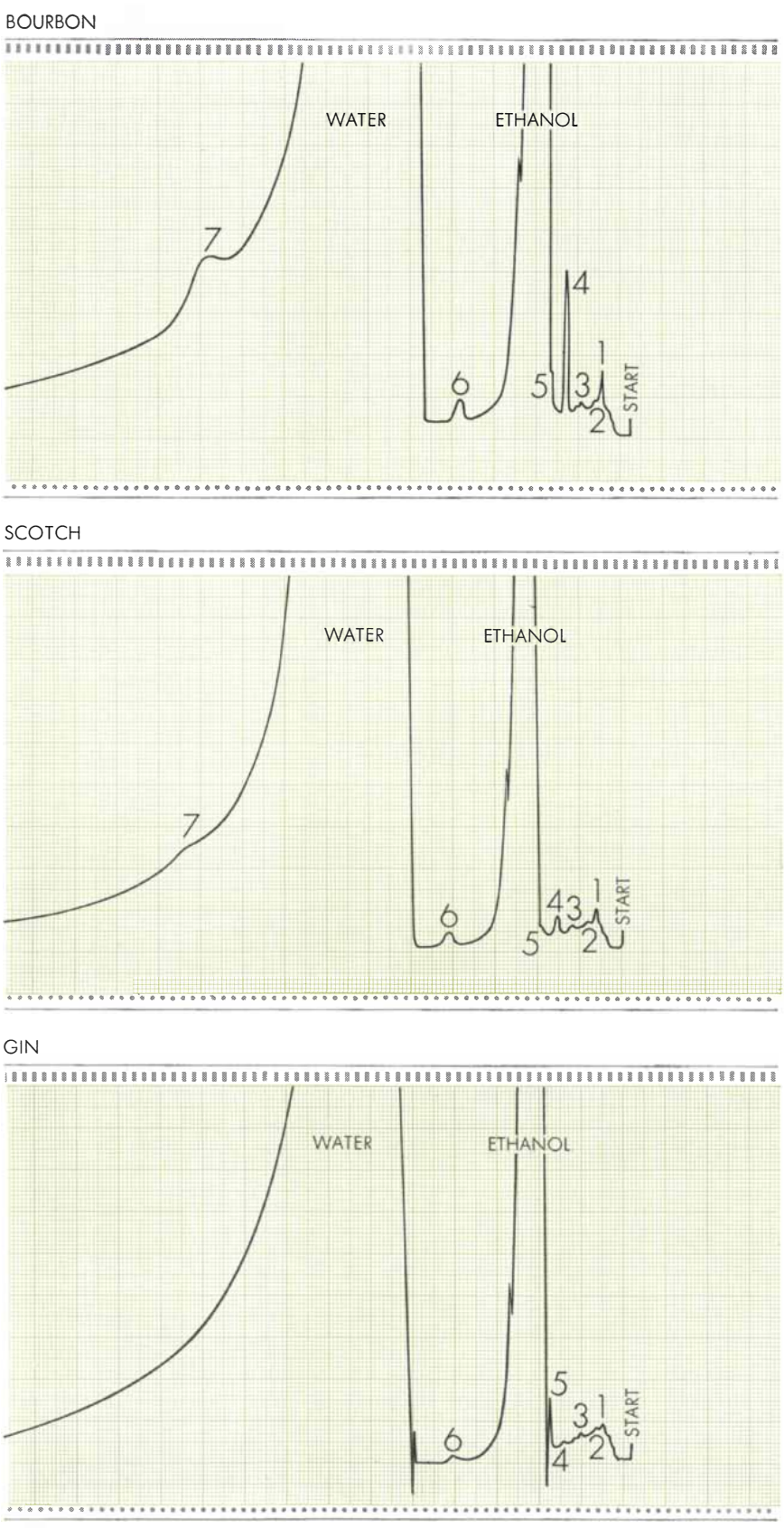
Actually it is not necessary for the components of a sample to be anywhere near their boiling points for gas chromatography to work. At the University of Arizona we have analyzed samples of volatile inorganic halides (for example, niobium chloride) at temperatures near their melting point, or in the vicinity of 250 degrees C. Other investigators have operated machines at 500 degrees C. that will chromatograph compounds boiling as high as 625 degrees C.

An important advance in the design of gas chromatographs was made about 1956 by Marcel J. E. Golay, a consultant to the Perkin-Elmer Corporation. Golay, a student of information theory, conceived the improvement after making a theoretical study of the migration of a solute through a packed column. In the fashion characteristic of theorists he sought a simplified model to substitute for the actual highly complex situation prevailing in a tube packed with porous particles of random shapes and sizes. He selected for his model a bundle of capillary tubes, equal in diameter to the granule size of the packing, which were evenly coated with the partitioning medium. Upon analyzing his calculations Golay concluded that a single, very long coated capillary tube would achieve separations equivalent, if not superior, to those produced by packed columns and do so in a much shorter time and under less severe conditions of temperature and driving pressure. Golay met his skeptics by preparing some of the first columns himself. They amply fulfilled his predictions.

Commercial columns of his design usually employ a capillary tube having an inside diameter of .01 inch. The tubes, ranging from 150 to 1,000 feet in length, are coiled into a compact helix [*see illustration at right on page 59*]. If these fine capillary columns are not to be flooded, the sample size must be extremely small, usually about five-millionths of a cubic centimeter in liquid volume, or about five-thousandths of a cubic centimeter after vaporization. To obtain such minute volumes a sample some 20 times larger is vaporized and shot through a stream splitter that ad-



PERFORMANCE OF OLD AND NEW INSTRUMENTS is demonstrated by fractograms of two similar essential oils: the terpene fractions of lemon oil and lime oil. When analyzed on a standard two-meter packed column, the two oils produced the upper pair of fractograms. When analyzed on a 175-foot capillary (Golay) column, they produced the detailed lower pair. The peaks labeled "6" are made by limonene ($C_{10}H_{16}$), which has a lemon-like odor.



1 ACETALDEHYDE
2 FORMALDEHYDE
3 ETHYL FORMATE
4 ETHYL ACETATE
5 METHANOL
6 PROPANOL
7 ISOAMYL ALCOHOL

FRACTOGRAMS OF POTABLE SPIRITS provide a sensitive measure of volatile components that influence taste and aroma. These analyses confirm that Scotch and gin contain fewer such components than bourbon. (Isoamyl alcohol is fusel oil.) Samples were run on a two-meter packed column. Peaks were identified by adding various known compounds to a whiskey that had previously been analyzed. Analyses were made by Robert B. Carroll, a chemical consultant, and Lawrence C. O'Brien, then at the Perkin-Elmer Corporation.

mits about 5 per cent to the column and discards the remainder. Ordinarily a few minutes to half an hour are required for such samples to migrate through the column. As an extreme example of what can be achieved with a capillary column and a highly sensitive detector, it has been possible to record 14 peaks—each representing a separate compound in a sample of closely related hydrocarbons —in less than two seconds.

The areas under different peaks in a fractogram are roughly proportional to the fractional amounts of each substance in the original sample. With care the method is accurate to about 2 per cent. In general the investigator has two methods for discovering exactly what substance is represented by a particular peak. The commonest method is to use samples of known composition to calibrate the machine. Alternatively he may isolate the column effluent that produced a given peak and characterize it by some suitable analytical technique, for example by using an infrared spectrophotometer or a mass spectrometer. The gas chromatograph will separate not only compounds with closely similar properties but also various forms of individual compounds. In organic chemistry almost all but the simplest compounds can exist in two or more forms known as isomers. These are molecules containing the same number and kind of atoms fitted together in different geometrical arrangements [*see illustration on page 64*].

In some cases gas chromatography provides direct clues to compound identification. The volume of gas, called the retention volume, that precedes a particular solute through the column depends on the nature of the solute, the choice of partitioner and the temperature. Within limits, retention volume is not overly sensitive to length of column, driving pressure, flow rate or the amount of partitioner employed. As a result one can determine retention volumes for various compounds of interest and use these volumes for identifying unknown samples [*see illustration on opposite page*]. A considerable effort is now being made to utilize gas chromatography for determining the structure of molecules by

relating retention volume to particular molecular configurations.

Much of the explosive growth of gas chromatography can be attributed to the petroleum industry, which has to deal with materials of extraordinary complexity. Crude oils commonly contain more than 150 different hydrocarbons, many of them isomers of each other. For separating them gas chromatography has proved a powerful tool. Oil firms have now begun to use gas chromatographs for continuous monitoring of process streams in the refinery. Chromatographic analyses will be transmitted to a computer, which will automatically calculate the optimum operating conditions for catalytic cracking towers. Gas chromatography is almost the only method available for detecting certain catalytic poisons that impair the polymerization process when present in concentrations of only 50 parts per million.

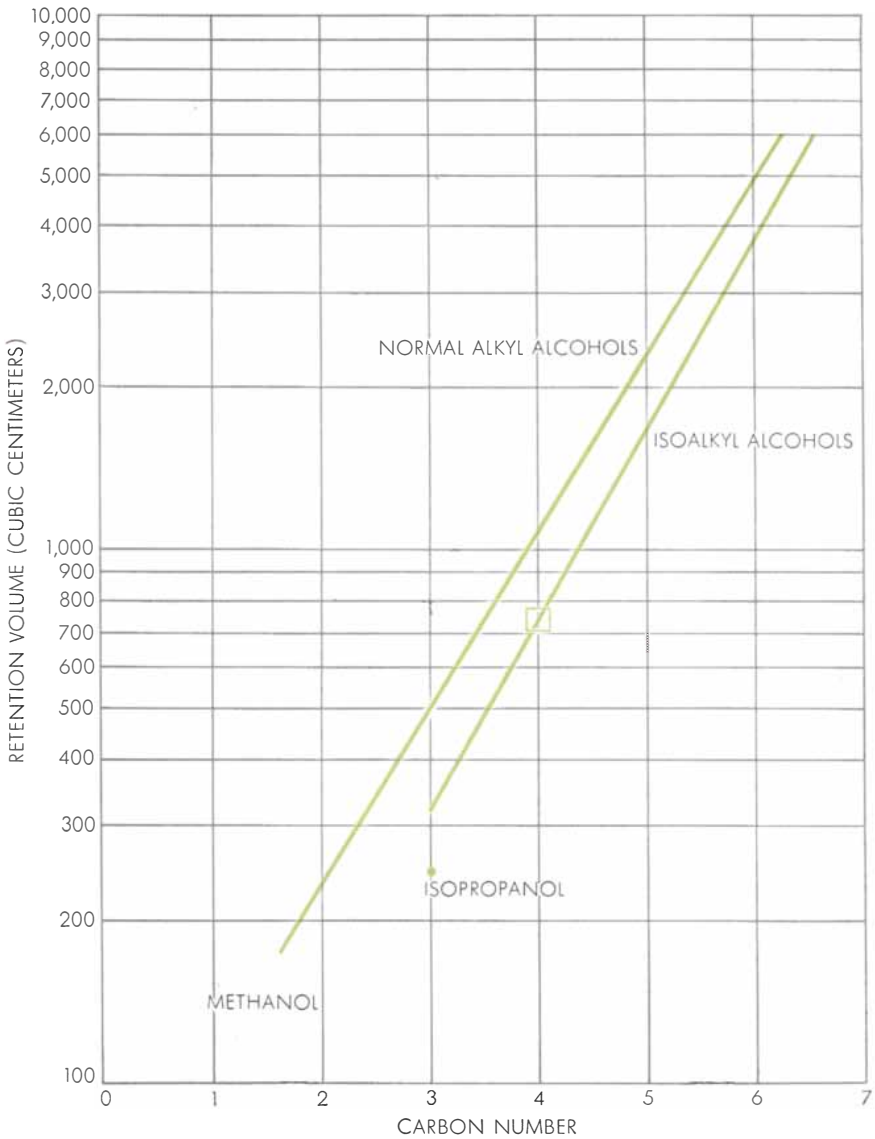
Automotive engineers use gas chromatography for analyzing the exhaust of engines under a variety of operating conditions with various fuels. The results are used to improve both engines and fuels and also contribute to a reduction in the air pollution created by engine exhausts.

Elsewhere, fractograms are rapidly replacing the opinions of "sniff and taste" panels as a method of assaying the uniformity of instant coffees, blends of whiskey and many other products whose commercial acceptance depends on subtle flavors and aromas. In such products gas chromatography can often detect trace components present in only one part per billion. It is, in fact, the first analytical instrument to rival the human nose in sensitivity.

Before long one can reasonably expect that gas chromatography will be used not only as an analytical tool but also as a method of preparing ultrapure materials. Columns are now operating that can refine and separate the components in batches about one ounce in size. If the process can be made continuous, it should be able to provide laboratory chemicals and even commercial compounds having a wholly new order of purity.

Recently Donald E. Johnson, Sara Jo Scott and Alton Meister of Tufts University announced success in a long-sought goal: separation by gas chromatography of derivatives of the amino acids. The method may prove superior to the liquid-solid chromatographic method, employing a column packed with ion-exchange resins, that has been widely used for the analysis of the amino acids in proteins [see "The Chemical Structure of Proteins," by William H. Stein and Stanford Moore; SCIENTIFIC AMERICAN, February].

A gas chromatograph of remarkable capabilities is now being developed by the Aerojet-General Corporation and the Jet Propulsion Laboratory of the California Institute of Technology; it will be placed aboard the *Surveyor* moon probe scheduled for launching in 1963. Upon reaching the moon the probe will pick up samples of lunar crust, grind them and feed them into a heater, where they will be pyrolized. The gas chromatograph will include two types of detector to analyze samples pyrolized at 150, 325, 500 and 1,000 degrees C. The heater and chromatograph must consume no more than 10 watts of current. The whole apparatus must weigh no more than 11.5 pounds and must fit inside a box measuring 8 by 8 by 10 inches. Finally, to withstand the shock of landing on the moon, it must tolerate a deceleration force equivalent to 100 times the force of gravity on the earth. An important objective of the lunar chromatograph is to learn whether or not the moon's crust contains complex organic compounds of the type associated with living matter. This is an impressive assignment for an analytical tool that has come into general use only within the past five or six years.



COMPOUND IDENTIFICATION is often possible with gas chromatography when the sample is known to contain one of a limited number of compounds. For example, normal alkyl alcohols, whose carbon atoms form a straight chain, require a greater volume of carrier gas to drive them through a given column than isoalkyl alcohols having the same number of carbon atoms in a branched chain. Thus if an unknown four-carbon alcohol has a retention volume of 750 cubic centimeters of carrier gas (*square*), one can be sure it is isobutanol and not normal butanol, which would have a retention volume of about 1,000 c.c.

The Ecology of the High Himalayas

Around 15,000 feet the slopes below Mount Everest support a typical alpine community of plants and animals. Above this altitude there is a unique community that is founded on wind-blown organic matter

by Lawrence W. Swan

The several parties of adventurous climbers who have stood on the summit of Mount Everest during the past decade have not tarried there long enough to find out whether or not the top of the earth harbors any permanent inhabitants. It may be that the upper limit of the settled community of life lies somewhere below on the flanks of the mountain. Little is known about the ecology of the high Himalayas under the lofty peaks of Everest, Kanchenjunga, Makalu and Cho Oyu. This area, embracing some 2,000 square miles of wilderness high above the tree line, is without vehicles or laboratories. The investigator is only as good as his lungs, legs and endurance; he must walk and climb for a month to acclimatize himself, and even then, in the thin air among the barren rocks, he finds it difficult to shake the impression that he is only one step from the moon.

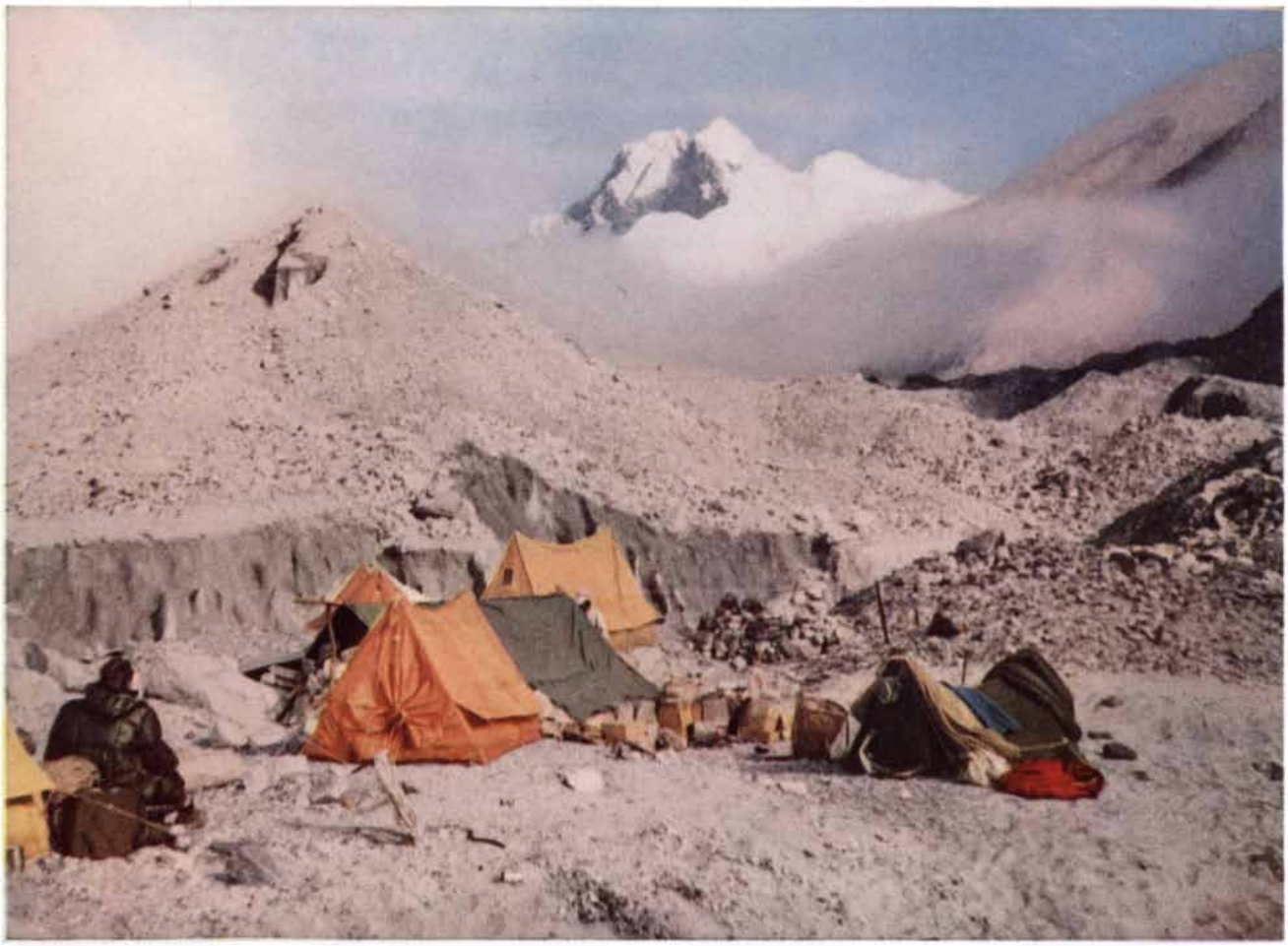
Lack of air sets the primary ceiling on the altitude to which a man may climb and function. But the black, yellow-billed birds called choughs (*Pyrrhocorax graculus*) visited the high camps of early Everest expeditions at nearly 27,000 feet, and last year the Indian expedition to Everest found the frozen carcass of an eagle at over 25,000 feet. The British explorer George Lowe, who has spent as much time as anyone at mountain altitudes above 23,000 feet, has told me of watching from the slopes of Everest while a flock of bar-headed geese (*Eulabeia indica*) flew in echelon directly over the summit. On an April night from a camp at 15,000 feet on Barun Glacier, I myself have heard the distant honking of these birds flying miles above me unseen against the stars over Makalu, on their way to the lakes of Tibet. It is known that the bar-headed geese start from the lakes of India at sea level and complete their spring migration in a single majestic flight; one can only speculate on what adaptations permit them to accomplish this feat. All of these birds, however, must be reckoned along with men as no more than occasional and transient visitors to the high places of the Himalayas.

The first creature credited as a permanent resident of the extreme heights of these mountains was a species of jumping spider (family Salticidae). Several immature specimens were collected at 22,000 feet on Mount Everest by members of a British expedition in 1924. For many years this find was a subject of controversy. Small spiders can be carried great distances by their air-borne threads, and it was argued by some that the Everest spiders had been carried up the side of the mountain by the wind. Those who insisted that the spiders had been collected from their native habitat had to solve a problem of logic. Spiders are universally predaceous; it was necessary to show that there were insects as well as spiders at 22,000 feet. Furthermore, there would have to be plant food for the insects. The collectors had seen neither plants nor insects, only rock and ice. One partisan advanced the self-defeating notion that the spiders ate other spiders. Spiders do eat other spiders, but this would scarcely provide the basis for a permanent population, at any altitude.

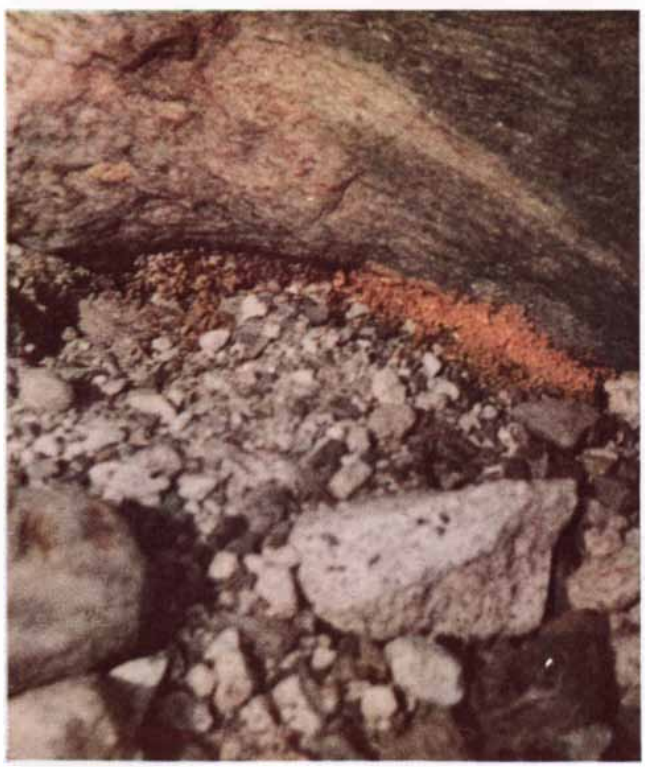
As a student of the ecology of the alpine regions of North America, I had my first opportunity to look into the enigma of the jumping spiders of Mount Everest in 1954 when I accompanied the American Himalayan Expedition to Makalu. (Last year I made a second trip to the region, on an expedition led by Sir Edmund Hillary and sponsored by the World Book Encyclopedia.) At first it seemed that these spiders were truly a wind-blown myth. There were no jumping spiders of any species seen during my first month of acclimatization on the lower slopes of the mountain.

Spiders of many other kinds, however, were observed occupying easily understandable environmental niches. Below the tree line, at 13,500 feet, in the sheltering fir and rhododendron forests, there were orb-weaving spiders. For some distance above the tree line the irregular webs of theridiid spiders were common, but these disappeared with the shrubs. In the higher regions I collected grass spiders of the family Agelenidae. Still higher there were ground-hunting wolf spiders of the family Lycosidae, but these became scattered and infrequent in the rock-strewn slopes at 17,000 feet. Above this level there were some plants and hidden insects, but spiders—even wind-blown spiders—were not to be seen. At higher levels the south-facing slopes of the range were sheathed in massive ice.

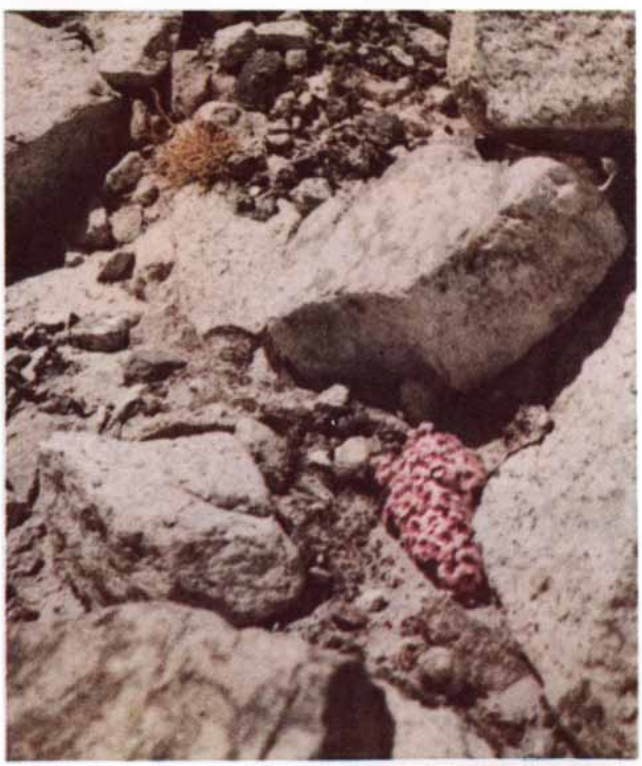
The alpine zone of the Himalayas, above the tree line and below the upper limit of green plants, supports the complete sort of biological community that is observed in other comparable regions of the world. The heights to which it reaches are a function, from place to place, of local conditions, determined especially by the altitude of the snow line, the character of the soil, the availability of water in the liquid state and the exposure of the mountain slope to sunlight. Up to 17,000 feet there is still what can be called a plant cover, dominated by dwarf rhododendron (*Rhododendron setosum* and *R. anthopogon*) and juniper (*Juniperus squamata*) and including various grasses, sedges, buckwheats, gentians and small primulas, plus the sandwort (*Arenaria*), edelweiss (*Leontopodium*), rock jasmines, (*Andro-*



CAMP IN THE HIMALAYAS was pitched at 18,000 feet on Barun Glacier during 1954 American Himalayan Expedition. The highest white peak in background is Lhotse; next highest to right is Everest. Photographs on this and following page were made by the author.



HIGHEST KNOWN PLANT, a cushion plant (*Stellaria decumbens*), was found at 20,130 feet on the northern slope of Makalu.



PINKS (*Parrya lanuginosa*), named for their color, were found at 18,500 feet on Makalu. At upper left is a small brown sedge.

PATCH OF PLANT LIFE growing on a "shelf" of a slope appears as a dark oval at right in this photograph taken at 19,300 feet. The view is down the slope. The shelf is an area of water drainage. The snow seen farther down the slope is part of Barun Glacier.

BARREN ARID ZONE below a snowcap is seen from 20,000 feet. The barrenness of the area indicates that the snowcap does not give rise to surface water or streams. Although no plants were found, there were springtails (small wingless insects) under the rocks.

sace), sagebrush (*Artemisia*) and joint pines (*Ephedra*).

Insects are common in this region up to 16,000 feet. At these altitudes I have collected ants, bees, wasps, flies, butterflies, moths, beetles, true bugs, aphids, leaf hoppers, stone flies, May flies, thrips and grasshoppers. The behavior pattern of many of the insects illustrates a special feature of the environment at high altitudes: the sudden and extreme temperature changes that produce a variety of microclimates, which change from hour to hour in the course of a day. Flying insects disappear at night into crevices and holes. When the sun is shining, they are remarkably active; in cloudy weather they behave erratically. It is a common sight to see bumblebees and flies running on the ground or actually lying torpid beside a rock. More striking is the behavior of some butterflies: they not only come to earth during cloudy weather but lie on their sides in a manner most unbecoming to butterflies.

The common ground-hunting wolf spiders appear to be more resistant to cold than their insect prey. I have seen them active in the open when the snow was falling. They were carrying captured insects. To all appearances they had taken advantage of the sunless hours to seize ordinarily more active prey in the state of numbness and torpidity brought on by the cold. These observations are explained by the temperature curves that determine the changing microclimates [*see illustration on page* 73]. In the late afternoon, when the sun has sunk below the surrounding mountains, the warmest available environment is the surface of the ground. It is at this time, when flying insects are seeking night shelter, that the ground spiders go abroad.

The temperature of melting snow hovers around 32 degrees Fahrenheit in sun or shade. I have seen daddy longlegs (phalangids) running on snow in the sun; their activity showed that their body temperature was much higher. I found one phalangid that had somehow been trapped in the snow. The heat of its black body had melted the snow and the helpless creature, in spite of its long legs, had slowly descended into a self-made hole, where it had frozen. In the sunlight on snow a black phalangid may have a body temperature approaching 90 degrees F.; fortunately its long legs keep its body away from the snow. A black insect on the snow, unless it could live on the film of melting surface water, may well be doomed to sink into the snow.

At night a black-bulb thermometer exposed to the sky records a lower tem-

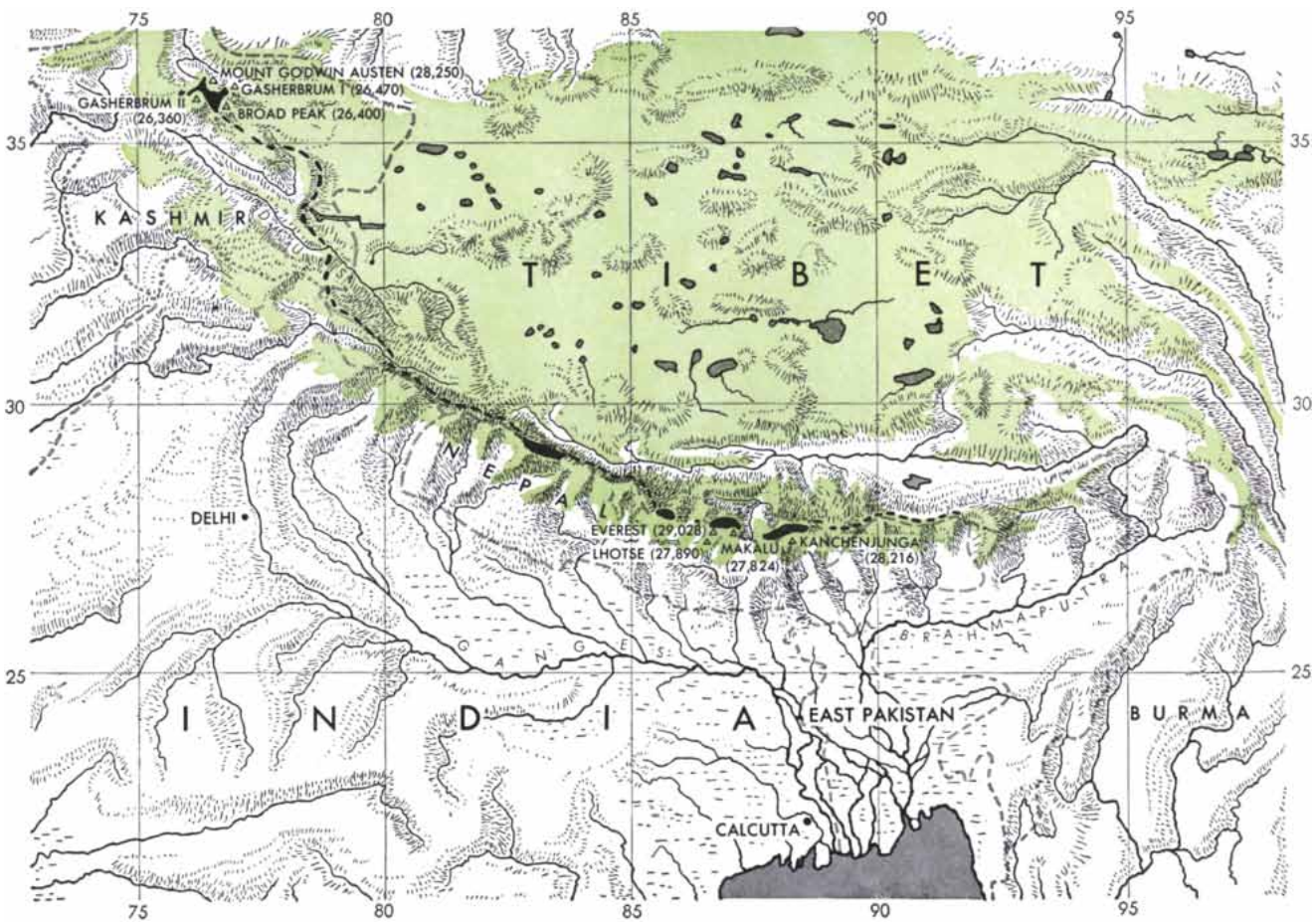
SUMMIT OF EVEREST (*center*) **is seen from southwest in this aerial photograph. Rock near summit is exposed and wide snowless areas on mountains to the north extend up to 22,000 feet.**

perature than a sheltered instrument. This is a measure of the intense reradiation of heat to the night sky. Hence the environment of nocturnal animals is very cold. Mammals such as mice, foxes and snow leopards find their lairs or shelters below ground, where the daily temperature variation (as indicated by the curve for ground temperature at a depth of six inches) is much narrower. This is the warmest available secluded environment; if the nocturnal mammals slept in the sun, they could well be too warm. On the same mountainsides, therefore, insects live in a tropical environment side by side with mammals that lead their active lives in an arctic world of subfreezing temperatures. These are the extremes, and the habits of other animals fall between them. Individual differences in behavior and ability to move from one place to another thus provide opportunity for members of the alpine community to find a wide variety of environments.

Since most reports of the Himalayan snow line refer to an elevation of about 17,000 feet, it may not be apparent how life can extend upward to more than 20,000 feet. The southern faces of the eastern Himalayas are exposed to a snowy deluge between June and September, and the snow on the outlying peaks may accumulate at 15,000 to 16,000 feet. Deeper in the range—toward Tibet—the precipitation drops off rapidly. Beyond the highest crest, in Tibet itself, it may decline to less than 15 inches. The northern gradient of the lighter snowfall gradually lifts the altitude of the snow line. In the innermost Himalayas, where there is less cloudiness and correspondingly a greater intensity of sunlight, the very term "snow line" becomes inappropriate. Tongues of snow descend to 18,000 feet, but vast areas are snowless with rocky extensions rising to great altitudes. If there is a continuous slope, and if the mountain mass is sufficiently large, the snowless rock may reach to 23,000 feet.

Near the end of May in 1954 our explorations led us up the glaciers toward the northern slopes of Makalu. Here, near the crest of the Himalayas, where the heaplike ridges of Tibet stand in sharp contrast to the more heavily snowed slopes to the south, the environment changed abruptly. At the upper limits of the alpine zone there were large regions bare of snow. And we could see, on the northern shoulders of Mount Everest, the same rock and snow buttresses where the jumping spiders had been collected 30 years before. In this setting, at 18,000 feet on the bare rocks beside the glacier, my eye was caught by the unmistakable bouncing and hesitating movements of a small black salticid spider. From this point to above 20,000 feet they were the only spiders collected. They were indeed permanent residents of a most unusual and desolate region.

After some study it became apparent that the spiders had available as prey a sparse population of anthomyiids: little flies that resemble the common housefly. These they stalked in the sun. When the sun was obscured by clouds, the spiders retreated under the rocks. Here they preyed on springtails: crawling and jumping insects of the order Collembola. Anthomyiid flies and springtails are for

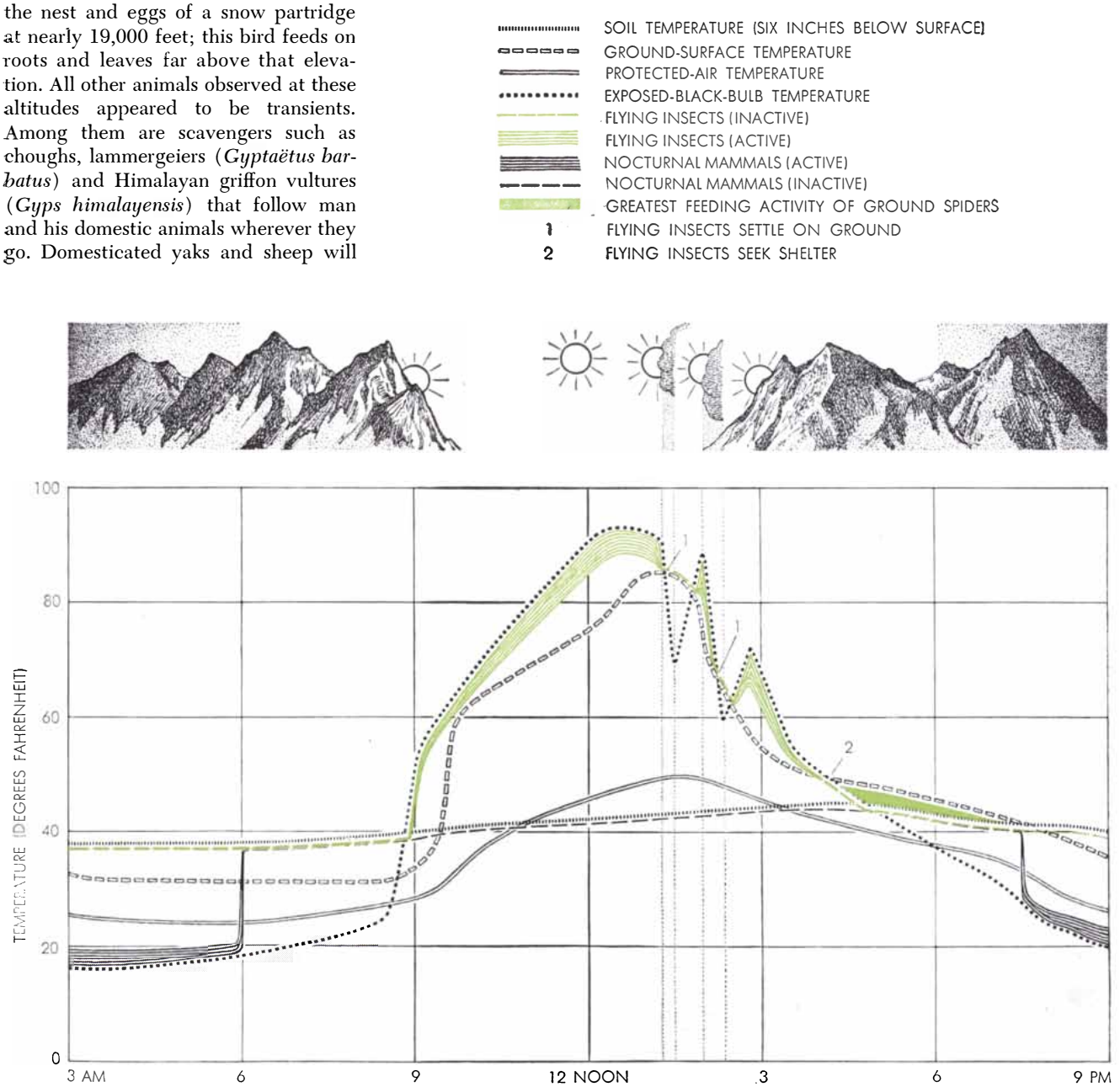


LIFE AT EXTREME ALTITUDES of 19,000 to 22,000 feet in the Himalayas is represented on this map by a group of small black areas. The gray areas are lakes. The land area above 13,000 feet is in color. The numbers in parentheses indicate altitude in feet.

the most part fungus-eaters or live on rotting vegetation. Plants and the fungi that promote their decay, although scarce and scattered, still persist at these altitudes.

In addition to the anthomyiid flies and springtails, the salticid spider may have another prey; the pupal case of a fly found on one occasion under a rock carried the neat round emergence hole of an unknown insect parasite. The salticid, in any event, is the primary predator of this supremely simple food chain. Herbivorous and predaceous mites, together with small centipedes, may range above 19,500 feet, but they were not collected above 19,300 feet. Once I found the nest and eggs of a snow partridge at nearly 19,000 feet; this bird feeds on roots and leaves far above that elevation. All other animals observed at these altitudes appeared to be transients. Among them are scavengers such as choughs, lammergeiers (*Gyptaëtus barbatus*) and Himalayan griffon vultures (*Gyps himalayensis*) that follow man and his domestic animals wherever they go. Domesticated yaks and sheep will wander wherever plants are available, and the same is true for wild sheep such as the bharal (*Pseudois nahura*). These animals are preyed on by snow leopards, which together with wolves and foxes may pursue them in their wanderings to very high altitudes. The small Tibetan weasel (*Mustela altaica*), which seeks out the eggs of snow partridges, is capable of raiding over wide areas wherever snow partridges are found. Mice of various kinds and small mouse hares, or pikas (*Ochotona ladacensis*), have been recorded at 19,500 feet, but they are more characteristic of the lower-altitude communities, where they provide a basic food for predators.

At about 20,000 feet the community of life thins out drastically. Plants become restricted to two general types of niche. They congregate where there is some subsurface drainage of water from a higher snow field, and they grow around the base of rocks. Plants such as the sandwort, edelweiss, the fluffy *Saussurea* and gentian, which are more general at 16,000 feet, appear to grow



ACTIVITY OF INSECTS AND MAMMALS at 16,000 feet on Ripimu Glacier in eastern Nepal was recorded by the author on October 10, 1960. The "Exposed-black-bulb temperature" is most representative of the environmental temperature of insects.

MAKALU AND VICINITY were visited by the 1954 American Himalayan Expedition, in which the author participated. The map, keyed to legend at right, shows the distribution of plant life in the region around Makalu and the location of the salticid spiders found by the author, as well as the route of the expedition (*colored broken lines*) and its camps (*roman numerals*). Numbers indicate altitude

only in the rock-base niche at these higher elevations. The grasses and sedges, which are hardier, become circumscribed to the same niche but at correspondingly higher elevations. At 20,130 feet I found a small cushion plant (*Stellaria decumbens*) and in this area no evidence of other plants. It seemed that this was near the upper limit for flowering plants; in all likelihood 20,130 feet stands as the highest altitude at which any living plant has been collected. There were, however, many additional slopes I did not succeed in exploring; it is reasonable to expect that flowering plants can be found still higher.

Lichens, so often considered a characteristic feature of high altitudes, are scarce, small and often dead at elevations of above 18,000 feet in the Himalayas. These plants are dependent on surface water, and their miniature size and infrequency point clearly to the dessicated state of the environment. Water as a liquid is largely confined to the subsurface and, except for glacial pools or snow fields covering an impervious base, is rarely seen. In addition, the extremely small quantities of water vapor in the air may preclude the formation of dew. On the dry, rocky slopes the availability of water is perhaps the major limiting factor for life. The concentration of plants in wetter spots below the drainage points of snow fields brings the lichens once more into evidence. But the lichens do not appear here in their usual role as pioneers on rocks; they occur rather as secondary growths, entangled in the spongy heads of prostrate rooted plants. Their position and form are mute testimony to the presence of subsurface water.

A small patch of yellow or pink flowers on a barren, rock-strewn slope calls attention dramatically to the rock-base niche. It is obviously a favored locality, but it has been somewhat neglected in ecological studies. Whereas this niche may be a conventional matter at lower elevations and in the family garden, at high altitudes it is something special. Some of these unusual qualities become evident after a snowfall. Rocks tend to protrude from the snow and, in contrast with the snow, which reflects the light, the bare rock surface absorbs radiant energy from the sun. Snow in the sun at high altitudes sublimates into vapor rather rapidly and melting is diminished. Next to the rock, however, the temperature increase is such that the snow melts rapidly and the water seeps under the rock, where its evaporation is slowed.

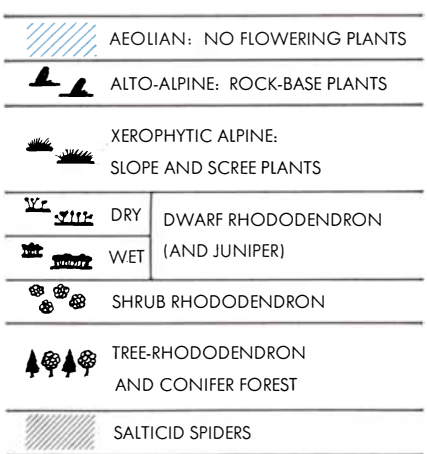
In addition to these manifest advantages, the rock-base niche possesses a more subtle attribute. The lee side of the rock is an efficient trap for wind-blown debris. Dead insects blown high onto snow fields indicate clearly that winds transport larger materials, but the most significant debris is pollen. Juniper bushes produce huge quantities of pollen, and tents pitched some distance away from these shrubs may acquire a yellowish cast. In addition, the many high-altitude flowers seem to carry more pollen than equivalent species at lower altitudes, and the relatively large number of pollinating insects emphasizes this apparent abundance.

I was not able to verify the actual trapping of wind-blown pollen by rocks. But the quantities of dust and soil filling the spaces beneath tilted rocks seemed to suggest that pollen could not avoid being captured by the reverse wind currents on the lee side of obstacles. The most convincing evidence was a collection of fluffy seeds under a rock situated far beyond the highest level of growth for the plant. It seems that much more organic debris is blown onto a mountain than off it. The rough slopes transform the whole range into a sort of immense debris separator.

Springtails generally turned up under rocks wherever there were plants or some indication of plant remains. Yet under rocks on totally barren slopes at nearly 20,000 feet, on which there was no visible indication of plants, past or present, some springtails could still be found. In such a location the presence of these tiny insects clearly suggests that they subsist on wind-blown organic debris. If so, they must surely be present at still higher altitudes, far above the level at which flowering plants can survive. Thus in the fastness of the Himalayas, beyond the true alpine zone that is delimited by the presence of green plants, there is a new ecological system to be explored: the supra-alpine or aeolian community, sustained by wind-blown debris.

The springtails and the salticids and whatever other creatures share this realm with them would require some moisture and therefore periods of time when the rock-base niche experiences temperatures above freezing, but a consistent and prolonged growing season would not be necessary. Surprisingly, the maximum temperature recorded on a sunny day may be higher at higher altitudes. At 18,000 feet I have recorded 92 degrees F. on the rock surface and 60 degrees F. at a six-inch depth in sandy soil. The air temperature in the shade was 55 degrees F. All these temperatures were higher than equivalent recordings at 16,000 feet. With increasing altitude there is less atmospheric absorption of transmitted radiant energy, and in general at these highest altitudes there is less effective cloudiness. Furthermore, since the higher slopes and ridges are less frequently in the shade of still higher ridges, in good weather they receive more intense sunlight for longer periods. It may be less obvious why the high peaks also become so cold. The answer is that, with decreased density, the air no longer delays the heat loss by reradiation during intervals of darkness and cloudiness; snow and ice eventually supervene, and the hottest sun cannot reach the energy-trapping rock base through this reflecting surface.

Nevertheless, where the concentration of winds or the angle of slope prevents the accumulation of snow, surface temperatures above freezing may be expected at enormous altitudes. Certainly the Everest spiders bear this out: they were not frozen at 22,000 feet. Icicles hanging from rock faces at even higher elevations confirm the fact that thawing temperatures do occur. Climbers have told of experiencing uncomfortable warmth at great altitudes. Jung Marmet and Ernst Schmidt, who climbed Everest in 1956, actually removed their down-filled clothing because of the heat



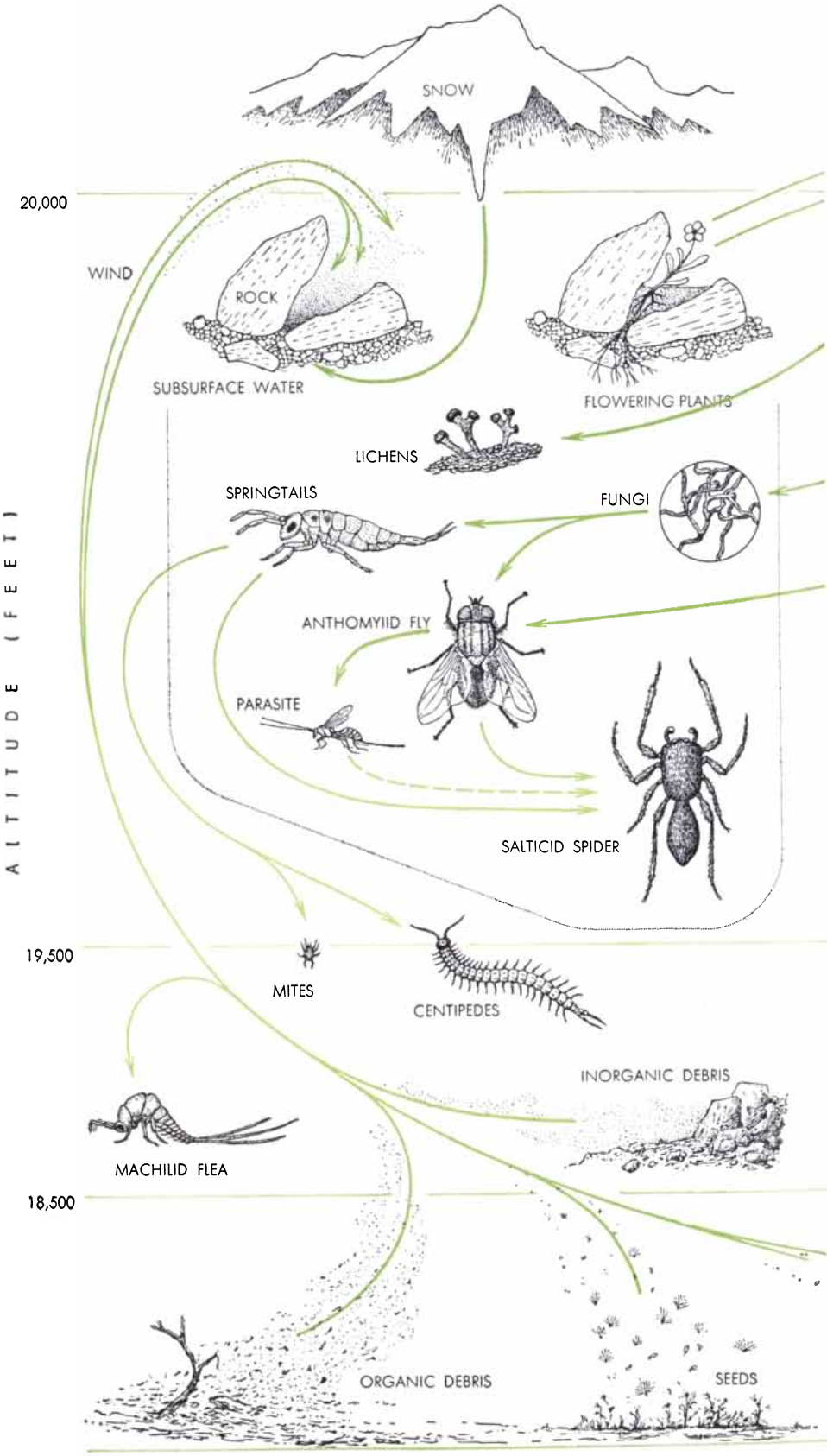
in feet. The aeolian zone, which is discussed in the text, is a new life zone containing insects and other organisms but no plants.

at an altitude of 28,000 feet. Such conditions can only prevail in sunshine and when the wind is reduced, but they are not infrequent on mountain summits. Photographs made on the summit of Everest by Sir Edmund Hillary in 1953 and Adolf Reist in 1956 (one of two men of the Swiss expedition to reach the summit) reveal a snowless expanse of rock and scree on a gentle slope only a few feet from the highest point. It is interesting to speculate whether springtails could survive here. There would in all likelihood be some organic debris even in this outermost part of the earth, and temperatures above freezing on occasion in some favored, wind-sheltered cranny might well occur. If springtails could not survive for lack of moisture, perhaps fungi or fungus-like bacteria, acting on microscopic quantities of pollen, may be present.

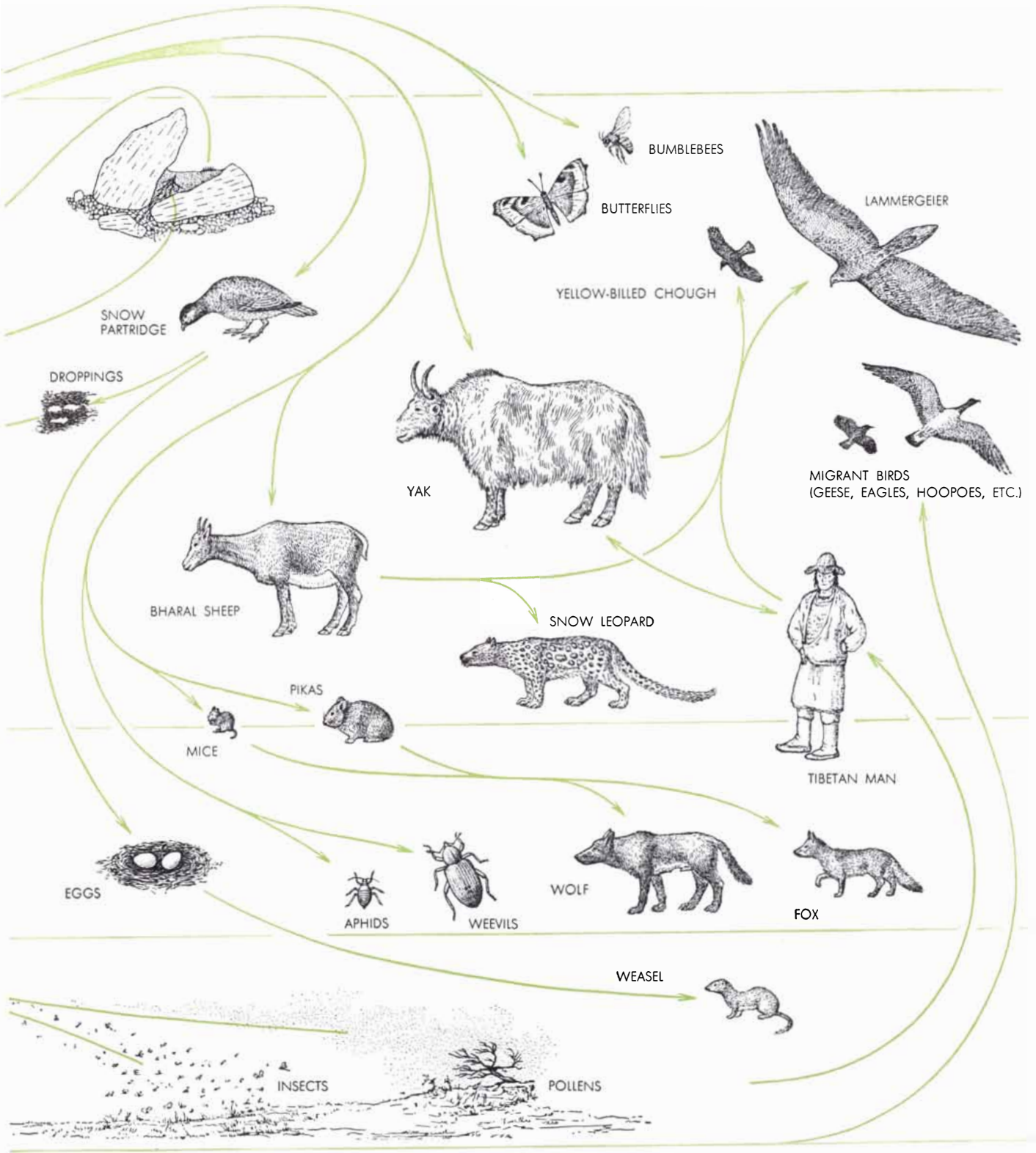
Barren and hostile to life as the aeolian province appears, a more forbidding environment is that which is presented at lower altitudes by the freshly cut rock rubble that covers a glacier. Here the angular slabs move and tumble, leaving gaping chasms and black voids between the boulders. A resting bird or an occasional transient fly seems to come from another world where there is life. Terrestrial man, when he dares to enter this domain, moves slowly and dangerously. It is a place to shun.

In just this sort of ungenial wasteland I was astonished to find at altitudes between 17,500 and 19,000 feet some large and active insects that are apparently confined to this incredible niche. They were dark-colored glacier fleas (*Machilanus*) belonging to the family Machilidae in the order Thysanura. Machilids are supposedly scavengers; this species could live, therefore, on wind-blown debris. They would sun themselves on the rocks until approached, and then, by strong flexing movements of their bodies, they would leap in random bounds to avoid capture. Time and again they would fall off the rocks and disappear into the dark gulfs deep in the glacier. It seemed as if they could never return to the surface.

It is curious that the animals that survive in the most inhospitable places and are pioneers in the zones beyond plant life are members of the orders Thysanura and Collembola, the oldest and most primitive insects. Perhaps there is a distant analogy between the highest altitudes and the sterile land



ECOLOGY AT HIGH ALTITUDES in the Himalayas is outlined. With obvious exceptions, arrows indicate ecological relationships; broken arrow, one assumed to exist. Arrows lead



from organisms that are fed or preyed on by the organisms to which they point except in the case of "Tibetan man" and the "Yak," whose relationship is mutually beneficial. Above 19,500 feet the organisms within the light dotted line are permanent residents.

of the Silurian period, when air-breathing arthropods evolved from their aquatic ancestors. These same primitive insect types may have been among the vanguard of animals on land, and it may be that the first land animals fed on the wind-blown debris that accumulated among the barren rocks of the world beyond the fringe of shore plants.

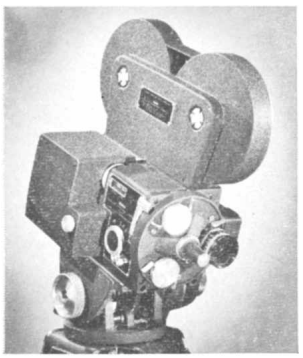
There is also an analogy between high altitudes and the deep sea. Both environments range beyond the limits of photosynthetic plants, and the inhabitants of these opposite realms survive on debris. Estimating on the basis of the abundance of life, it would seem that the ocean bottom, with its efficient gravity feeding system, is less hostile than the dry and frigid peaks that are provisioned by wind.

LAMMERGEIER (*Gyptaëtus barbatus*), seen here with a fledgling, is one of the largest flying birds. A scavenger that resembles both eagles and vultures, it is found in mountainous regions from the Pyrenees to northern India. Photograph was made by Eric Hosking.

Kodak reports on:

time-lapse at the professional level . . . the pencil that enrages the mind . . . Ektaline, sweet Ektaline . . . playing tag and other games

Clear, steady movies



This is a professional motion picture camera. It is called the *Kodak Reflex Special Camera (16mm)*. Its price is $1895. (Any amateur who buys it imperils his amateur status, but that's his lookout, not ours.) For a professional camera the price is remarkably low, particularly since it is the latest and most versatile of professional 16mm cameras and everybody knows that the cost of professional equipment in most fields rarely goes in any other direction than up. The base price includes a removable synchronous motor for 24 frames/sec, both 400- and 100-foot film chambers, and a Kodak Cine Ekton Lens, 25mm *f*/1.4. An accessory is available for any kind of time-lapse photography. Another accessory records synchronized sound. Etc., etc.

However long this recital were spun out, we doubt that the person for whom we spent 10 years making this camera is the kind who would commit himself on the strength of this ad. If he will signify his interest to Eastman Kodak Company, Motion Picture Film Department, Rochester 4, N. Y., we shall work out some arrangement to bring him, the camera, and its accessories together.

Forced drafting

The truly creative mind tends to shy away from the petty problems of the drafting room. Then the creative mind gets angry and upset when damnable antiquated drafting procedures impede the swift and smooth transformation of its output into physical reality. Perhaps the petty problems are worth a few moments of the creative mind's time. They have solutions like

- speeding revision of drawings by picking up photographically everything from the existing drawing that is to appear in the revision
- converting drawings into rigid, dimensionally stable, non-staining, non-glaring, long-wearing overlays for contour projector screens
- making working drawings out of photographs of existing equipment instead of drawing everything
- photographic templates for standard or repeating elements in a drawing
- photographic intermediates for protecting original drawings, restoring old and worn ones, or avoiding waits for extra prints.

The Kodak Compass *is an irregular publication that will be sent free to whoever in your organization ought to be concerned with such matters. The first issue deals very plainly with pencils, inks, and eradication techniques for the new Estar Base drawing-reproduction films. Submit names to Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y. Same address for quic answers to questions stirred up by these remarks.*

THIS paper

"*My husband sells oscillograph paper. Competition is fierce. He comes home beat every night.*"

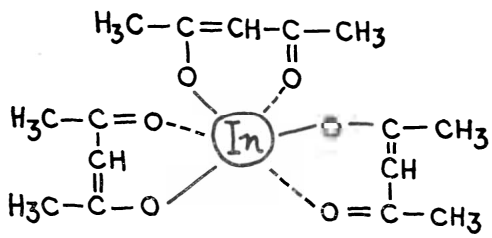
Few overhearing her would know what the poor soul is talking about, yet she speaks the truth. With research and development activity now constituting such a respectable fraction of the Gross National Product, oscillographs probably outnumber pickle barrels in this country at the present time. Oscillographers are correspondingly numerous. Methods that one sect of oscillographers prefers above all else another sect can't see for dirt. One sect prefers automatic oscillogram processors. Paper manufacturers like us find their favor worth competing for. Therefore we announce a new advance in media for their use.

An advance in the old art of papermaking came first. Then new emulsions were devised to work properly with the new base. Then proper processing chemicals were devised for the new emulsions. Then the combination was extensively proved out under practical conditions of use by parties interested only in end results and hardly at all in the how and why. They found that

1. THIS paper dries thoroughly at high processor speeds *without creases. 180 in./min. is not too fast.*
2. THIS paper gives trace lines that stand out as black as the ace of spades. *Background is nice and clean.*
3. THIS paper isn't fussy about how long it sits around before use. *O.K. to keep plenty on hand.*
4. THIS paper is rugged. *No cracking, no crumbling.*
5. THIS paper holds its dimensions. *Justifies careful measurement.*

"*THIS*" *won't do for a trademark. (The code name for the field trials was "Kind 1534.") Let's call it* Kodak Ektaline Paper. *It comes in the two usual speeds for oscillographs,* Kodak Ektaline 16 Paper *and* Kodak Ektaline 18 Paper. Kodak Ektaline Chemicals *come as liquids. The stabilization principle used in the automatic oscillogram processors came from Kodak, too. An inquiry to Eastman Kodak Company, Photorecording Methods Division, Rochester 4, N. Y., puts everything in place right up to the moment.*

A speculation in indium



We may look back upon *Tris(2,4-pentanediono)indium* (Eastman 8015) as marking one more stage along chemistry's road from cookbook to quantum mechanics. Must be close to half way by now.

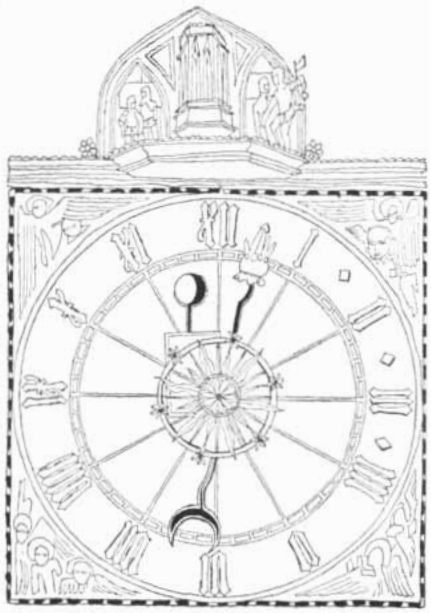
Our story about the indium chelate of acetylacetone starts with a strong kitchen flavor. We made it as a tag for tagging silicone lubricants to facilitate spectrographic identification of suspicious spots. Such detective stunts are part of the way of life in a film factory. Then it occurred to us that others—perhaps some engaged in the mysteries of setting up catalyst beds—might like an indium compound of definite composition and solubility properties. Perhaps they think more in terms of electron configuration than of recipes. Perhaps they might find the effect of enolate resonance on the normal $5s^25p^1$ configuration of the indium atom puts it in the right condition to join the rest of a catalyst system, after which the organic accoutrement of the indium is burned off and reaction rates shoot way, way up and everybody has a wonderful time. Perhaps and perhaps not.

Some 3900 Eastman Organic Chemicals can be ordered from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company), who will gladly supply a catalog of them. The reasons why it seemed necessary to add a given compound to the catalog are sometimes a little hard to follow.

Price subject to change without notice.

Kodak
TRADE MARK

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science



SCIENCE AND

More Bombs

The first blast set off by the U.S.S.R. over Siberia last month marked the end of a hopeful epoch. For three years the major atomic powers had refrained from playing actively with nuclear fire. President Kwame Nkrumah of Ghana, addressing the Belgrade meeting of "nonaligned" powers, spoke for many aligned individuals as well when he said: "It is a shock which forcibly brings home to us the supreme danger facing mankind."

The U.S.S.R.'s avowed intention of developing rocket-carried "superpowerful nuclear bombs of 20, 30, 50 and 100 million tons of TNT" underscored the size of the potential conflagration. Big nuclear bombs are incendiary weapons: the heat radiation from the Hiroshima bomb, which was equivalent to about 20,000 tons of TNT, caused fatal burns at distances up to nearly a mile—about the same as the radius of the destructive blast. Since the effective range of radiation increases as the square root of the explosive energy, whereas blast increases only as the cube root [see "The Hydrogen Bomb: II," by Hans A. Bethe; SCIENTIFIC AMERICAN, April, 1950], the deadly heat of a 100-megaton bomb would reach out some 70 miles: a single bomb that flattened New York City could incinerate people from Bridgeport to Trenton, covering an area of about 15,000 square miles. Whatever the size of the weapons used—as several observers have pointed out, four 25-megaton bombs would cover the same area—the ability of men to burn up whole metropolitan regions seemed about to be realized.

New Atomic Weights

Carbon 12 has replaced oxygen as the official standard for atomic weights as the result of action taken a year ago by the International Union of Pure and Applied Physics and now concurred in by the International Union of Pure and Applied Chemistry. The shift means a recalculation of the scale of atomic weights, and the new figures will differ slightly but significantly from the present values; oxygen, for example, will be 15.9994 instead of 16.0000.

Until now two different scales have been in use. The "chemical scale" took the average mass of natural oxygen, a mixture of three isotopes, as being equal to 16 units. The "physical scale" assigned the value of 16 specifically to the isotope oxygen 16, the most abundant isotope. Among both groups there were substantial as well as parochial objections to abandoning either scale in favor of the other. Such a shift would have changed the atomic weights enough to have required revision of many physicochemical constants.

In recent years, however, new determinations of the relative abundance of the oxygen isotopes have made chemists willing to improve the accuracy of their tables. The adoption of carbon 12 as the new base requires a change of only 37 parts per million in the present chemical scale of atomic weights. From the physicist's point of view carbon 12 is a good base because of its importance in mass spectroscopy.

Worrisome Wires

The International Astronomical Union has recorded its official opposition to Project West Ford, an Air Force plan to place 350 million hairlike wires, each three-quarters of an inch long, in an orbit some 2,000 miles above the earth. The needles would serve as passive reflectors for space communication experiments [see "Communication Satellites," by John R. Pierce, page 90].

Both optical and radio astronomers have objected to the scheme since it was first proposed about two years ago by

THE CITIZEN

workers at the Lincoln Laboratory of the Massachusetts Institute of Technology. Optical astronomers feared that the needles, by reflecting sunlight, would increase the brightness level of the night sky and spoil observations of faint astronomical objects lying behind the needles' orbit. Radio astronomers worried that the needles might reflect enough of the thermal radiation given off by the earth to obscure faint radio signals from distant objects. Sponsors of the West Ford project have replied that the interference would be negligible and that in any case the needles would be sent into an orbit specially chosen so that pressure of sunlight would drive them down into the earth's atmosphere, where they would burn up within a few years. Early in August the Space Science Board of the National Academy of Sciences endorsed the project, assuring the scientific community that the Government planned no further launchings of wires until the results of the West Ford experiment had been fully analyzed.

The International Astronomical Union, at its meeting late in August, issued the statement that it would remain opposed to the West Ford launching "until the question of permanence [of the wires] is clearly settled in published scientific papers, with adequate time being allowed for their study." The statement added that if something went wrong with the launching, the details of which are classified, the wires might remain in orbit indefinitely and prove "disastrous to future observations."

Proteins from Light

Photosynthesis is beginning to look like an all-purpose biochemical manufacturing process. Green plants are now found to use the energy from sunlight to convert carbon not only into starches and sugar but also into amino acids.

At last summer's Fifth International Biochemical Congress in Moscow, J. A. Bassham of the University of California described a series of carbon 14 tracer experiments on the green alga *Chlorella*. Fully 30 per cent of the tagged carbon supplied to the plants turned up directly in amino acids rather than in carbohydrate. Labeled acids have not been traced any further, but the rate at which

they disappear indicates that they must be incorporated into protein.

Although evidence is not yet conclusive, Bassham and his colleagues believe that photosynthesis also uses some carbon for the synthesis of fatty acids and probably a number of other compounds as well.

Second Biggest Dish

The world's farthest seeing steerable radio telescope went into operation in Australia during the summer. Its antenna, a parabolic dish measuring 210 feet across, is 40 feet smaller than the largest steerable reflector at Jodrell Bank in England. But the wire mesh "mirror" is more accurately shaped—to a tolerance of half an inch, compared with four inches for the English instrument. This should give the new telescope a tenfold advantage in range; it is expected to penetrate about a billion light-years into space. Although its performance will soon be surpassed by still larger reflectors now under construction, it will long occupy a position of unique importance as the largest steerable telescope in the Southern Hemisphere.

Designed to operate at wavelengths down to 10 centimeters, the instrument will be tuned most often to 21 centimeters, the wavelength emitted by neutral hydrogen in space. Among the first projects for which it will be used are fine-scale mapping of the spiral arms of our galaxy and the Great Nebula in Andromeda, and a radio survey of the Clouds of Magellan.

Coatless Viruses

"A new dimension" has recently been added to the picture of virus disease processes, says a biochemist at Johns Hopkins University. Writing in *Science*, Roger M. Herriott points to the discovery that laboratory preparations of the bare nucleic acid cores of many viruses can invade cells and cause infection. He proposes that viral nucleic acid may play a similar part in natural infections, which would account for several puzzling features of these diseases.

Whole virus particles consist of a nucleic acid core inside a protein "overcoat." According to the current view the protein acts as a minute hypodermic needle, injecting its core into susceptible cells. Once inside, the viral nucleic acid takes over the metabolism of the cell, forcing it to synthesize new nucleic acid and new protein coats. Eventually the

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cell breaks open, releasing whole virus particles, which then attack other cells.

In the body's system of defense against this process the chief weapon—the immune reaction—acts only on the protein. Highly specific antibodies are manufactured that combine with the viral protein and thereby destroy its ability to attack cells.

Although these facts are established beyond doubt, there is considerable evidence that they do not tell the whole story. Part of it may lie with the nucleic acid, now known to be infectious even without a protein overcoat. Herriott mentions several experiments indicating but not proving that infected cells spew out bare cores as well as finished virus particles. There is even a possibility that some of the cores are provided with a covering of other material, such as fat, against which no antibody is manufactured. Nucleic acids are attacked by an enzyme in the blood known as nuclease, but the reaction is not instantaneous. Some of the newly released bare cores (as well as any protected by fatty coats) may be able to enter other cells before they are destroyed.

Herriott discusses several phenomena that can be explained by such a process: (1) The long-lasting immunity that follows many virus diseases depends on a continued production of antibodies. The production could be stimulated by a low-level infection, maintained by bare nucleic acid, which produces just enough whole virus to keep the mechanism of immunity operating. (2) In the course of certain infections in man and other animals, infective agents are found in the blood together with high concentrations of antibody. These agents could be viral nucleic acid. (3) Some diseases, such as serum hepatitis, are characterized by long periods (up to 50 days) of viremia (virus in the blood) before the onset of symptoms. If the viruses were covered with protein, they should stimulate the production of enough antibody to destroy them in this length of time. (4) Viruses are being found responsible for a growing list of cancers in animals, but "few such agents, if any, have been found associated with malignant growth in man." Perhaps the agents consist of nucleic acid "which functions *in situ* but, when transferred to another host, is so slow in infecting other cells that it is destroyed by the nucleases."

One way to test some of his hypotheses, Herriott suggests, is to inject viral nucleic acid into animals previously immunized with killed-virus vaccine. In these vaccines the nucleic acid has been

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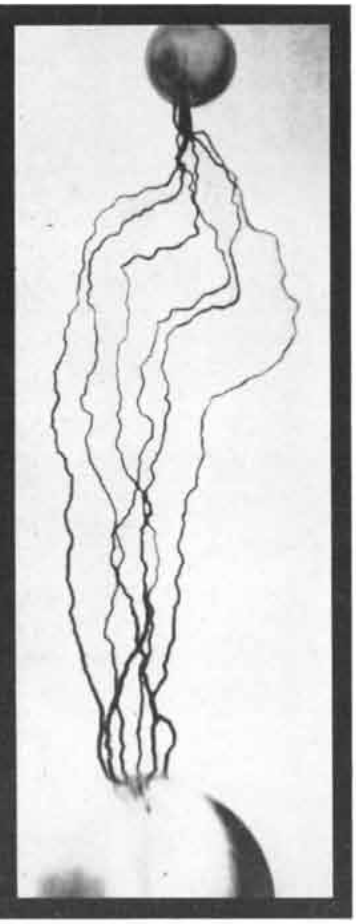


inactivated, but the protein retains its ability to stimulate antibody production. Since the vaccinated animal "presumably has no tissue or local immunity and possesses only antibodies which do not inhibit the free nucleic acid, there is every reason to expect some cells to become infected." If these infected cells release only whole virus, "the antibodies induced by the vaccine should stop the infection promptly." If infectious nucleic acid is also released and "spreads the infection to other cells and tissues, then symptoms may be observed."

Blitzen and Donner

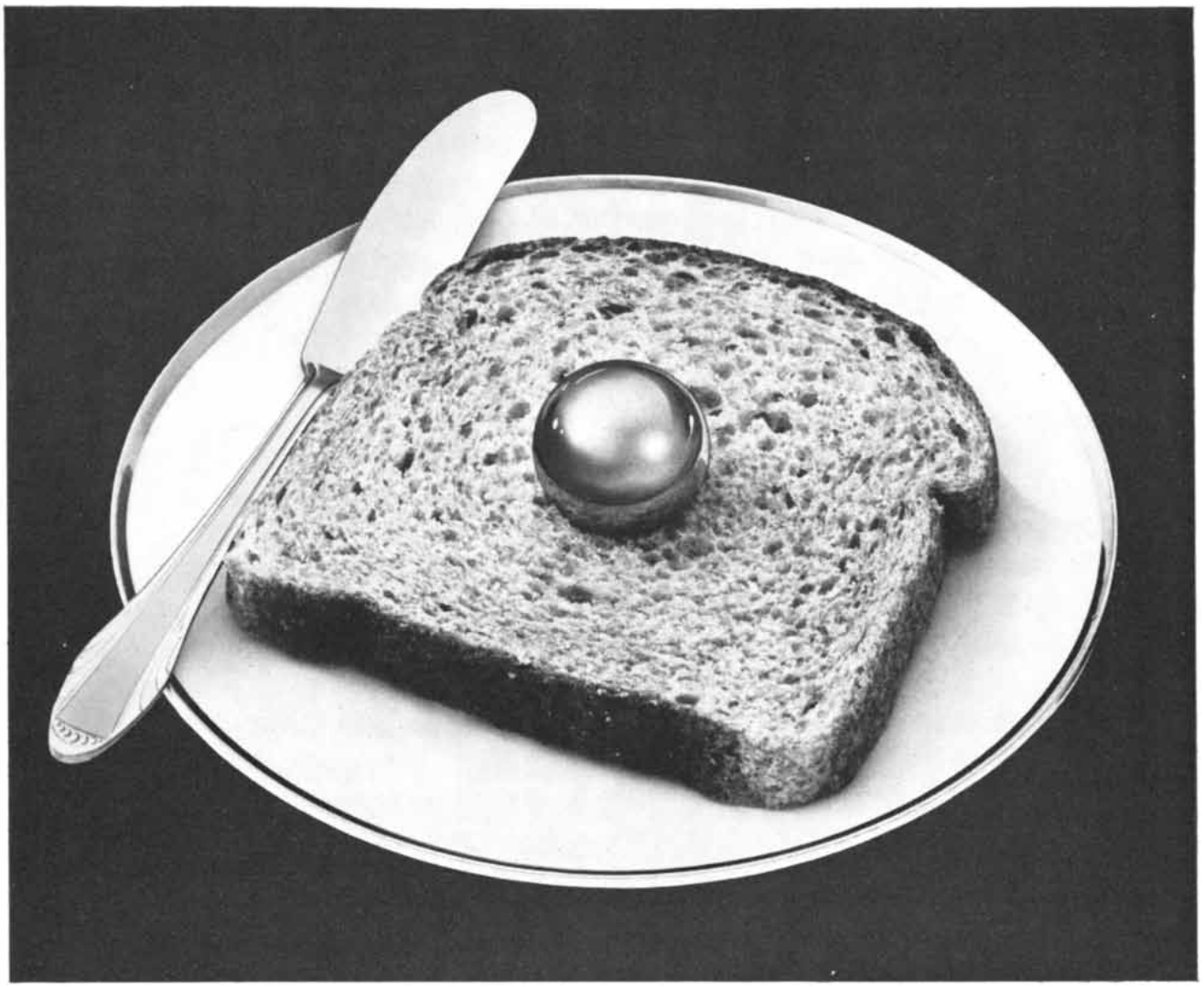
How hot is a stroke of lightning? According to Yu. N. Zhivlyuk and S. L. Mandel'shtam of the Lebedev Physics Institute in the U.S.S.R., who say they have determined the temperature for the first time, the answer is about 20,000 degrees centigrade. These measurements, reported in the Soviet *Journal of Experimental and Theoretical Physics*, are based on spectra obtained by aiming a spectrograph at the center of a thunderstorm and exposing a photographic film to the light of several successive flashes.

Knowing the temperature of the lightning, the physicists were then able to make the first calculation of the force of a thunderbolt—that is, of the pressure in the shock wave produced by the discharge. Directly ahead of the flash the value can exceed 1,000 pounds per square inch, and at a distance of 15 feet it is still about 10 pounds per square inch, strong enough to crack a nine-inch brick wall.

Mutation by Injection

By injecting adult male fruit flies with alien genetic material—deoxyribonucleic acid (DNA) from other strains of fruit flies and from rats—two British investigators have succeeded in inducing observable effects on the heredity of the insects' offspring. O. G. Fahmy and Myrtle Fahmy of the Royal Cancer Hospital report in *Nature* that the progeny do not incorporate any of the specific genes of the injected DNA but show a much higher rate of mutation (especially in the production of a class of mutants called *Minutes*) than do the progeny of an untreated control group.

It was the transfer of specific hereditary characteristics from one strain of bacteria to another by the simple exposure of one strain to the DNA of the other in the classic experiment of Oswald T. Avery, Colin M. MacLeod and Maclyn



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McCarty in 1944 that established DNA as the carrier of genetic information. Since then efforts to bring about such genetic transformation in higher organisms have failed. The French investigators who reported in 1957 that they had effected gene replacement in ducks were later unable to confirm their results.

The Fahmys found rat DNA as effective in inducing mutations as DNA from other fruit flies, and they found that their subjects were most likely to produce mutated offspring if they were injected with DNA when their sperm cells were approaching or had reached maturity. From this and other evidence they conclude that the injected DNA has general rather than specific effects, increasing the tendency to mutate among genes that occasionally mutate spontaneously. The DNA incorporated into the germ cells is transferred, along with the male chromosomes, to the egg; the induction of mutations takes place during chromosome replication, in the first cleavage of the fertilized ovum.

Artificial Stress

If nervous tension helps to cause heart disease, as has long been suspected, how does it produce its effects? An experiment performed at the Harvard Medical School suggests that at least part of the mechanism involves the direct chemical action of "stress hormones" on cardiovascular tissue.

A. C. Barger, J. A. Herd and M. R. Liebowitz, who reported their work in the *Proceedings of the Society for Experimental Biology and Medicine*, have studied the effects of adding the adrenal hormone epinephrine to the blood flowing through the hearts of living dogs. To do this they implanted a plastic tube in the coronary artery through an incision in the chest.

Ten days after the operation the electrocardiogram of the five experimental animals had returned to normal. After another two weeks the experimenters began infusions of epinephrine through the catheter. During the administration of the hormone the wave shapes in the electrocardiogram changed in a characteristic way in all the animals. If an infusion was continued for an hour or two and then stopped, the acute pattern gradually evolved into a different set of wave forms, which persisted for from seven to 10 days. The chronic pattern, the investigators say, "closely resembles the electrocardiographic pattern noted in patients with so-called myocardial ischemia" (deficiency in the blood supply of the heart muscle).

HIGH PURITY ELEMENTS

SOUTH PLAINFIELD, N. J., Oct. 1 -- ASARCO CENTRAL RESEARCH LABORATORIES, USING SPECIAL REFINING AND ANALYTICAL TECHNIQUES, HAVE SUCCEEDED IN PURIFYING SELENIUM SO THAT NO NICKEL OR IRON CAN BE DETECTED AT 5 PARTS IN 100,000,000. LEVELS OF OTHER IMPURITIES IN ASARCO HIGH PURITY ELEMENTS CAN AT TIMES BE MORE SPECIFICALLY LIMITED TO MEET CUSTOMERS' SPECIAL REQUIREMENTS.

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(< denotes less than ppm indicated)

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	ANTIMONY	A-60	<1	<1	<1	<2	<1								
✓	ARSENIC	A-60		<1											
	BISMUTH	A-58		2	1		1	2						<1	
	CADMIUM	A-60		<1	<1		1								
	COPPER	A-58	No Impurities Detectable by Spectrographic Analysis												
	GOLD	A-59		<1	<1		<1	1							
	INDIUM	A-58		<1			1		<1	1					
	LEAD	A-59	<1	<1	<1										
	SELENIUM	A-58		<1		<1					1			<1	
	SILVER	A-59		<1	<1		<1								
	SULFUR	A-58											1	1	
	TELLURIUM	A-58		<1	<1										
✓	THALLIUM	A-60		1	1		<1	<1					2	<1	
	ZINC	A-59		<1	<1		<1								<1

✓ *Denotes element improved since last published analyses.*

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COMMUNICATION SATELLITES

A summary of prospects for this revolutionary means of transmitting telephone and television signals over the entire earth. It now seems likely that the first such system will be operating within five years

by John R. Pierce

The first transatlantic telegraph cable was opened in 1866; the first transatlantic radiotelephone circuit, in 1927—a span of six decades. Another two decades passed before the unreliable radiotelephone circuits were supplemented by a transatlantic telephone cable. It now seems possible that no more than a decade will pass between the opening of the submarine telephone cable in 1956 and the inauguration of commercial communications using space satellites. In orbit thousands of miles above the earth, satellites will be able to relay not only telegraph and telephone messages but also television pictures, and they will be able to relay them not just between major countries but—as President Kennedy noted in a recent policy statement—to the farthest corner of the globe.

It would be a mistake to minimize the technical difficulties of creating a global communication network in space. As we shall see, they are formidable. Yet the attractions of such a network are so compelling that the incentives to get the job done are great. The short radio waves used in radiotelephony cross the oceans only by reflection from the ionosphere. Short-wave transmission is often of poor quality and sometimes it fails completely when the ionosphere is disturbed by solar storms. Submarine cables are greatly superior to short-wave radio for telephony, but they are only a little more effective in providing broad-band transmission capacity. The original 1956 cable between North America and Great Britain had 36 voice channels, now increased to 96 by a high-speed switching device called TASI (for Time Assignment Speech Interpolation) that fits the additional channels into the pauses that occur in normal conversations. A new cable, to be finished in 1963, will be able to carry 128 voice channels without the use of TASI, and about twice that number with TASI, but their combined band width is still far short of the 1,000 channels needed to carry a full television signal. In fact, the total number of voice channels now available—both radio and cable—between North America and overseas points throughout the world is now only about 550. In contrast the number of transcontinental telephone circuits is almost 2,300.

With 76 million telephones in North America and 58 million in the rest of the world, the demand for transoceanic circuits can be expected to grow rapidly, even without considering the extraordinary band-width needs of television. Submarine cables now connect the U.S. with Europe, Hawaii, Puerto Rico and Cuba. Cables are being laid between Puerto Rico and Antigua in the British West Indies and between Florida and Jamaica. The longest cable yet planned, extending some 3,900 miles from Hawaii to Japan, is scheduled for completion in 1964. In addition, the British Commonwealth is building a world-wide cable network, which will cost $250 million. The band-width limitations of these cables will be essentially the same as those of the cables now in service.

The cables of large capacity that carry television signals overland are special coaxial cables consisting of a copper wire supported by polyethylene spacers inside a copper tube about three-eighths of an inch in diameter. To preserve the quality of the signal it must be boosted by repeaters every four to eight miles. The submarine cable is also coaxial, but its watery environment and the necessity for a long, trouble-free life enforce certain design restrictions. Partly because power is limited to what can be supplied at the two land terminals and partly because reliability must be emphasized, the repeaters are spaced about 45 miles apart. As a result the capacity of the present submarine cable is only about one-fiftieth that of the land coaxial cables.

The other overland communication system with broad-band capacity is the microwave relay, in which radio beams with frequencies between 4,000 and 12,000 megacycles are transmitted between line-of-sight relay towers. Essentially it is this system that would be extended to provide signal links between ground stations and satellites and back to earth again.

The Growth of an Idea

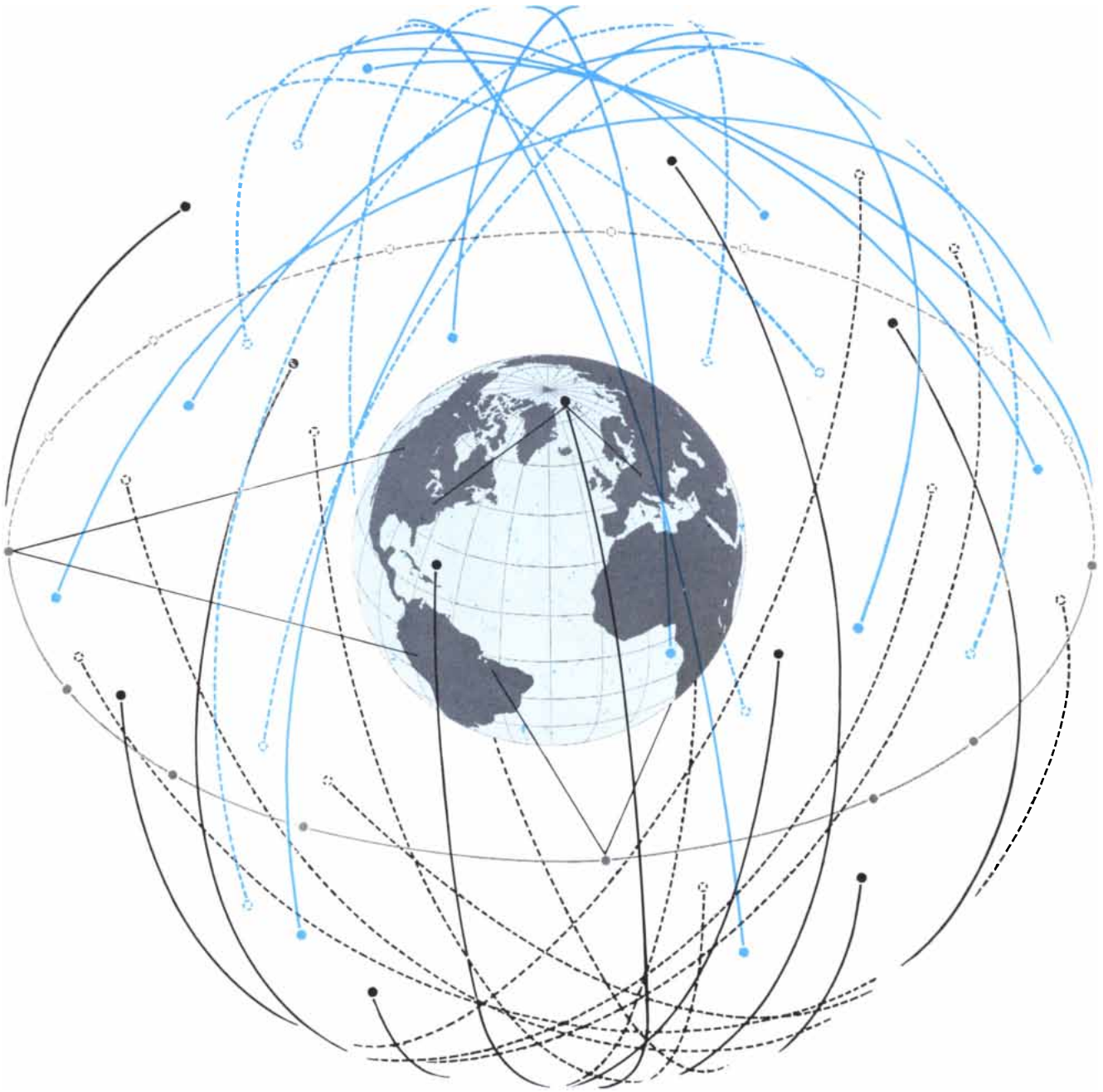
The idea of using satellites for communication is at least 16 years old. Arthur C. Clarke, a British science writer, proposed satellites for relaying and broadcasting in an article in *The Wireless World* in 1945. He pointed out that a satellite in an orbit 22,300 miles above the surface of the earth would complete one circuit of the earth in one sidereal day. If such a satellite were to move in the plane of the Equator and in the same direction as that of the rotation of the earth, it would hang stationary in the sky. If three such satellites were equally spaced in the same orbit, one or another of them would always be visible everywhere on the earth's surface except for a relatively small and virtually unpopulated region near each pole. Clarke proposed placing manned space stations in such an orbit and equipping them with radio broadcasting and relaying equipment.

When I first wrote about satellite communication in 1955, I proposed "passive" reflecting spheres such as the satellite *Echo I*, or oriented reflecting

mirrors, as well as "active" satellites equipped with radio receivers and transmitters. I suggested that such satellites might be placed either in 22,300-mile-high "stationary" orbits or in lower orbits, where they would move more rapidly. In the latter case one would need to launch more than 30 satellites in order to assure that at least one of them would be visible at two ground terminal points almost all the time. The ground antennas would have to track such satellites as they moved across the sky.

In a paper delivered in London in 1960 at a meeting of the International Scientific Radio Union, Walter E. Morrow, Jr., of the Lincoln Laboratory of the Massachusetts Institute of Technology proposed a simpler sort of satellite system: a belt of fine wires half a radio wavelength long, circling the earth like the ring of Saturn. The ground-terminal antennas would point at a common portion of the belt, and the wires at that point would reflect a signal from the transmitter to the receiver. Different orbiting wires would of course serve as reflectors at different times. The position of the belt of wires could be stationary but not the positions of the wires forming it. A global system would require only two belts, one passing over the poles, the other circling the Equator [*see illustration on page 93*].

Both Clarke and I overlooked one important matter in connection with 22,300-mile-high stationary satellites: the finite speed of radio waves. The propagation time to and from a 22,300-



RANDOM-ORBIT SYSTEM, of the type proposed by American Telephone and Telegraph Company, could provide communication service 99.9 per cent of the time to any region on the earth's surface. The system would require 40 satellite repeaters (relay stations) in random polar orbits and 15 in equatorial orbits at an altitude of about 7,000 miles. With one-third more satellites the grade of service could be raised to 99.99 per cent; the average daily outage of 10 seconds could be predicted days in advance.

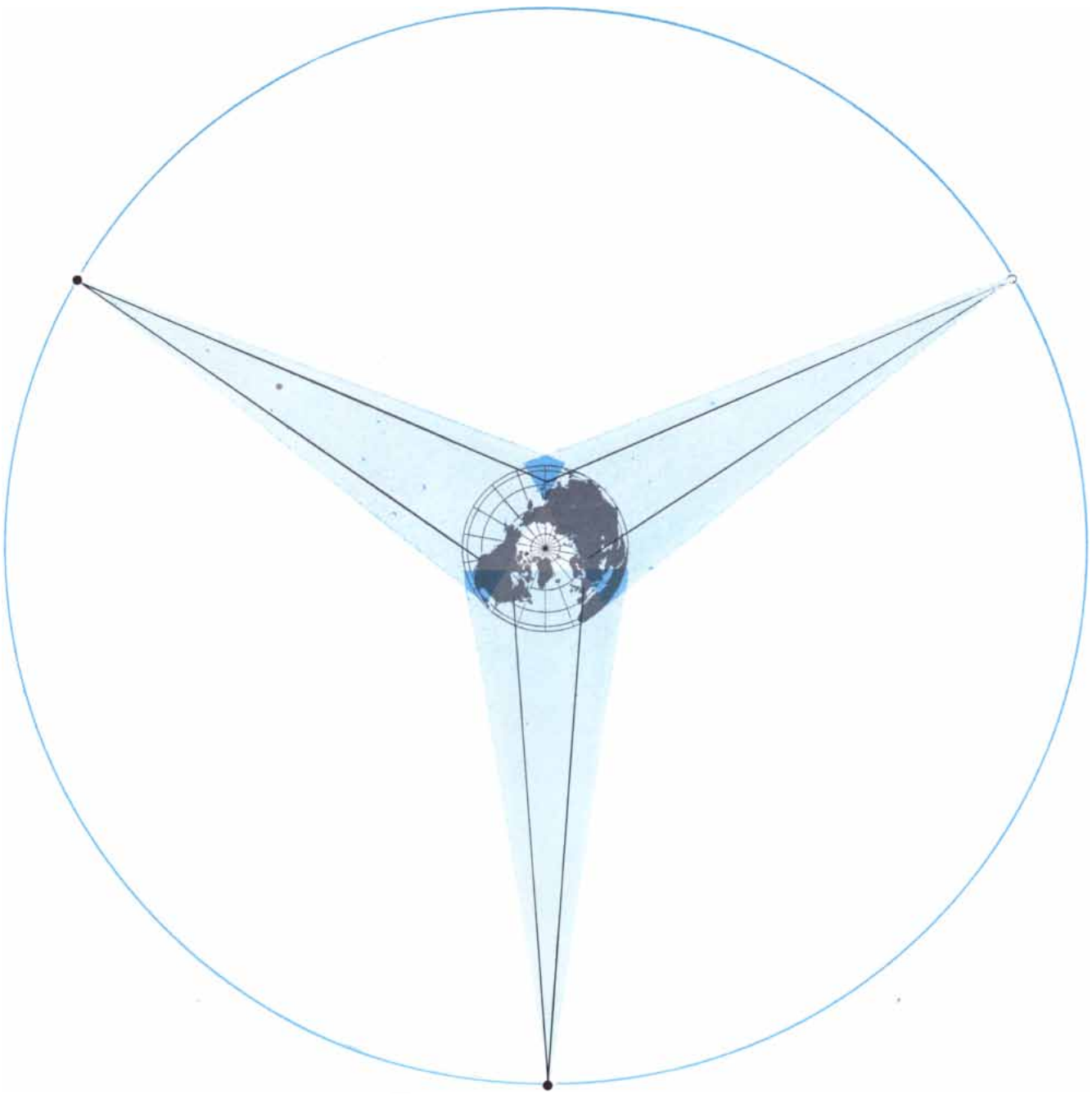
mile-high repeater is about a quarter of a second. Therefore a speaker cannot receive a reply to a remark for about half a second. Tests indicate that this delay may not interfere with a telephone conversation if a four-wire circuit is used; that is, if completely independent paths are provided from each telephone transmitter to each telephone receiver.

Actual telephone circuits, however, are always limited to two wire links, over which one both talks and listens. When a round-trip delay of half a second is introduced into such a circuit, an intolerable echo occurs. To get rid of the echo it is necessary to use an echo suppressor, which interrupts transmission at one end while the person at the other end is talking.

Echo suppressors do not seriously interfere with a conversation when the round-trip delay is less than a tenth of a second. Some preliminary experiments indicate that circuits with a delay of half a second and echo suppressors may be objectionable to a large fraction of users, and that conversation is sometimes brought to a halt when both users speak at once. Only further investigation will show how serious this really is.

The Satellites Themselves

It is a long step between proposing communication satellites and actually building them and making them work. A professional poet once told an amateur: "Sonnets are made of words, not of ideas." The realization of satellite



"STATIONARY"-ORBIT SYSTEM would require only three satellite repeaters (and perhaps a stand-by for each) equally spaced above the Equator at an altitude of 22,300 miles. Rotating eastward at the same apparent speed as the earth, they would seem to stand motionless in the sky. Since they would drift out of position periodically they would have to carry small rockets or gas jets that could be used to re-establish the proper orbit. A few extra satellites in polar orbits would be needed to serve the polar regions.

communication depends on the exploitation of two arts. One is the new, expensive and uncertain art of rocketry and space flight. To date only about half of U.S. satellite launchings have been successful. Satellite communication can come into being only through this art, and through the use of vehicles that have already been developed at great cost by the Government primarily for other purposes.

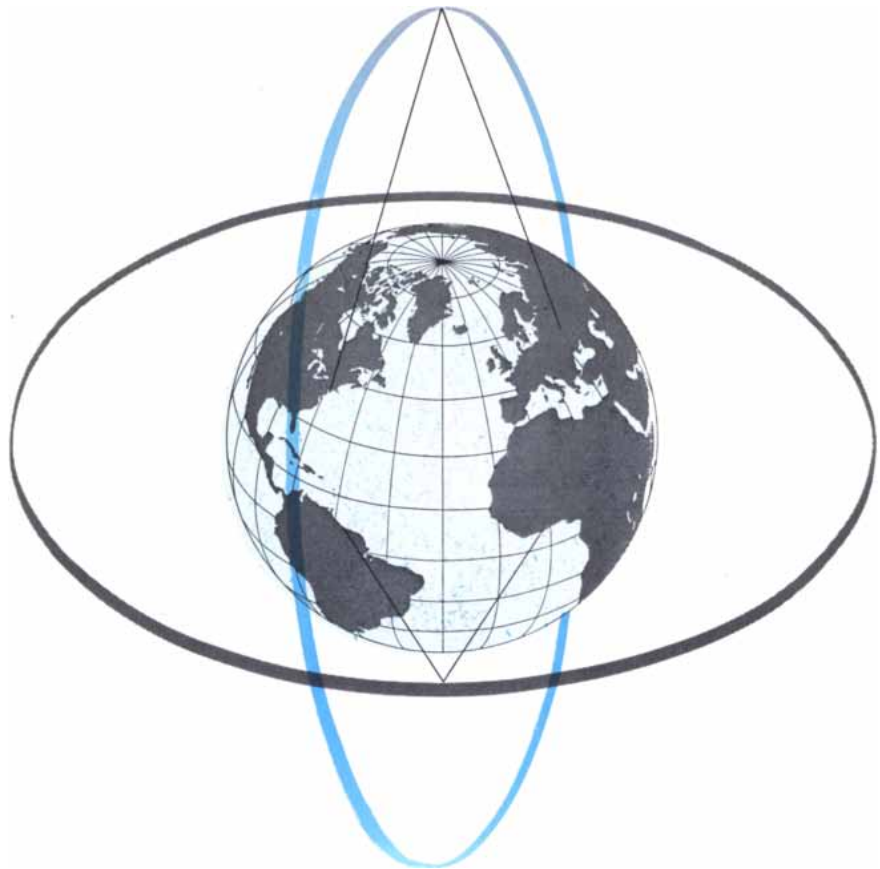
The other art is the mature one of electronics. So long as we stay on the ground, it can provide us with powerful transmitters, sensitive receivers, huge antennas, complex computers and tracking systems, and subtle methods of signal reception. The electronic space payload itself, however, is another matter. Repeated operational failures show us that it presents new problems.

I shall say nothing further concerning the problems of launching and guidance. Let us consider related problems that are very important to some types of satellite communication: maintaining the satellite in an appropriate orbit (called "station-keeping") and maintaining it in its appropriate orientation in space.

If a 22,300-mile-high satellite is to hang stationary in the sky, periodic readjustments in orbit will be necessary. These can be made by gas jets or other impulse-producing means under radio control from the ground. Because of the distances involved the satellite should be equipped with a directional antenna that will beam power only to the disk of the earth, and this too will require periodic adjustment. Small adjustments could be made by spinning small flywheels in the satellite, thereby causing the satellite itself to turn in the opposite direction. Larger changes could be made with gas jets. Beyond this, if solar cells are used for power, one might wish to orient the solar cells with respect to the sun. All such adjustments could be made either automatically, by devices aboard the satellite, or by commands given from the earth.

What is the state of the art of station-keeping and orientation? Nose cones of Atlas rockets have been successfully oriented for tens of minutes. Satellites of the *Discoverer* series have been oriented for several days. If communication satellites are to compare economically with cables, they must be oriented for at least two years.

Over this period of time gas valves may leak, bearings may freeze, some brief malfunction of orientation gear may set the satellite spinning. If orientation and station-keeping gear depend on commands from earth, can we really count on its responding to our commands and being unaffected by signals of other origin? We will be able to answer such questions only on the basis of experiments and experience.



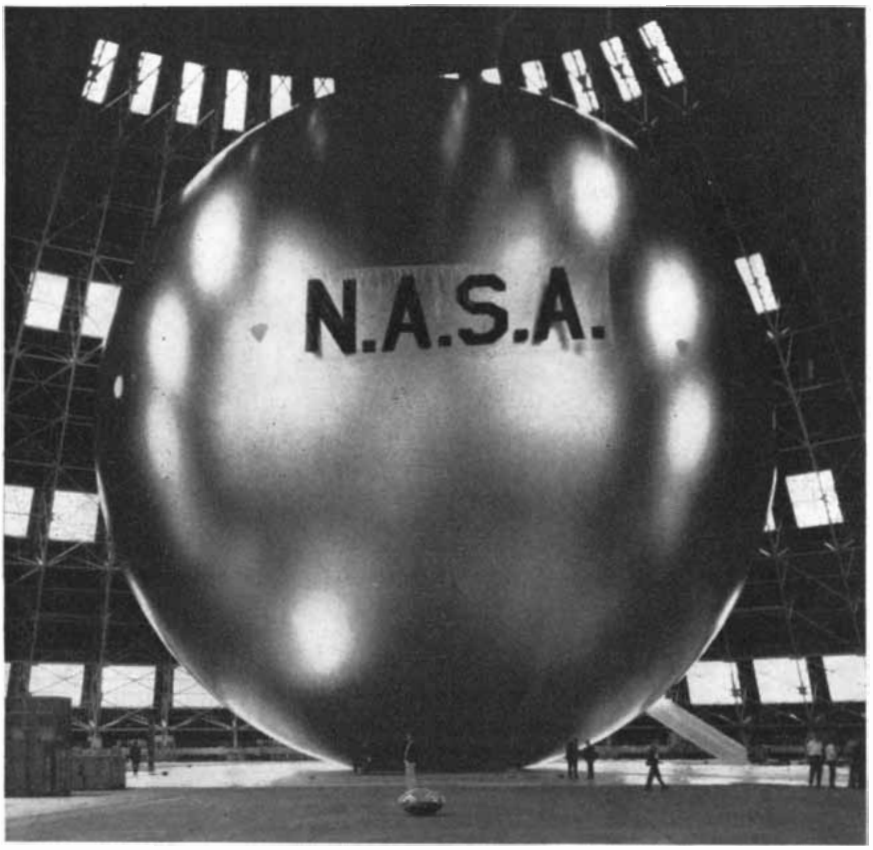
REFLECTING-WIRE SYSTEM, proposed by Lincoln Laboratory of the Massachusetts Institute of Technology, could provide global communications with only two tenuous rings, one polar and one equatorial, composed of millions of tiny wires about an inch long. The wires would circle the earth at an altitude of 3,000 to 4,000 miles. Ground stations in the northerly and southerly regions of the earth would communicate by bouncing signals off the wires traveling over the poles. Stations near the Equator would use the equatorial belt.

What one would like to find, of course, is some way to exploit natural forces to keep a satellite oriented automatically. One possibility is to use the earth's magnetic field, at least for medium-altitude satellites. At altitudes of a few thousand miles the earth's field is strong enough to serve as a reference and could even provide enough force to orient a space craft. At an altitude of 22,300 miles the field is not only small but also changes with time, since it depends in part on the flow of charged particles from the sun.

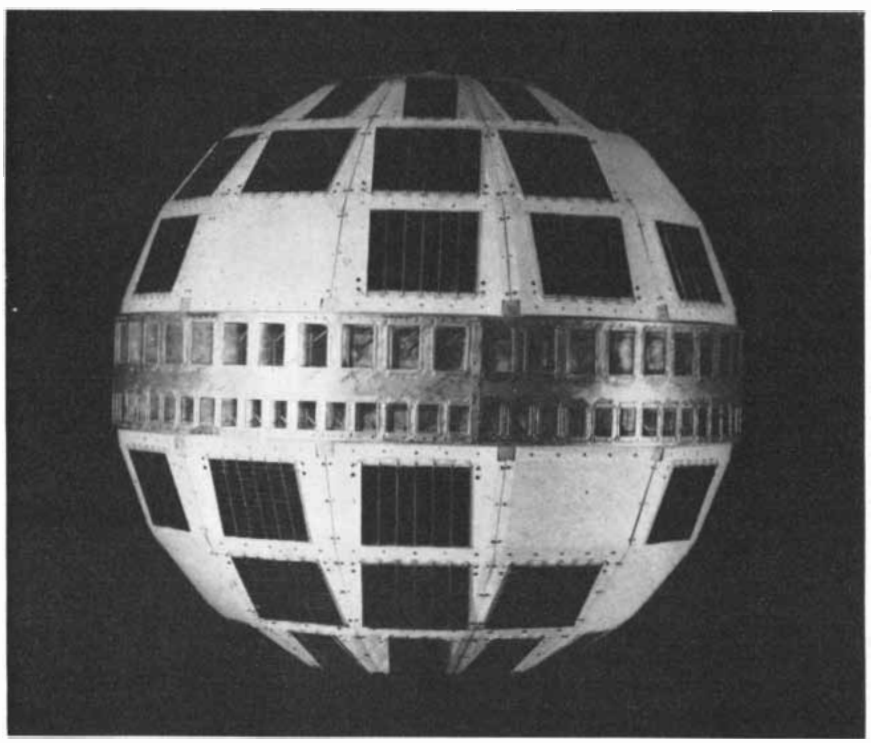
Still other natural forces might be exploited at low altitudes. For a given angular velocity centrifugal force increases with increasing radius of orbit, whereas the force due to gravity decreases with increasing radius. Imagine a satellite consisting of two equal weights tied together with a wire and aligned so that the wire points to the center of the earth. The centrifugal force will be greater on the outer weight, and the force of gravity will be greater on the inner weight. There will be a small tension in the wire. If the system is displaced, it will tend to return to its radial orientation.

But how small the force is! If the two weights are 100 pounds each and are 10 feet apart in an orbit 2,000 miles high, the tension in the connecting wire would be only about 20 milligrams. This is large, however, compared with some competing forces. Sunlight exerts a pressure of only about a tenth of a milligram for every square foot of shiny surface. The real problem is not lack of adequate force but the difficulty of damping out the slow oscillations that would keep the wired system from settling down in its desired orientation.

Simple spin orientation, used in the *Tiros* weather satellites, will keep the spin axis of a satellite pointed in one direction for a time. As a satellite travels through the earth's magnetic field, how-



ECHO II, 135 feet in diameter, is a larger and more rigid version of the first balloon satellite, *Echo I*, launched in August, 1960, and still in orbit. Made of plastic film about .0005 inch thick, vapor-coated with aluminum, *Echo I* became badly wrinkled within six months. For greater rigidity the plastic film of *Echo II* is laminated between two thin sheets of aluminum foil. It can be packed into a canister 41 inches in diameter for launching.



A.T.&T. EXPERIMENTAL SATELLITE, 34 inches in diameter, is being developed by Bell Telephone Laboratories. Antennas circle the satellite in two belts; solar cells are arrayed elsewhere on the surface. The National Aeronautics and Space Administration will launch the device next spring for a fee of about $6 million, to be paid by A.T.&T.

ever, small electric currents are generated within it and gradually retard its rate of spin. Such a satellite must be respun from time to time.

The Problem of the Van Allen Belt

Space poses problems beyond keeping satellites in place and oriented. One of the most serious is the effect of high-energy protons circulating in the inner Van Allen belt, which is most intense at an altitude of around 2,000 miles and which extends, with some diminution, to perhaps 5,000 miles. Electronic devices housed within the satellite will be reasonably well shielded from this proton radiation, but solar cells cannot easily be protected. Covering the solar cells with thin plates of sapphire, about a tenth of an inch thick, will shield them from the electrons of the outer Van Allen belt, which is most intense some 13,000 miles up, but it is not practical to use enough sapphire to protect them completely against the more energetic protons. Because of uncertainties in the extent, intensity and composition of radiation in the inner Van Allen belt, we are uncertain as to when the efficiency of a solar cell will fall to some preset design limit, say 5 per cent. The best present estimate is that in the center of the inner Van Allen belt solar cells will retain more than half of their original efficiency of 13 per cent for about 10 years.

Other problems are concerned with vibration and acceleration during launching, temperature control once in orbit (where heat can be dissipated only by radiation), leakage of pressurized containers and so on. In sum, the practicality of satellite communication depends on obtaining long service life in the novel environment of space.

Transmission and Reception

Let us now turn to another class of problems: those concerned with the transmission and reception of signals. Because it is costly to put weight in orbit, satellite transmitters must be kept low in power. The weight of electronic circuitry itself is negligible. The chief source of weight is the power supply: solar cells and storage batteries. (Nuclear power sources may eventually offer weight savings, but this remains to be shown.) In designing an economic satellite communication system, therefore, one must use the lowest power consonant with highly reliable service. This power is determined not only by the sensitivity

of receivers but also by the strength of competing signals—that is, by noise.

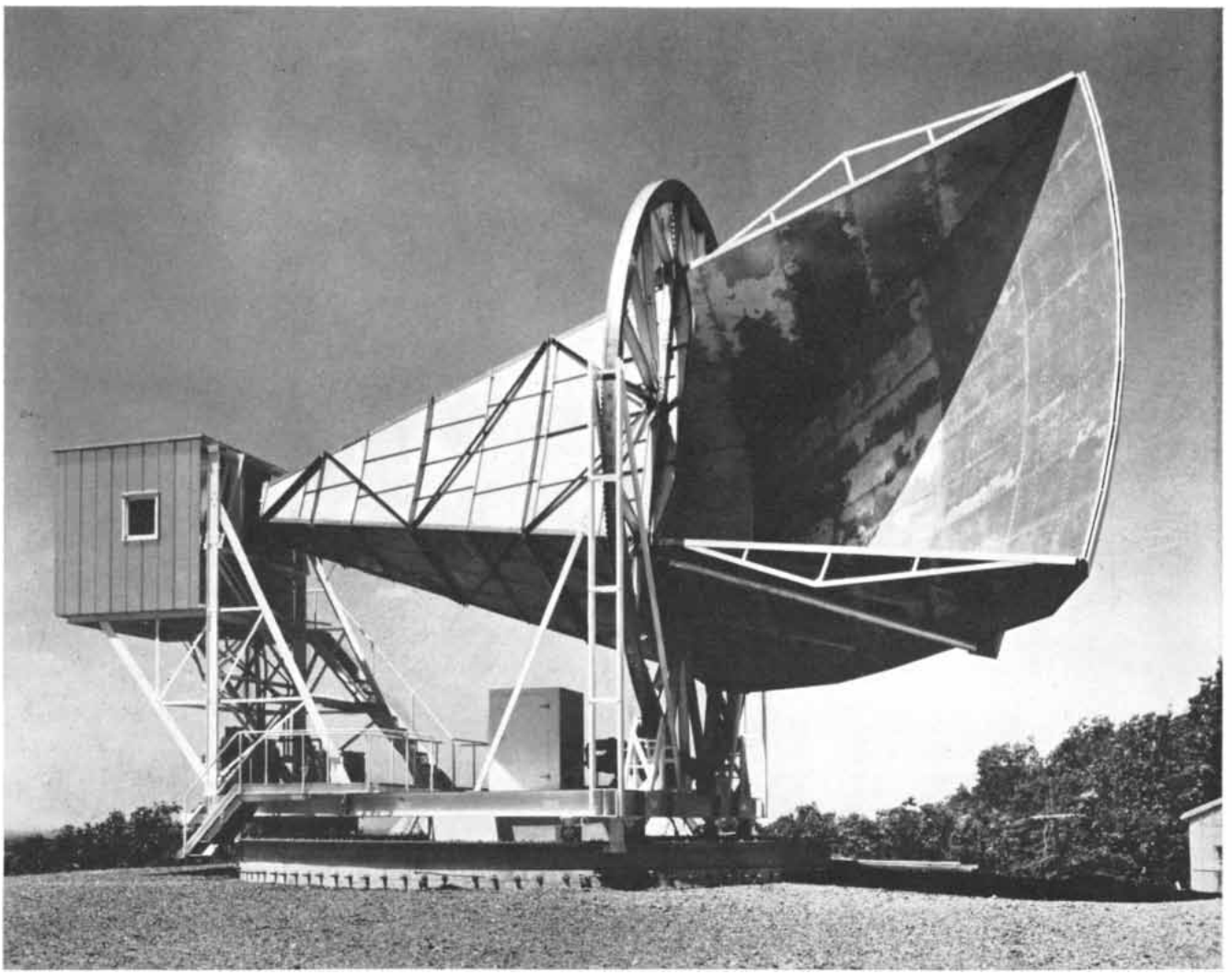
In evaluating the effects of noise we need some scale of measurement. A convenient scale is one based on the electromagnetic radiation emitted by hot objects. For example, the filament of an incandescent lamp glowing at a temperature of a few thousand degrees Kelvin (degrees centigrade above absolute zero) produces about the same amount of noise as that added to the signal by a good microwave receiver of 1950 design. Since then maser amplifiers have been developed with a noise level so low that it corresponds to a temperature of only about 10 degrees Kelvin. Hence it is now possible to detect signals that would have been hopelessly drowned in the noise produced by receivers of 10 years ago.

When we aim a ground antenna at a satellite sending signals from space, we must contend with background noise from a variety of sources. First there is the general cosmic noise discovered by Karl G. Jansky in 1932, which has led to the development of radio astronomy. This noise varies not only from point to point in the sky but also with frequency. Fortunately at microwave frequencies cosmic noise is not a serious problem.

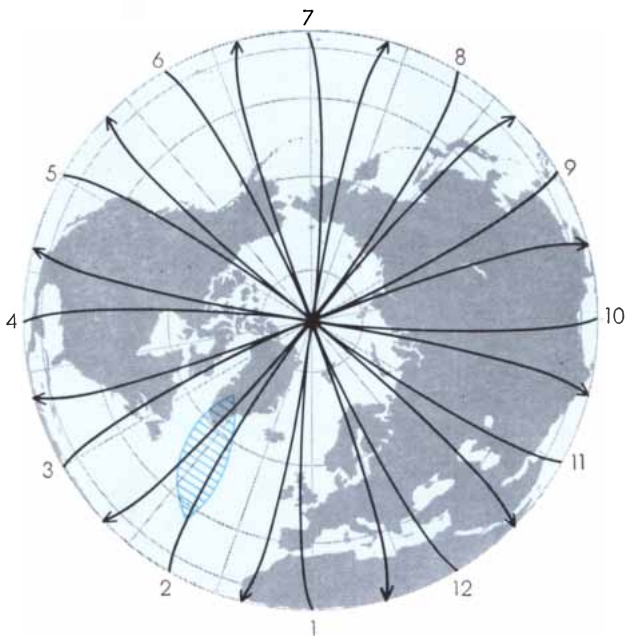
The sun, however, has a microwave noise temperature of about 6,000 degrees K. and the moon a noise temperature of about 70 degrees K. This means that one cannot receive signals from a satellite passing directly in front of the sun, and the signals will be somewhat noisy when the satellite is in front of the moon.

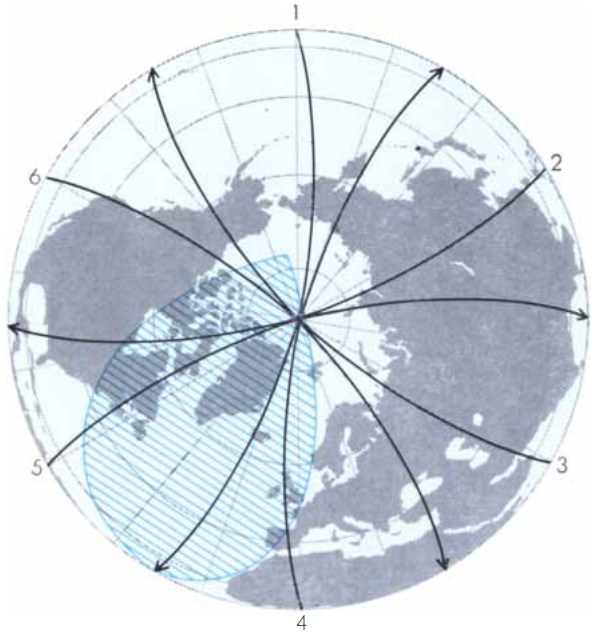
A more pervasive source of noise is the earth's atmosphere itself, which has a temperature of about 300 degrees K. Calculations and observations made by D. C. Hogg of the Bell Telephone Laboratories show that fortunately atmospheric noise is acceptably low for transmission frequencies lying between 1,000 and 10,000 megacycles, provided that receiving antennas are not pointed lower than 7 degrees above the horizon [*see bottom illustration on page 98*]. It would be undesirable in any case to aim antennas closer to the horizon, since they might then begin pulling in signals from ground microwave systems.

The solid earth also emits noise at a temperature of about 300 degrees K. A parabolic dish antenna pointed straight up receives, around the edge of the dish, noise corresponding to a temperature of about 50 degrees K. This residual



HORN-REFLECTOR ANTENNA, built by Bell Telephone Laboratories at Holmdel, N.J., is about 10 million times more sensitive to radio waves reaching it from in front than to radiation striking it from behind. Thus background noise contributed by thermal radiation from the earth's surface is minimized. The horn has been used to receive signals reflected from *Echo I*. The signals enter the open window in the horn and strike the aluminum reflecting surface at far right, whose curvature corresponds to an edge section cut from a parabolic dish. The reflector focuses the signals on a sensitive maser receiver housed at left. The antenna is about 50 feet long.





VISIBILITY RANGE OF SATELLITES is a major factor affecting the design of a space communication system. The areas shaded in color show where satellites traveling at various altitudes must pass to lie within radio "view" of both New York and Paris. The four altitudes depicted are, left to right: 1,040, 3,960, 6,450 and 12,550 miles, corresponding to orbital periods of 2, 4, 6 and 12

ground noise can be still further reduced by using a horn-reflector antenna [*see illustration on preceding page*]. This is an antenna whose reflecting surface is paraboloidal, corresponding to an edge section cut from a parabolic dish. The receiver is placed at the focus, and a metal horn extends from the focus to enclose the paraboloidal reflector. A window in one side of the horn permits the incoming radio waves to reach the reflector. Such an antenna is only about one ten-millionth as sensitive to radiation from behind as it is to radiation from in front. The horn reflector and maser receiver built to detect signals from the satellite *Echo I* achieved a noise level corresponding to a temperature of 24 degrees K. A noise temperature of 15 degrees K. seems attainable in the near future, and a value of less than 10 degrees K. seems possible.

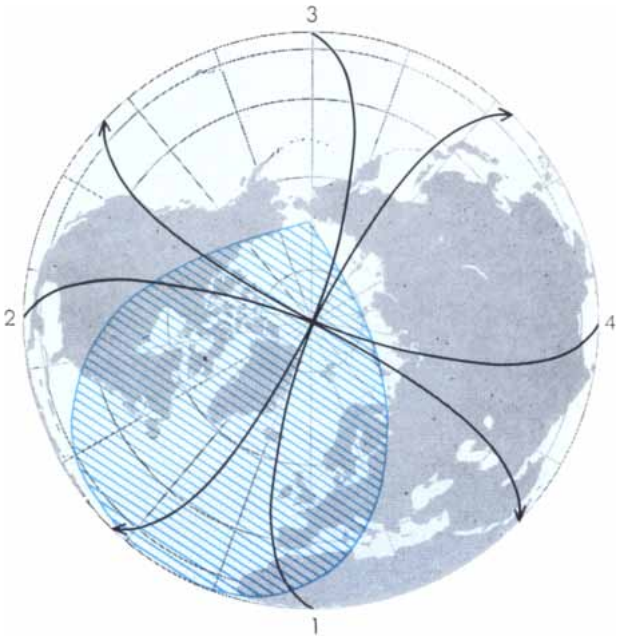
One other atmospheric source of noise remains to cause trouble: microwave noise arising from the heat of rain. Hogg has observed noise exceeding 100 degrees K. at 6,000 megacycles for a few minutes during a heavy storm, and noise as high as 70 degrees K. when no rain ever reached the ground. We cannot say how often rain noise might interrupt service in a satellite communication system. Interruptions could be minimized by using two receiving sites instead of one and spacing them far enough apart so that heavy rain would seldom be generating noise at each.

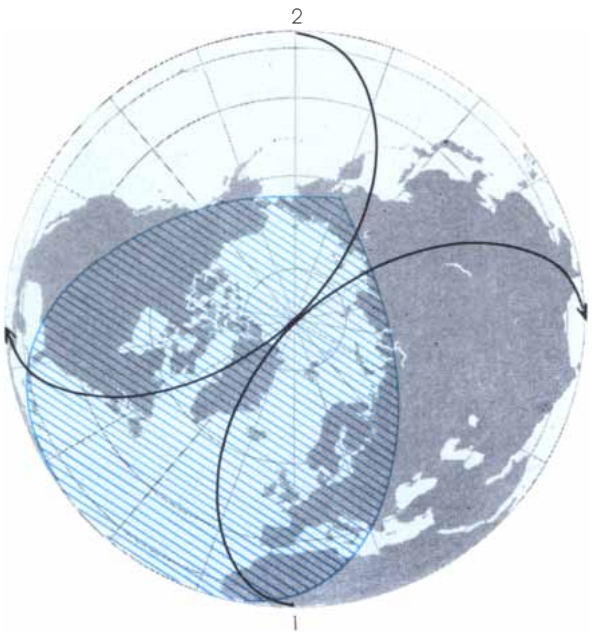
Having established the noise temperature of the sky, earth and atmosphere, the communication engineer next considers how noise is related to the band width of the signal he wishes to transmit and receive. The total noise power reaching a microwave receiver is proportional to the band width of the signal. Therefore the total noise power in a television channel will be about 1,000 times that in a telephone channel, because the television channel has about 1,000 times the band width of the telephone channel.

If this were all, one would merely need 1,000 times more power to transmit one television signal or 1,000 voice signals than to transmit one voice signal. Unhappily matters are much more complicated. A large number of people can talk simultaneously on one broad-band channel. One person talks only part of the time, and he talks loudly an even smaller fraction of the time. Thus the composite signal generated by 1,000 talkers has a peak power considerably less than 1,000 times that generated by one talker. It is clear that the amount of transmitter power required to provide a satisfactory received signal depends on the kind of signal to be transmitted as well as on the noise temperature and the band width.

The power required depends also on something else: the method of signaling, or modulation. Nearly everyone now knows that commercial radio employs two modulation methods: amplitude modulation (AM) and frequency modulation (FM). AM uses a narrow-band-width transmitter whose output is varied in amplitude in response to the original signal. In broad-band FM the transmitter frequency is varied, in response to the signal, over a frequency range that is many times the band width transmitted at any instant. If the frequency is varied up and down from the center frequency by 10 times the band width, the improvement in signal-to-noise ratio is about 100 times.

A rough, qualitative explanation of the improvement is as follows. Noise implies an uncertainty in measuring, at the receiving end, either the amplitude or frequency (or both) of the signal being transmitted at a given instant. In AM we are concerned only with the amplitude of the received signal, in FM only with its frequency. In AM we can vary the amplitude of the signal only from zero to twice its average value, and it is against this range of variation that we must measure the magnitude of the noise. To increase the signal-to-noise ratio in AM the sole recourse is to increase the average amplitude, which means raising the power of the transmitter. In FM, however, we can improve the signal-to-noise ratio by varying the frequency of the signal over an arbitrarily wide range. In sending a signal having a frequency of, say, 5,000 cycles per second we can, for example, vary the frequency of the transmitted signal back and forth over a range of 50,000 cycles per second, 100,000 cycles per second or even more than that. Since the uncertainty that noise introduces in our frequency measurement, at the receiver, remains more or less constant,





hours. The shaded areas exclude satellite positions closer to the horizon than 7.5 degrees, where signal reception would be impaired by background noise. In a two-hour orbit a satellite would spend at most only seven minutes within radio range of New York and Paris; in a 12-hour orbit it could be in range 4.5 hours. The calculations for these charts were made by Space Technology Laboratories.

it becomes a smaller and smaller fraction of the total frequency band over which the transmitted FM signal is swept.

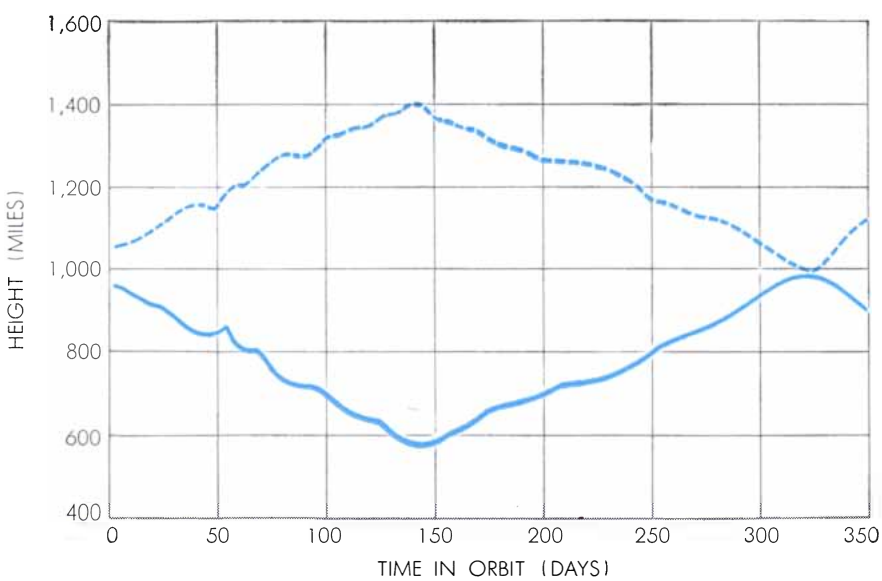
Ordinarily in receiving an FM signal a receiver must have a band width as wide as the total range of frequencies covered by the transmitted signal. Moreover, for the receiver to operate at all in the presence of noise the signal must be about 20 times more powerful than the noise. If the receiver band width is broadened to receive a wide-deviation FM signal, the receiver picks up noise across the entire band, and this minimum ratio of signal to noise may be hard to obtain.

Fortunately in 1939 J. G. Chaffee of the Bell Telephone Laboratories described a receiver for FM signals with a band width small compared with the range of frequencies over which the transmitter sweeps. In this receiver the output is "fed back" to alter the tuning of a comparatively narrow-band receiver, so that the receiver is always tuned to the received signal, regardless of how the signal frequency is swept back and forth. The use of Chaffee's FM-with-feedback receiver substantially reduces the transmitter power required in a satellite communication system. There are, of course, still other forms of broad-band modulation, including various pulse-modulation systems, that can provide a signal-to-noise advantage comparable to that gained with wide-deviation FM and an FM-with-feedback receiver.

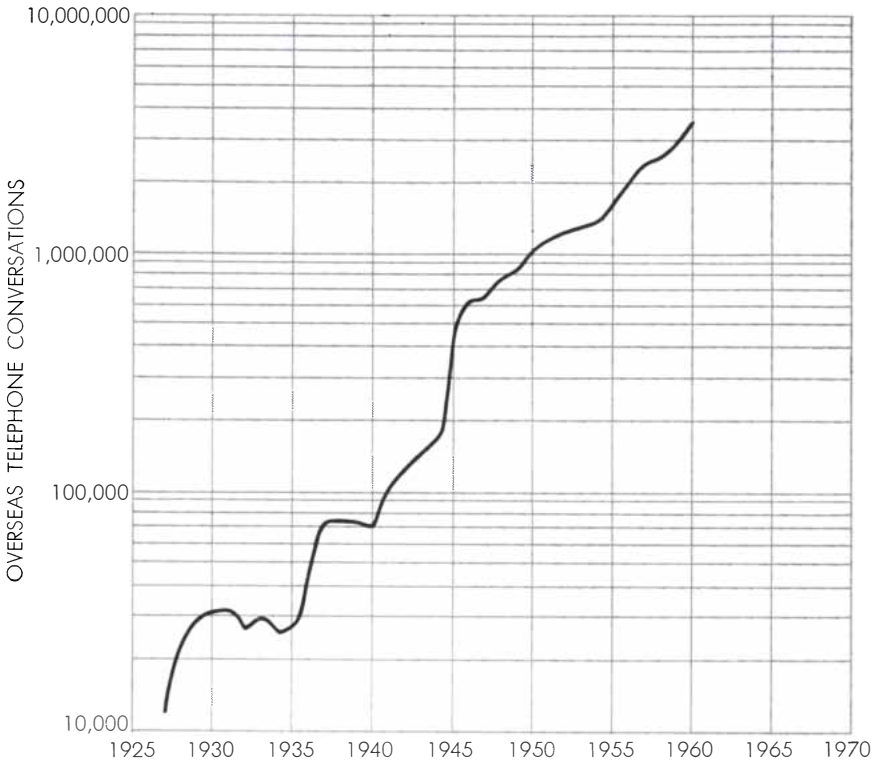
Now let us sum up the power requirements for a communication satellite, taking into account the various sources of noise, the capabilities of a maser receiver and the advantages of broad-band modulation. What power is required to transmit a television signal or between 600 and 1,000 telephone signals? We will assume a horn-reflector antenna with an aperture 60 feet square. For an unoriented satellite radiating equally in all directions at a height of from 2,000 to 3,000 miles, the required power is about two watts. Almost exactly the same power will serve for an oriented satellite at any greater altitude, up to and including one at 22,300 miles, if the satellite is equipped with a directional antenna that beams a signal just over the disk of the earth.

This is a particularly fortunate power level. In tests in progress, a type of microwave generator called a traveling-wave tube has continuously supplied somewhat more than five watts of power for more than four years and is still going strong. I believe that two-watt traveling-wave tubes could last for more than a decade in space.

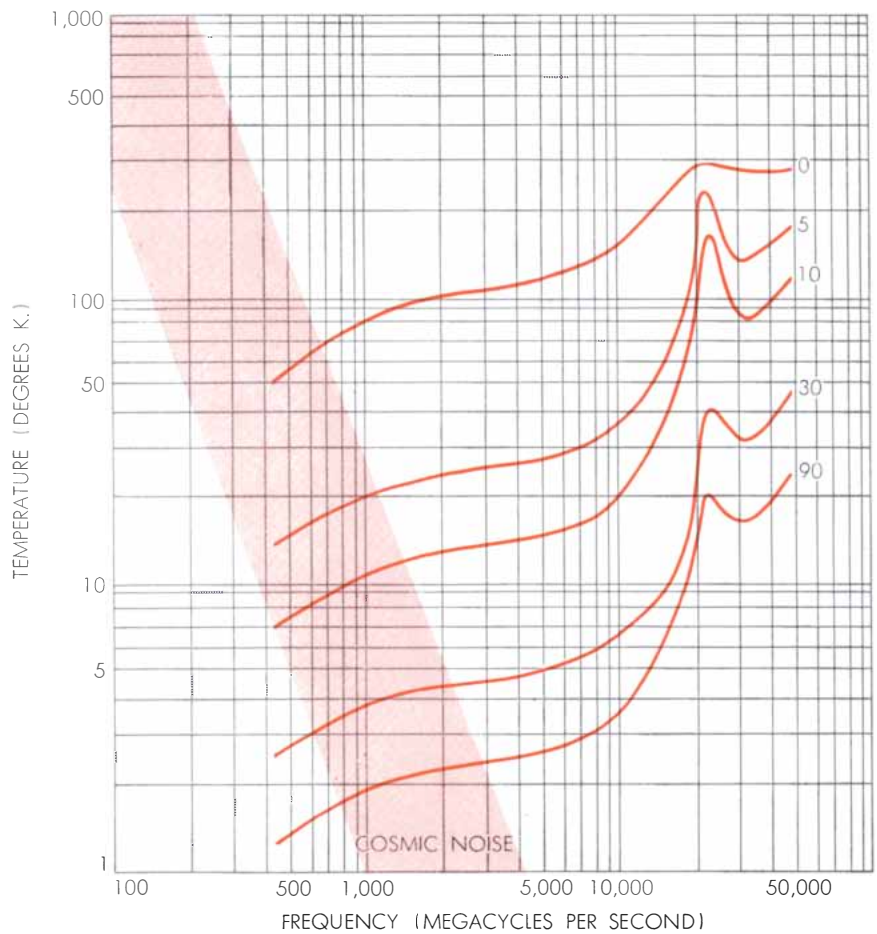
Moreover, a broad-band two-watt sig-



ALTITUDE OF *ECHO I* has varied curiously since its launching over a year ago. At first the slight pressure of sunlight raised the maximum altitude (apogee) while lowering the perigee. Later apogee and perigee came together; now the two are diverging again.



OVERSEAS TELEPHONE TRAFFIC has increased almost exponentially since the first radiotelephone circuit was opened between New York and London in 1927. In 1956 the first transatlantic telephone cable was placed in service with a capacity of 36 voice channels, since raised to 96. To all overseas points there are now some 550 radio and cable circuits.



NOISE INTERFERENCE with space communications is minimal at frequencies between 1,000 and 10,000 megacycles. Cosmic noise is radio noise from deep space. The five curves show the atmospheric noise reaching an antenna at various degrees of elevation.

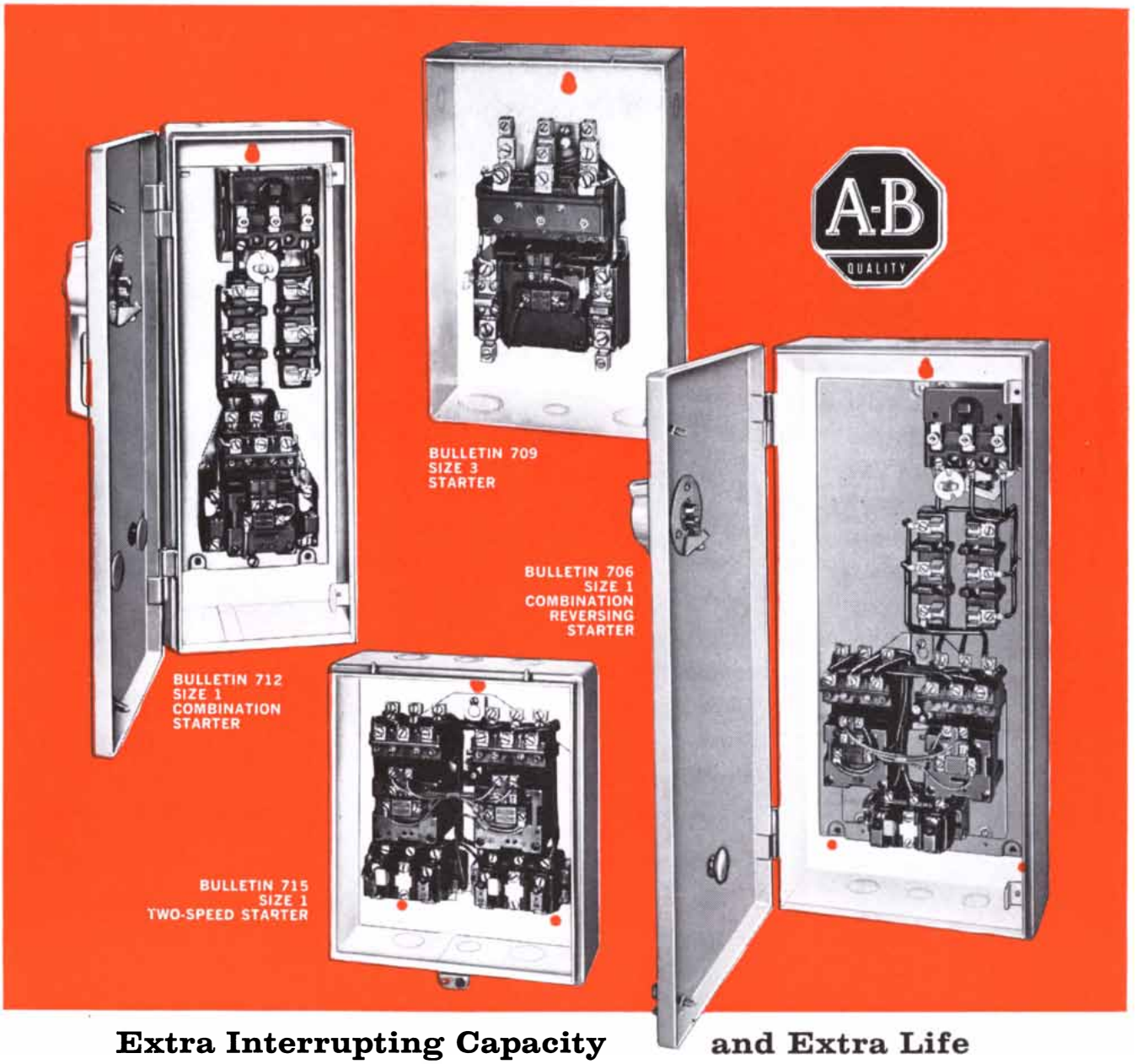
nal will not interfere with conventional ground microwave receivers over which it may pass. Nor, because of the improved signal-to-noise ratio afforded by broad-band modulation, will the signal from a satellite in one part of the sky interfere with the simultaneous reception of a signal from a satellite in another part of the sky. The directivity of antennas will allow the simultaneous use of many satellites operating on the same frequency.

The Ground Stations

Compared with the problems already discussed, the problems associated with ground terminals are less serious. Some of them are well illustrated in Project Echo. Echo is a National Aeronautics and Space Administration satellite communication project in which Bell Laboratories has participated. A 100-foot, 130-pound aluminized plastic balloon was launched on August 12, 1960, in an orbit about 1,000 miles high, reaching an extreme latitude of 48 degrees. The orbit of *Echo I* has changed rapidly, chiefly because of the intermittent pressure of the sunlight and in part because of atmospheric drag [*see illustration at bottom of preceding page*].

The Echo balloon carries, for tracking purposes, two 108-megacycle transistorized transmitters powered by solar cells. (The transmitters are now dead.) For communication purposes the balloon was illuminated by signals from a number of ground stations. The principal exchange of signals took place between the Holmdel station of the Bell Telephone Laboratories in New Jersey and the Goldstone station in California operated by the Jet Propulsion Laboratory of the California Institute of Technology. Holmdel transmitted at 960.05 megacycles using a 10-kilowatt transmitter feeding into a dish antenna 60 feet in diameter. Goldstone illuminated the balloon at 2,390 megacycles with an 85-foot dish antenna and received Holmdel's reflected signals with the same antenna. Holmdel used a horn-reflector antenna to receive Goldstone's signals.

A rather elaborate system was devised for pointing the Holmdel and Goldstone antennas accurately at *Echo I*. Signals from the balloon were received by the Minitrack network of the National Aeronautics and Space Administration, and in addition the balloon was tracked by radar. Radar data and data from Minitrack stations were transmitted to the Goddard Space Flight Computation Center in Washington.



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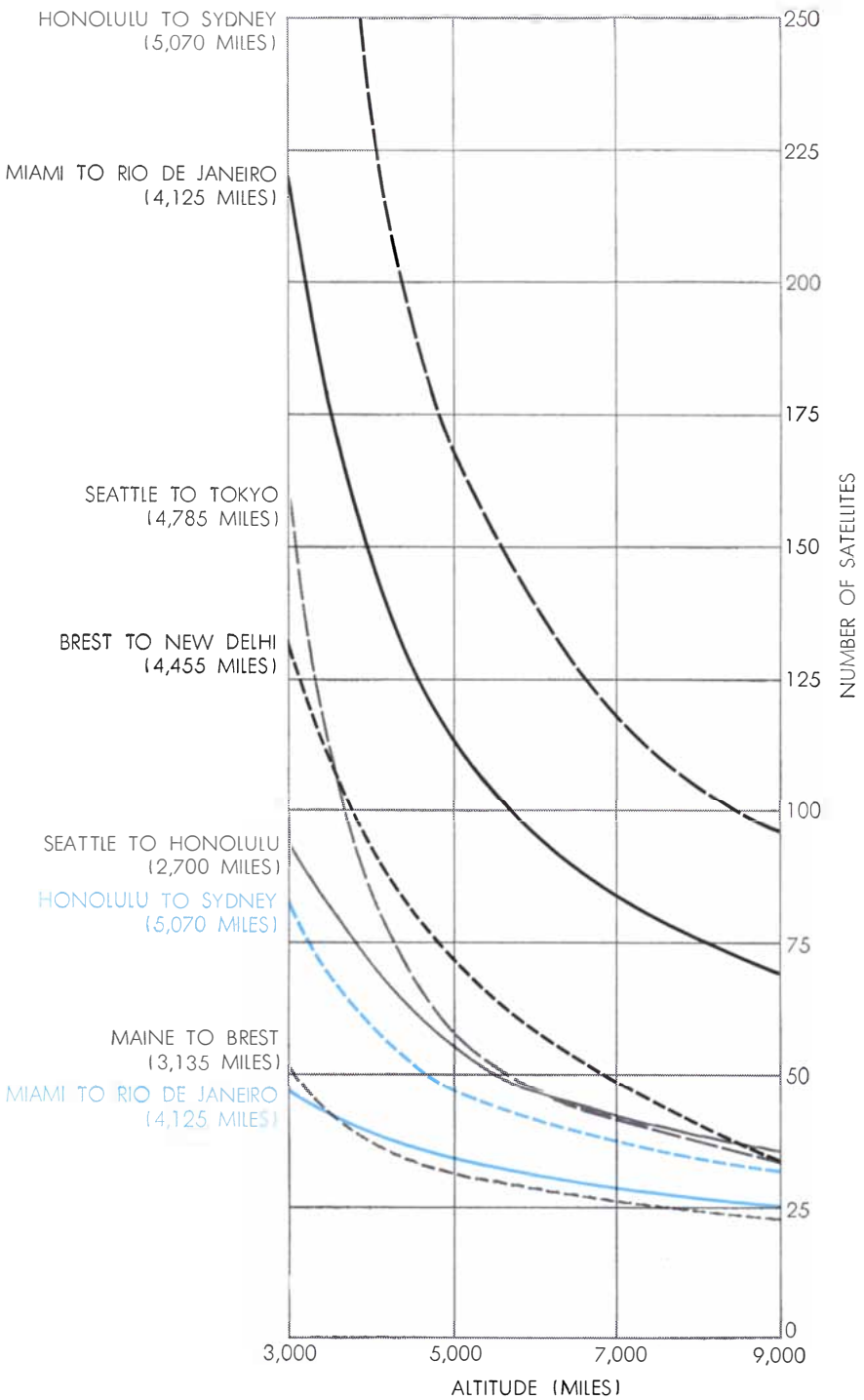
The center computed the satellite's orbit and also the data needed for pointing the antennas. The pointing data were transmitted to Holmdel and Goldstone by teletypewriter and received on punched tapes. At four-second intervals the tapes provided data for time, azimuth, elevation and rate of change for both asimuth and elevation. The tapes were fed into a digital-to-analogue converter, which then controlled the aiming of the antennas. The errors usually ran to about 10 minutes of arc, which corresponds to about one-third of the visual diameter of the moon. Optical and radar tracking were available to correct or replace the computed tracking.

Goldstone's 85-foot antenna and asso-



NUMBER OF SATELLITES required to provide service 99.9 per cent of the time between typical pairs of cities declines sharply as satellite altitude increases (*also see illustration at top of pages 96 and 97*). The black and gray curves are for satellites in random polar orbits. For connecting cities lying close to the Equator, or on opposite sides of it, satellites in equatorial orbit (*colored curves*) are much more effective than satellites in polar orbit.

ciated receiver, employing a parametric amplifier, had a noise temperature of about 300 degrees K., compared with 24 degrees K. for Holmdel's more sensitive maser receiver and horn-reflector combination. When the Echo balloon was in the most favorable part of its orbit, the signal received at Goldstone was about 24 decibels, or about 250 times, above the noise in a six-kilocycle band; the signal at Holmdel, about 34 decibels, or 2,500 times, above the noise. When the balloon was in the most unfavorable position for sender and receiver, the signal-to-noise ratios deteriorated by a factor of almost 10. If a narrow-band form of modulation (for example, AM) had been used, these lower signal-to-noise ratios would have been too low to provide a good telephone circuit. The signals were actually transmitted in broad-band FM and received by FM-with-feedback, and in general achieved the high quality expected. Two-way telephone conversations were conducted between Holmdel and Goldstone, and telephone pictures and "speedmail" were successfully transmitted. Clear signals reflected from Echo were also received in Europe.

In spite of the technical success of the Echo experiment, one must conclude that signal reflection from this passive type of satellite is only marginally practical as a means of communication. The balloon became increasingly wrinkled during its first six months in orbit, and as a result the reflected power began to fluctuate over a range of more than 10 to 1. Development of a rigid balloon might solve this problem, but there are other difficulties. To achieve a five-megacycle band width, which would be suitable for carrying 1,000 telephone circuits or one television channel, it would be necessary to use transmitters with 50 to 100 kilowatts of power and receiving antennas more than 100 feet in diameter.

Proposed Experiments

Until more experience has been gained with various types of satellite it is impossible to predict when a practical satellite communication system will arrive and what form it will take. It is proper, therefore, that vigorous experimentation be conducted.

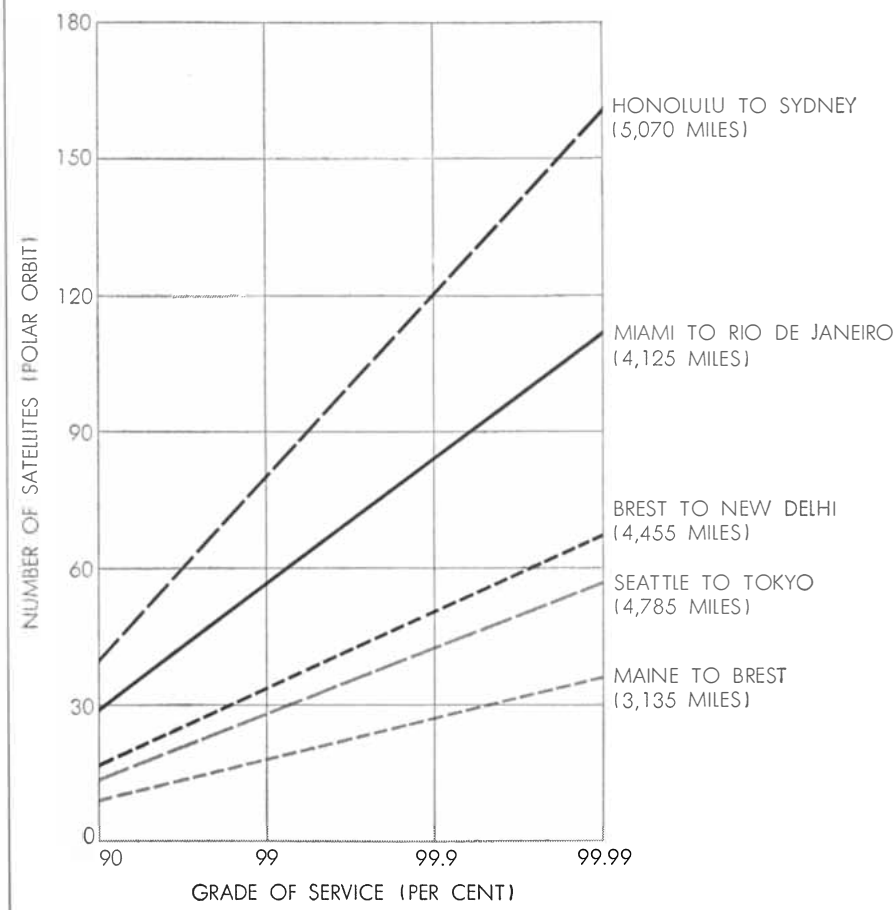
The goal of the Army's Advent program is a system using 22,300-mile-high satellites with orientation control and station-keeping. Although this system may suit military requirements, the signal travel time to such distant satellites

may prove unacceptable for commercial telephone service.

The Air Force plans an experimental launching of a belt of wires, which would provide a simple and effective communication system of limited band width. Astronomers have objected that the belt, being relatively fixed in space, might impair both optical and radio observations of the sky in a way that a moving satellite would not [see "Science and the Citizen" in this issue]. In any event, the initial belt will be placed low enough so that the wires will re-enter the atmosphere and be destroyed within a year or two. Experiments at higher altitudes could be conducted with wires that would disintegrate in a specified time.

As an alternative to high-altitude satellites, belts of wires and balloons, the American Telephone and Telegraph Company has proposed a system using between 50 and 120 simple active satellites in orbits about 7,000 miles high. With the large rockets now being developed, a dozen or more of these satellites could be placed in orbit in a single launching. In a relatively short time their orbits would assume random paths crossing—or nearly crossing—the poles. For efficient coverage between ground stations at low latitudes, a number of satellites should also be placed in orbit around the Equator. A system of 40 satellites in polar orbits and 15 in equatorial orbits would provide service 99.9 per cent of the time between any two points on earth. A.T.&T. has proposed that the system contain about 25 ground stations so placed as to provide global coverage. Bell Telephone Laboratories is building an experimental satellite to test the feasibility of such a system; NASA has agreed to launch it early next year for a fee of about $6 million, to be paid by A.T.&T.

The cost of a global satellite communication system will be large—on the order of $500 million—but no larger than the cost of undersea cables that could provide the same geographical coverage. (One cannot say the "same service," because undersea cables do not yet provide the band width needed for television.) Assuming that the experiments of the next few years are encouraging, there should be no lack of capital, domestic and foreign, to share the cost of a world-wide satellite communication system.



QUALITY OF SERVICE is proportional to the number of satellites used. The curves are for random polar orbits at an altitude of 7,000 miles. A service grade of 99.9 per cent means that communication will be interrupted .1 per cent of the time, or an average of 1.4 minutes per day, usually made up of several much briefer periods predictable well in advance.

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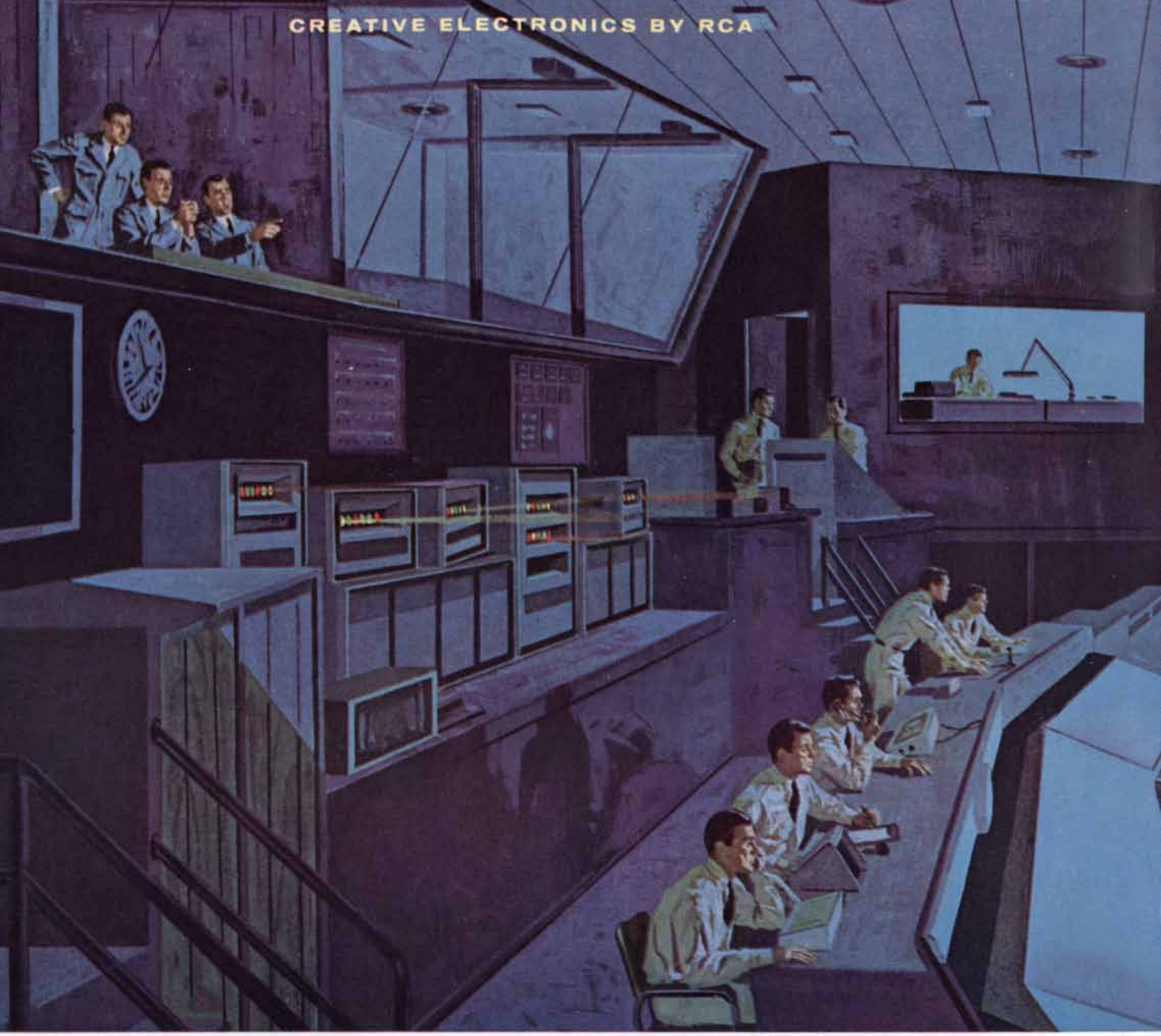

NORAD ON THE ALERT

Inputs from BMEWS Provide Instantaneous Missile Data Direct to NORAD Headquarters

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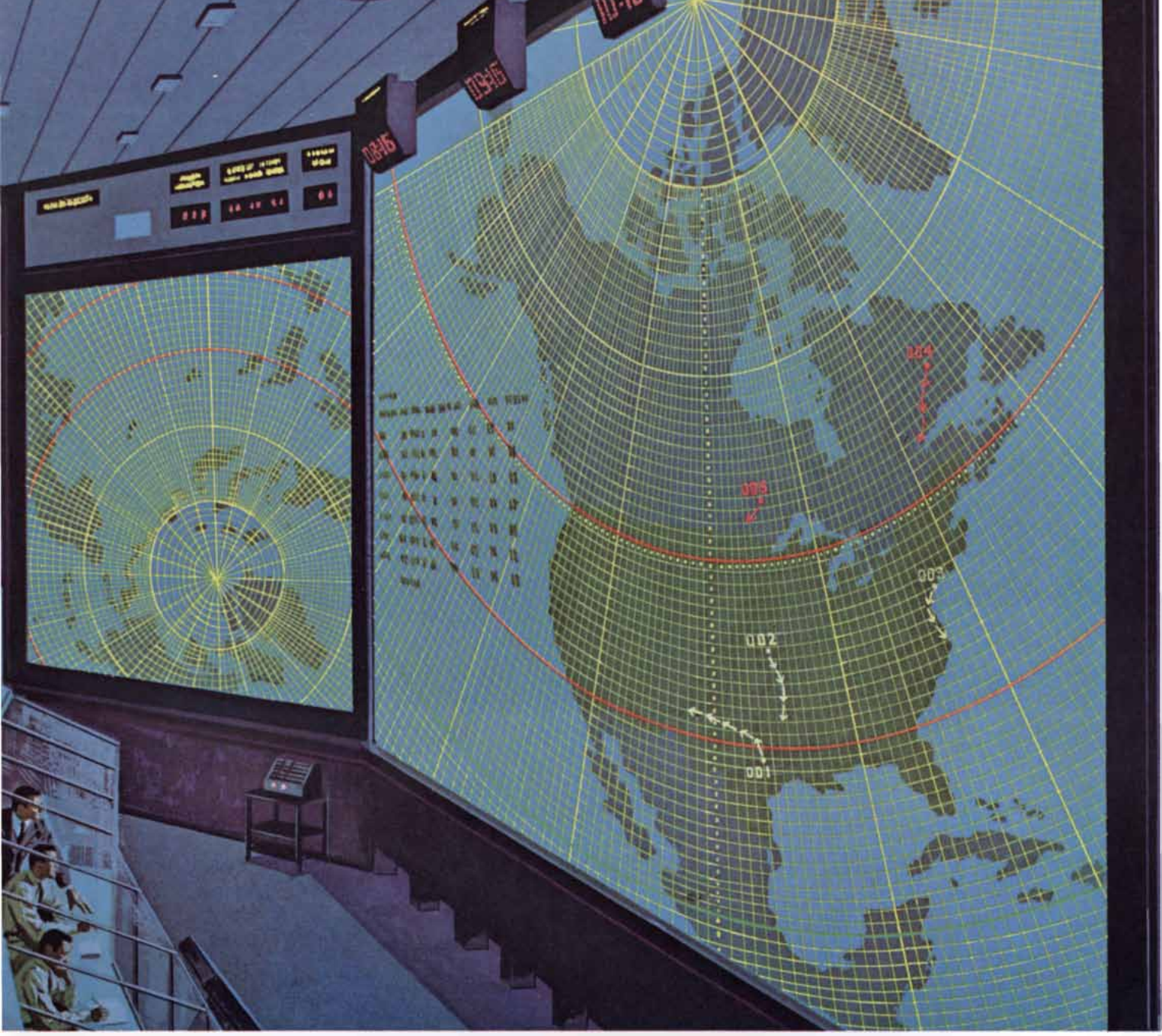
At BMEWS installations operated by USAF Air Defense Command, computers read out missile tracking data from giant radars. This information is simultaneously relayed to NORAD's Combat Operations Center.

The Radio Corporation of America is prime systems contractor for BMEWS. At the COC, RCA's Display Information Processor computing equipment automatically evaluates missile sightings, launch sites and target areas. By means of data processing and projection equipment installed by RCA and a team of other electronics manufacturers, the findings are displayed on huge, two-story high map-screens in coded color symbols, providing the NORAD battle staff with an electronic panorama of the North American and Eurasian land masses.

The handling of BMEWS inputs at NORAD is an example of how RCA data processing capabilities are assuring the high degree of reliability so vital to continental defense.



At NORAD Headquarters, RCA computing equipment, the Display Information Processor (control console shown here) receives sightings data from BMEWS and processes it for automatic readout.

RCA is prime system contractor for the sprawling BMEWS three-site radar network whose probing electronic fingers reach deep into space to provide early warning of missile attacks.

RCA's Automatic Checkout & Monitoring equipment continuously tests and checks performance of portions of the system and alerts an operator when a monitored signal exceeds certain limits.

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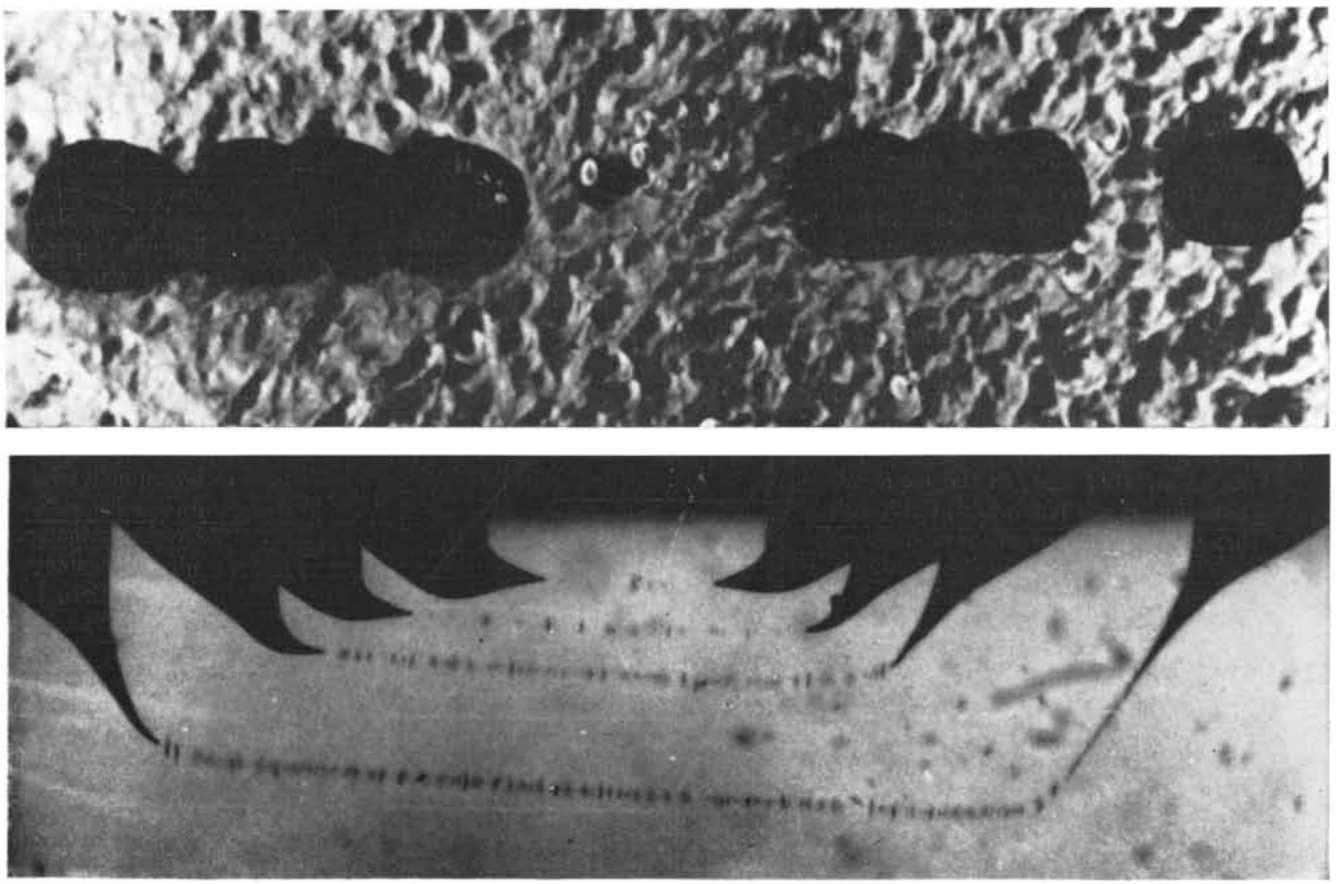
Observing Dislocations in Crystals

These significant imperfections in the regular latticework of a crystal were first proposed on theoretical grounds. Now they can be directly observed in a number of ways

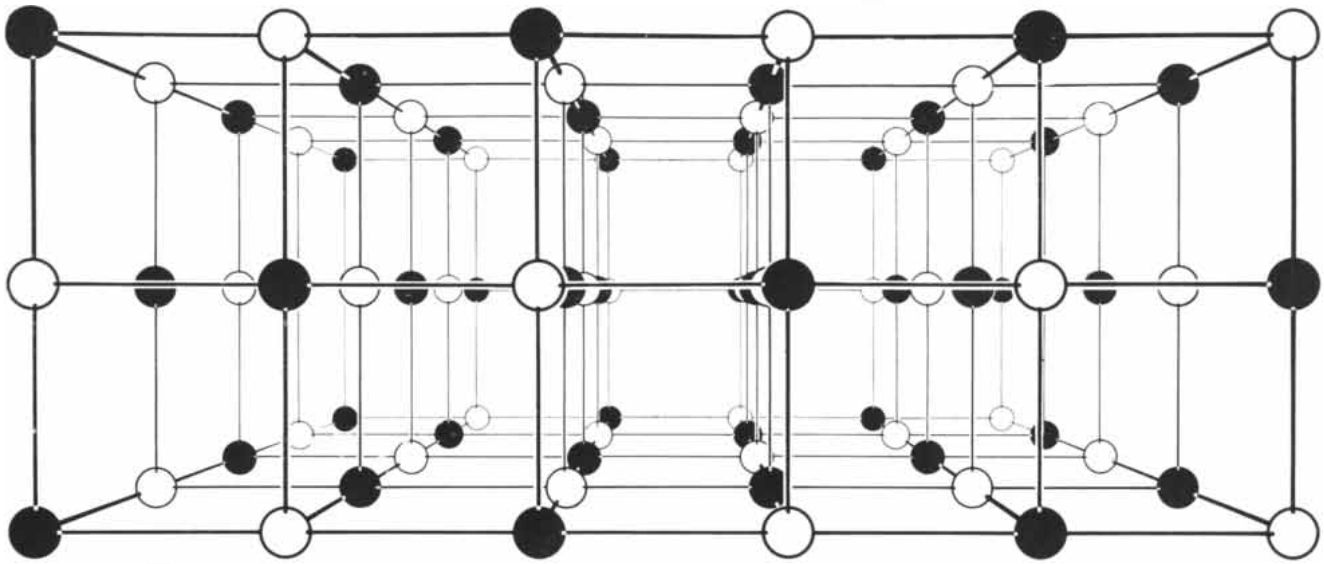
by W. C. Dash and A. G. Tweet

The past 25 years have seen an enormous advance in the understanding of crystalline solids. No small share of the credit for this progress belongs to one basically simple concept: the dislocation. When first proposed in 1934, the dislocation was wholly a product of scientific imagination—a picture of a hypothetical imperfection in the arrangement of atoms in a crystal lattice. The success of the dislocation in explaining some puzzling properties of crystals soon won it general acceptance, although for a long time there were authorities who doubted its reality. During the past decade, a number of methods have been developed for making dislocations observable. The question of reality is now settled, and it has become possible to study directly a feature that for a long time eluded investigators because of its small scale. At present some exciting practical possibilities are beginning to emerge from the work.

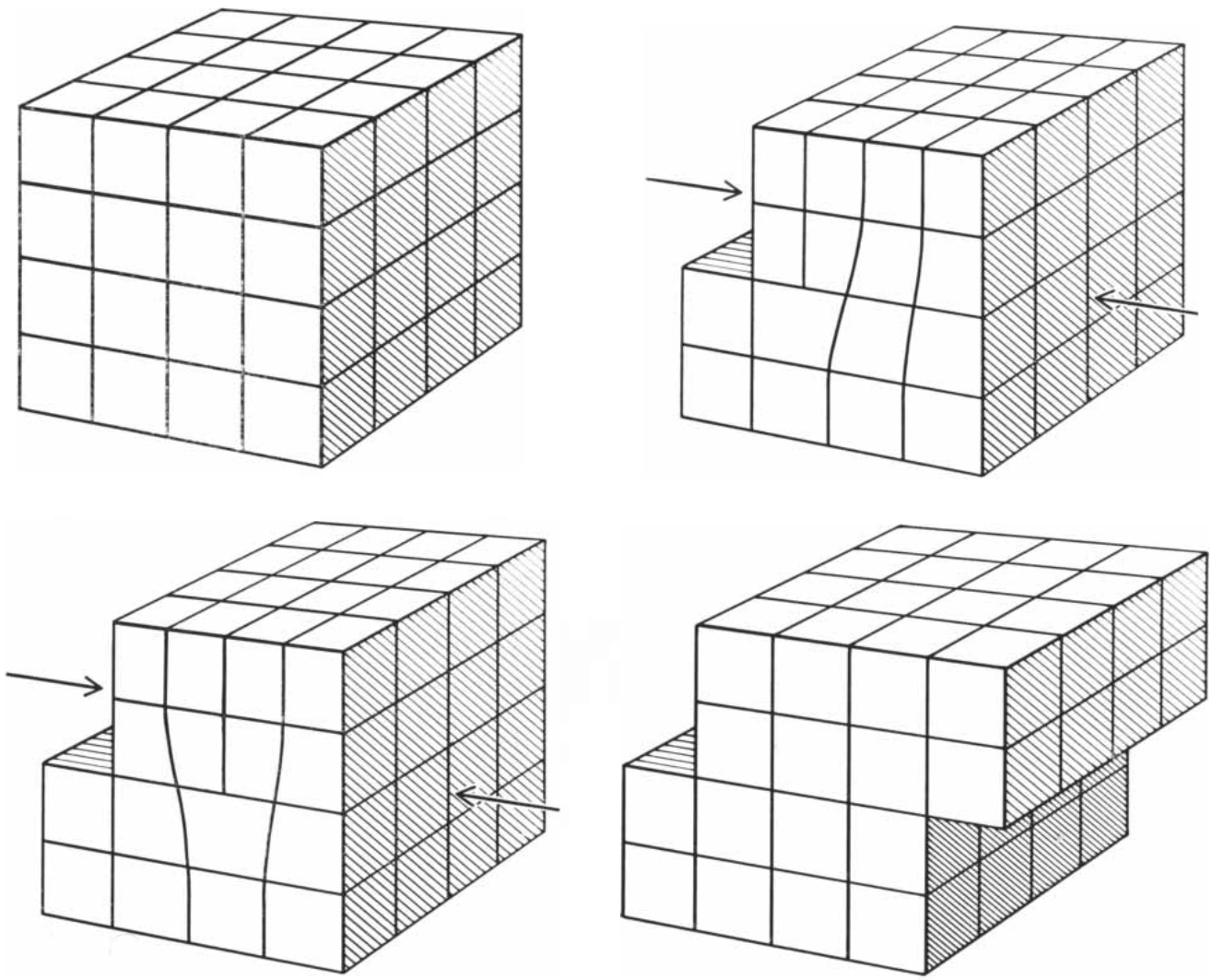
Dislocations were proposed to explain the weakness of metals. Calculations based on the assumption of perfect crystal lattices indicated that metals should be hundreds of times stronger than they are. It was therefore independently suggested by Geoffrey I. Taylor in England, Egon Orowan in Germany and Michael Polanyi in England that real crystals con-



DISLOCATIONS IN SILICON are visualized by two techniques in these micrographs by W. C. Dash. The top picture shows "etch pits" eaten into the surface of a crystal at the site of emerging dislocations. The cross section at bottom, made by transmitted infrared radiation, shows the same pits in silhouette. The loops connecting them have been made visible by "decoration" with copper.



ORDERLY ARRAY of atoms in a regularly repeated lattice is characteristic of crystals. This diagram shows schematically the arrangement of atoms in an idealized cubic crystal such as sodium chloride. The atoms are all situated at the corners of cubic cells.



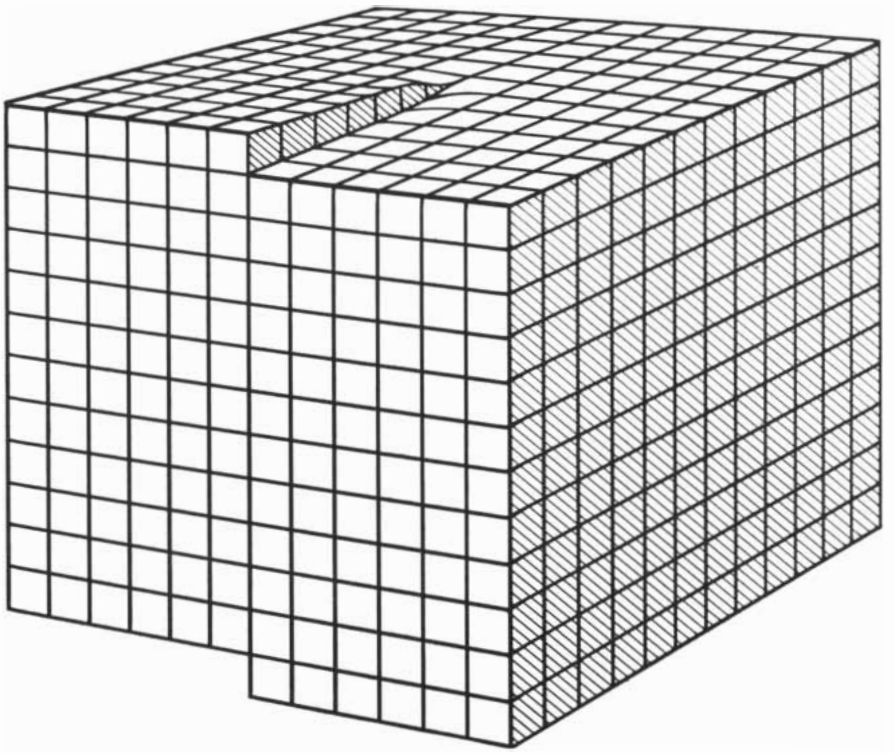
EDGE DISLOCATION is diagramed. At upper left is a simplified drawing of a perfect crystal like the one at the top of the page. Under stress part of the crystal is squeezed one atomic spacing (*upper right*). An "extra" plane of atoms appears; the region at its base is an edge dislocation. The dislocation moves across the crystal (*lower drawings*), deforming it in a series of discrete steps.

tain regions of mismatch, in which the atoms are not lined up in perfect array. The mismatch they envisaged is the type that would result if part of the upper half of a crystal had slipped a distance of one atomic spacing over the lower half [*see illustration at bottom of opposite page*]. At the end of the region of slip the upper part of the crystal contains an extra plane, or sheet, of atoms. Along the bottom edge of this plane runs what is called an edge dislocation, and the atomic bonds for some distance around it are either stretched or compressed.

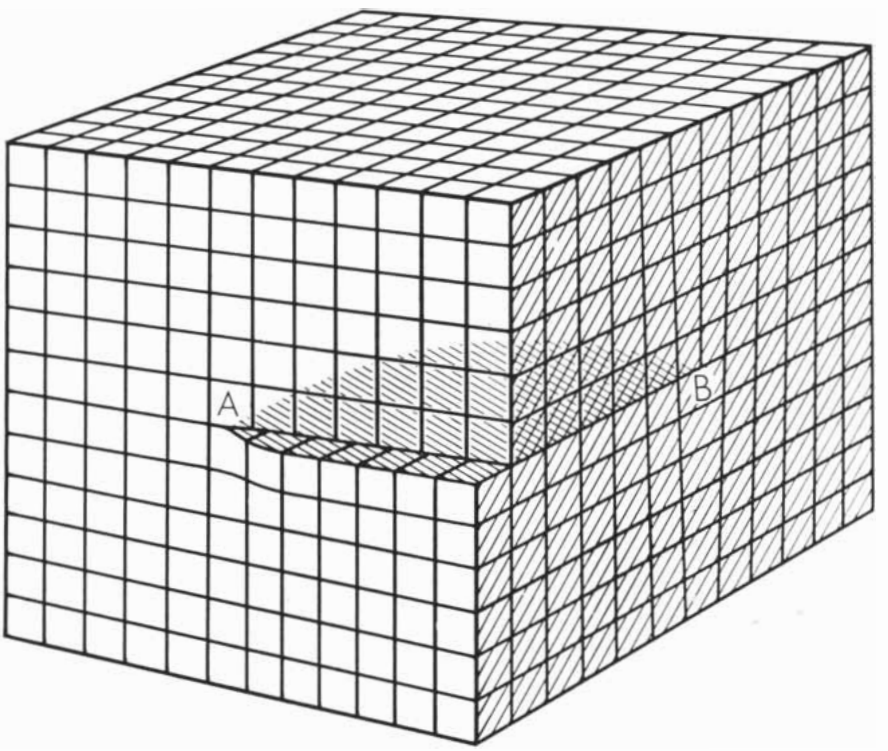
As Taylor and the others pointed out, a crystal containing edge dislocations would yield much more readily than a perfect crystal to a shearing stress. The force would push the extra sheet of atoms through the crystal; it could break the bonds between atoms row by row instead of all at once [see "Dislocations in Metals," by Frank B. Cuff, Jr., and L. McD. Schetky; SCIENTIFIC AMERICAN, July, 1955]. Moreover, the model agreed with the fact that crystals usually deform along individual "glide planes."

Soon afterward J. M. Burgers, a Dutch physicist, proposed a second kind of dislocation, in which two parts of the crystal are slipped parallel to the line of dislocation rather than perpendicularly to it, as in the edge dislocation. This in effect converts a stack of parallel atomic planes into a spiral ramp winding through the crystal around the dislocation line [*see illustration at top of this page*], whence the name "screw dislocation." Subsequently it was realized that the edge and screw types are simply limiting cases of a continuum, in which the dislocation line can assume various angles to the direction of atomic displacement. In other words, most dislocations contain both a screw and an edge component [*see illustration at right*]. The important point about all dislocations is that they are regions of distortion in the lattice and move rather easily when subjected to a force.

The concept accounted for the weakness of metals. But the macroscopic behavior of a crystal is the result of the motion of a great number of dislocations and the interactions among them. It was therefore difficult to establish the quantitative relationship between experimental results and the properties of individual dislocations, which the theorists were studying with simplified models. On the other hand, the atomic details of lattice distortions could not be



SCREW DISLOCATION occurs when planes of atoms (*represented here by small cubes*) are slipped past each other along the dislocation line instead of perpendicularly to it as in an edge dislocation. The result is a spiral ramp through the crystal, visible at the surface.



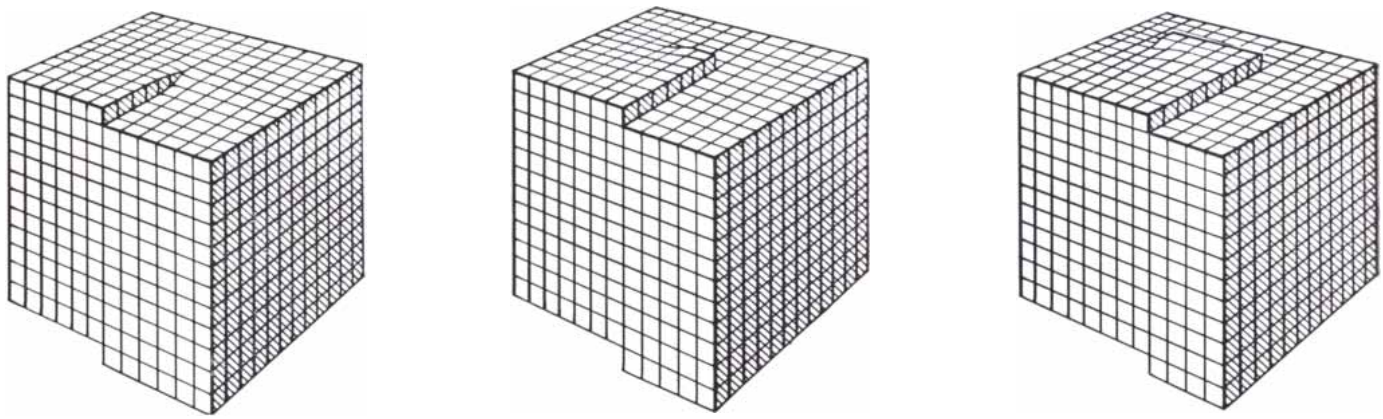
EDGE AND SCREW DISLOCATIONS merge continuously with one another, and most actual dislocations are mixtures of the two. This dislocation line (*arc AB*) begins as a screw at point *A* and ends up as a pure edge dislocation by the time it reaches point *B*.

made visible in themselves. The spacing between atoms in a crystal is of the order of three angstrom units (one angstrom unit is a ten-millionth of a millimeter); only in the past few years have electron microscopes been capable of resolving objects as small as 10 angstrom units across.

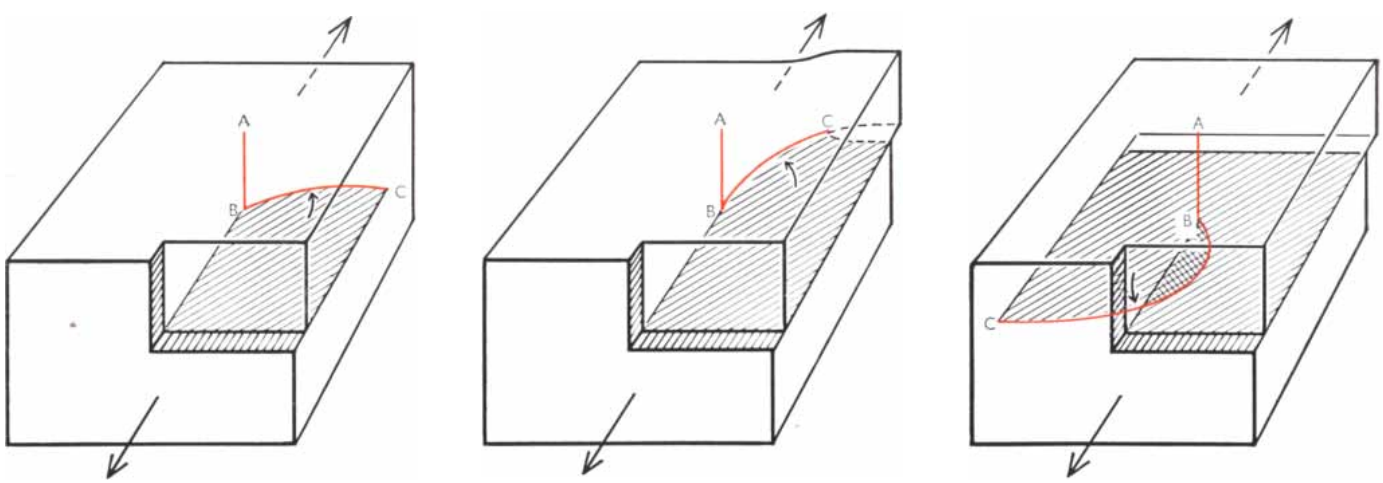
The first direct evidence for individual dislocations came from studies of crystal growth. When atoms from a liquid or vapor alight on the surface of a growing crystal, they attach themselves most easily to the lattice if they can form bonds with other atoms already on the surface as well as with those in the complete layer below. As a new layer grows, its boundary forms a step one atom high, against which new arrivals can fit and incorporate themselves into the lattice. In 1949 F. C. Frank of the University of Bristol realized that screw dislocations provide a step where the ramp emerges at the surface. Furthermore, the step can perpetuate itself indefinitely. As new atoms arrive along its length, they wind it into an ever growing spiral ramp [*see upper illustration on these two pages*]. Frank's theory soon received experimental proof. L. J. Griffin of the University of London made a micrograph of growth spirals on beryl crystals [*see top illustration on page 112*], and many such observations have been made since.

A growth spiral, however, results from a random process, and whether one will be observable on a given crystal surface is a matter of luck. F. Hubbard Horn, Ernest F. Fullam and John S. Kasper of the General Electric Research Laboratory found a more dependable way to make screw dislocations visible. In the course of some work with aluminum boride crystals they discovered that certain reagents attack growth spirals on the surface, dissolving a hole through the thin crystal platelets at the center of the spiral. Evidently the core of a screw dislocation is chemically more reactive than the perfect parts of a crystal.

Upon treating other crystals with appropriate reagents they saw that the holes, or "etch pits," would form even where there were no spirals. Presumably these pits marked points at which dislocations intersected the surface. Proof of the idea was provided by F. Lincoln Vogel, W. G. Pfann, H. E. Corey and E. E. Thomas of the Bell Telephone Laboratories. They had etched a germanium crystal and obtained a row of closely spaced pits. By means of X-ray analysis they demonstrated that the row lay along the boundary between two crystal grains. Such a boundary is in effect a series of edge dislocations, and Burgers had calculated that the distance



SPIRAL GROWTH PATTERN is produced by a screw dislocation. The emerging ramp of the dislocation (*left*) provides a step, where newly arriving atoms attach themselves in preference to other sites on the crystal surface. Since the rate of attachment is approximately the same everywhere along the step, the new atoms wind themselves into a spiral, perpetuating the step as a spiral ramp. This



FRANK-READ MECHANISM explains how a crystal can continue to deform, apparently indefinitely, in a small region instead of reaching the surface and leaving a perfect lattice, as in the bottom illustration on page 108. Under stress (*arrows*) segment *BC* of dislocation line *ABC* begins to move. But it is anchored at point *B* and therefore pivots around *B*, leaving an offset of one atomic

between dislocations should depend on the angle between the grains. The Bell Laboratories group measured the angle and the spacing of the pits and found that they agreed with Burgers' formula.

Etching is now a standard technique. It has been used to verify a number of predictions of dislocation theory. For example, John J. Gilman and William G. Johnston of the General Electric Research Laboratory have confirmed that glide planes contain many dislocations.

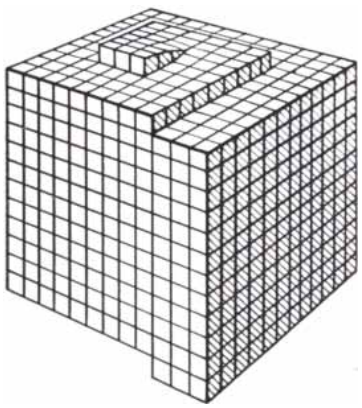
The same workers also learned to use etch pits for tracing the motion of dislocations. They observed that the pit formed at the site of a dislocation has sharply pyramidal sides. If the dislocation is moved by applying a force and the crystal is etched again, a new, sharply pointed pit forms. At the same time the old pit smooths out and becomes flat-bottomed because it no longer contains a core that is preferentially attacked. Repeated etching therefore makes it possible to observe the direction and velocity of dislocations moving in response to stress [*see bottom illustration on next page*].

Applying pulses of force ranging in duration from .001 second to one day, Johnston and Gilman studied the relation between stress and velocity in lithium fluoride. For velocities less than about 1 per cent of the velocity of sound (the maximum speed at which dislocations can move through a crystal), the velocity increases very sharply: doubling the stress increases the velocity by as much as a factor of 1,000,000.

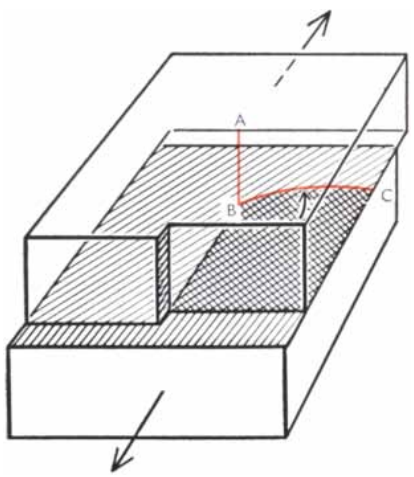
Valuable as the etch-pit technique is, it suffers from a serious limitation: it traces the distribution and movement of dislocations in only two dimensions—that is, along the surface. To be sure, by etching a sufficient number of times the experimenter can penetrate to successively deeper layers of a crystal and so map out the third dimension. But this is a tedious way to try to follow a complicated group of dislocations.

In transparent crystals three-dimensional patterns are much more readily observed by a method known as decoration. If a crystal is supersaturated with atoms of certain foreign materials, the impurity tends to precipitate out as colloidal specks. The specks grow more readily in regions of distortion and so they concentrate along dislocation lines like beads on a string. Light passing through a transparent crystal is scattered and absorbed by the specks, which are therefore visible at moderate magnifications. S. Amelinckx and his co-workers at the University of Ghent used decoration to study dislocations in rock salt, calcium fluoride and other transparent materials. One of their photomicrographs, showing a net of dislocations in potassium chloride, is reproduced at the upper left on page 113. Amelinckx was able to show that the complicated geometry of the network agrees in detail with the mathematical theory.

By taking advantage of the unique photosensitive properties of silver bromide and silver chloride, J. W. Mitchell, now at the University of Virginia, has studied dislocations in these two salts. Specks of colloidal silver are formed along dislocation lines when these crystals are exposed to light. Among the experiments Mitchell and his students have performed with photosensitive salts is one that helps to demonstrate the effects of internal stresses. They embedded tiny glass spheres in growing crystals of

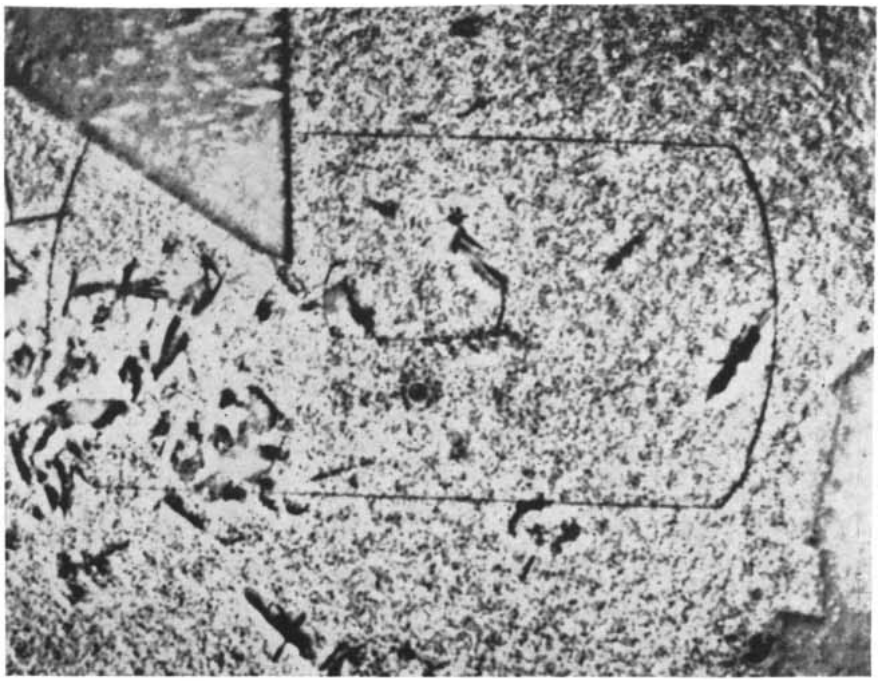


method of crystal growth was proposed by F. C. Frank to explain how crystals can grow from vapor or solution as fast as they do.

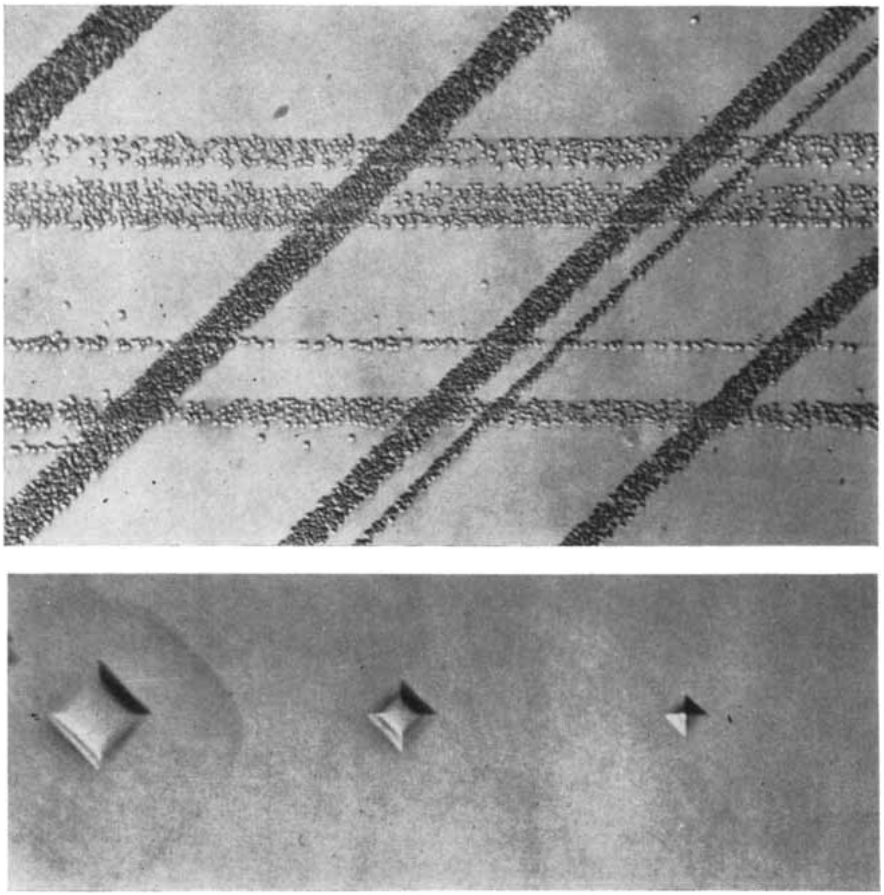


spacing each time around. Diagonal hatching indicates area that has slipped one spacing; crosshatched area has slipped twice.

COPPER CRYSTAL, stressed by pulling at both ends, is heavily deformed by multiple atomic offsets along its preferred glide planes. Such behavior of metals under stress supports dislocation theory. This photomicrograph was made by S. S. Brenner at the General Electric Research Laboratory.



FIRST EVIDENCE for the existence of screw dislocations, and confirmation of Frank's growth theory, was this photomicrograph, made by L. J. Griffin at the University of London, of two ramps (from a left-hand and a right-hand screw dislocation) on a beryl crystal.



ETCH-PIT METHOD of observing dislocations is illustrated by these photomicrographs taken by John J. Gilman and William G. Johnston at the General Electric Research Laboratory. In the upper picture a reagent has eaten rows of tiny pits on a lithium fluoride crystal along the glide planes in which dislocations are concentrated. Lower picture shows how a sharp pit (*right*) is formed at the site of a dislocation and more rounded ones at former sites.

silver chloride. Glass contracts more slowly on cooling than silver chloride does, so that as the crystals cooled regions of compressive stress were created around the spheres. The force generated a series of dislocation loops that moved outward from the spheres like smoke rings [*see illustration at upper right on opposite page*].

One of the authors (Dash) has extended the decoration method to silicon, which is opaque to visible light but transparent to infrared. It is possible to grow silicon crystals that contain very few imperfections, and therefore to study individual dislocations in detail. Moreover, dislocations in silicon are mobile above 600 degrees centigrade but almost immobile at room temperature. As a result a crystal can be deformed at high temperatures and the resulting dislocations can be "frozen" for examination at room temperature.

An etching technique for silicon has also been developed, and so the two methods of visualizing dislocations can be compared. In one experiment a crystal was treated in such a way as to generate dislocations in a small region of one surface; the dislocations formed a series of expanding loops within the crystal. Etching created pits where each of the dislocations intersected the surface, and decoration with copper delineated these interior loops. Under infrared illumination the decorated dislocation lines were seen to be continuations of the etch pits [*see illustrations on page 107*].

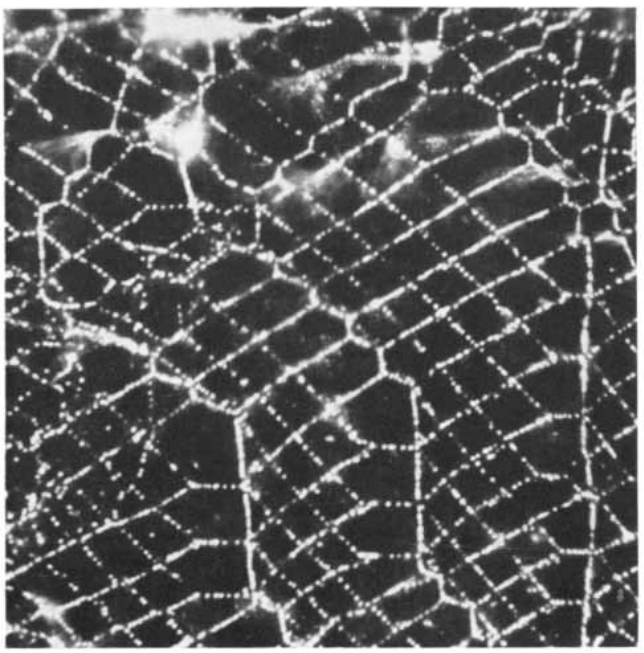
More general tools of crystal analysis —electron diffraction and X-ray diffraction—have also been brought to bear on the problem of observing dislocations. In a sense they are more direct: the way in which a beam of electrons or X rays is reflected from the planes of atoms in a crystal depends quite simply on the geometry of the planes. Therefore a disturbance in the diffraction pattern is directly related to the very disarray that constitutes a dislocation.

One of the most powerful of the diffraction techniques was developed by P. B. Hirsch and his co-workers at the University of Cambridge. They work with specimens about 1,000 angstrom units thick, formed by electropolishing a metal foil. When these films are put in an electron microscope, the electron beam passes through them, and the image formed by diffraction is recorded on photographic film. Electron diffraction makes it possible to observe dislocations in motion when a specimen is

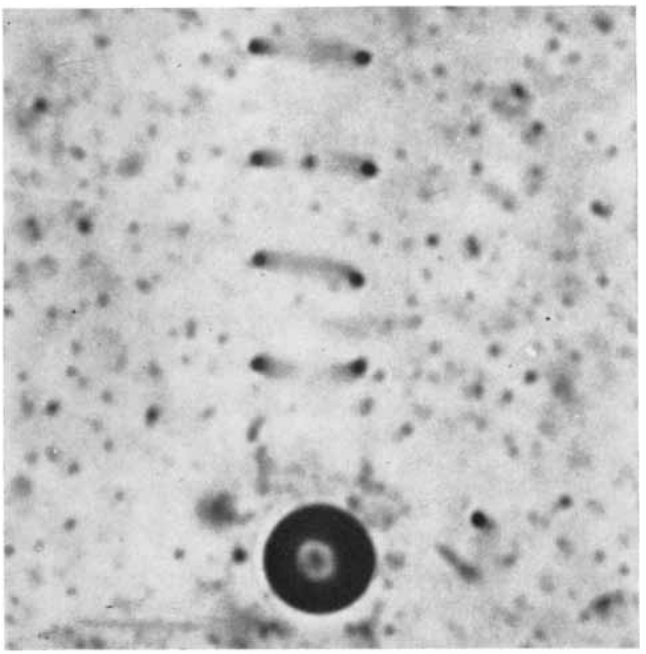
stressed or heated; from motion-picture films made by Hirsch's group and others a good deal has been learned about the interactions of dislocations with each other, with other imperfections and with the surface of crystals.

In principle X-ray diffraction works in the same way as electron diffraction. Because X rays are more penetrating they can be used on thicker specimens and therefore on a wider range of substances. Moreover, with the X-ray diffraction method it is easy to determine the direction of the atomic displacement in a dislocation. On the other hand, X-ray diffraction does not magnify and it requires longer exposure times; hence it is not well adapted to following the motion of dislocations.

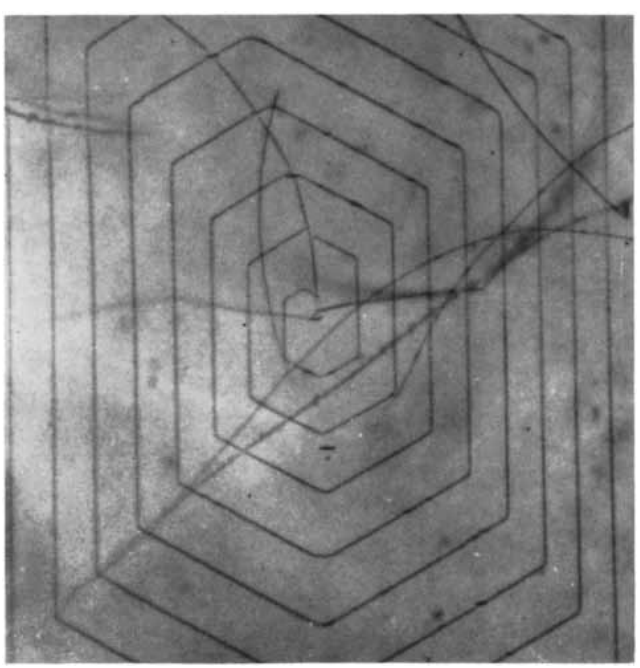
It should be emphasized again that neither electrons nor X rays form an



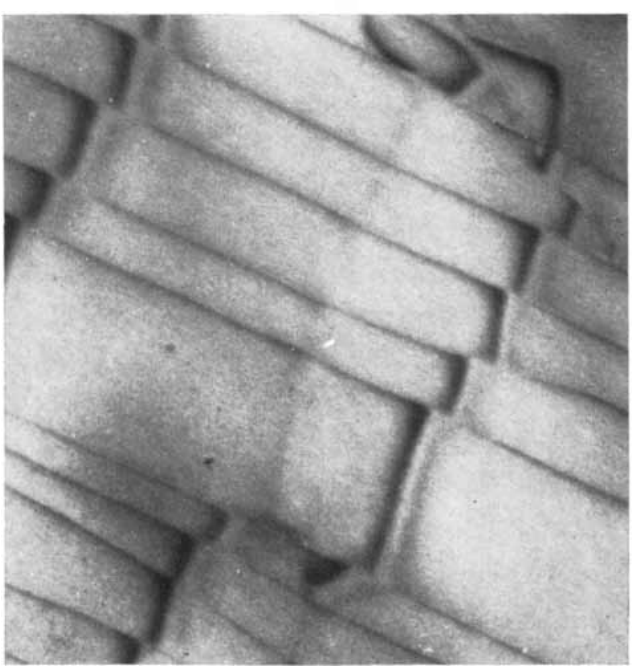
DECORATION TECHNIQUE reveals the imperfections in a transparent crystal because the decorating substance (silver in this case) precipitates along dislocation lines. This photomicrograph of potassium chloride was made by S. Amelinckx at the University of Ghent.



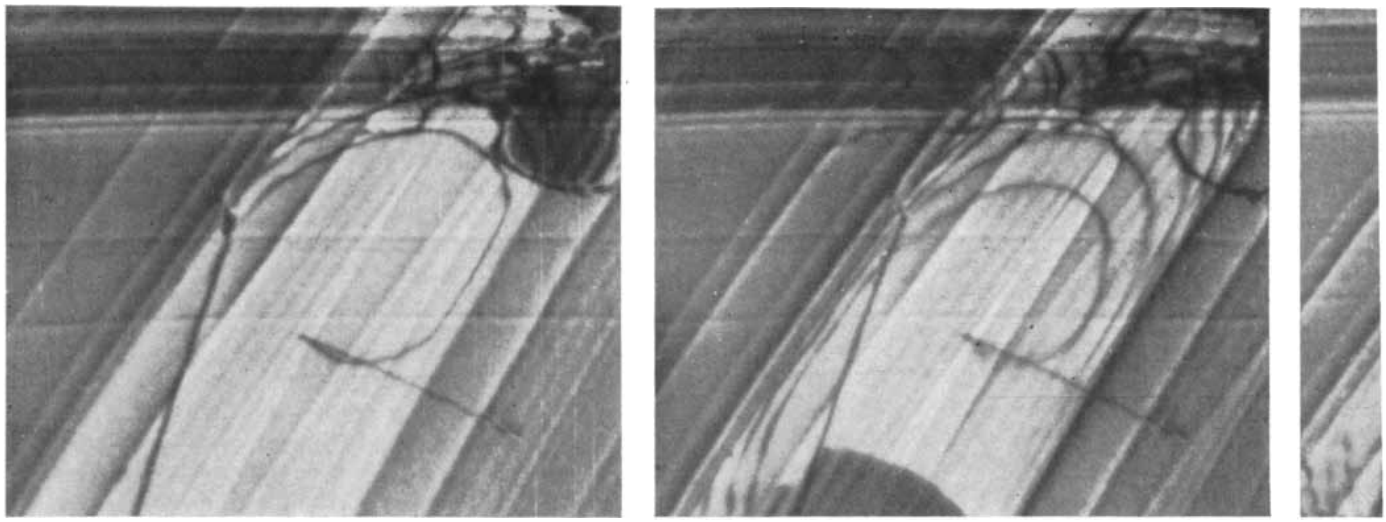
"SMOKE RING" dislocation loops appeared in silver chloride when silver, concentrating along dislocations formed as the glass bead (*bottom*) cooled, became visible upon exposure to light. Micrograph was made by J. W. Mitchell at the University of Bristol.



FRANK-READ DISLOCATION, a spiral of the type diagramed at the bottom of pages 110 and 111, was observed by Dash in this photomicrograph of a silicon crystal decorated with copper. Infrared light was used because silicon is opaque to visible light.



ELECTRON MICROSCOPE provides a more direct method of observing the strains caused by a dislocation. This electron micrograph of dislocations in aluminum, magnified 60,000 diameters, is by P. B. Hirsch and co-workers at the University of Cambridge.

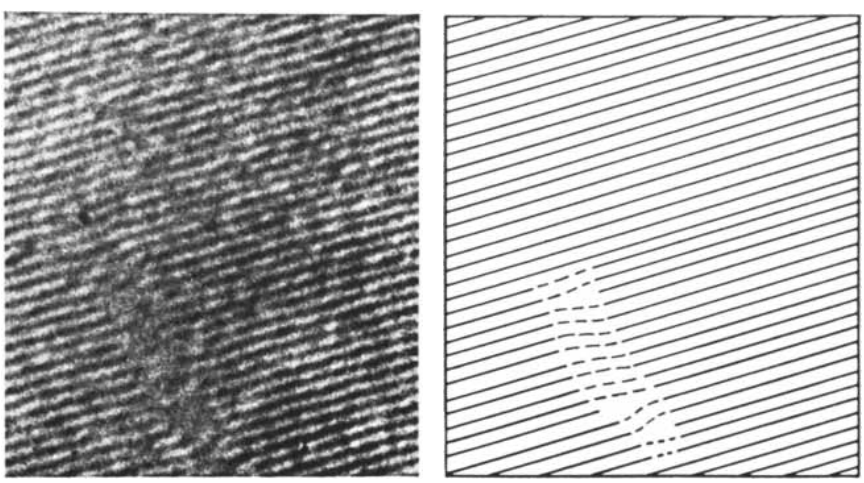


MULTIPLICATION OF DISLOCATIONS in the manner proposed by Frank and Read was photographed as it occurred in this series of electron micrographs by H. G. F. Wilsdorf of the Franklin Institute. The specimen, a thin foil of stainless steel, has been en-

actual picture of dislocations in an atomic crystal. The dimensions are too small. There are some crystals composed of large molecules, however, in which the separation between lattice planes is much larger than it is in most inorganic crystals such as metals and salts. Platinum phthalocyanine is one such crystal; having a lattice spacing of 12 angstroms, it is just within the resolving power of the electron microscope. J. W. Menter of the Tube Investments Research Laboratories in England has made an electron micrograph of this material in which the extra planes of three edge dislocations are visible [*see illustration below*]. Here is the ultimate direct proof that dislocations exist, and they look just as their inventors thought they would.

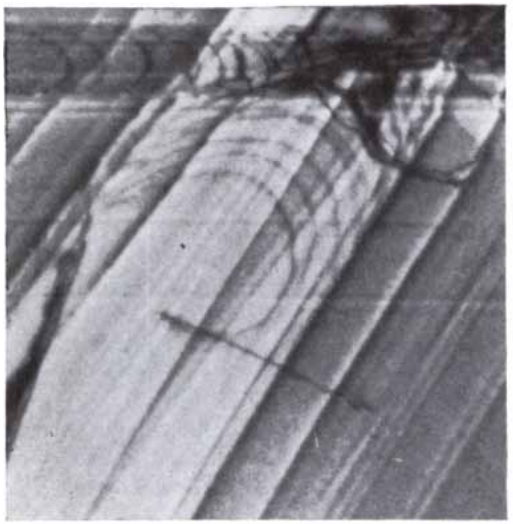
Indeed, a number of the theorists' wonderfully ingenious conjectures have been confirmed by the techniques described in this article. A striking example is the Frank-Read mechanism for multiplying dislocations. To understand why such a mechanism is necessary, consider again the motion of a dislocation through a crystal. The earlier brief discussion glossed over a crucial point. When a moving dislocation line reaches the surface of the crystal, the dislocation disappears, leaving behind a more nearly perfect array. In the process the parts of the crystal have slipped only one atom spacing. Even if a sample contained a very large number of dislocations, it would seem that a distorting force should quickly push them all out to the surface. Thereafter the material should be extremely strong. Yet in fact a crystal can deform almost indefinitely even along a few limited glide planes.

In 1950 Frank and W. T. Read, Jr., of the Bell Laboratories proposed a way out of the difficulty. It was already known that if one dislocation intersected another or encountered a large impurity atom, its motion would be impeded or stopped. Suppose, Frank and Read suggested, that the dislocation was snagged at one end and that the rest of it was free to move. Then a continued application of force would make it sweep around over its glide plane, producing an offset of one atomic spacing each time around [*see illustration at bottom of pages 110 and 111*]. Similarly, if the lines were anchored at two points, the portion in between would bend out and sweep around in a series of closed loops, in a manner resembling the motion of the hands of a swimmer doing the breast stroke. Six years after the idea was put forward, Dash succeeded in photographing a Frank-Read loop source in operation in a silicon crystal. Since then similar patterns have been observed in other crystalline materials.



ACTUAL PICTURE of dislocations is possible with crystals the lattice sites of which are occupied by large molecules. Extra planes are visible (*as diagramed in the drawing at right*) in this electron micrograph by J. W. Menter of Tube Investments Research Laboratories. The crystal is platinum phthalocyanine; the distance between planes is 12 angstrom units.

The work on silicon has provided a more detailed picture of how dislocations multiply and propagate in the material, and this in turn has led to a method of producing crystals that contain no dislocations whatever. The process for making them is adapted from one developed by Spyro Kyropoulos at the University of Göttingen. Silicon is melted in a crucible heated from below so that the temperature of the liquid decreases from bottom to top. The end of a small "seed" crystal is dipped into the surface of the melt,



larged about 65,000 diameters. The expanding dislocation loops are clearly visible.

and the liquid begins to solidify on it. Then, very gradually, the seed is withdrawn, pulling the growing crystal after it [*see illustration on next page*].

In its original version Kyropoulos' method produces a large, pure crystal but one containing as many as 100,000 to 100,000,000 dislocation lines per square centimeter. They come originally from dislocations in the seed. As atoms add themselves to the lattice, the imperfections are extended into the newly grown region. Then, as the solid is withdrawn from the melt, the dislocations multiply. The reason for this is that the outside of the crystal, cooling faster than the inside, tends to shrink and so to squeeze the material in the interior. The stress causes dislocations to spread through the body of the crystal and multiply by processes such as the Frank-Read mechanism.

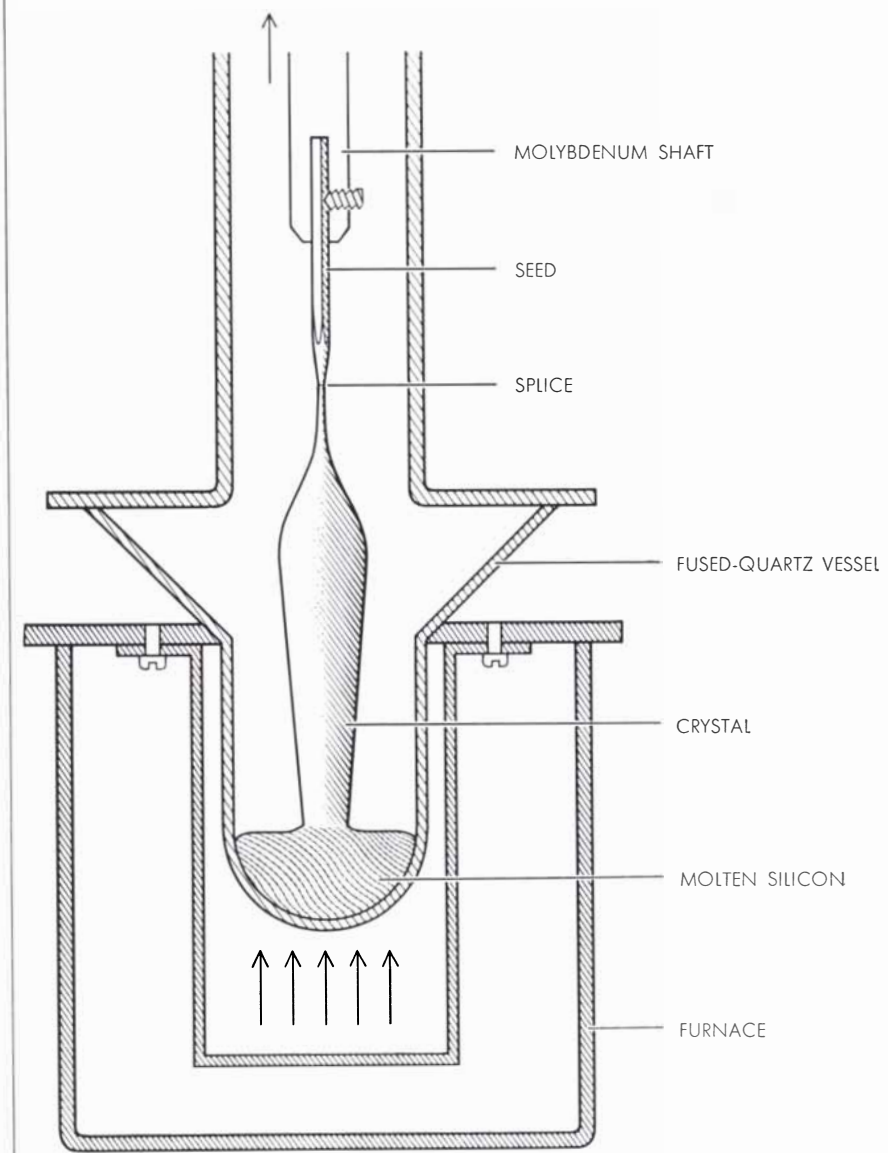
By controlling the rate of surface cooling with the aid of a properly placed heating element, the thermal stress can be eliminated and the number of dislocations drastically reduced. But the ones from the seed are still there. Recent studies in our laboratory have shown how they too can be eliminated.

It was found that dislocations in both silicon and germanium tend to propagate along certain preferred directions in the cubic crystal lattice. If any of these directions runs down the long axis of a seed crystal, dislocations in the seed move easily into the new material below it. If, however, the seed is carefully cut so that none of the preferred directions are parallel to the axis, dislocations tend to grow laterally but not downward. As the growing crystal is pulled out of the melt, the dislocations

move out to the sides and stop. After a short time they have all been left behind, and the material now solidifies in a perfect crystal. From this point on even severe temperature fluctuations do not generate new dislocations. Perfect silicon and germanium crystals weighing as much as 50 grams have already been made; in principle, at least, the method should be capable of producing much larger ones.

Experiments are now under way to determine whether dislocation-free crystals are as strong as theory predicts they should be. Preliminary results indicate that perfect silicon crystals are about 30 times stronger than ordinary ones at 900 degrees C. (The effect of dislocations on the strength of silicon must be tested at high temperature because of the low mobility of dislocations in this crystal when it is cool.)

The early experiments have demonstrated another fact: These perfect crystals do not stay perfect for long under ordinary conditions. Minute imperfections on the surface—oxidized spots, for example, or places accidentally touched by another object—are sources of dislocations that propagate throughout the body when it is heated. With further study it may be possible to devise a way to keep out dislocations permanently, and to realize the tremendous potential strength of crystalline solids.



DISLOCATION-FREE SILICON is produced by the method diagramed above. Silicon is melted in a furnace; heat, applied at the bottom (*arrows*), decreases with height above the melt. A "seed" crystal is dipped into the melt and slowly withdrawn. Proper orientation of the seed and control of temperature make it possible to eliminate all dislocations. The dislocation-free crystals that result are found to be far stronger than ordinary silicon crystals.

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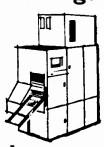

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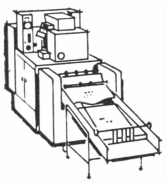

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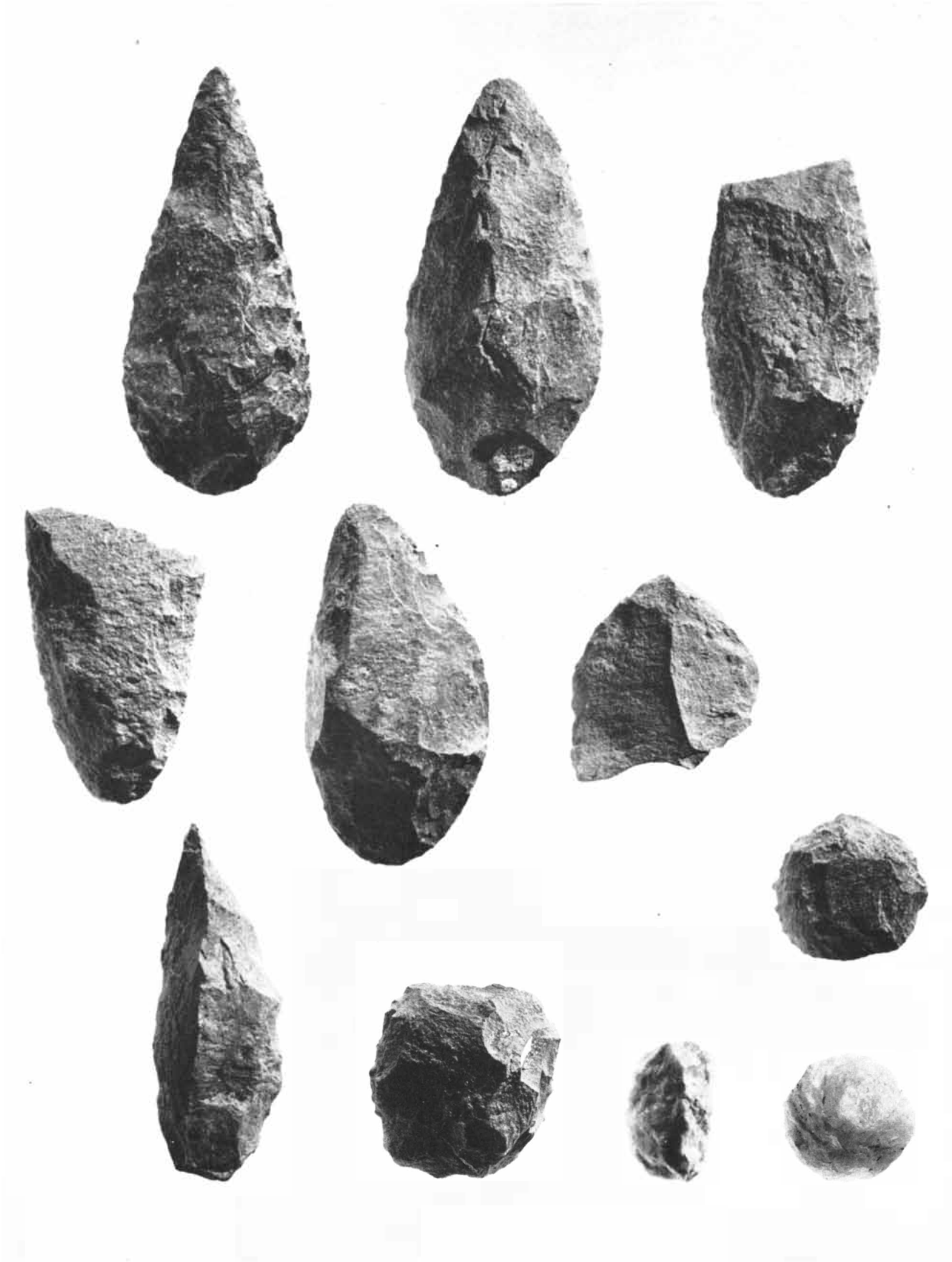


STONE TOOLS at Isimila were made some 75,000 years ago. Their diversity in size, shape and material suggests each type had its own use. Shown here, from top left to bottom right, are: two hand axes, two cleavers, knife, scraper, "discoid," pick, core scraper, chopper and "spheroid." The hand axes are 11 inches long. Chopper and spheroid are made of quartz; all others, of the mineral mylonite.

Isimila: A Paleolithic Site in Africa

The stone tools of early man have seldom been found exactly where he left them. Now excavations in Tanganyika have exposed campsites littered with tools that provide clues to their users' way of life

by F. Clark Howell

The prehistorian who studies the earlier part of the Old Stone Age is attempting to reconstruct the habits and behavior of peoples dead for more than 75,000 years. In going about the task he is not encumbered by an oversupply of evidence: the total inventory comprises a few fragments of human skeletons; some bones of the animals that the early hunters killed (and vice versa); pieces of wooden implements, preserved through rare accidents; and large numbers of the chipped stones with which man then carved, scraped and battered out his living.

If one is to extract much valid information about the way of life these artifacts represent, one must examine them in the settings in which they were used—in "archaeological context." For a long time, when Europe was the main theater of archaeological exploration, stone tools dating from the early Paleolithic period were not seen this way. Abandoned at the exposed sites where their makers had lived (men did not become cave dwellers until rather late in the Old Stone Age), the tools were subsequently disturbed and even transported over considerable distances during the glaciations of the Pleistocene epoch. During the past 30 years or so much research on early man has been conducted in the unglaciated landscape of central Africa. A number of undisturbed, open living sites have been turned up. One of these, at Isimila in southern Tanganyika, has provided an assortment of Paleolithic tools in archaeological context. Together with my colleagues Maxine R. Kleindienst and Glen H. Cole, I have spent a considerable part of the past several years excavating and analyzing the material. It has provided valuable new insights into the activities of early man.

A number of the undisturbed sites are situated in or are adjacent to the Great Rift Valley of eastern central Africa. These include Kariandusi and Olorgesailie in Kenya and Olduvai Gorge in northern Tanganyika. Olduvai Gorge presents the longest known sequence of Pleistocene living sites. There L. S. B. Leakey of the Coryndon Museum in Nairobi has recently discovered remains of the oldest known toolmakers, dating back some 1,750,000 years. The Isimila site is situated not in the Rift Valley but in the Iringa highlands of southern Tanganyika, and the tools there are not nearly so old. They belong to the style of manufacture known as Acheulean, after the place in northern France where an abundance of such tools has been found. Current estimates place the beginning of the Acheulean industry about 300,000 years ago, in the middle of the Pleistocene, and the end about 75,000 years ago, toward the end of the last interglacial period. Judging by the geological formations represented there, Isimila seems to have been inhabited for only a few thousand years near the end of the long span of the Acheulean period.

The geological history of the site was traced for us by Edward G. Haldemann and Ray Pickering of the Department of Geological Survey of Tanganyika. Millions of years ago the place was a major river valley. Then a series of upward and downward geological movements transformed the landscape, leaving the old valley as a small trough at an

EXCAVATION SITE was dotted with tools and rubble, exposed by erosion of Isimila beds. Nine living sites were excavated in three upper levels. One was excavated in fourth.

AERIAL VIEW of Isimila, looking northeast, shows main areas of sheet erosion. Trenches at middle right are excavation H20 in Level 4, the only bed containing fossil animal bones.

elevation of 5,400 feet, drained only by a small stream. During a period of increased rainfall in the middle of the Pleistocene the surrounding hills were covered with trees. Later the climate became drier and scrub vegetation replaced the woodland. Soil slipped and washed down from the deforested hills, choking the outlet of the basin and damming up an elongated body of water. This was alternately a marsh and a shallow pond, sometimes with an overflow. A steady deposition of silt in this basin eventually filled it to a depth of more than 60 feet with alternating beds of fine clay and coarser sandy sediment. The whole silting process seems to have required a few thousand years at most, and during this time early Stone Age hunters camped around the water hole.

There are five distinct beds of coarse sediment. Recent erosion has bared a good part of the upper three, and we have excavated them extensively. They contain an extraordinary number of living areas, all of them littered with tools. Indeed, it is hardly possible to walk over the site in any direction without stepping over quantities of finished and partly finished tools and waste chips. Since these upper layers are quite acid, no bone (except for a single hippopotamus tooth) has been found in them. In the fourth layer, however, we found bones of a number of animals, representing both extinct and still existing species. The skeleton of a hippopotamus, with the head and legs missing, looks very much as though it had been slaughtered or scavenged by human beings. The lower layers also yielded tools, but very few living areas to provide context.

With artifacts scattered so liberally through the three upper layers, the delimitation of a living area is somewhat arbitrary. In certain places, however, the pieces lie at the bottom of the sandy bed, on the surface of the underlying clay or within an inch or two of it. Horizontally they are densely distributed in a central region, becoming sparser with distance from the center. Although the boundaries may be uncertain, it seems quite clear that these assemblages mark out a site occupied for some time.

Nine living areas have been extensively excavated in the upper three levels, and one in the fourth bed has been partially exposed. The existence of several occupation areas on each level provides the first opportunity to compare different assemblages of tools known to be roughly contemporaneous. At other sites it has been possible only to compare them with those from different strata. Con-

HIPPOPOTAMUS BONES found in Level 4 form skeleton lacking head and extremities. The animal may have been slaughtered or scavenged by early man. This level contained fossil animal bones, of both extinct and extant species. No human bones were found.

HAND AXES found on Level 1 were resting on edge, as their users left them. Only one other Paleolithic site in Africa yielded tools resting in this position. It has been suggested that implements left lying thus were used for a specialized purpose, as yet unknown.

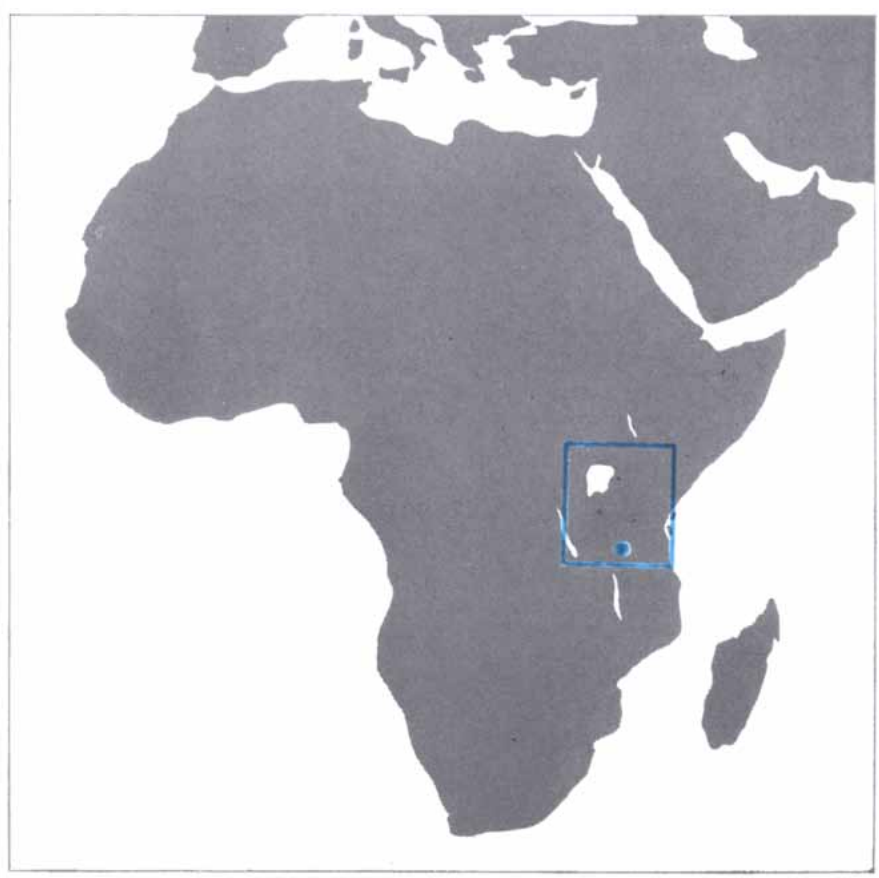
sequently the work at Isimila is forcing a revision of some widely held notions about the earlier Old Stone Age.

Our method of studying the occupation site was simple enough in principle but tedious and exacting in practice. After carefully excavating an area, we examined, classified and tabulated each one of the hundreds of tools that were exposed, as well as the numerous bits of rubble and waste chips. From these counts we were able to prepare charts showing the relative frequency of each type of object at each place [*see illustration on pages 126 and 127*].

Of what use is all this detail? In part the answer is still uncertain. When the same sort of analysis has been carried out at other sites, a comparison of the data may bring out new facts and relations. At Isimila alone, however, there was enough diversity to provide an entirely new idea of the full range of the Acheulean tool complex and to reveal an unsuspected degree of specialization.

Before proceeding to a description of what we found, a word about the different kinds of tool is in order. Unlike earlier toolmakers, the Acheulean craftsmen did not merely trim up likely looking stones that were ready to hand. They knew how to strike flakes from boulders or large stones and then fashion the blanks into a wide variety of standardized shapes. The kinds of rock with which they worked—mylonite (a strongly coherent rock containing fine mineral grains), granite, quartz and quartzite—show that they had mastered the most intractable raw materials.

The stone artifacts at Isimila fall into several classes. These include large and small shaped tools, pieces that were modified or slightly trimmed, pieces that were used but not trimmed and waste products. Within these classes various types of tool can be recognized and differentiated on the basis of the kind and the treatment of edges, the nature of the secondary trimming and so on. The tool types also exhibit different shapes or forms, and these vary between assemblages from the same site as well as between those from different sites. The large shaped tools with sharp cutting edges are usually made of mylonite and occasionally of quartz or quartzite. Ac-



LOCATION OF ISIMILA is shown by the **blue dot at right of center on** this map of **Africa.** Most of the continent escaped glaciation during the ice age and still preserves some of the open-air sites at which early man camped in the period before he began to inhabit caves.

cording to their shape and type of edge they are designated as hand axes, cleavers, knives, flake scrapers and "discoids" [*see illustration on page 118*]. The list of the blunter large pieces—generally of granite, quartz or quartzite—includes picks, core scrapers, choppers and "spheroids." Small tools are most often quartz, and their worked edges are frequently notched or otherwise shaped for scraping or perhaps for piercing.

Although many of the names suggest that the purposes for which the different tools were used are known, this is not at all true. In some cases, however, the most common guesses seem fairly plausible. It appears likely that the large blunt tools, which were always made of particularly durable varieties of stone, were meant for heavy duty. The small tools may have been used for working wood.

The hand ax was formerly thought to be an all-purpose tool, used for cutting, skinning, digging and so on, but the evidence from the undisturbed living sites at Isimila and elsewhere contradicts this notion. The sharp edges of the hand axes and some of the other large tools suggest beyond doubt that they were used only on soft substances. Recently some authorities have suggested that certain of the large sharp pieces were used for skinning and dismembering thick-skinned animals.

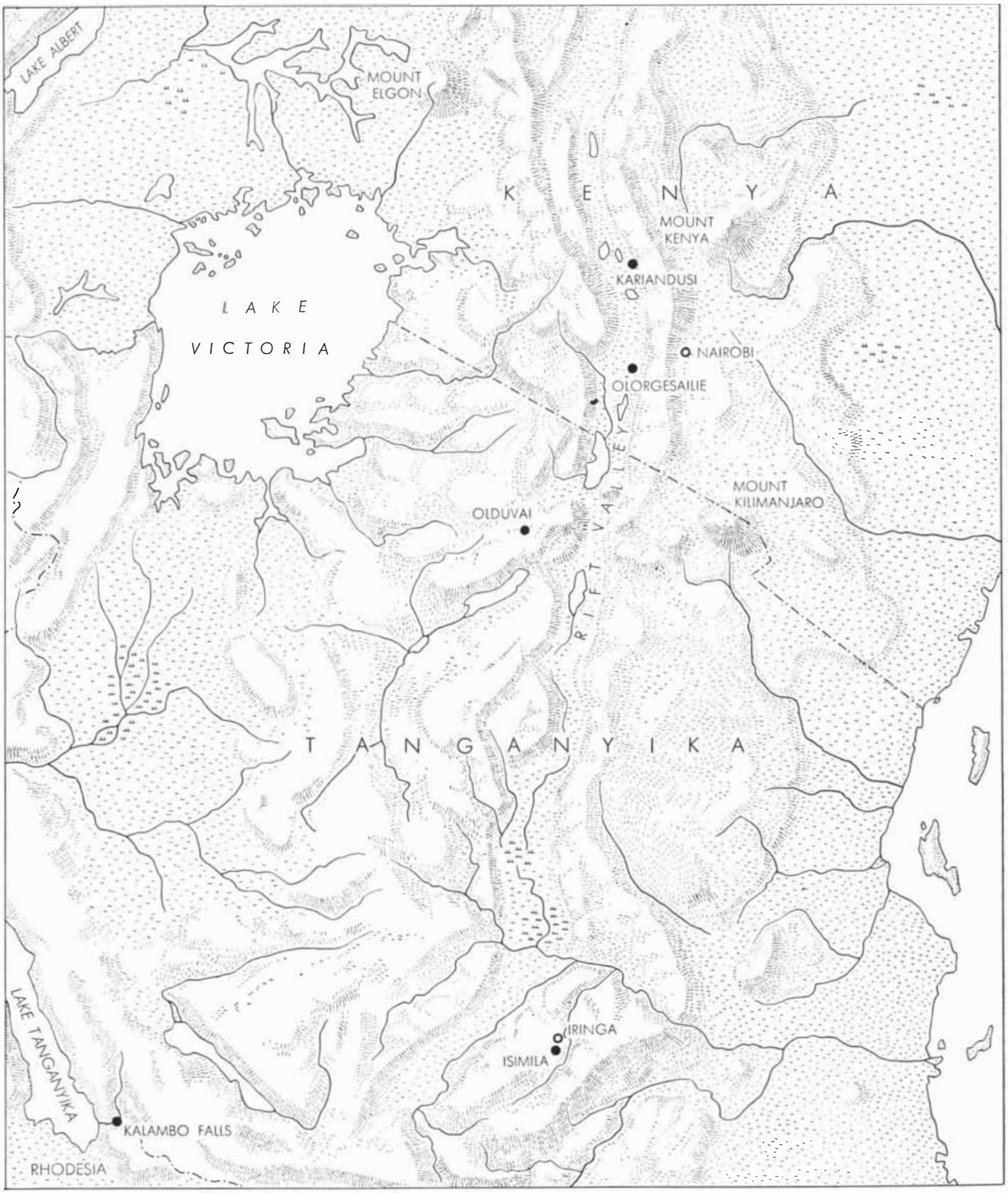
There is no proof for any of these hypotheses. Some of the evidence is distinctly mysterious. For example, both at Isimila and at another East African site several hand axes were found resting on one edge. Were they merely stuck in the ground after their users had finished their work or does their position indicate some specialized application? With further research such questions may be answered. Meanwhile the list of names serves to describe an assortment of well-defined tool types, whatever their purpose. The conventional labels furnish the prehistorian with an essential system of classification.

Among the various living areas at Isimila we could distinguish three distinct types of tool assemblage. The first type, represented in six places, has been traditionally regarded as the typical Acheulean tool kit. It consists mostly (up to 70 per cent and in one case even more) of large, sharp-edged tools—notably hand axes, cleavers and knives. The rest of the collection is divided about equally into large blunt tools and small flake tools. There are few waste products. The second type, of which there are two examples, is just the reverse:

small tools predominate (40 to 60 per cent). Here there are few large cutting-edged tools and a fairly large quantity of waste products.

Both of these general categories have been observed in other Paleolithic sites in East Africa. The third type is new. Found at one place in the third level, it contains a few small tools and a few large cutting-edged ones, the latter of an unusual shape. About half of the total is made up of large, heavy-duty tools—principally picks, core scrapers and choppers.

Before the excavations at Isimila were undertaken, different styles of individual tools and different tool kits had always been found at separate sites, or in separate levels of the same site. Therefore they were usually held to reflect the passage of time and changes in culture or technology. Some authorities have attributed the first two types of tool kit we found at Isimila to distinct "cultures"



RIFT VALLEY AREA holds most of the human occupation sites recently excavated in eastern Central Africa. Shown here as black dots, from Kenya in the north to Rhodesia in the south, are Kariandusi, Olorgesailie, Olduvai Gorge, Isimila and Kalambo Falls.

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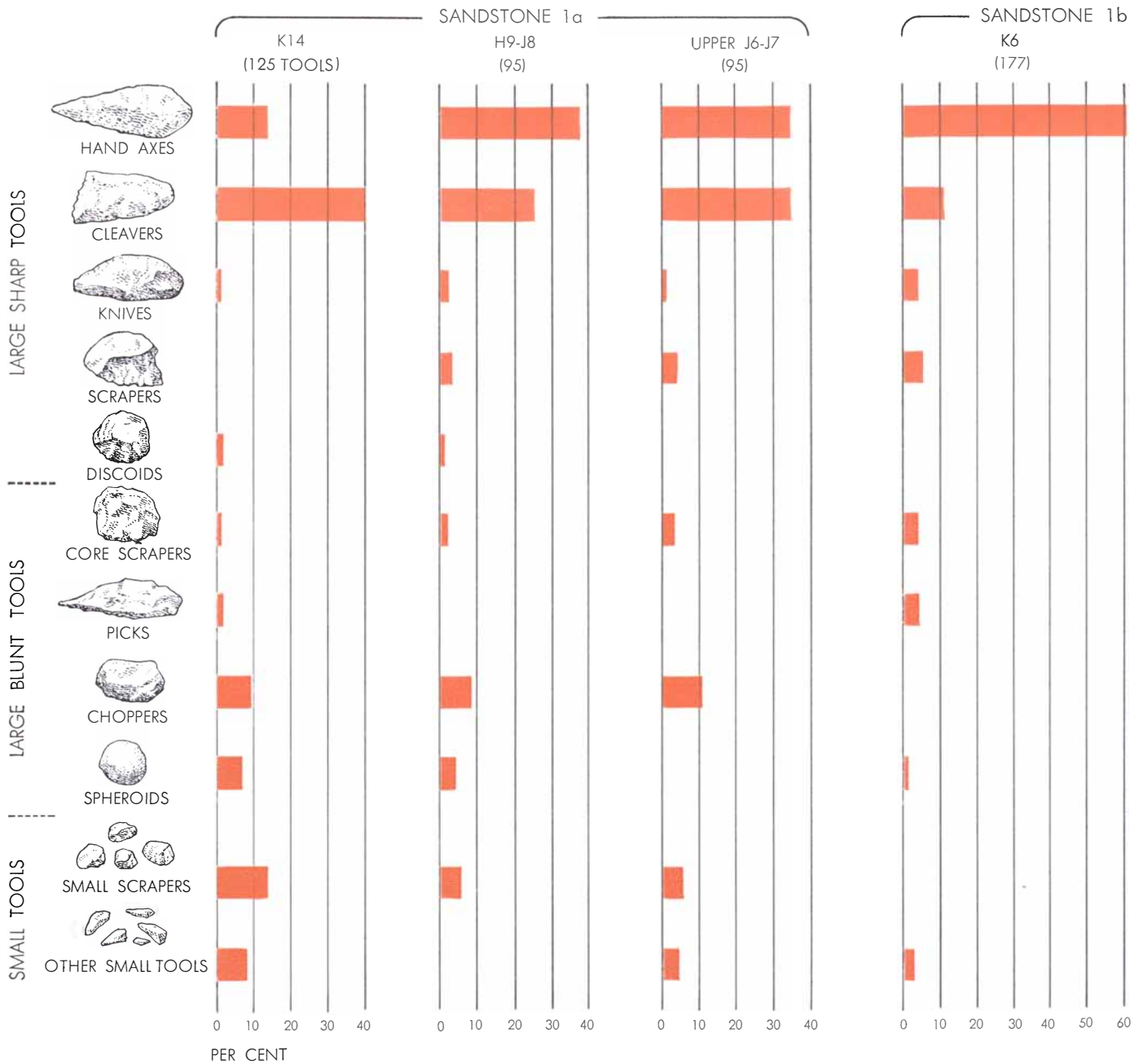
with different ecological adjustments and subsistence patterns. There has even been talk of two different species of man.

The results at Isimila make such interpretations highly questionable. The place was occupied for a relatively short time. Yet a wide variety of tools and tool kits appears at different places within a single level. It seems most likely that in this case differences in tool kits reflect different activities. Members of the same group may well have been simultaneously performing different tasks requiring different tools.

On the other hand, variations in individual styles in similar assemblages also found at Isimila may mean that more than one band of early men occupied the site at about the same time. For example, in one living area most of the hand axes are shaped like spearheads, in another most are egg-shaped. In one tool kit the sides of many of the cleavers converge; in a similar one they are largely parallel. Miss Kleindienst has discovered regional differences in the workmanship of certain tools at a number of East African Acheulean sites. Perhaps groups from different localities may have concentrated at the same campsite together. Stylistic variations had been known in the tools of hunters and gatherers of the present day and of Neolithic times, but it was interesting to find them so much earlier.

Similarly, there are differences in materials from one occupation site to another even in the same level. In some locations the full range of raw materials is represented; in others, only one or two varieties. The mylonite used for large cutting-edged tools also varies from site to site in color, hardness and flaking qualities. To some extent the variation may simply reflect the sources that were available at a given time. But it could also mean that the toolmakers selected



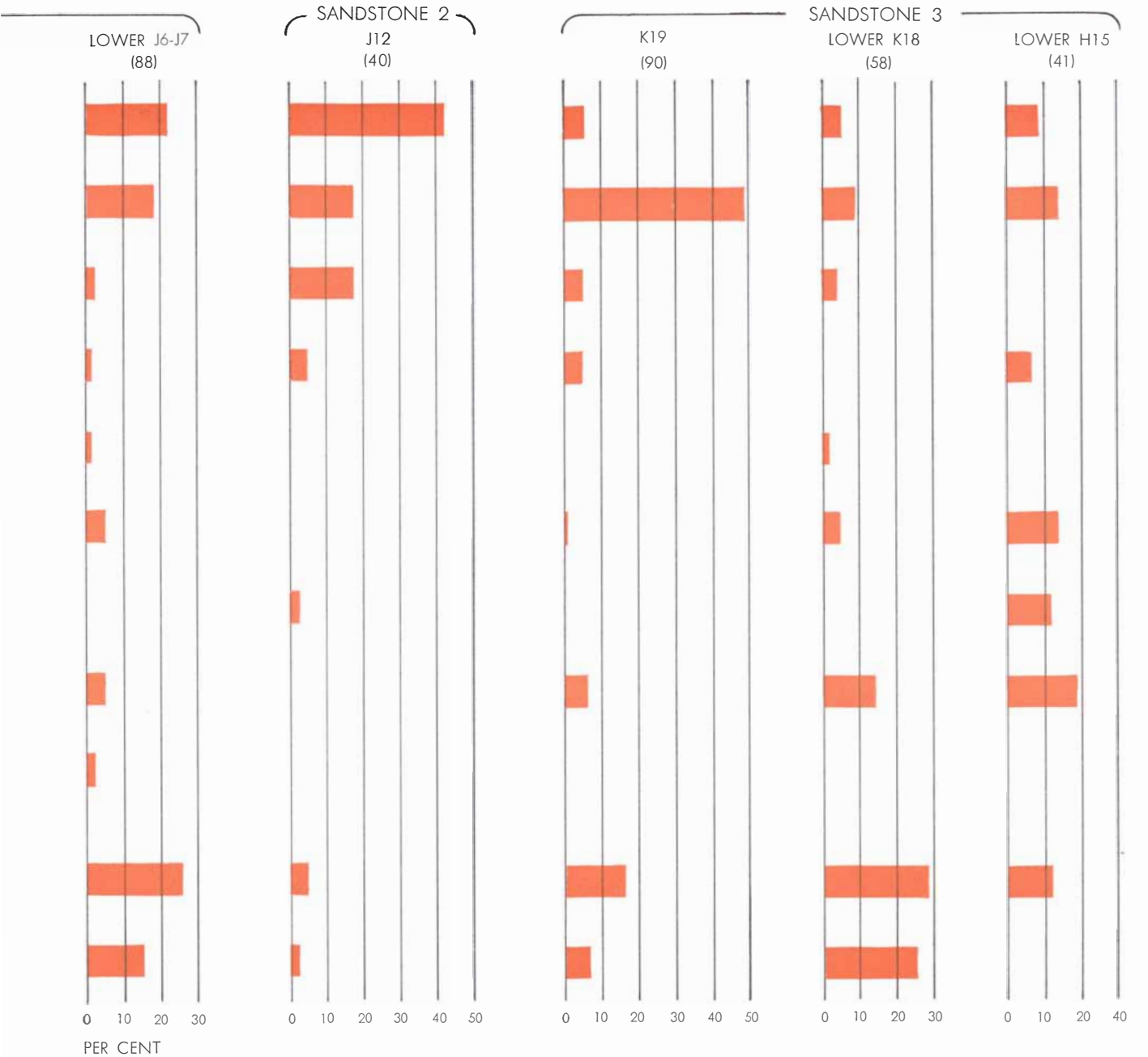
TOOL ASSEMBLAGES at nine sites in the three upper levels of the Isimila beds are shown in this chart based on an analysis by Maxine R. Kleindienst. At six sites (K14, H9-J8, Upper J6-J7, K6, J12, K19) large sharp tools predominate. At two (Lower K18, Lower J6-J7) small tools are numerous. At one (Lower H15) large blunt tools form the majority. This assemblage is unique for this

their materials from a number of exposed deposits, choosing the kinds best suited to the pieces they were working on. Conceivably different bands may even have enjoyed exclusive rights of exploitation to sources they had discovered. This would account for differences between the varieties of stone used at different sites in the same level.

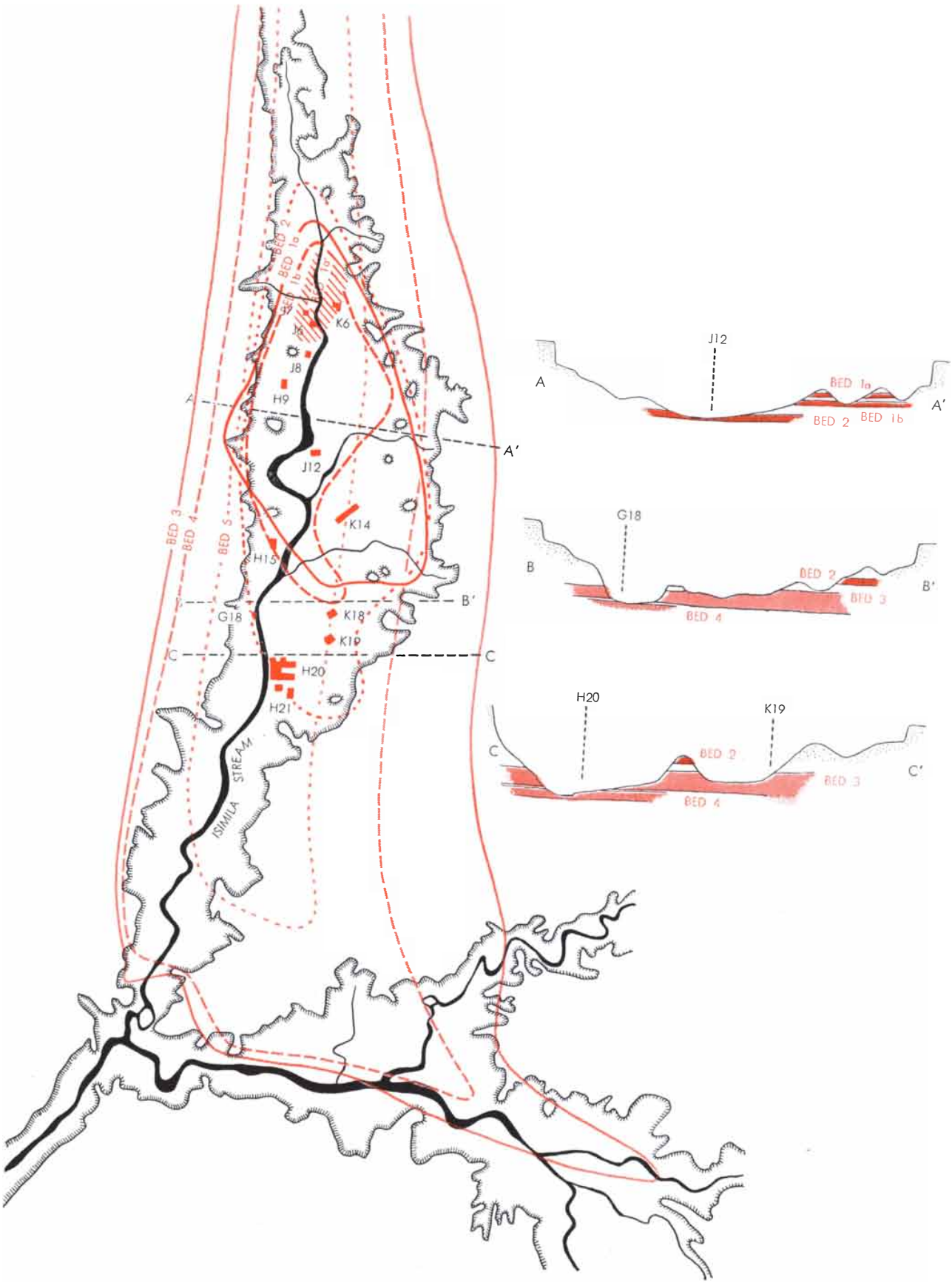
The pattern of stone rubble found at different locations varies with the type of tool kit and tells its own story. Where there are small tools there is usually a good deal of rubble, most of it chips of the tool material. Evidently these pieces were fashioned at the living sites where they were used. In the case of large tools, on the other hand, the living areas contain relatively few waste products of the same materials. Such waste as is there looks as though it was the product of minimal reworking or sharpening. Most of the tools were evidently made elsewhere.

One factory site has been uncovered at Isimila. The frequencies of both tools and waste products there are quite unlike those at any living place. The workshop contains few finished, or even semi-finished, large tools. There are some roughed-out specimens and some fresh blanks. Most of the inventory consists of large flakes of mylonite struck off in shaping the blocks of raw material from which the blanks were subsequently produced.

Certain of the living areas contain a puzzling distribution of stone pieces: a good many large tools and, as usual, little or no factory waste products but a large amount of extraneous rubble. In these places the inhabitants must have deliberately amassed stone rubble. What they wanted it for we have no idea, but there is little doubt that they went out and collected it. Other open sites in East Africa as well as some caves in Europe



period in East Africa. It had been thought that each kit represented a different time or culture. But all kits are present on Level 3, at roughly contemporaneous sites. It may be that they were made by the same people and each was used for a different task. At all sites except one (Lower J6-J7) a few tools are omitted from the count. These were broken and too damaged to be identified by name.



reveal evidence of the same activity.

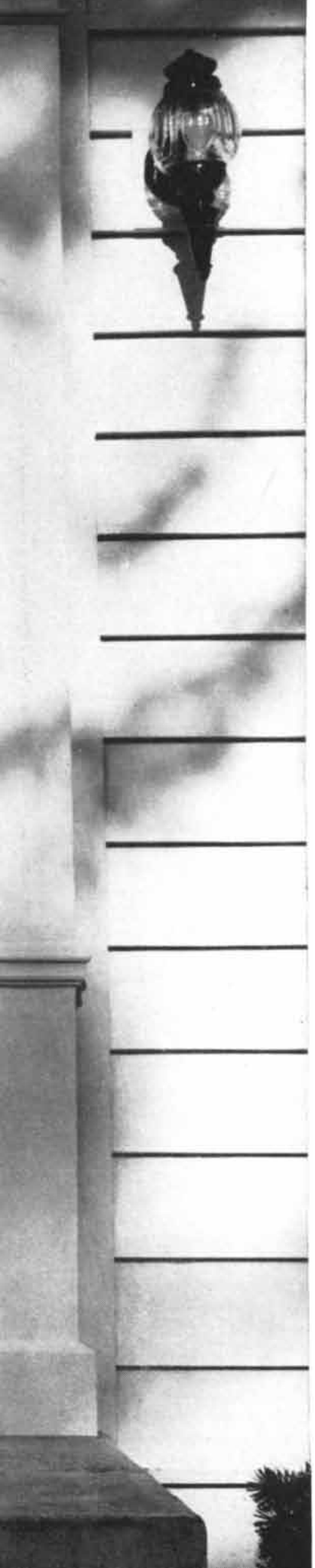
At Isimila we found no wood or any evidence of fire. Both have been uncovered at other Acheulean sites, however. Pieces of wood preserved at Kalambo Falls in Rhodesia and at three European deposits—in Germany, Spain and England—indicate that men in the earlier Old Stone Age made wooden implements and weapons, including hardwood spears and what are probably clubs and throwing sticks. Charred wood, charcoal and ash at Kalambo Falls and in two African caves testify to the use of fire during the latter part of the Acheulean period.

From the recent work at Isimila, as well as at other undisturbed open-air sites, a much fuller picture of the life of Paleolithic man has begun to emerge. It shows a more varied and specialized technology and perhaps a higher degree of social organization than had been envisaged before. As always, the new information suggests still further questions: How large were the groups that camped at the open-air sites? Were there several different families in the same band? Were there different bands? How long did the people stay? Days? Weeks? Did they come back several times a year?

The very profusion of the remains at Isimila constitutes a puzzle in itself. What did the people want with all those tools? To be sure, the objects are not hard to make; a skilled prehistorian can turn one out in a few minutes. It is likely that the cutting-edged tools were discarded and replaced as soon as they lost their edge. Even so, the quantity seems out of proportion to any conceivable need.

Not all the problems may be solvable. But further studies of evidence in the archaeological context of the earlier Old Stone Age cannot fail to enlarge our understanding of man's place in nature.

PLAN OF ISIMILA VALLEY, looking north, shows the location of the excavated living sites and the extent of each of the five Isimila beds. The heavy black line represents the stream now running through the valley. The notched line indicates the limit of erosion. The beds were deposited in a pond around which early man made his camps. As the basin silted up, the campsites were buried. The pond gradually shrank until it was the size of bed *1a*′ and the region was no longer suitable for habitation. The schematic cross sections at right show five levels of the Isimila beds at points corresponding to those marked on the plan.



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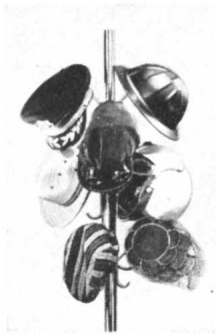

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AUDITORY LOCALIZATION

It is well known that the ability to determine the direction of sound depends on having two ears. But how does the brain use the information from the ears to make the determination?

by Mark R. Rosenzweig

Anyone who has ever gone temporarily deaf in one ear can testify to the advantages of binaural hearing. Sounds heard through one ear only are difficult or impossible to localize, and they lose their quality of depth. For human beings the ability to localize sound is more than a convenience; for some animals it is a necessity. Two ears are better than one if a person is trying to understand one voice against a background of other voices. (This is what acoustical engineers call the cocktail-party problem.) Two ears provide bats and certain night-flying birds with their fantastically sensitive location system.

That a pair of separated receivers should facilitate localization is reasonable enough. Each ear receives a slightly different sound pattern from a given source. The difference is somehow used by the brain to fix the position of the source. For more than 150 years investigators have been trying to find out how. Recently there has been considerable progress, but the process is still far from completely understood.

So far as the records show, the first person to look into the matter was the Italian physicist Giovanni Battista Venturi (1746–1822). Nowadays Venturi is remembered for his research in fluid dynamics. In fact, his name has become a common noun: the venturi, or venturi tube, is a standard device for measuring the flow of fluids. Venturi also turned his talents to many problems outside of physics. He studied visual and auditory perception, wrote on economics and history and was active in politics during the Napoleonic period.

In his work on auditory localization Venturi stationed a blindfolded subject in the middle of an unobstructed meadow. Circling around the subject at a distance of about 150 feet, the experimenter periodically sounded a note on a flute or rang a bell. When the sound came from a direction at right angles to "straight ahead," the listener could easily identify the direction. If he kept his head still, he often confused sounds coming from directly in front of him with sounds coming from behind him. When the source was diagonally in front of him or diagonally in back of him on the same side, the subject frequently was unable to distinguish front from back, but he never had any trouble with right and left. If the test sound was sustained for a few seconds and the listener was allowed to turn his head, he did not make these mistakes.

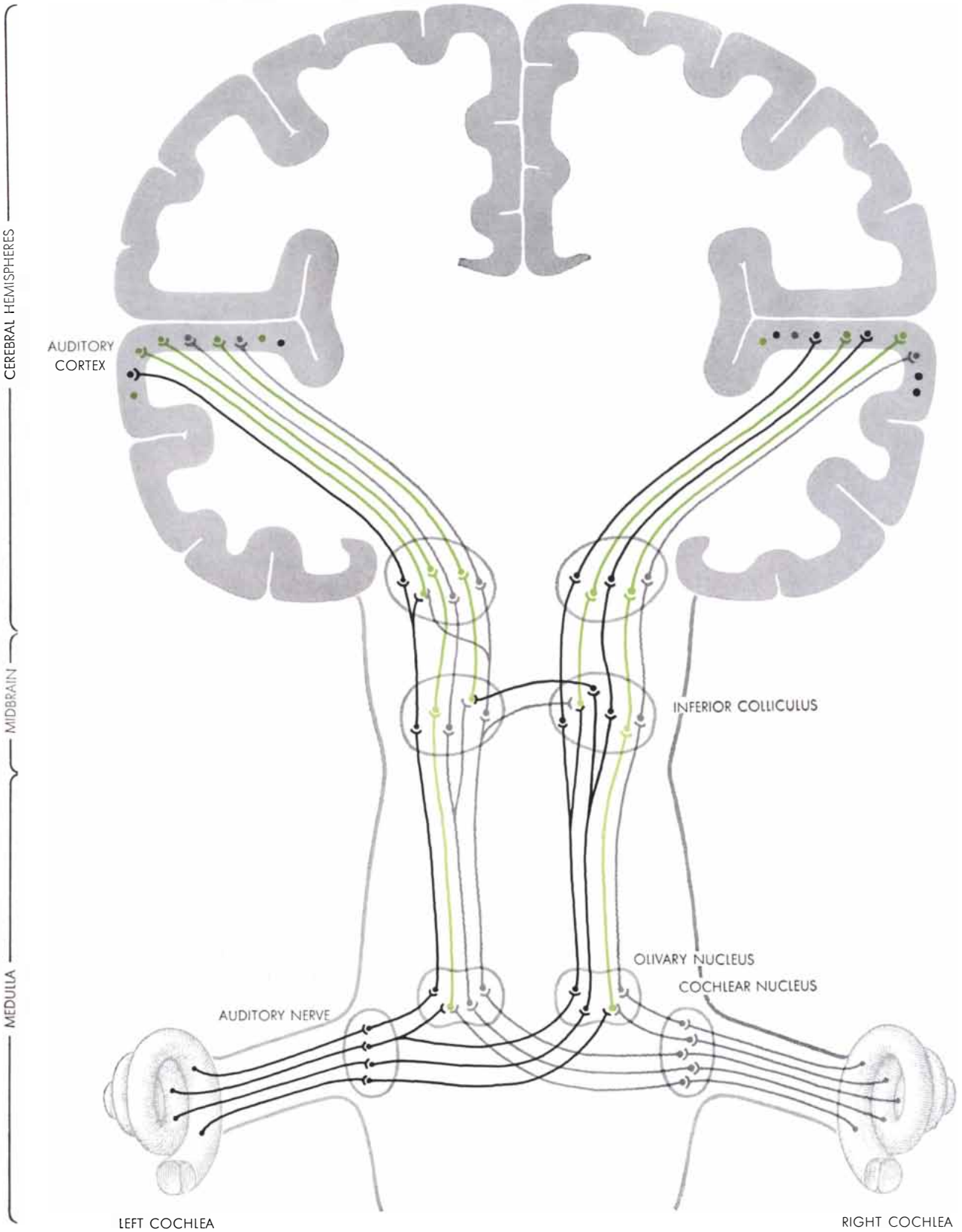
Venturi also found that a person with one deaf ear could localize sounds, but only if he turned his head while the sound continued. The subject simply turned until the sound was loudest, at which time his good ear directly faced the source. The experimenter noted that subjects with one deaf ear never localized brief sounds accurately.

Venturi concluded that a listener uses the relative intensities of the stimuli arriving at his ears to localize sound. He believed, furthermore, that the process involves judgment, and he denied the possibility of physiological interaction of the neural messages from the ears. "Since we distinguish the two simultaneous sensations of the two ears," he wrote, "and since their different intensities furnish us knowledge of the true direction of the sound, therefore one must conclude that the two sound impressions do not mix together inside the skull." This interpretation was to prevail for more than a century.

Notwithstanding the fact that Venturi published his findings no less than four times between 1796 and 1801—twice in German and once each in French and Italian—they made remarkably little impression. His observations and conclusions were occasionally mentioned in early 19th-century texts, but they were not credited to him. Later they were forgotten altogether. In the 1870's the British physicist Lord Rayleigh repeated essentially the same experiments, with the same results, apparently with no knowledge of Venturi's work. He believed that the observations supported the common view that localization is judged on the basis of the relative intensities of stimulation at the two ears.

Shortly after 1900 a German physician named Stenger devised an ingenious clinical hearing test that effectively demolished the ordinary view of localization, although no one seems to have realized it at the time. The test, which is still in use, was designed to expose people feigning deafness in one ear. Anyone who pretends to be deaf in his right ear, for example, will report hearing a tone if it is presented to his left ear through an earphone. What happens if the tone is now presented to the left ear and simultaneously but more intensely to the right ear? The listener hears the sound as coming from the right. The malingerer will therefore give himself away by saying that he does not hear any sound, in spite of the fact that it is just as intense as before at his admittedly good left ear. The effectiveness of this test makes it clear that the listener hears only a single localized sound and does not compare separate sensations arising at the two ears. Unfortunately the obvious meaning of the clinical discovery was ignored by students of auditory perception.

In 1911 there was published the first suggestion that a different mechanism—small differences in the time of arrival



AUDITORY-NERVE PATHWAYS connect the cochlea of each ear with the auditory areas of the cerebral cortex. At the lowest level of the auditory system (the auditory nerves and cochlear nuclei) the pathways are completely separate. (In this greatly simplified diagram of the system the pathways from the left ear are shown in black; those from the right ear are shown in gray.) At the next level (the olivary nucleus in the medulla) some of the nerve fibers from the cochlear nuclei of both ears converge on the same nerve cells. These cells, which thus carry messages from both ears, are shown in color. At successively higher levels of the system there is increasing convergence, and increasing interaction, between messages from the two ears, as is indicated by the larger proportion of cells in color. The majority of nerve pathways starting in one cochlear nucleus cross to the opposite side of the brain.

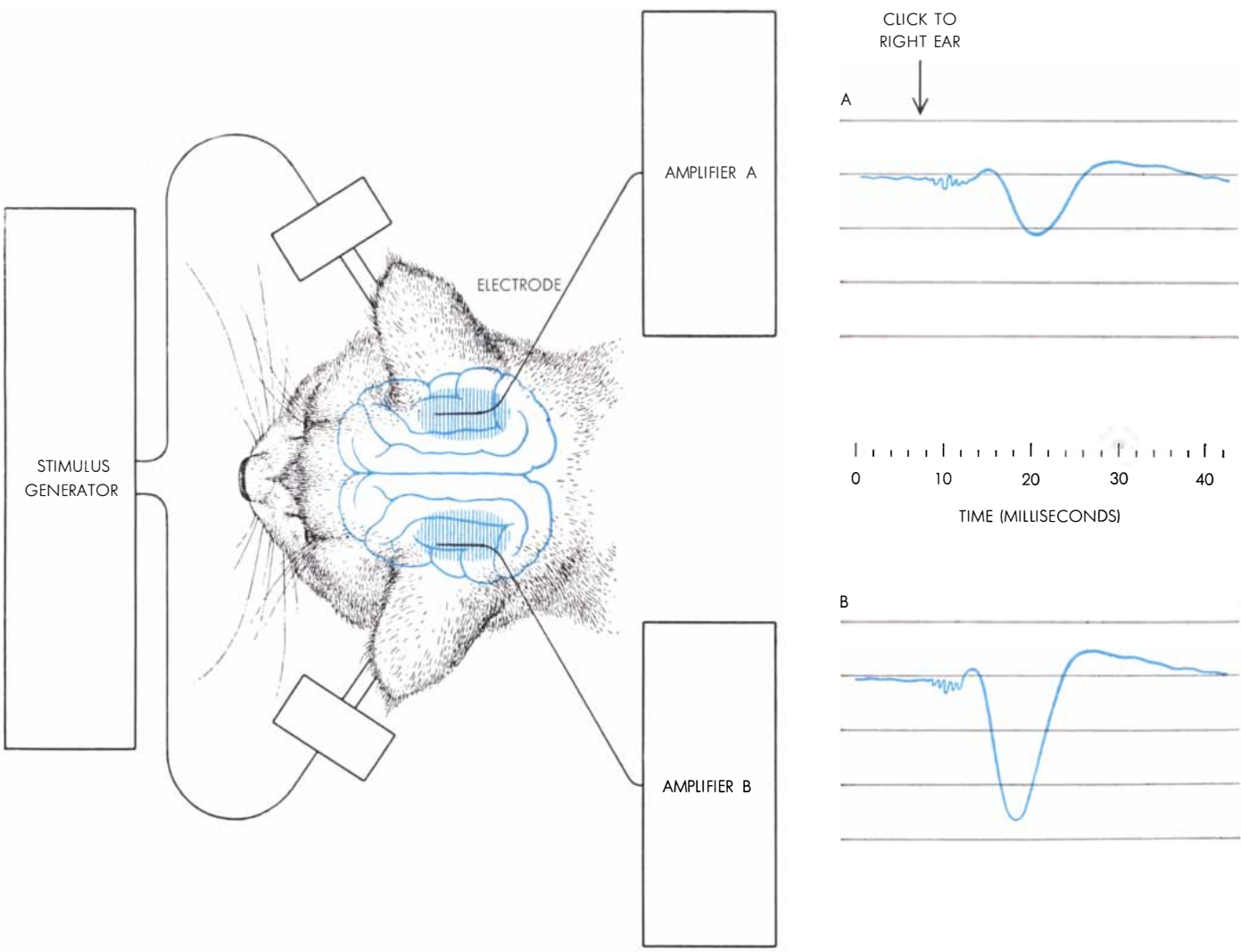
of a sound at the two ears—might influence the apparent location of the source. A sound originating directly to the right side of the head reaches the right ear about .0005 second before it reaches the left ear. A sound originating five degrees to the right of straight ahead or straight back reaches the right ear only .00004 second earlier than the left ear. Could perception of location be based on such minute time differences? During World War I the question was investigated secretly, both in France and Germany, in connection with the development of sound locators to detect airplanes. The tests showed that time differences of the order of .0001 second (with no accompanying differences in intensity) do indeed serve to locate the source of sound. Such intervals are far too small to allow the sound to be heard as separate stimuli by the two ears.

When the results were made public after the war, the judgment theory of localization was finally abandoned and a search was begun for the neural mechanisms underlying the process. During the 1920's there was a good deal of speculation about possible mechanisms. The 1930's saw the beginning of a mounting volume of experimentation on the electrical activity of the nervous system in response to auditory stimulation, as well as a revival of studies of the effect of brain damage on localization. The latter investigations had first been conducted in the 1880's.

Whenever a nerve conducts messages, small changes in electrical potential travel along the fibers of its constituent cells. With suitable equipment experimenters can tap the electrical signals as they travel from each ear up the auditory pathways to the auditory cortex [*see illustration on preceding page*]. My colleagues and I have pursued this line of research for a number of years, first at Harvard University and later at the University of California.

Our subjects were anesthetized cats. As sources of stimuli we used independent earphones, one at each ear. Tiny electrodes inserted at various points in the auditory neural pathways fed signals into our amplifier and recorder.

Stimulating the cats' ears with a brief,

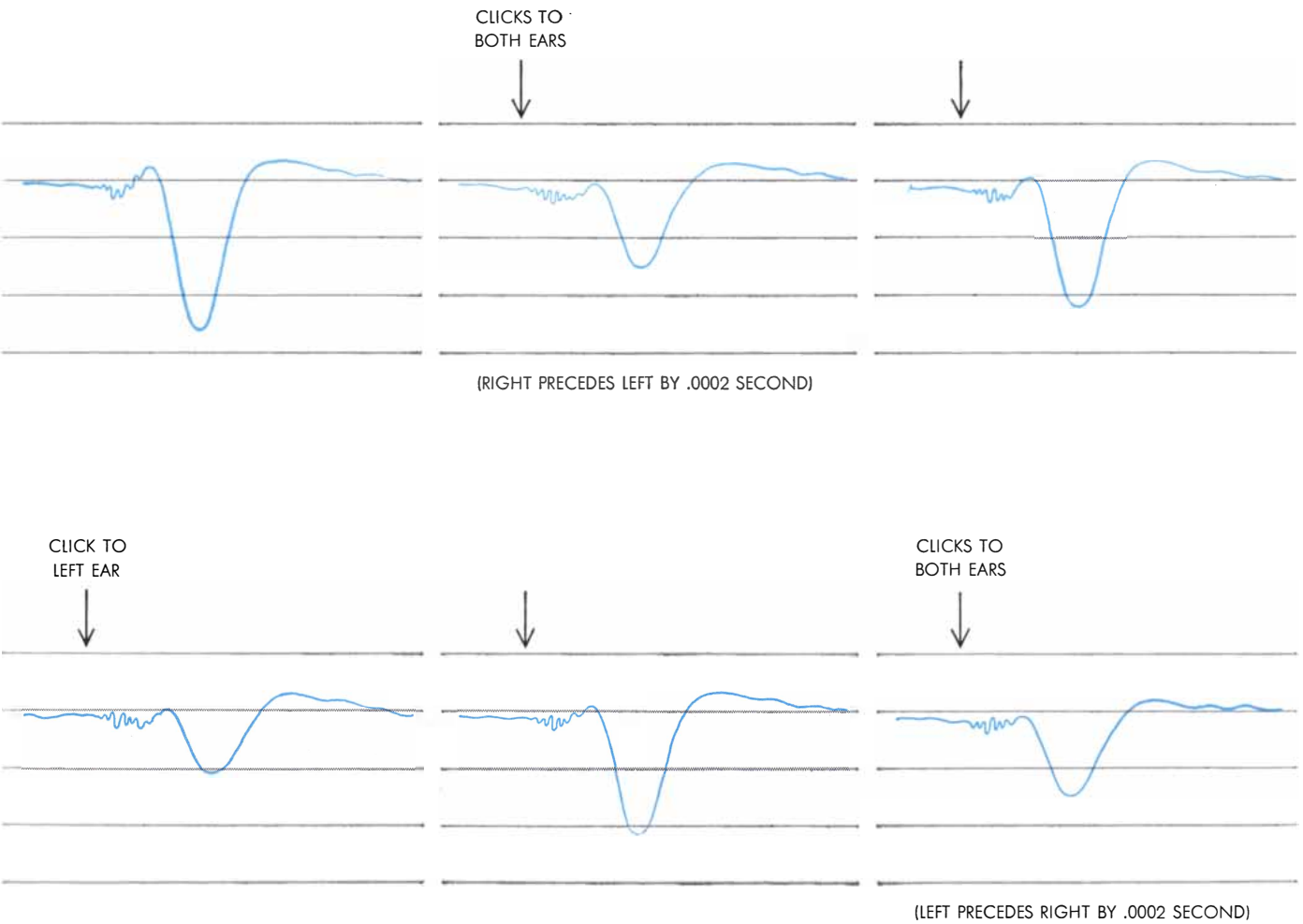


RESPONSES OF AUDITORY CORTEX, recorded through openings in the skull of an anesthetized cat, vary according to the stimulus conditions. Four electrical response curves for the cortex of the right hemisphere appear at top; those for the left cortex, at bottom. When only the right ear is stimulated, there are responses in the auditory cortex on both sides of the brain; response from the left

sharp click produced characteristically different electrical responses at each of the levels of the auditory system. Moreover, we found that, at every level in the neural pathways serving each half of the brain, an input to the ear on the opposite side of the body elicited a larger response than it did on the same side [*see illustration on these two pages*]. Most of the neural systems of the body run contralaterally in this way: from one side of the brain to the opposite side of the body. This asymmetry is less pronounced in the auditory system than in most others, but it is clearly present. Because of the asymmetry we could always tell which ear had been stimulated by comparing the responses at the two sides of the brain. A basis for an elementary localization—discrimination of right from left—appeared clearly in the neural responses.

These first experiments corroborated some earlier findings, obtained in a different way. It has been known for many years that nerve cells can be stimulated to activity by small electric currents. In the 1870's physiologists began to map the functional regions of the brain by applying currents to portions of the exposed brain and observing the different bodily responses that were evoked. In this way the British neurologist Sir David Ferrier delimited several sensory regions of the cerebral cortex, including an area devoted to hearing. When Ferrier touched an electrode to the auditory cortex on one side of a monkey's brain, the ear on the other side of the head pricked up, and the animal often turned its eyes or head to that side. In Ferrier's description it was as if a shrill note had been sounded in the ear. Moreover, the "sound" was always on the opposite side of the head from the stimulus.

In the past 25 years or so human testimony has confirmed Ferrier's observations. Patients whose cortex was being mapped in preparation for brain surgery have reported what they felt when electric current was applied to different regions of the brain. A great deal of such information has been obtained by Wilder Penfield and his associates at the Montreal Neurological Institute. When the auditory area is stimulated, patients say they hear sounds, even though no sound waves have reached



side is larger. When only the left ear is stimulated, the response from the right side is greater. When both ears are stimulated with a small time interval between clicks, the response tends to resemble the response to the prior stimulus alone. Thus when a click to the right ear precedes one to the left by .0002 second, the response from the left side is slightly larger than that from the right, and vice versa.

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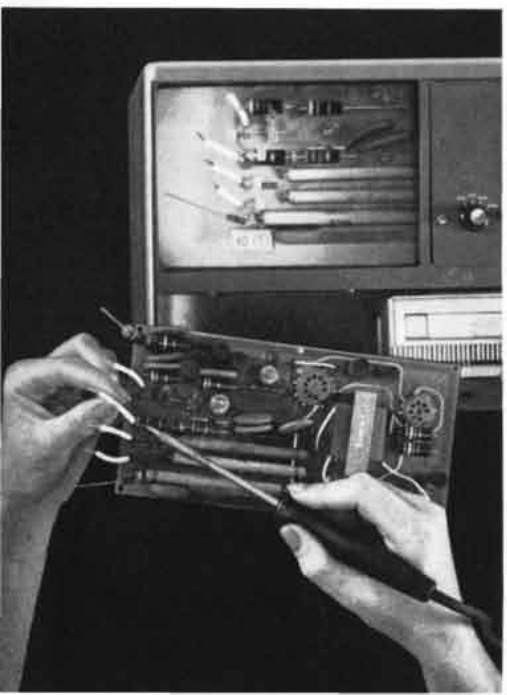
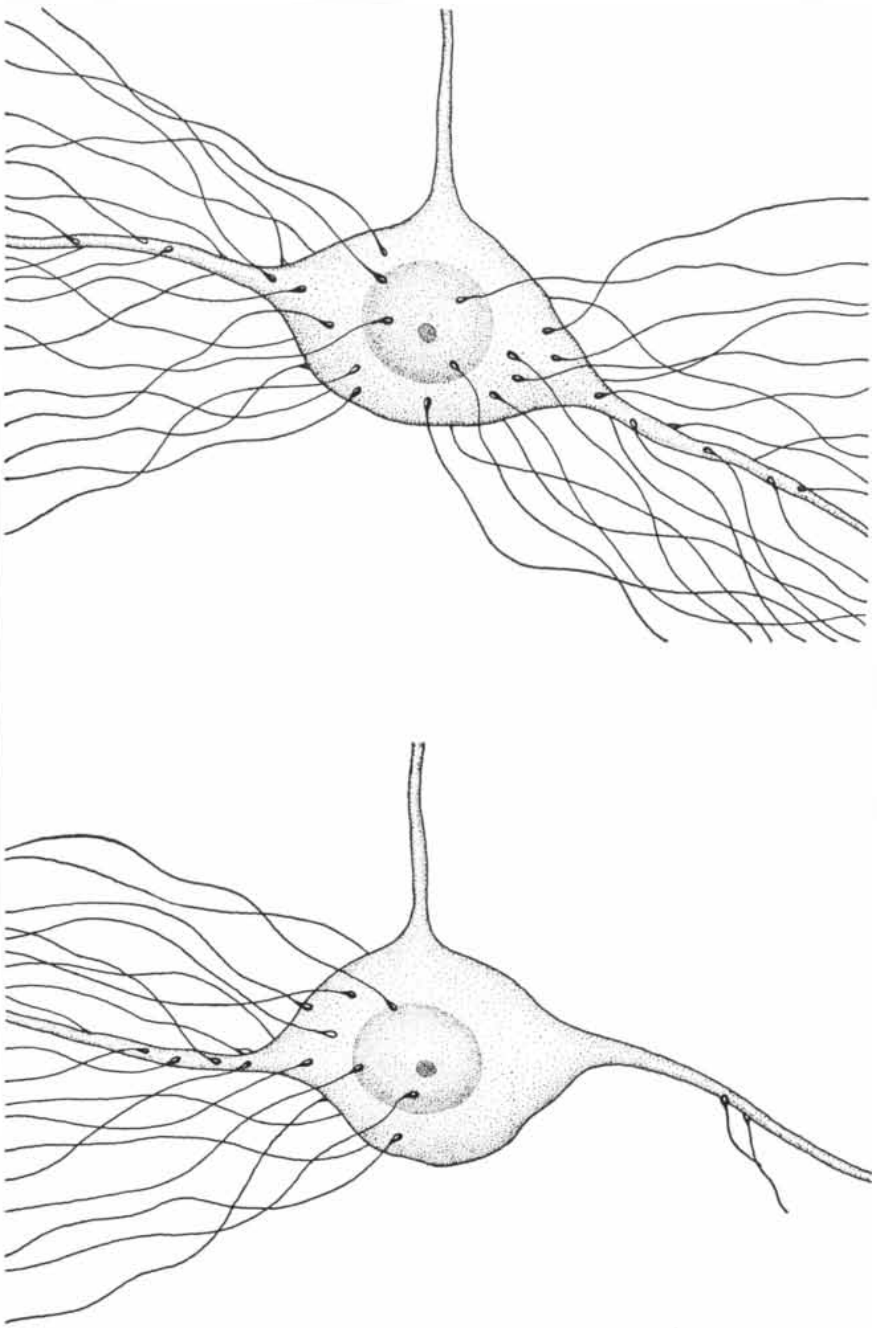


their ears. When the right side of the brain is stimulated, the patient usually hears the sound as coming from his left; when the left side is stimulated, he hears it as coming from his right. Occasionally the sound seems to come from both sides, but never only from the same side as that on which the brain is stimulated.

All the experiments point to the same conclusion: each ear is represented more strongly in the opposite side of the brain than in the same side, and a sound delivered to one ear alone excites more neural activity in the opposite side than in the same side.

Under normal hearing conditions, of



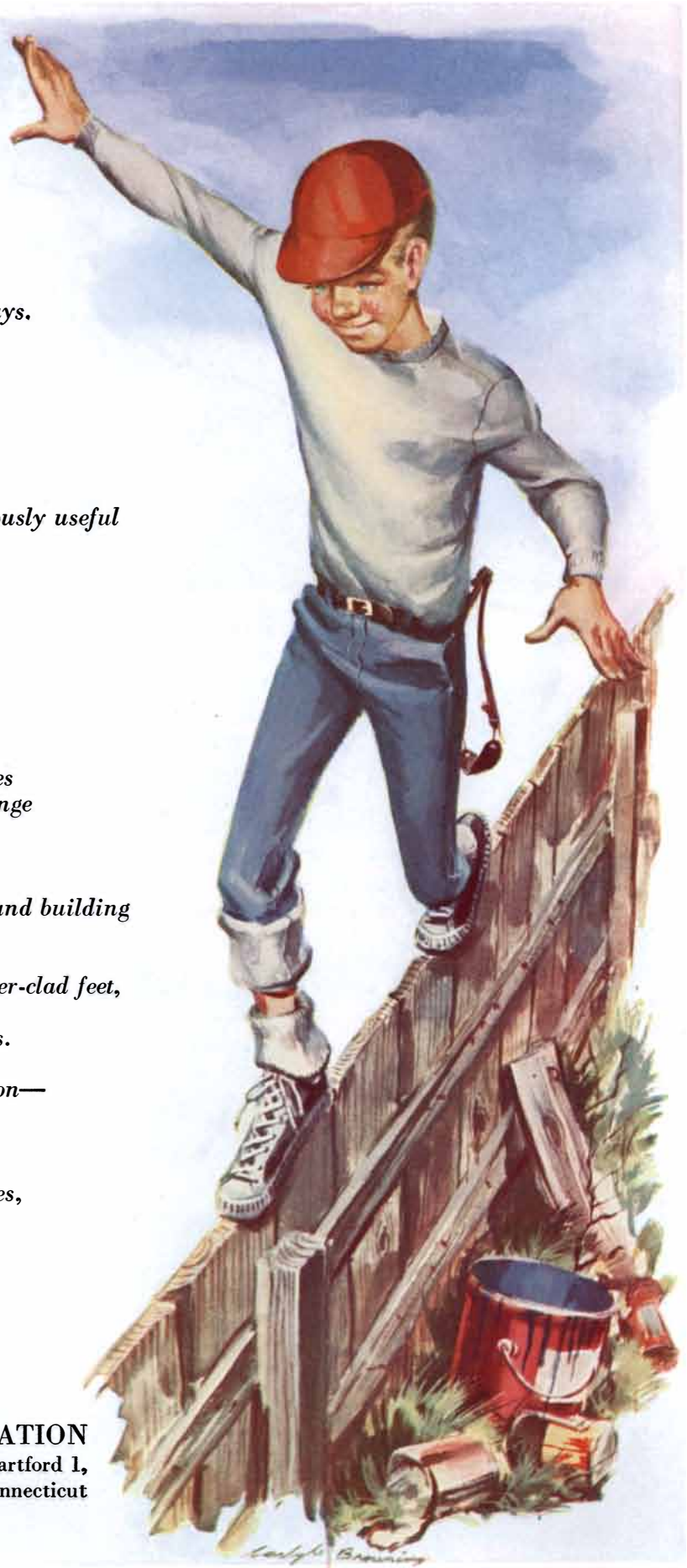
CELLS OF OLIVARY NUCLEUS normally receive connections from the cochlear nuclei of both ears (*see illustration on page 133*). In a normal cell (*drawing at top*) the incoming fibers (*thin black lines*) from the cochlear nuclei terminate on the dendritic "poles" of the cell. When the cochlear nucleus on one side of the brain stem is destroyed, the fibers leaving that nucleus degenerate; cells of the olivary nucleus lose almost all their connections on that side, demonstrating that each pole receives its connections from the ear on the same side.

course, both ears receive sound, not just one at a time. We extended our experiments with cats by stimulating both ears and recording the electrical activity along the auditory pathways. When we began, it was generally doubted that small differences in the time of arrival of a sound wave at the two ears could be preserved in the neural messages during the 10 milliseconds required for them to travel from the ear to the cerebral cortex. We soon discovered, however, that the electrical pattern does reflect such differences. If the interval was a few milliseconds, long enough so that the two electrical responses showed up separately, the response to the earlier stimulus partially inhibited the response to the later one. With shorter intervals the electrical responses fused into one, but the amplitude was chiefly determined by the first stimulus. Stimulating the ears in the order left-right produced a larger response on the right side of the brain; stimulating in the order right-left, a larger response on the left side. This remained true down to intervals of a tenth of a millisecond, although differences between responses became harder to detect as the interval grew smaller.

Differences in the intensity of stimulation at the two ears were found to produce comparable effects. Feeding a more intense sound to the right ear evoked larger responses on the left side of the brain, and the other way around. The patterns in the nervous system therefore reflect all the differences in the pattern of stimulation—temporal order of stimulation, time interval, and relative intensities of the stimuli at the two ears. (Under ordinary circumstances the temporal and intensity cues reinforce each other. The ear on the side opposite to the source of sound receives not only a later signal but also one of lower intensity, because of the shadowing effect of the head.)

We next carried our investigation down the auditory pathway from the cortex toward the ears. The interaction between the two sides was found to decrease steadily the lower we went. Some interaction can be traced, however, down as far as the olivary nucleus, a group of nerve cells in the medulla that is the next to the last station before each ear. In these nuclei the anatomist W. A. Stotler of the University of Oregon Medical School has found cells that receive connections from both ears [*see illustration on preceding page*]. At the Walter Reed Army Institute of Research, Robert Galambos and his associates have

Born to it!



Board fences are hard to find these days.
And it's a pity, too.
Boys are born to balance on them.

Take the little guy over yonder.

Like all boys,
he has a highly sophisticated
system of control—one that's outrageously useful
on a board fence.
He has sensing devices
to signal just the right muscles,
and muscle mechanisms
to take just the right action—
even if it amounts only to
wiggling his toes
in his sneakers.

A lot of former walkers of board fences
are today looking ahead to new challenge
out in a vast region
called space.

Some are here with us . . . designing and building
control systems for space vehicles.

Instead of imparting motion to sneaker-clad feet,
we've got to move control surfaces,
nozzles, even entire rocket powerplants.
And instead of wiggling toes,
we've got to steer space craft by reaction—
developing small thrust pulses
at their sides.

Just as boys have an affinity for fences,
we feel we are born to assignments
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recently been able to record the activity of single nerve cells in the olivary nucleus. They found that some of the cells respond differently according to which ear receives the earlier stimulus. At the last station before the ear—the cochlear nucleus—there is no indication of binaural interaction.

The picture of increasing interconnection of pathways as they go from lower to higher centers suggests that the higher brain centers may be required for auditory localization. The first direct attempt to test the matter goes back 80 years to the work of an Italian physiologist, Luigi Luciani. Experimenting on dogs, he removed the part of the brain then considered to constitute the auditory cortex. To test the effect on localization he blindfolded the animals and tossed small bits of food on the floor near them, observing how promptly and accurately they retrieved the food. When the operation was performed on only one cerebral hemisphere, the ability to localize was impaired, particularly in the case of sounds originating on the other side of the head. A bilateral operation disrupted localization completely. In the course of time Luciani's studies were generally forgotten. Seen from the vantage point of the present, his results lead to the right answer, but in themselves they are not conclusive. The dogs' ability to localize recovered somewhat several weeks after the operation, perhaps because Luciani never cut away all of what is now known to constitute the auditory cortex.

In the 1930's interest in Luciani's approach revived. Two independent groups reported that cats with the entire cerebral cortex removed could still localize sound. In both experiments, however, the test sound was sustained for several seconds, and the animals were allowed to move their heads. More recent studies by William D. Neff and his collaborators at the University of Chicago served to indicate that the cortex is necessary for auditory localization. From the design of the experiments, however, it was not clear whether the cats had actually lost the ability to localize or had merely lost the ability to keep their attention fixed on the task.

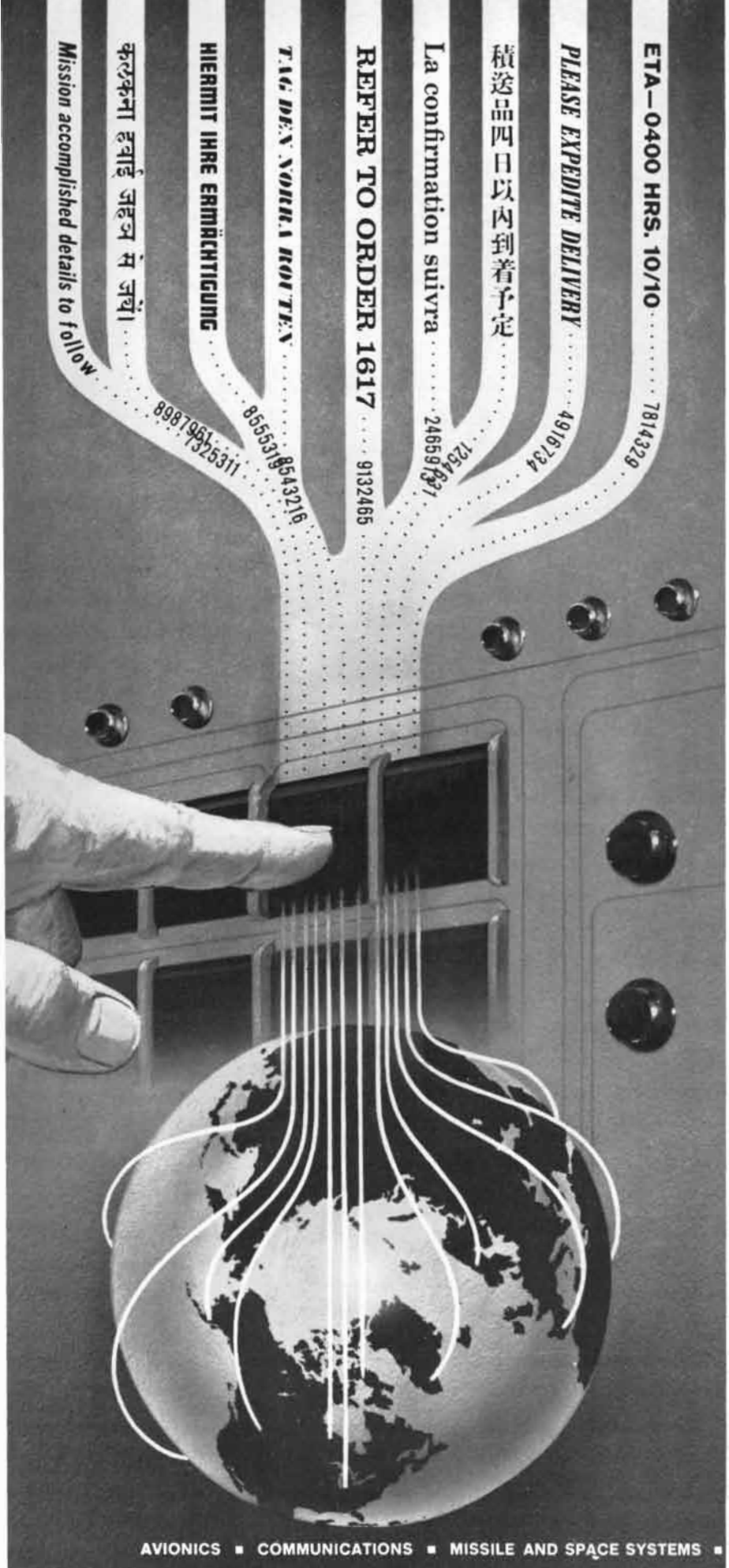
Finally, in 1959, Walter Riss of the State University of New York Downstate Medical Center reported a series of more conclusive experiments. Also working with cats, he removed the auditory cortex in some of the animals and other regions of the cortex in a group of control animals. Both groups were tested with

two types of stimulus, one very brief and the other sustained. The brief noise was produced by dropping a food pellet on the platform on which the animal stood; the sustained noise, by rapping the pellet repeatedly against the edge of the platform. He compared the performance of the two groups, recording the accuracy with which the animals turned their heads to face the sound and also measuring the time that they took to reach the food.

In tests with the single brief stimulus the animals without an auditory cortex performed at a random level. The control cats, on the other hand, turned their heads promptly toward the sound every time. With the repetitive stimuli, the performance of the experimental cats was somewhat better. They seemed to sample the sound field by movements of the head and ears. Their first reaction was correct in half the trials. Throughout the tests the experimental animals showed no deficiency of attention, so their poor performance could not be attributed to impairment of this faculty. Riss came to the conclusion that the auditory cortex is necessary for localizing the instantaneous position of a sound—the performance that is characteristic of binaural perception.

What emerges from all the studies so far is a physiological picture—in the higher mammals at least—that partially accounts for the ability to locate a source of sound. Starting at each ear and leading to the cerebral cortex is a chain of neurons. There are several stations along the chain where some neurons end and others begin. At all but the very lowest of these stations the pathways from the two ears overlap to some extent, the degree of overlap increasing as the pathways ascend. Neural impulses from one ear consequently have an increasing probability of encountering impulses from the other as they approach the cortex. Depending on the conditions of stimulation, which in turn depend on the relative positions of the listener and the source of sound, the converging impulses make some groups of nerve cells become more active and others less so. The different patterns of activity that result in the auditory cortex are correlated with different locations of auditory stimuli.

Here, for the present, the story ends. Of course, the cortex in its turn must send neural impulses to further centers so that localization ultimately evokes different patterns of behavior. Exploring this part of the neural pathway is a job for the future.



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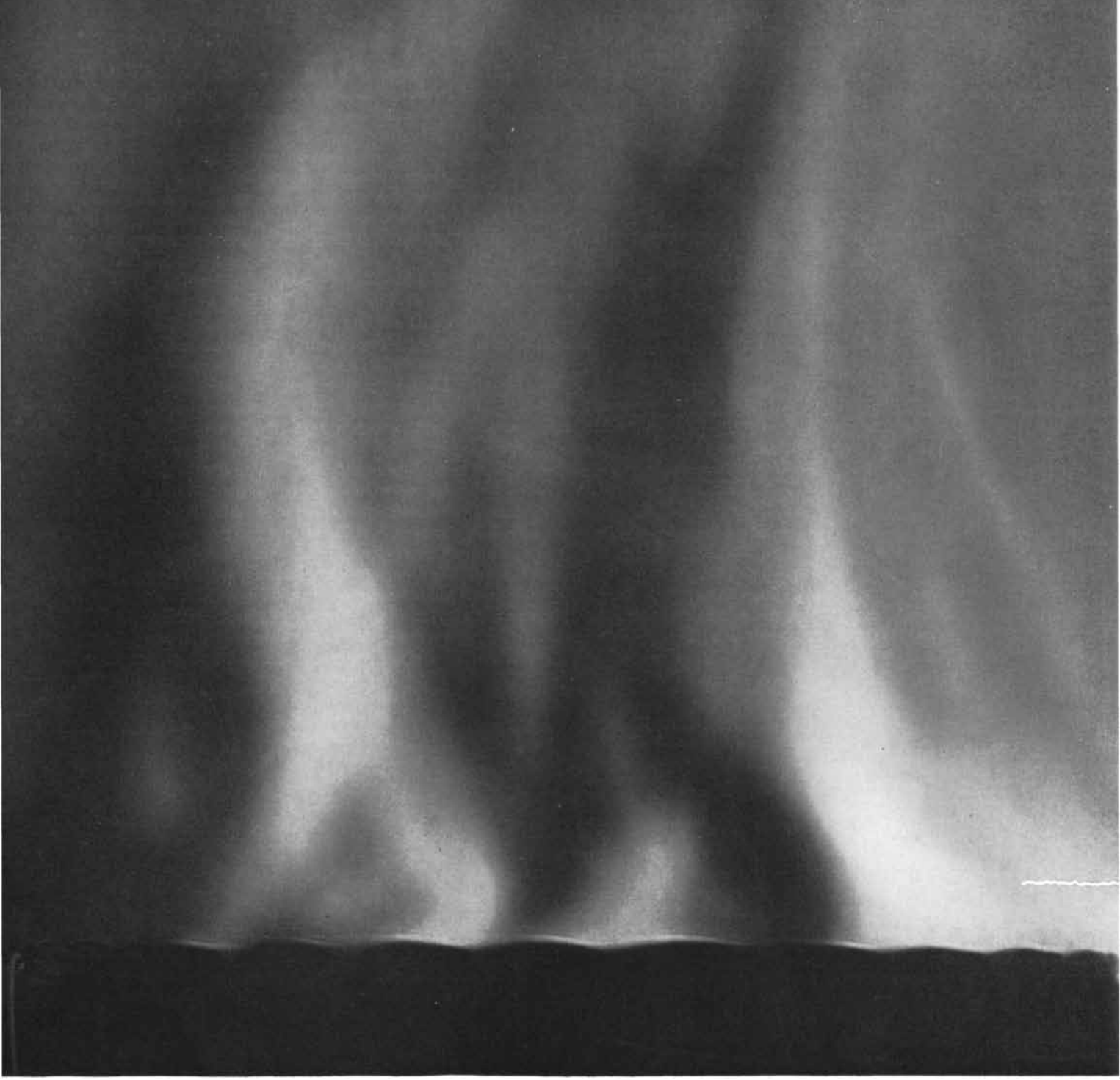

THIS IS THE AROMA OF INSTANT COFFEE

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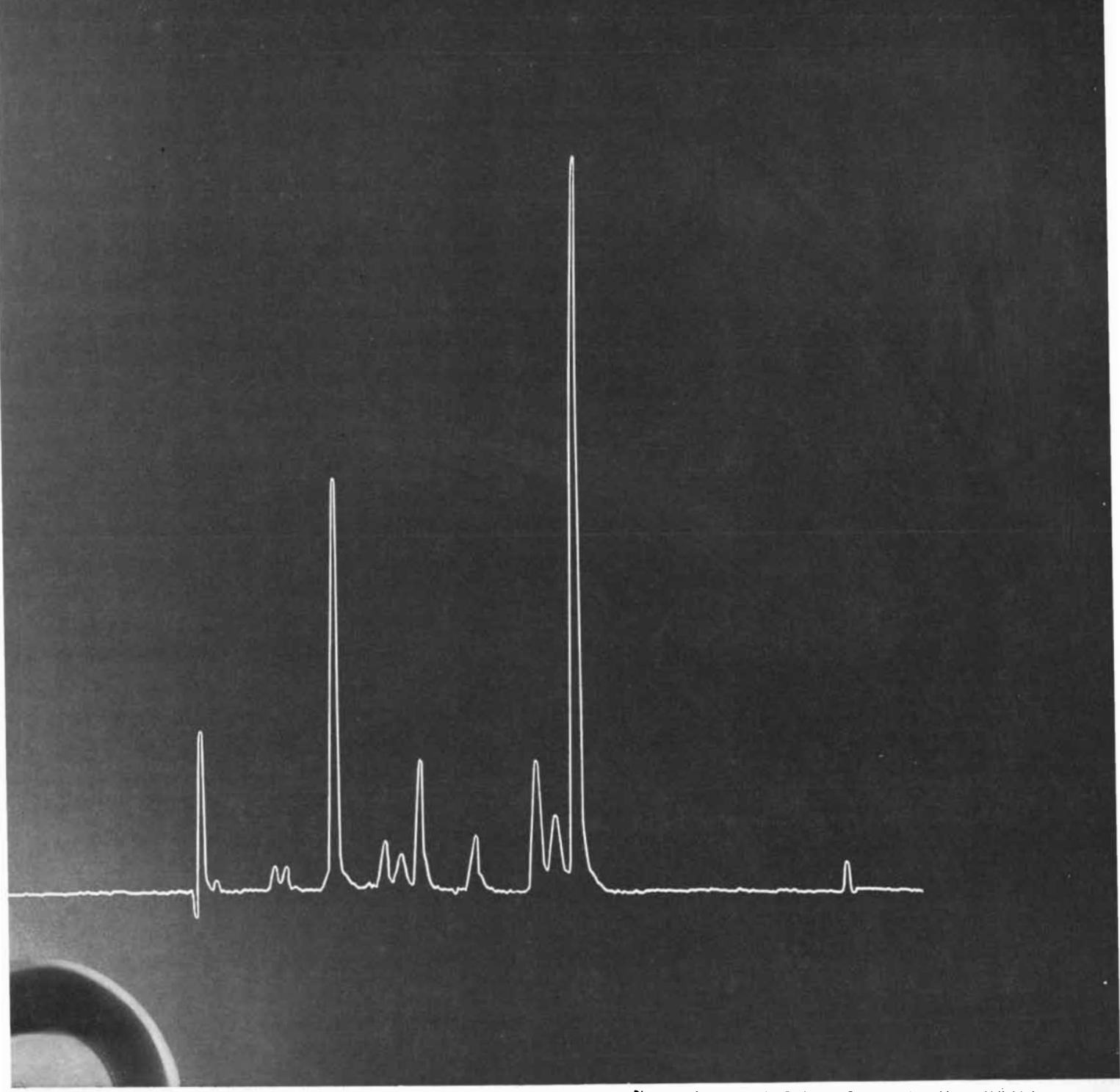
Gas chromatography answers this need. Perkin-Elmer's Vapor Fractometer, based on this analytical technique, separates the most complex mixtures into their component parts and measures the concentration of each.

The Schlieren photograph above shows the density of the aroma-bearing vapors rising from a cup of coffee. The chart at the right, made with a Vapor Fractometer, shows the components of coffee vapor sampled directly from a jar of instant coffee. Each pure component, recorded as a peak, can be trapped and separated by the Vapor Fractometer for identi-



Photograph courtesy Air Reduction Company, Inc., Murray Hill, N. J.

fication by infrared spectroscopy—another field in which Perkin-Elmer is pre-eminent.

Before chromatography was perfected, chemists could not begin to describe the make-up of many complex compounds. Now, within minutes, a technician can run a complete record, comparing it with standards for identification. Gas chromatography has opened up many new avenues of research and process control in food, petroleum, cryogenics, chemicals.

This is another example of Perkin-Elmer instruments for scientific measurement. P-E's experience with precise measurement techniques is also applied to building complex electronic-optical systems. These do vital jobs such as missile aiming and tracking. For a new brochure that outlines P-E's products and capabilities for industry, science and defense, write to Public Relations Department, Perkin-Elmer Corporation, 800 Main Avenue, Norwalk, Connecticut.

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THE MAGNETISM OF THE OCEAN FLOOR

A sensitive magnetometer towed behind a ship detects small variations in the earth's magnetic field. The variations present a puzzling new picture of that part of the earth's crust which lies beneath the sea

by Arthur D. Raff

In 1952 Ronald G. Mason of the Scripps Institution of Oceanography tied a magnetometer to the stern of a research ship and towed it halfway across the Pacific, from Samoa to San Diego. That was the first time anyone at the Scripps Institution had measured precisely the earth's magnetic field over a broad reach of ocean. The results proved quite interesting because the field showed much greater local variations than would have been expected from the topography of the ocean floor. Since then Mason and several more of us at Scripps have continued the work. We have discovered a vast expanse of geomagnetic anomaly that is different from the anomaly elsewhere. The strange pattern of the oceanic field has yielded some valuable geological information and has raised some fascinating new questions about the structure and history of the earth.

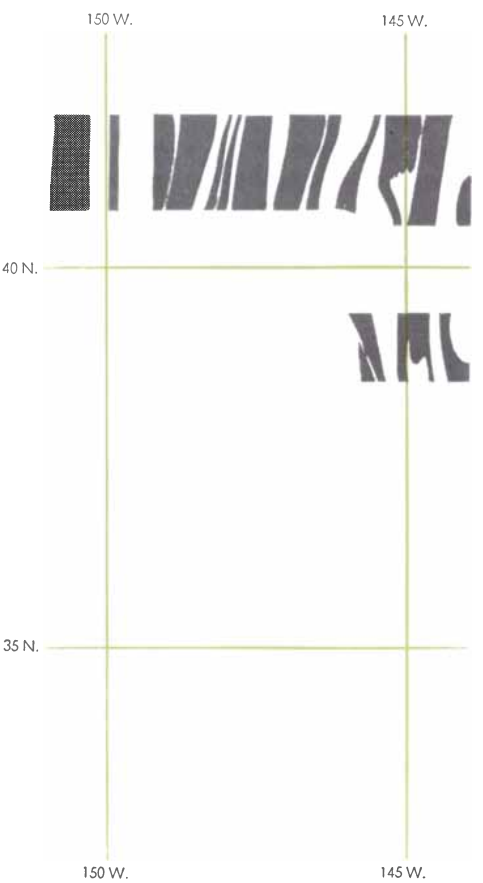
The pattern has been obtained by measuring with great precision the strength of the earth's total field along a series of closely spaced parallel lines. Except during magnetic storms (when observations are ignored) the total field is made up essentially of two parts: (1) the earth's general field, which varies smoothly from about 25,000 gammas (.25 gauss in ordinary magnetic units) near the magnetic equator to 65,000 gammas near the magnetic poles; (2) a local, or anomalous, component arising from magnetic rocks and minerals in the earth's crust. The difference between the calculated strength of the general field at any point and the actual strength measured there is an indication of the anomalous component. This value reflects the composition and formation of the crust down to the level where its temperature reaches the Curie point, that is, the temperature above which the earth's substance is too hot to be magnetized. Under the continents this level is about 15 miles down; under the oceans, about 28 miles.

By the time of Mason's first cruise prospectors were already carrying out extensive magnetic surveys over dry land, looking for minerals and petroleum [see "The Airborne Magnetometer," by Homer Jensen; SCIENTIFIC AMERICAN, June]. There was no such economic incentive to chart the oceans. Our investigation grew out of sheer curiosity.

Mason had borrowed his original magnetometer from the Lamont Geological Observatory of Columbia University. After looking at the records we made a magnetometer of our own, adapting a submarine detector, and towed it on several Pacific cruises. In all of them we found strong magnetic anomalies that we could not correlate with the topography, except over certain ridges and widely scattered sea mounts (undersea volcanoes). Like most volcanic mountains, sea mounts consist of strongly magnetic rock. Aside from confirming the general magnetic "roughness," we were learning very little from these measurements over isolated routes and our enthusiasm was waning fast.

Then in 1955 the U.S. Coast and Geodetic Survey assigned the ship *Pioneer* to a research project in deep water off the West Coast. It was to steam along east-west track lines five miles apart, holding to the prescribed course within 150 yards. The Survey was willing to tow our magnetometer so long as we did not interfere with their work. We almost passed up the opportunity, but we finally decided to give it a try for a couple of months.

When we had enough magnetic profiles, Mason drew up a contour map. Such a chart resembles a weather map, except that the lines trace out paths of equal magnetic intensity rather than constant barometric pressure. A single glance was enough to show that we had something quite new in geophysics. Over the whole map the anomalies ran roughly parallel to one another and in a north-south direction. No dry-land surveys had ever revealed a lineation that approached this one in uniformity and ex-



LINEATED PATTERN produced by magnetic anomalies in the earth's crust under the northeast Pacific Ocean is startlingly apparent when the positive anomalies are

shown in gray and the negative anomalies in white. The Murray fault is marked by *A* and *A;* the vertical broken lines show the displacement of one anomaly. The Mendocino fault lies at approximately 40 degrees north latitude and the Pioneer fault at about 38 degrees. The lineated pattern at the right was discovered in the *Pioneer* survey. The pattern extending to the left was found in later surveys along the Mendocino and Pioneer faults. The lineations strongly resemble stress patterns that appear in certain plastics.

tent. Now we persuaded a number of people to take turns at the monotonous task of riding the *Pioneer* back and forth over the ocean in order to attend the magnetometer. By late 1956 the ship had surveyed a strip of ocean several hundred miles wide extending from Mexico 1,400 miles north to the Queen Charlotte Islands, off British Columbia. The north-south magnetic lineation appeared throughout the area. In several places the pattern was sharply broken along an east-west line, so that the striations above and below it did not match [*see illustration on pages 146 and 147*].

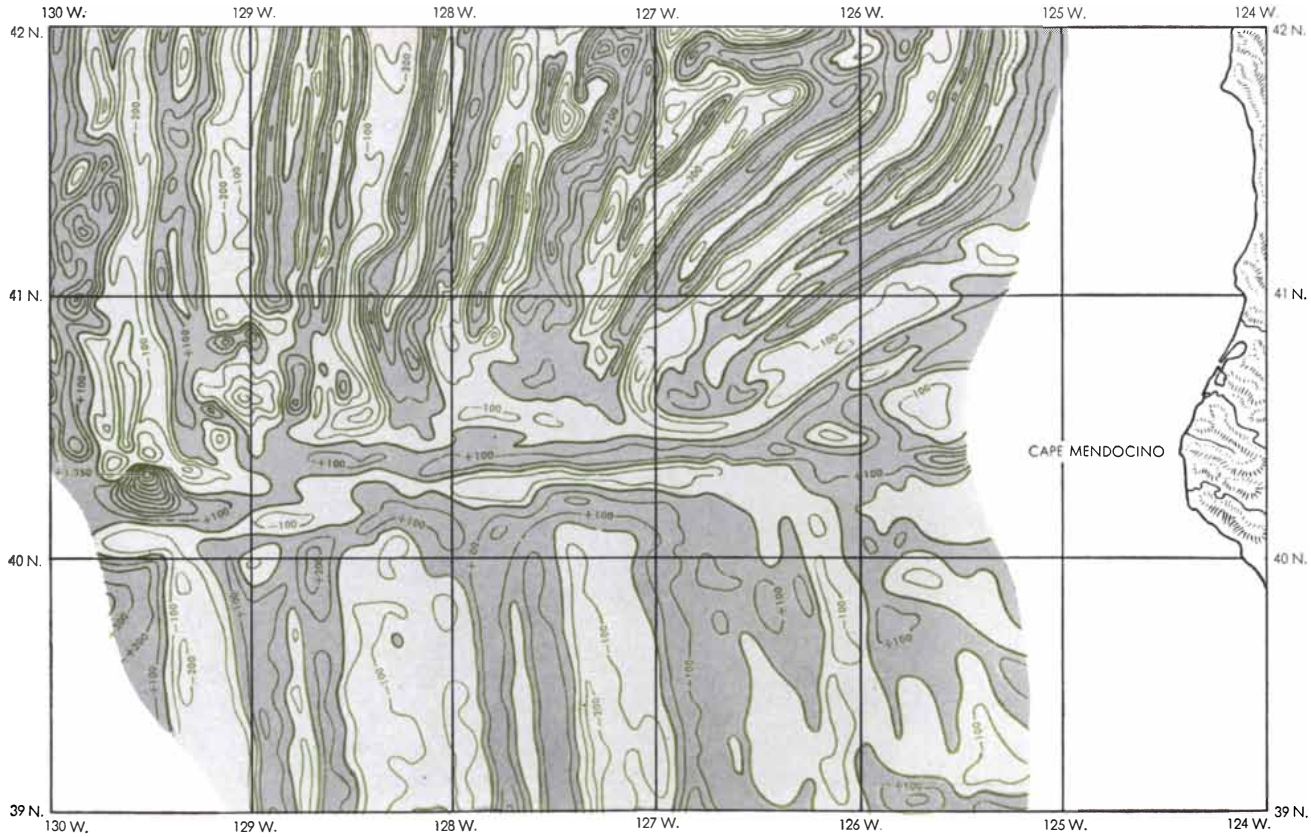
Although the significance of the lineation was—and still is—a mystery, the meaning of the discontinuities was immediately clear. Whenever a geologist sees such a break in a lineated structure, he knows he is looking at a fault. This is a place where the earth's crust has cracked, and one side has slipped in some direction with respect to the other side. Of the three major discontinuities on our map, the southernmost coincided with the Murray fault, a fracture that had been discovered several years earlier. Examining the striations more closely, we saw that if those on the north side of the break were shifted some 80 nautical miles to the west, the two patterns would match. Evidently the magnetic lineation had been frozen into the crust before the faulting occurred. It now provided a measure, the only reliable one available, of the amount of displacement along the shear line of the undersea fault.

The other two large breaks we had found represented the Pioneer fault, discovered on this survey, and the Mendocino fault, well known for its great undersea cliff rising 6,000 to 9,000 feet above the ocean floor. When we tried to match the contour lines of these faults, we were unable to do so no matter how far we shifted them.

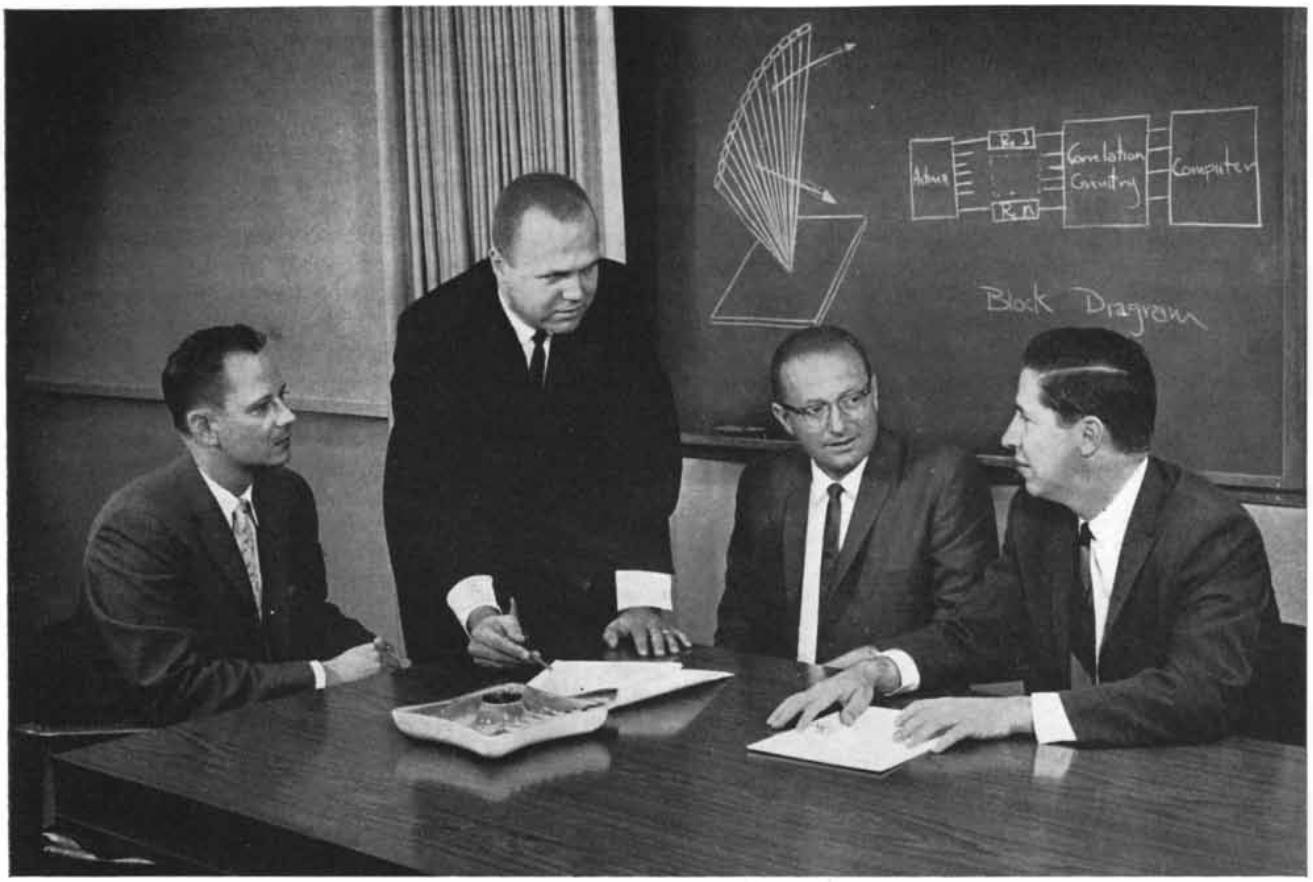
Our colleague Victor Vacquier suggested that the slippages might extend beyond the western limits of the *Pioneer* survey. Accordingly in 1958 Vacquier and I took magnetic readings farther west on a few tracks north and south of the Pioneer fault [*see illustration on pages 152 and 153*]. We finally found a match that revealed a displacement of more than 130 nautical miles, with the north side of the fault slipped to the west with respect to the south side.

The next year, with the Scripps ship *Baird*, we extended our magnetic survey several hundred miles to the west, north and south of the Mendocino fault, but without locating a match. The following spring Vacquier and Robert E. Warren stubbornly pushed the measurements still farther west. Their effort paid off. They finally found the corresponding sections of the pattern, which showed that the north side had slipped to the west with respect to the south side by approximately 600 miles. Furthermore, the slippage of the Mendocino is added to that of the Pioneer, giving a total displacement of well over 700 miles between the blocks of crust south of the Pioneer and north of the Mendocino.

Horizontally displaced faults have always presented a puzzle: no distinctive topographic features mark their ends; the cracks simply stop. What happened to all the crust that was moved? At one end or the other it should have thrust upward, folded or sunk down, but there is usually no trace of any



MENDOCINO FAULT on the *Pioneer* magnetic survey is as apparent as it is on topographic charts of the ocean bottom, where it is characterized by a great undersea cliff. The magnetic "contours" here are drawn through points of equal magnetic intensity. Contour interval is 100 gammas. Positive anomalies are shaded darker gray than negative anomalies. On this map the earth's smooth magnetic field has been subtracted, leaving only local irregularities. A typical sea mount is at far left along the line of the fault.



Discussing a system for space target detection (left to right): Dr. R. W. Bickmore, Technical Assistant to the President; Laboratory managers H. E. Shanks and M. G. Chernin; and M. D. Adcock, Director of the Electromagnetic Systems Division.

A Report from American Systems Incorporated...

Multiple Space-Target Detection

One of the key tasks of modern sensor technology is the determination of the positions and velocities of aerospace vehicles. A particularly important aspect of this problem, now being studied by American Systems Incorporated, is the radar detection of multiple targets. Usually such targets move in relatively small clusters, at high altitude and extremely high velocities. To track the individual objects making up a cluster, new antenna array techniques are under consideration.

This study is being conducted by the Electromagnetic Systems Division, the activities of which encompass research in electromagnetic physics, development of complete sensor systems, and design of special microwave components. Among the scientists and engineers contributing to this work are Dr. R. W. Bickmore and H. E. Shanks, inventors of Time Domain Radiation, and M. G. Chernin, microwave specialist. With active contracts in a number of important areas, the Division is contributing both to basic research, and to the creation of special microwave systems.

The Division's programs include Time Domain and Doppler approaches to measurement of the radiation patterns of large antenna systems, investigation of signal interference problems in areas of high density radio and radar installations, and the development of passive reflectors providing coded target returns.

Front line technical efforts are also under way in six other Divisions of the Company.

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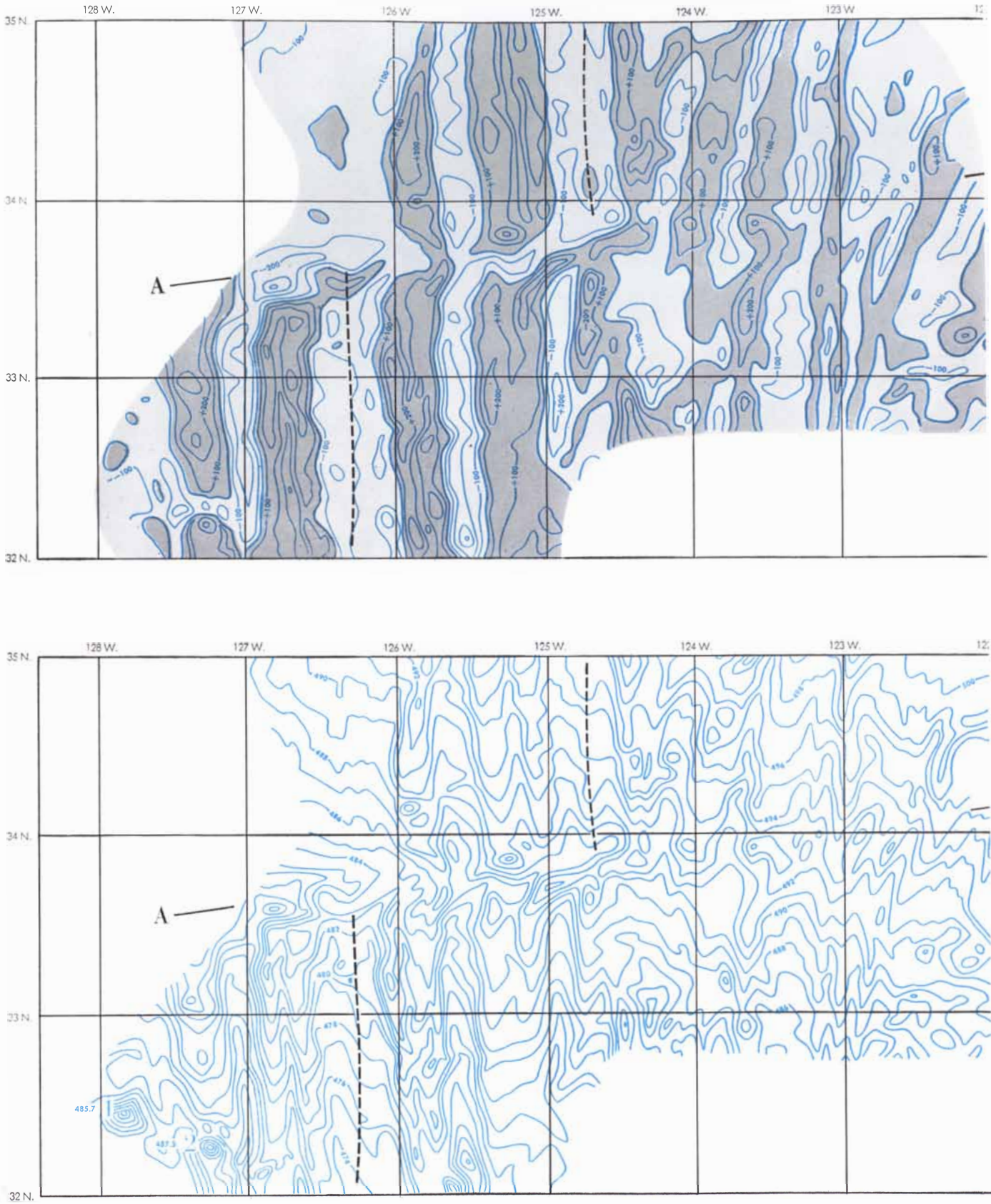
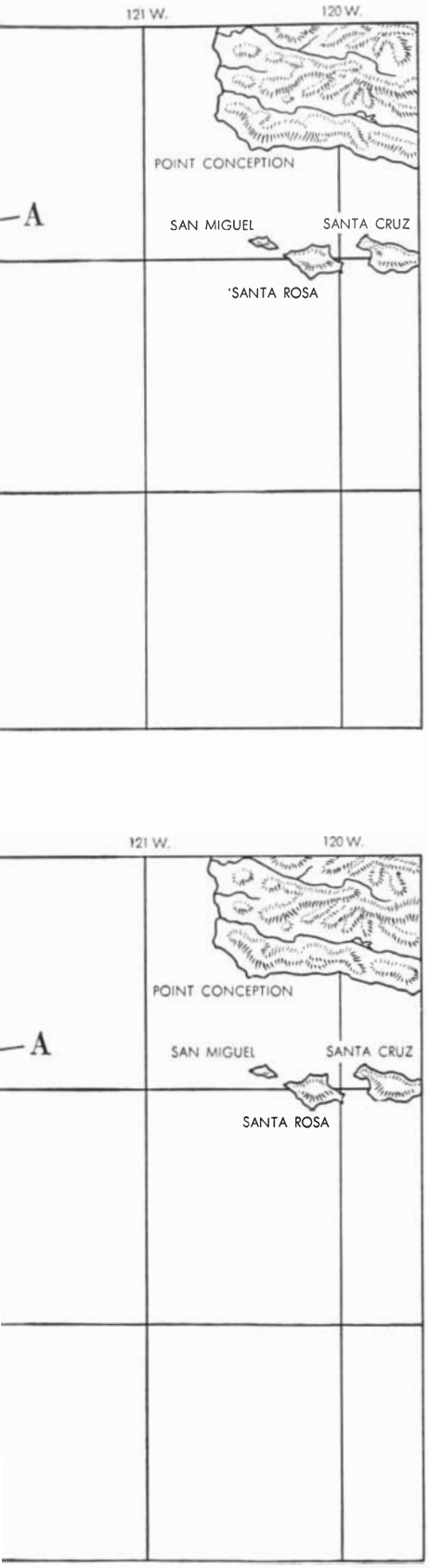


AREA OF MURRAY FAULT is shown here on two types of magnetic contour map. The top map gives only the magnetic-field anomaly (the earth's smooth field has been removed) in contour intervals of 100 gammas. The bottom map shows the total magnetic field, with contour figures in hundreds of gammas. Large figures 1 and 2 at lower left in bottom map mark typical sea mounts,



Fieberling 1 and Fieberling 2. *A* and *A* denote the Murray fault; broken lines mark matching anomalies across the fault.

of these processes. The enormous displacements of the undersea faults represent just so much more material to account for.

The magnetic measurements indicate that the Murray and Pioneer faults disappear short of the continental shelf. The Mendocino fault stops abruptly at the shelf, and, as a matter of fact, an east-west fault inland from it seems to have a shear in the opposite direction. Conceivably the oceanic crustal material of the Mendocino fracture slipped under the continental crust. It has also been suggested that all the movement was away from the continent, with material from the interior welling up to replace material that slipped way. This is little help; it merely transfers the missing material to the other end of the fault, wherever that is. Another problem is posed by the clean shear line of these large faults. All the movement apparently took place along a single, well-lubricated crack, and the crust even a short distance on each side is practically unaffected. This is hardly what one would expect in so tremendous a disturbance.

Whatever the answers, there seems little doubt that the earth's crust has shifted as much as 700 miles. Perhaps the idea of continental drift, which calls for displacements of a few thousand miles, is not so fantastic after all.

So far as faults are concerned, the magnetic surveys have underscored some old questions but have not raised new questions. The over-all north-south lineations are another matter. If the faults did not interrupt the contour lines, some of the striations could be followed for more than a thousand miles. No one supposes that the *Pioneer* survey reached either the ends of the pattern or its western boundary. What is the underlying structure that produces it? The only other geological features that approach the pattern in uniformity and extent are mountain ranges, but it is unlikely that they have much to do with it.

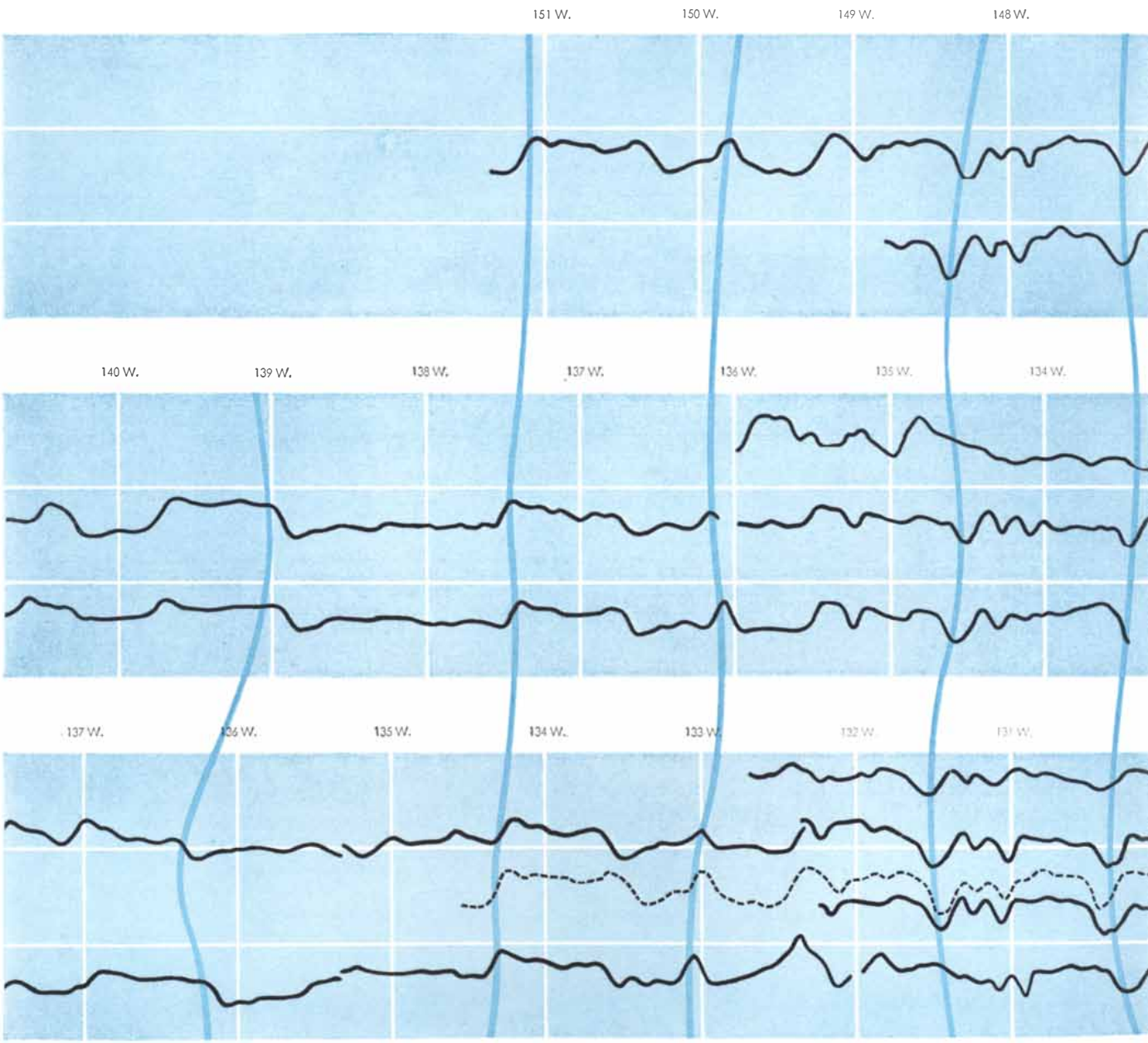
Interpreting magnetic anomalies is a process of trial and error. The geophysicist tries to visualize all the formations, no matter how farfetched, that could conceivably produce the observed pattern. Then he checks the model against other evidence. For example, a complicated system of electric currents in the crust and the ocean could account for our lineation. Not a shred of other evidence supports such an idea, however.

All the other models involve structures in the crustal rock, and there is little doubt that a lot of it must be basalt. This is the most highly magnetic of all

the common rocks. (Granite is next; limestone is almost entirely nonmagnetic.) Many of the anomalies we have recorded are so large that they could arise only from basaltic rock near the upper limit of its range of magnetic strength. The picture is consistent with evidence, accumulated over the years, that the earth's crust under the ocean consists primarily of basalt and that the continents consist of granite. Moreover, Mason and I have recently examined the many rocks dredged up from the Pacific by Scripps expeditions and have found most of them to be basalt and highly magnetic.

As we considered the great variations in magnetic anomaly, we wondered whether they might reflect corresponding variations in the magnetization of the basalt itself. An uneven crustal temperature, with alternate strips of rock above and below the Curie point, would cause such variation. But Richard P. Von Herzen of the Scripps Institution, who has measured the temperature of much of the Pacific crust, believes it is too cool to support a "hot spot" theory. Again, the right pattern of stress might do the job, since the magnetization of some rocks varies under stress. Calculation of the necessary forces, however, showed them to be highly unusual and unlikely.

The oniy possibilities we could think of involve some sort of ridged or striated pattern in the crustal rock, obscured by the overlying sediment. Mason has worked out several versions [*see illustration on page 154*]. The first was composed of thick strips of basalt, rectangular in cross section, thrust upward by

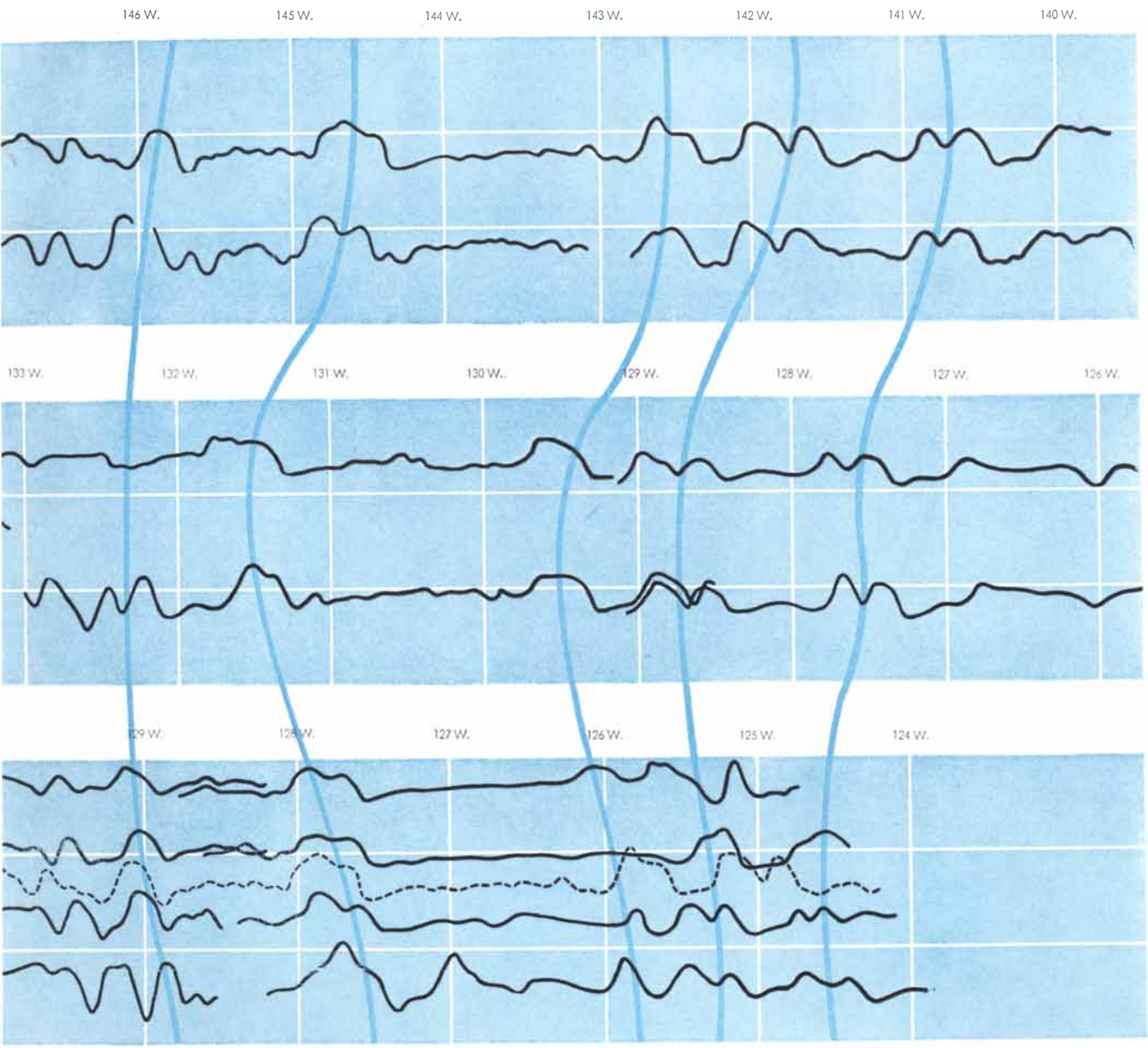


MATCHING MAGNETIC PROFILES across the Mendocino and Pioneer faults show how the amount of displacement along their shear lines was measured. The 10 vertical solid-color lines are drawn through matching sections of the profiles. The top block contains profiles taken north of the Mendocino fault; the middle block, profiles south of the Mendocino and north of the Pioneer

faulting. Seismic tests appear to rule out such large slabs. By detaching the slabs from the underlying basalt, reducing their thickness, bringing them up close to the ocean floor and increasing their hypothetical magnetization nearly to the limit, it is just possible to reconcile the seismic and magnetic data. In a rather different type of model the strongly positive anomalies are produced by ribbons of highly magnetic, volcanic basalt that flowed into previously formed channels and solidified. Still another proposal involves a thickening of strips in the main crustal layer combined with upthrust from below. The list is still longer, and none of the models can yet be absolutely ruled out. Of these models, however, the strips of solidified lava seem to us the most likely.

Whatever their exact form, these widespread and uniform striations in the earth's crust challenge the geologist to explain how they might have come about. The map of the *Pioneer* survey bears a striking resemblance to the patterns that appear in Bakelite and Lucite when they are placed under stress. This suggests to us that the present structure is the fossil record of ancient stresses. It is possible to think of other processes that could produce striations, but hardly on so large a scale.

Assuming that stress is the answer, it could have been either a north-south shearing force or an east-west force of tension or compression. Shearing would mean that each striation is a fracture, a notion that is not particularly appealing because of the great number of striations. Shear systems usually consist of one principal fault with a few lesser

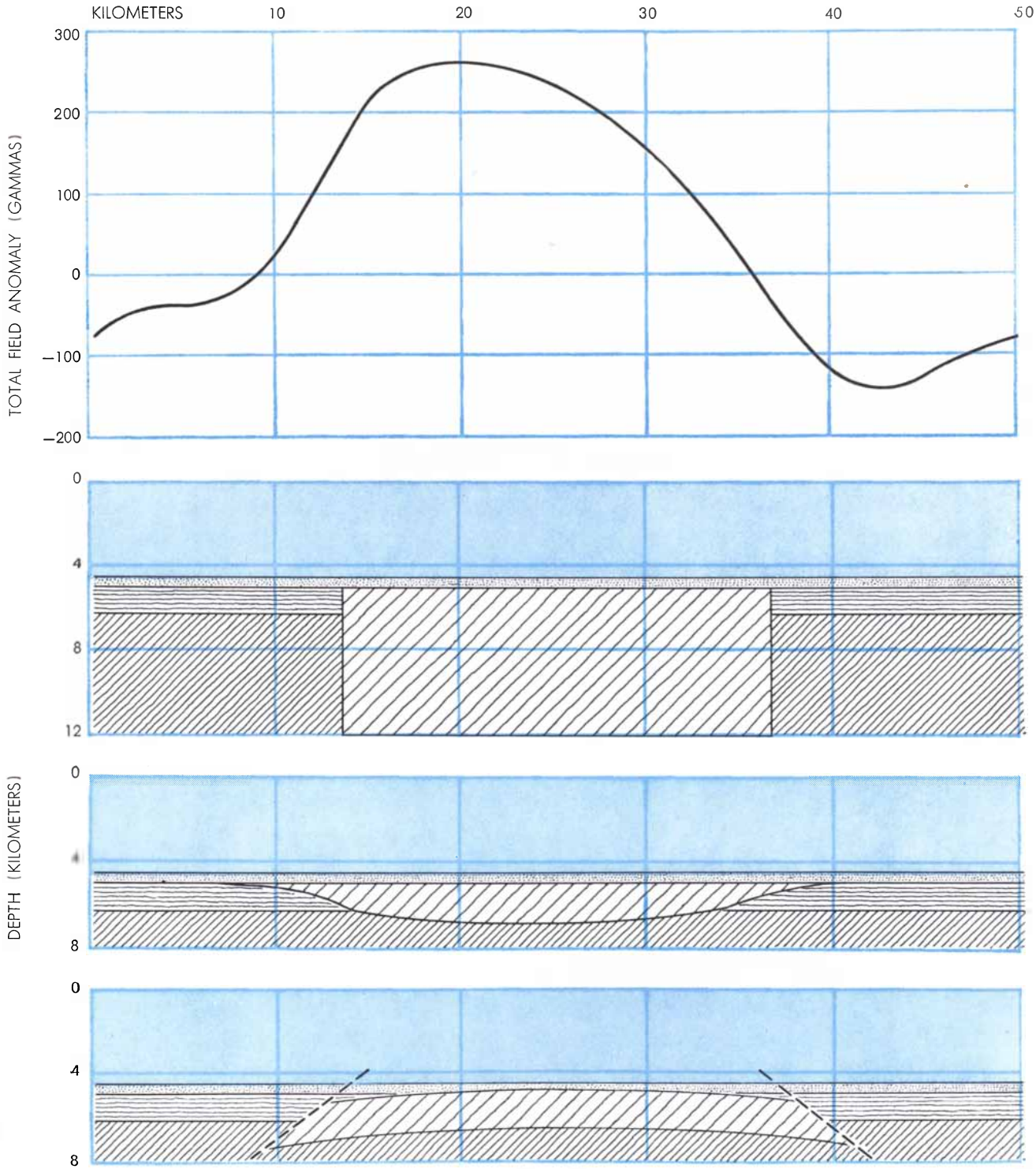


fault; and the bottom block, profiles south of the Pioneer fault. Longitudes of each block show that the north side of both faults shifted far to the west in relation to the south side. The total shift is more than 700 miles. Dashed profile in bottom block is the topmost profile inserted for close comparison. Detailed surveys are not necessary for this kind of matching; a few profiles suffice.

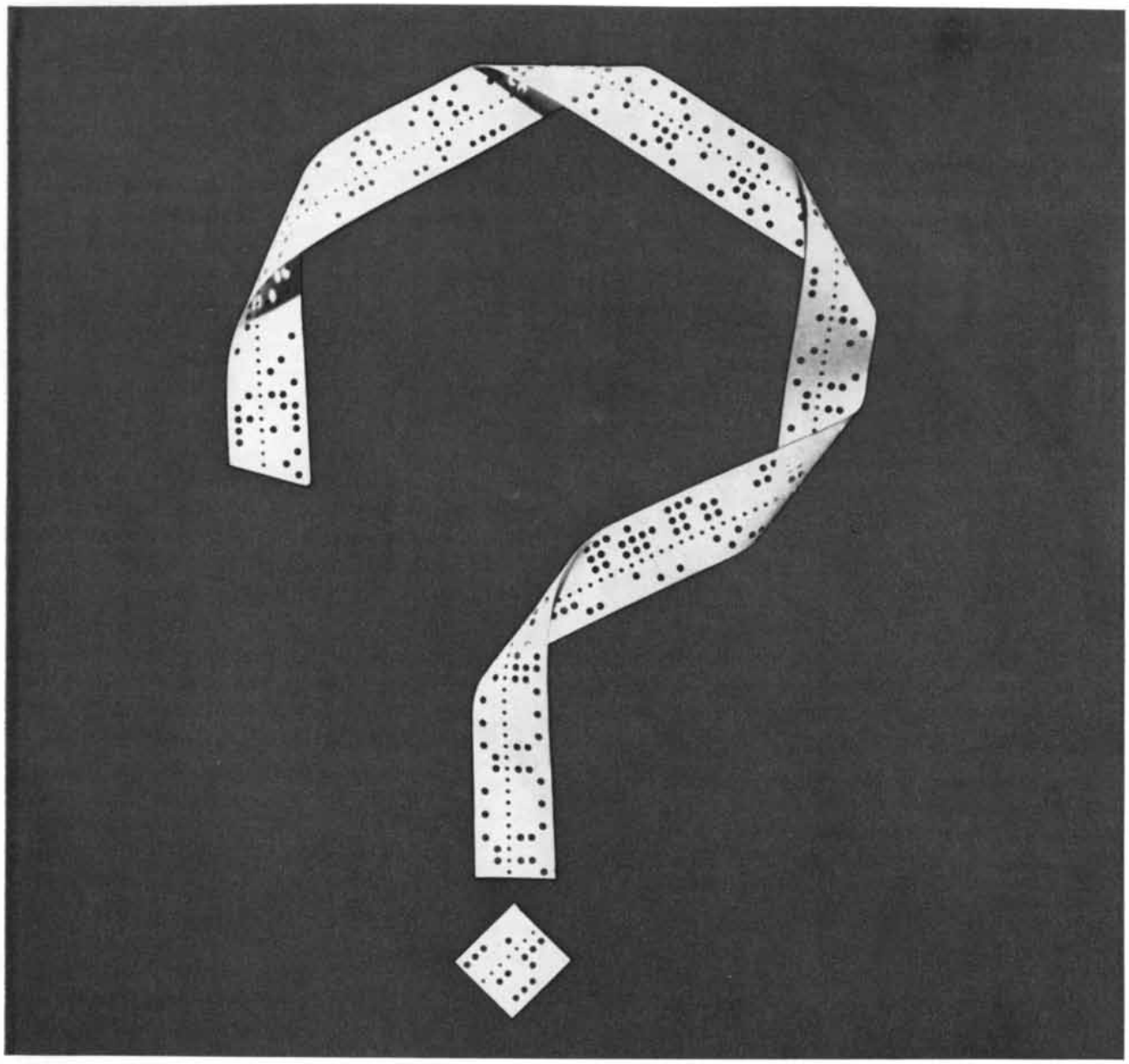
parallel faults. Thus east-west stress seems to be most probable.

Some geologists have suggested that the undersea striations resulted from the same stresses that built the mountains on the west coast of the Americas. To be sure, both systems run approximately north and south, but the mountains parallel the coast and the magnetic contour lines seem to have little relation to it. In fact, off California and Oregon the magnetic contours look as though they had been torn away from the over-all pattern and directed toward the coast.

The north-south direction of the pattern may well indicate a connection with the spin of the earth on its axis. If surveys in other regions also turn up extensive lineation parallel to the lines of longitude, the hypothesis will become almost a certainty. Rotation could oper-



CAUSE OF MAGNETIC ANOMALIES might be long rock slabs having cross sections shown by light hatching. A typical magnetic-anomaly profile is at top. The thick rectangular cross section would produce a similar curve. The first thin section, representing lava that flowed into a previously formed basin, would produce the same curve, as would the bottom section, created by upthrust from below. All are hypothetical. The author feels that lava flow probably produced the structures that cause the anomalies.



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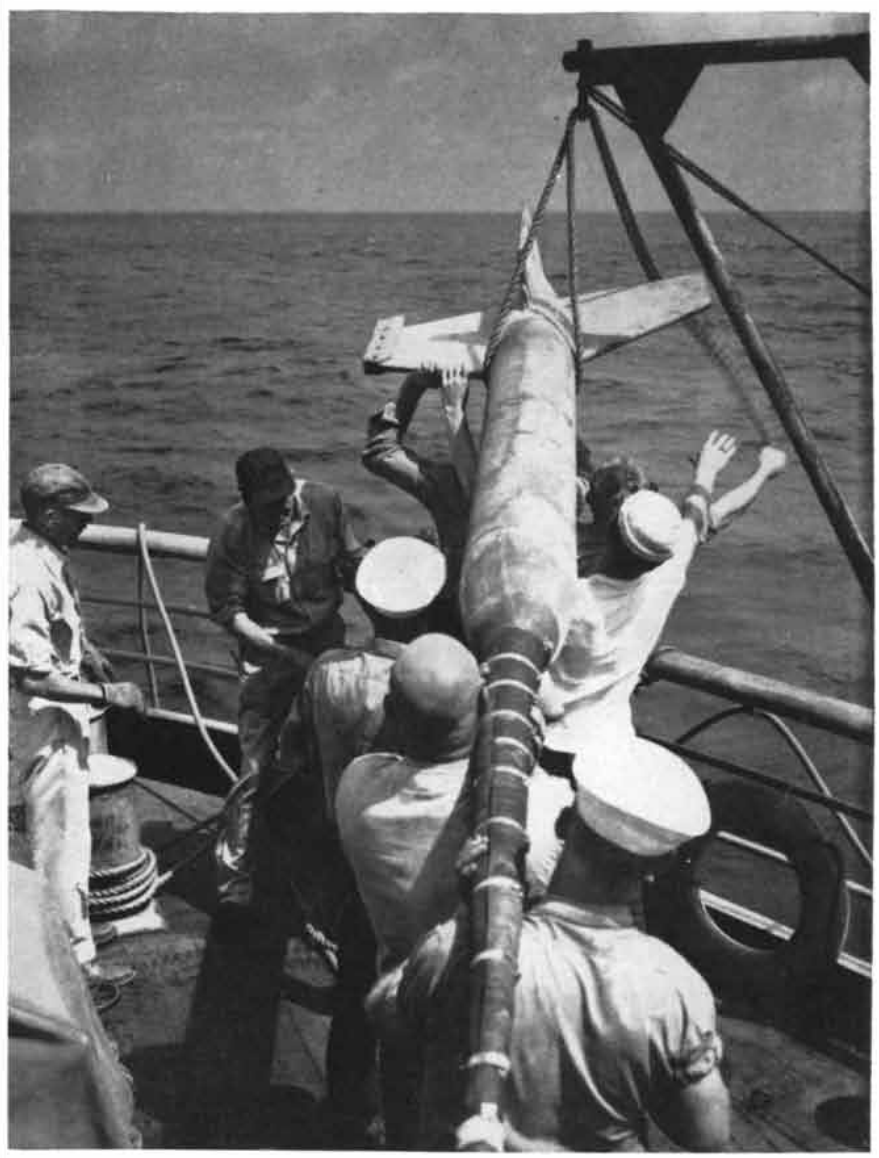
ate in several ways. Tidal action may have slowed the rotation of the earth enough in the time since the crust solidified to cause the equatorial circumference to shrink as the flat poles rounded up. Perhaps the thicker continents forced the thinner ocean crust to yield. This would have produced a squeeze type of trough-and-ridge system of low relief, permitting magma to rise through cracks and form thin, highly magnetic slabs. Another mechanism involves the earth tides. Each day a six-inch tide sweeps over the crust of the earth. Millions of years of this action may have fatigued the crust, making it fail along north-south lines. Another possibility is that long ago a period of severe earth tides brought on such a failure.

One further line of speculation may be mentioned. In the last few years a world-wide system of ridges has been discovered under the oceans [see "The Rift in the Ocean Floor," by Bruce C. Heezen; SCIENTIFIC AMERICAN, October, 1960]. The magnetic anomalies in the area of the Pioneer survey and in some other parts of the Pacific run generally parallel to the ridges there. It looks as though the two are related. A few scattered observations elsewhere have turned up anomalies parallel to ridges in some places but not in all.

Plans are now being made for detailed surveys in all the oceans. Combining magnetic observations with precise measurements of gravity assists greatly in delineating the structure of the crust and explaining the magnetic pattern. When the work is finished, it will add substantially to knowledge of the earth's history.



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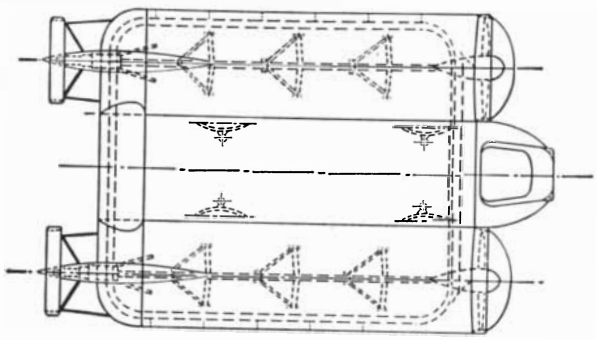

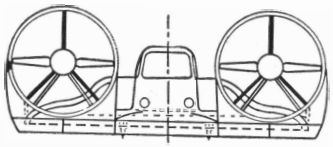

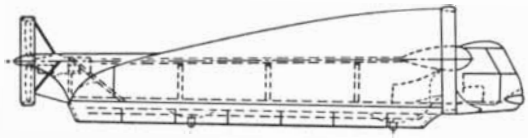

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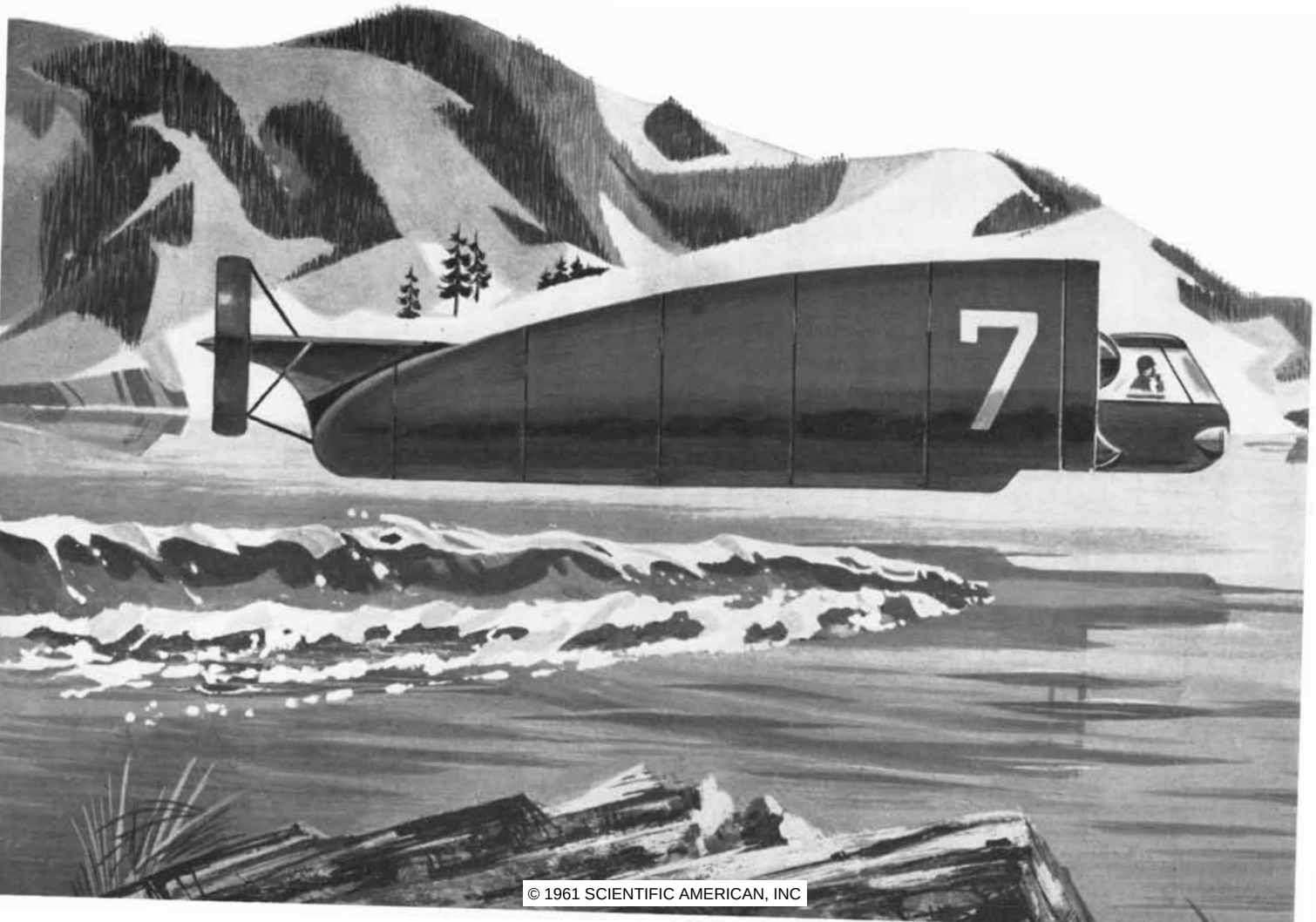

or high water

In 1959 the Army asked Aeronutronic Division of Ford Motor Company to investigate the practicality of air cushion vehicles.

Today Aeronutronic has advanced designs for two such carriers. Both will travel almost anywhere, skimming five feet above the surface, unhampered by the weather or the extremes of climate.

Although planned for different payloads and missions, both are highly maneuverable, simple to operate and easily and quickly serviced. They are specific answers to the problems posed by the limitations of conventional transportation.

The smaller of the two Aeronutronic-designed vehicles will weigh 8,000 pounds, carry a 2½ ton payload, cruise at 40 mph. It will have a range of 100 miles and a grade capability of 30%.

The big machine is a high-speed, heavy duty carrier. Weight: a hefty 44,500 pounds, payload: 22,000 pounds, speed: a fast 80 mph, range: 300 miles. It, too, will have a grade capability of 30%.

In spite of this evidence of accomplishment, Aeronutronic's work in the field has just begun. Army Transportation Command and Navy contracts are speeding further studies into the potentialities of the new vehicle. The ACV is destined to play a significant role in future military and civilian transportation.

Further information regarding the air cushion vehicle, as well as other exciting projects in work at Newport Beach, may be had by writing to Aeronutronic.

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MATHEMATICAL GAMES

Diversions that involve the mathematical constant "e"

by Martin Gardner

Recreational aspects of pi and the golden ratio, two fundamental constants of mathematics, have been discussed in this department. This month the topic is *e*, a third great constant. It is a constant that is less familiar to laymen than the other two, but for students of higher mathematics it is a number of much greater ubiquity and significance.

The fundamental nature of *e* can best be made clear by considering two ways in which a quantity can grow. Suppose you put one dollar in a bank that pays simple interest of 4 per cent a year. Each year the bank adds four cents to your dollar. At the end of 25 years your dollar will have grown to two dollars. If, however, the bank pays compound interest, the dollar will grow faster because each interest payment is added to the capital, making the next payment a trifle larger. The more often the interest is compounded, the faster the growth. If a dollar is compounded yearly, in 25 years it will grow to $(1 + 1/25)^{25}$, or \$2.66+. If it is compounded every six months (the interest is 4 per cent a year so each payment will now be 2 per cent), it will grow in 25 years to $(1 + 1/50)^{50}$, or \$2.69+.

Banks like to stress in their promotional literature the frequency with which they compound interest. This might lead one to think that if interest were compounded often enough, say a million times a year, in 25 years a dollar might grow into a sizable fortune. Far from it. In 25 years a dollar will grow to $(1 + 1/n)^n$, where n is the number of times interest is paid. As n approaches infinity, the value of this expression approaches a limit that is a mere \$2.718..., less than three cents more than what it would be if interest were compounded semiannually. This limit of 2.718... is the number *e*. No matter what interest the bank pays, in the same time that it would take a dollar to double in value at simple interest the dollar will reach a value of *e* if the interest is compounded continuously at every instant throughout the period. If the period is very long, however, even a small interest rate can grow to Gargantuan size. A dollar invested at 4 per cent in the year 1 and compounded annually would now be worth $\$1.04^{1960}$, a number of dollars that runs to about 35 figures.

This type of growth is unique in the following respect: at every instant its rate is proportional to the size of the growing quantity. In other words, the rate of change at any moment is always the same fraction of the quantity's value at that moment. Like a snowball tumbling down a hill, the larger it gets, the faster it expands. This is often called organic growth because so many organic processes exhibit it. The present growth of the world's population is one dramatic example. Thousands of other natural phenomena—in physics, chemistry, biology and the social sciences—exhibit a similar type of change.

All these processes are described by formulas based on $y = e^x$. This function is so important that it is called *the* exponential function to distinguish it from other exponential functions, such as $y = 2^x$. It is the only function that is exactly the same as its own derivative, a fact alone sufficient to explain *e*'s omnipresence in the calculus. Natural logarithms, used almost exclusively in mathematical analysis (in contrast to the 10-based logarithms of the engineer), are based on *e*.

If you hold two ends of a flexible chain, allowing it to hang in a loop, the loop assumes the form of a catenary curve [*see illustration on page 162*]. The equation for this curve, in Cartesian coordinates, contains *e*. The cross section of sails bellying in the wind is also a catenary, the horizontal wind having the same effect on the canvas as vertical gravity on the chain. The Gilbert, Marshall and Caroline islands are the tops of volcanic sea mounts: huge masses of basalt that rest on the floor of the sea. The average profile of the mounts is a catenary. The catenary is not a conic-

Through the sophisticated use of hydraulics and air, IBM engineers and scientists have developed the IBM 1301 disk storage. In this new disk memory, a hydraulic actuator simultaneously positions 40 magnetic data heads to read and write on magnetic disk surfaces. The special design of the hydraulic actuator combines speed, accuracy and reliability. The magnetic heads glide on a self-acting air bearing which requires no external air supply. Heads float at precise distances above disk surfaces, supported only by air flow generated by the rotating disks.

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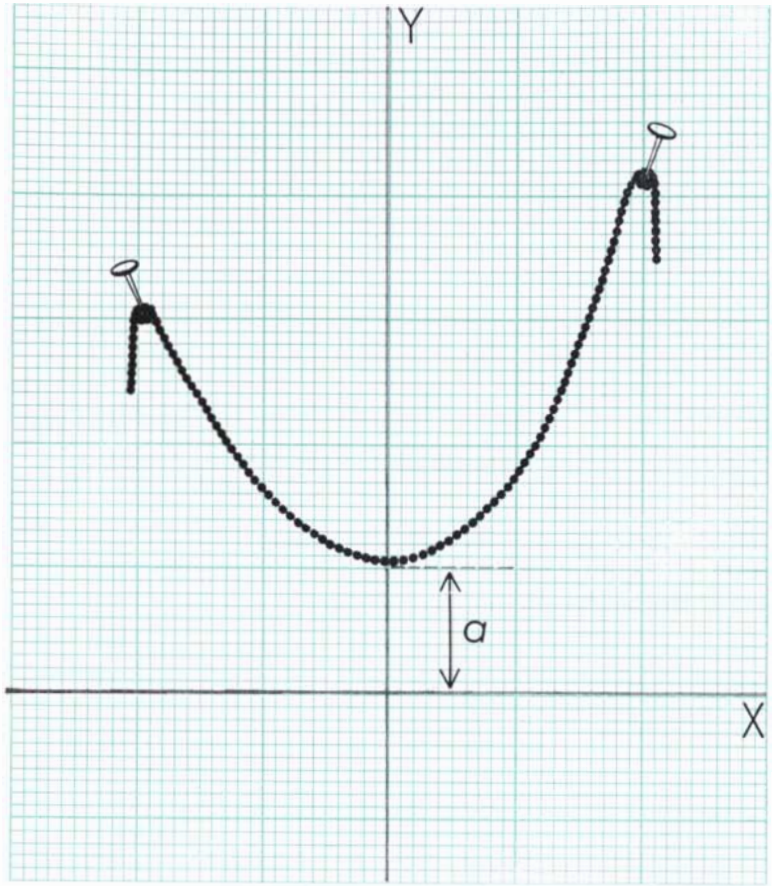

A chain hangs in a catenary curve. Its graph equation is: $y = \frac{a}{2}\left(e^{\frac{x}{a}} + e^{\frac{-x}{a}}\right)$

section curve, although it is closely related to the parabola. If you cut a parabola out of cardboard and roll it along a straight line, its focus traces a catenary.

No one has more eloquently described the catenary's appearance in nature than the French entomologist Jean Henri Fabre. "Here we have the abracadabric number e reappearing, inscribed on a spider's thread," he writes in *The Life of the Spider*. "Let us examine, on a misty morning, the meshwork that has been constructed during the night. Owing to their hygrometrical nature, the sticky threads are laden with tiny drops, and, bending under the burden, have become so many catenaries, so many chaplets arranged in exquisite order and following the curve of a swing. If the sun pierce the mist, the whole lights up with iridescent fires and becomes a resplendent cluster of diamonds. The number e is in its glory."

Like pi, e is a transcendental number: it cannot be expressed as the root of any algebraic equation with rational coefficients. It can only be expressed as the limit of an infinite series or as an endless continued fraction. The most familiar expression is the series obtained by expanding the formula $(1 + 1/n)^n$. It is usually written:

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \frac{1}{5!} \cdots$$

The exclamation mark is the factorial sign. (Factorial 3 is $1 \times 2 \times 3$, or 6; factorial 4 is $1 \times 2 \times 3 \times 4$, or 24; and so on.) The series converges rapidly, making it as easy as pie—in fact, much easier than pi—to calculate e to any desired number of decimals. In 1952 an electronic computer at the University of Illinois, under the guiding eye of D. J. Wheeler, carried e to the staggering total of 60,000 decimals! (The exclamation mark here is not a factorial sign.) Like pi, the decimals never end, nor has anyone yet detected an orderly pattern in their arrangement.

Is there a relation between e and pi, the two most famous transcendentals? Yes, many simple formulas link them together. The best known is Demoivre's formula:

$$e^{i\pi} + 1 = 0$$

"Elegant, concise and full of meaning," write Edward Kasner and James R.

Basic Research at Honeywell
Research Center
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Studies in the Magnetic Properties of Thin Metallic Films

Temporary or transient memories of electronic computers consist of small doughnut-shaped ferrite cores hand-assembled into many complex matrices. Bulk, speed of response and costly manufacture create inherent limitations. It now appears possible to overcome these by replacing ferrite cores with tiny spots of magnetic film vapor deposited on a smooth flat surface.

Today's electronic computer has a memory which is part of the brain of the machine. Larger machines commonly have two memories: one for permanent storage of information, the other for temporary storage of more transient information. The temporary memory consists of a collection of ferrite cores, each core shaped like a tiny doughnut and having a number of wires laced between it and other cores forming a matrix or grid. The wires carry either the pulse of electricity which magnetizes the core, or a similar pulse which is the core's response to interrogation.

A series of these pulses, handled in a binary number system, have become the language of the computer. To function binumerically, circuits represent "0" by not conducting current, and represent "1" by conducting. Each memory core can be magnetized in one direction for "0", the opposite direction for "1." To avoid ambiguities, cores are made so they are not readily magnetized in any direction other than these two.

Each small ferrite core can be magnetized or interrogated in about a microsecond (one-millionth second). Unfortunately, the assembly of ferrite cores discourages automation processes, making manufacture slow and costly. In addition, the tremendous bulk of many millions of cores properly assembled prohibits machines requiring considerably larger transient memories.

Current basic research indicates that one of the most promising successors to the ferrite core is a tiny spot of magnetic film about 1,000 Angstroms (four millionths of an inch) thick, deposited on a smooth flat surface. These films have been prepared in Honeywell's Research Laboratories from an alloy of nickel and iron by heating the alloy until it vaporizes in a vacuum. Each freed vapor particle travels until it strikes a cooler surface. There it condenses and stays, if the surface is suitable and immaculately clean.

It might be assumed that the task would be simple. However, as the vapor condenses and becomes solid, it seems to become peculiarly sensitive to the nature of the surface on which it is being deposited. Unless oriented by a magnetic field (created by large coils that encircle the vacuum chamber), the films could be magnetized in a number of directions instead of along the desired single line. When we obtain uniformly bi-stable spots, we are in effect duplicating the action of ferrite cores. We also may use the same cycle by which bits of information are stored and extracted by reversing direction of the magnetic field.

The coercive force necessary to reverse (or "flip") the direction of magnetization within a thin film is very low. Another important advantage stems from the fact that reversal may be accomplished either by employing a rotational mechanism (simultaneous rotation of all atomic magnetic moments) or a wall-motion mechanism (sequential rotation of the atomic magnetic moments in the form of a moving wall). Both may be induced through application of a coercive force as small as one Oersted. Of the two mechanisms, rotational is much the faster; it makes possible the reading and writing of 100,000,000 bits of information per second on a single spot, as compared to about 100,000 for ferrite cores.

Honeywell scientists have consistently produced 256 bit (16x16) matrices uniform to plus or minus 5% of energy. Only this uniformity makes it possible to use the films in circuits, since a given small electrical pulse applied to any film must flip that film.

Uniformity has been achieved in part through study of deposition techniques and experiments both with various types of substrata and with various methods of cleaning them before deposition. It has resulted also, through broader understanding of the mechanisms involved, in causing reversal of the magnetic field. Even more important, however, have been detailed investigations into the factors that lead to non-uniformity, and subsequent development of techniques that tend to eliminate them.

The most difficult task remaining seems to be linking the film spots with printed circuits which will probably replace the wires used with the ferrite cores.

Our research on thin films is both basic and applied. Applied, since our scientists are trying to create better, faster, smaller memory systems for the commercial and military computers our engineers design; and basic, since they are trying to understand and explain all the phenomena described, as well as others that are completely baffling.

If you are engaged in magnetics research and would like to know more about Honeywell's work on thin magnetic films, you're invited to correspond with Dr. Richard Prosen, Honeywell Research Center, Hopkins, Minnesota. Or, if you would like a simplified explanation of the binary number system and how to perform standard mathematical manipulations using this system, write to Honeywell Research, Minneapolis 8, Minnesota.

Newman in their book *Mathematics and the Imagination*. "We can only reproduce it and not stop to inquire into its implications. It appeals equally to the mystic, the scientist, the philosopher, the mathematician." The formula unites five basic quantities: 1, 0, pi, e and i (the square root of minus one). Kasner and Newman go on to tell how this formula struck Benjamin Peirce (a Harvard mathematician and father of the philosopher Charles Sanders Peirce) with the force of a revelation. "Gentlemen," he said one day to his students after chalking the formula on the blackboard, "that is surely true, it is absolutely paradoxical; we cannot understand it, and we don't know what it means, but we have proved it, and therefore, we know it must be the truth."

Because the factorial of a number n gives the number of ways that n objects can be permuted, it is not surprising to find e popping up in probability problems that involve permutations. The classic example is the problem of the mixed-up hats. Ten men check their hats. A careless hat-check girl scrambles the checks before she hands them out. When the men later call for their hats, what is the probability of at least one man getting his own hat back? (The same problem is met in other forms. A distracted secretary puts a number of letters at random into addressed envelopes. What is the probability of at least one letter reaching the right person? All the sailors on a ship go on liberty, return inebriated and fall into bunks picked at random. What are the chances of at least one sailor sleeping in his own bunk?)

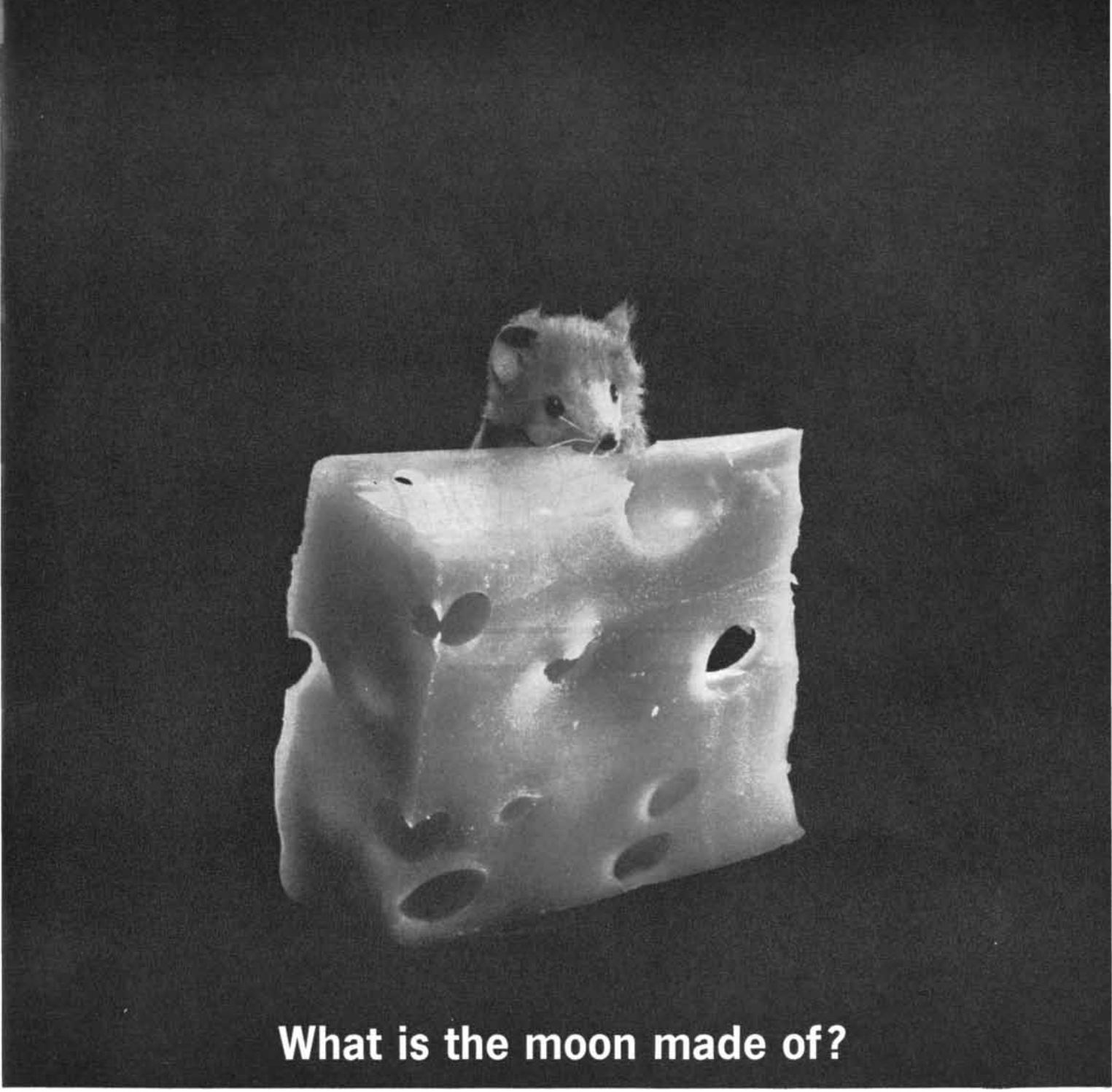
To solve this problem we must know two quantities: the number of possible permutations of 10 hats and how many of them give each man a wrong hat. The first quantity is simply 10!, or 3,628,800. But who is going to list all these permutations and then check off those that contain 10 wrong hats? Fortunately there is a simple, albeit whimsical, method of finding this number. The number of "all wrong" permutations of n objects is the integer that is the closest to $n!$ divided by e. In this case the integer is 1,334,961. The exact probability, therefore, of no man getting his hat back is 1,334,961/3,628,800, or .367879... This figure is very close to $10!/10!e$. The 10!'s cancel out, making the probability extremely close to $1/e$. This is the probability of all hats being wrong. Since it is certain that the hats are either all wrong or at least one is right, we subtract $1/e$ from 1 (*certainty*) to obtain .6321..., the probability of at least one man getting his own hat back. It is almost 2/3.

The odd thing about this problem is that beyond six or seven hats an increase in the number of hats has virtually no effect on the answer. The probability of one or more men getting back their hats is .6321... regardless of whether there are 10 men or 10 million men. The chart below shows how quickly the probability of no man getting back his hat approaches the limit of $1/e$, or .3678794411... The decimal fraction in the last column alternates endlessly between being a bit larger and a bit smaller.

A pleasant way to test the accuracy of all this is by playing the following game of solitaire. Shuffle a deck of cards, then deal them face up. As you deal, recite the names of all 52 cards in some previously determined order. (For example, ace to king of spades, followed by ace to king of hearts, diamonds and clubs.)

NUMBER OF HATS	NUMBER OF PERMUTATIONS	NUMBER OF PERMUTATIONS IN WHICH NO MAN GETS HAT BACK	PROBABILITY OF NO MAN GETTING HAT BACK
1	1	0	0
2	2	1	.5
3	6	2	.333333
4	24	9	.375000
5	120	44	.366666
6	720	265	.368055
7	5,040	1,854	.367857
8	40,320	14,833	.367881
9	362,880	133,496	.367879
10	3,628,800	1,334,961	.367879
11	39,916,800	14,684,570	.367879
12	479,001,600	176,214,841	.367879

The problem of the men and their hats



No. Guess again.

Potassium, uranium, thorium? Closer, but still guesswork. And guesses they'll be until man puts scientific instruments on the Moon to gather surface and sub-surface data and transmit these data to Earth.

The right answers will come with unmanned lunar spacecraft projects directed by Caltech's Jet Propulsion Laboratory for the National Aeronautics and Space Administration.

The planned Lunar Exploration Program begins with JPL's Ranger Project that will soon hard-land 50-pound instrument packages on the Moon to measure Moon quakes and temperature and radio their findings back to Earth.

Following the Ranger, the Surveyor will *soft*-land several hundred pounds of sensitive instruments on the Moon. Its objectives are to measure the physical properties of the Moon and analyze the composition of surface and sub-surface samples. Knowledge from these projects is essential to eventual manned landings on the Moon.

Under JPL direction, unmanned spacecraft for these projects and probes to the planets are being designed. Many disciplines are involved. Physics, electronic engineering, metallurgy . . . it's a long list.

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You win the game if you turn up at least one card that corresponds to the card you name as you deal it. What are the chances of winning and losing?

It is easy to see that this question is identical to the question about the hats. Intuitively one feels that the probability of winning would be low—perhaps 1/2 at the most. Actually, as we have seen, it is 1 minus $1/e$, or almost 2/3. This means that in the long run you can expect to have a lucky hit about two out of every three games.

Carried to 20 decimals, e is 2.71828-182845904523536. Various mnemonic sentences have been devised for remembering e, the number of letters in each word corresponding to the proper digit. In the time since I published some of these sentences (in the chapter on number memorizing in the first *Scientific American Book of Mathematical Puzzles & Diversions*) a number of readers have sent in others. Maxey Brooke of Sweeny, Tex., suggests: "I'm forming a mnemonic to remember a function in analysis." Edward Conklin of New Haven, Conn., went to 20 places with: "In showing a painting to probably a critical or venomous lady, anger dominates. O take guard, or she raves and shouts!"

There is a remarkable fraction, 355/113, that expresses pi accurately to six decimal places. To express e to six decimals a fraction must have at least four digits above the line and four below (*e.g.*, 2721/1001). It is possible, however, to form integral fractions for e, with no more than three digits above and below the line, that give e to four decimal places. Such fractions are not so easy to come by, as the reader will quickly discover if he makes the search. For those who enjoy digital problems: What fraction with no more than three digits above the line and three below gives the best possible approximation to e? The answer will be given next month.

Last month's problem involved a picture of a one-sided surface and the question of whether its single edge was knotted or not. If the surface is constructed with paper and cut as explained, the resulting endless strip will be free of any knot. This proves that the surface's single edge is similarly unknotted. The surface was designed so that its edge corresponds to a pseudo knot known to conjurers as the Chefalo knot. It is formed by first tying a square knot, then looping one end twice through the knot in such a way that when both ends are pulled, the knot vanishes.

The checker problem in July (moving

TAMING THE WILD BLUE YONDER

Primary responsibility for research, development, production, testing and evaluation of the Air Force's newest weapons systems—this is the mission of the recently created Air Force Systems Command. To its men—our defense architects—this mission presents the eternal challenge . . . that of taming the wild blue yonder.

AFSC

In pursuit of this challenge AFSC must call upon the vast resources of industry and of education, as well as those of the military. AC Spark Plug is being called upon to develop and produce the small, yet highly accurate inertial guidance system for the TITAN II. This is but one example of American industry and government working together so peoples of the world may live together—in peace.

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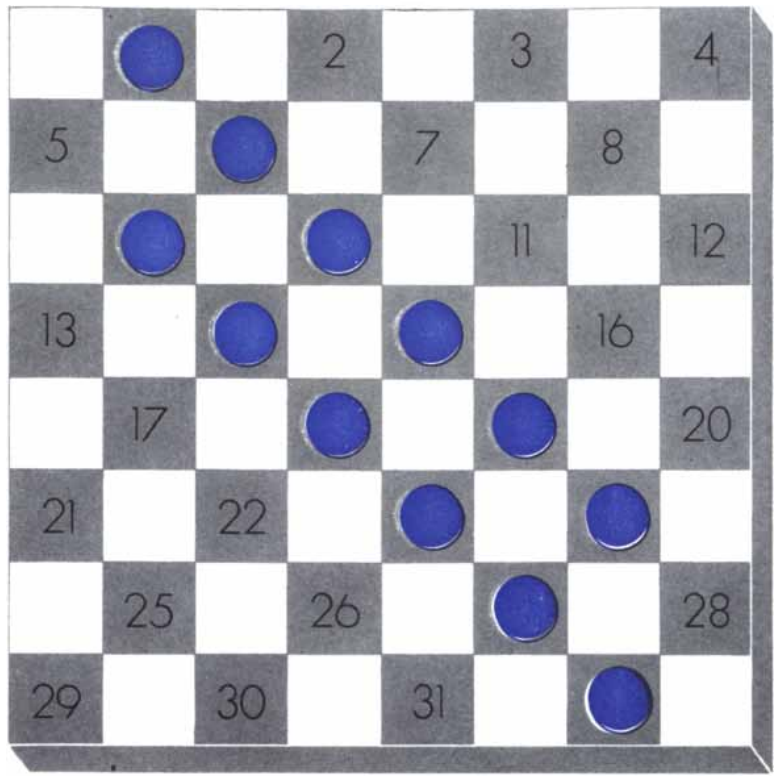


Position of checkers after 10 moves

12 checkers from one side of the board to the other, using halma moves) brought a heavy (but most welcome) response from readers. At the time this is written, 30 readers solved the problem in 23 moves, 49 solved it in 22 moves, 31 in 21 moves and 14 in 20 moves. The 14 winners, in the order their letters are dated, are: Edward J. Sheldon, Lexington, Mass.; Henry Laufer, New York, N.Y.; Donald Vanderpool, Towanda, Pa.; Corrado Böhm and Wolf Gross, Rome, Italy; Otis Shuart, Syracuse, N.Y.; Thomas Storer, Melrose, Fla.; Forrest Vorks, Seattle, Wash.; Georgianna March, Madison, Wis.; James Burrows, Stanford, Calif.; G. W. Logemann, New York, N.Y.; John Stout, New York, N.Y.; Robert Schmidt, State College, Pa.; G. L. Lupfer, Solon, Ohio; and J. R. Bird, Toronto, Canada.

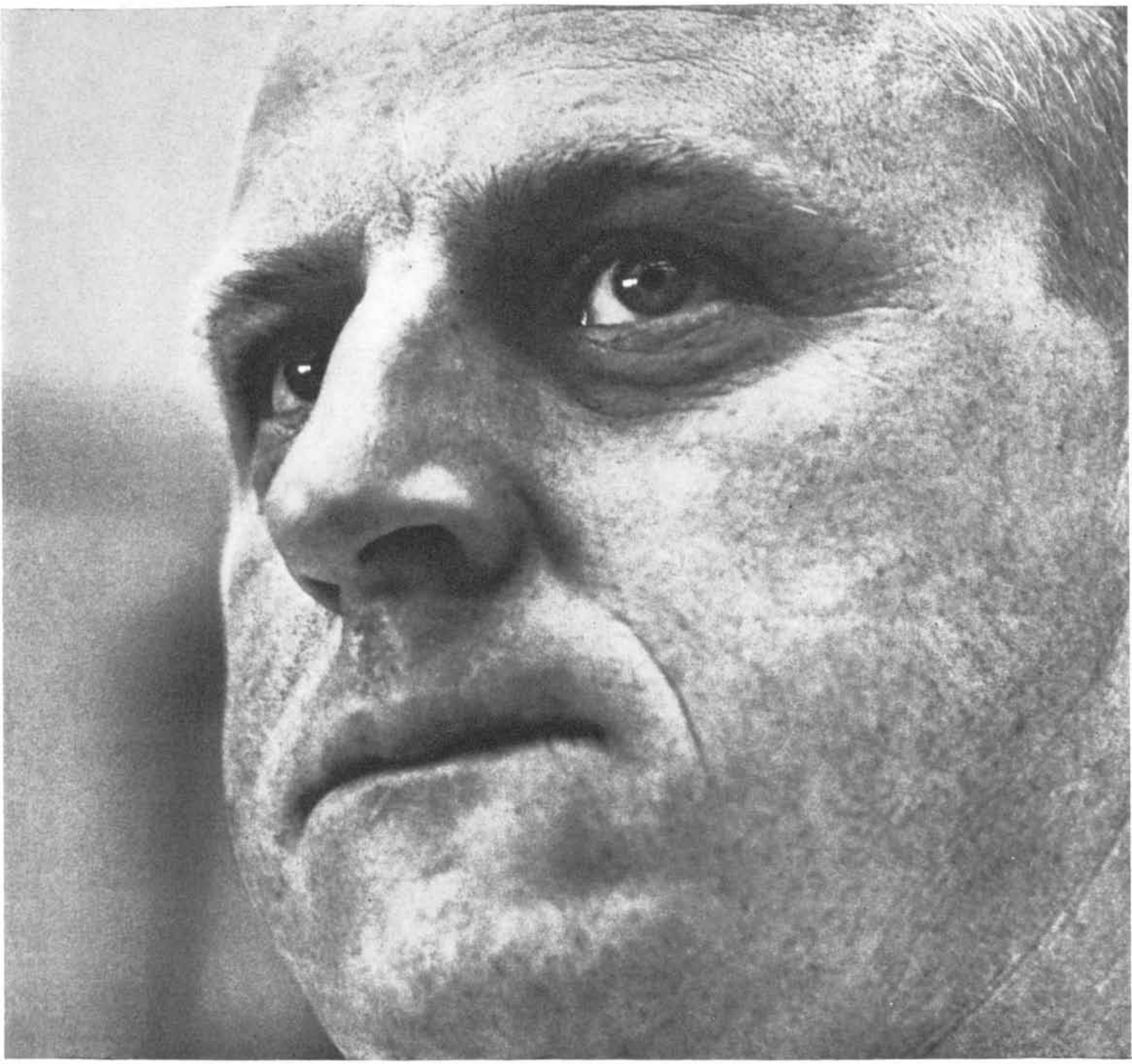
No proof that 20 is the minimum was received, although many readers indicated a simple way to prove that at least 16 moves are required. At the start, eight checkers are on odd rows 1 and 3, four checkers on even row 2. At the finish, eight checkers are on even rows 6 and 8, four checkers on odd row 7. Clearly four checkers must change their parity from odd to even. This can be done only if each of the four makes at least one jump move and one slide move, thereby bringing the total of required moves to 16.

It is hard to conceive that the checkers could be transported in fewer than 20 moves, although I must confess that when I presented the problem I found it equally hard to conceive that it could be solved in as few as 20 moves. Assuming that the black squares are numbered 1 to 32, left to right and top to bottom, with a red square in the board's upper left corner, Sheldon's 20-move solution (the first answer to be received) is as follows:

1. 21–17	11. 14–5
2. 30–14	12. 23–7
3. 25–9	13. 18–2
4. 29–25	14. 32–16
5. 25–18	15. 27–11
6. 22–6	16. 15–8
7. 17–1	17. 8–4
8. 31–15	18. 24–8
9. 26–10	19. 19–3
10. 28–19	20. 16–12

This solution is symmetrical. The illustration above shows the position of the checkers after the tenth move. If the board is now inverted and the first 10 moves are repeated in reverse order, the transfer is completed. So far as I know, this is the first published solution in 20 moves. It is far from unique. Other symmetrical 20-move solutions were received, along with one wildly asymmetrical one from Mrs. March, the only woman reader to achieve the minimum.

Do you share his driving determination to know?



An unsolved problem is a nagging challenge to him. The word "impossible" is an impertinence.

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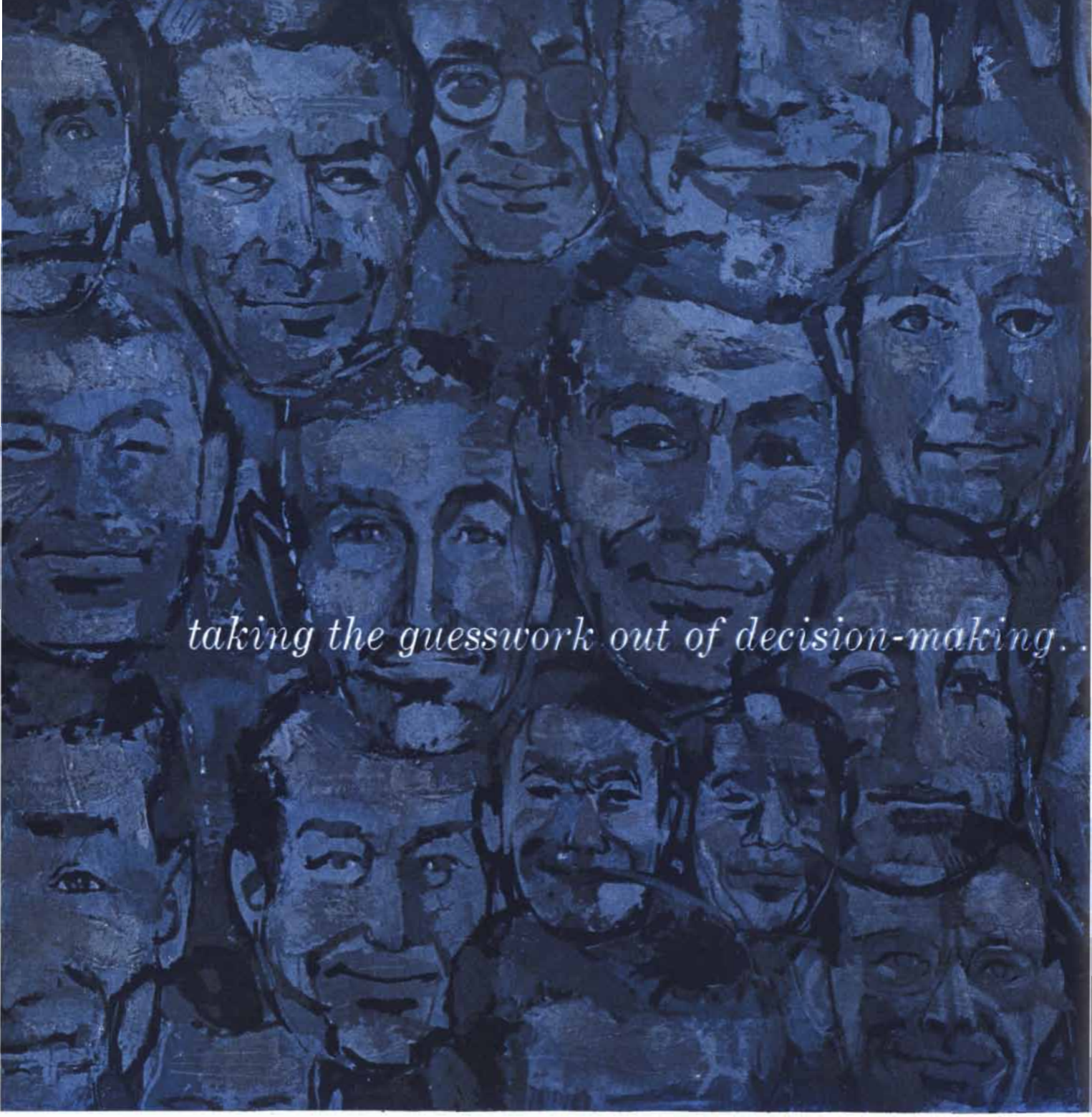

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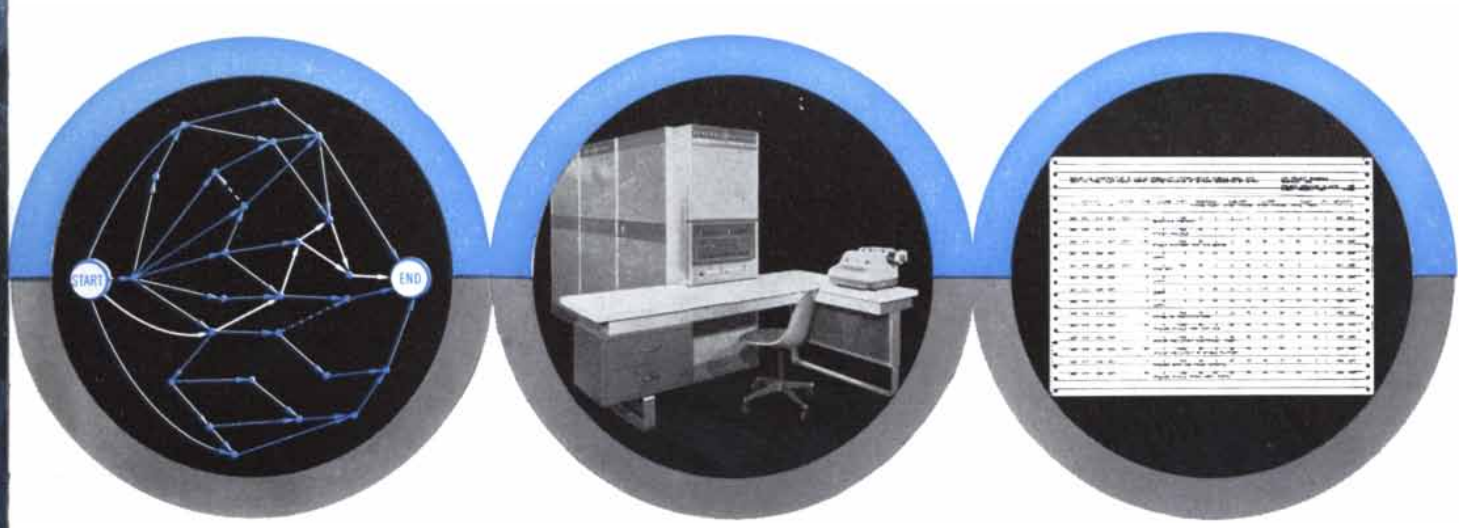

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THE AMATEUR SCIENTIST

An amateur investigates the origin of Venezuela's peculiar fog: the calina

Conducted by C. L. Stong

To physical meteorologists fog and haze are not merely nuisances or hazards. They are also fascinating aspects of weather that provide opportunities to observe how water vapor in the air precipitates as droplets of water.

A water droplet cannot grow in the atmosphere unless it contains a minimum of about 5,000 molecules of water. The probability of so many molecules assembling in one place by mere chance is very low. Physicists agree that condensation must be triggered by a nucleus—a speck of some material in the air that attracts water molecules. If this is so, then every one of the myriad droplets comprising fog and haze and every drop of rain that falls must start with a nucleus. Most nuclei are crystals of sea salt. All rain, even that which falls in the deep interior of the continents, contains traces of salt [see "Salt and Rain," by A. H. Woodcock; SCIENTIFIC AMERICAN, October, 1957]. But because the estimated volume of spray thrown into the air by whitecaps and by surf breaking on beaches does not appear to be great enough to supply a salt crystal for every droplet that forms in the air, the question remains open.

The collection and analysis of the water droplets is complicated by the fact that no two fogs are exactly alike. Moreover, they usually appear at irregular times and for unpredictable intervals. In a few regions, however, a persistent fog occurs as a regular feature of the annual weather pattern. One example is the deep haze that blankets Venezuela every year, usually from early December to the middle of April. The mystery of how this haze forms is deepened by the fact that it appears only during the dry season, when the relative humidity approaches that of a desert. This year Guillermo Zuloaga, a geologist of Caracas who is chairman of the research committee of the Creole Petroleum Corporation, decided to turn amateur meteorologist long enough to make a study of the fog.

"Traditionally," Zuloaga writes, "people have called our haze the *calina*, an old Spanish word defined as 'a thick hot air, like a fog, which rises in very hot weather and sets the air on fire.' Because the presence of the *calina* coincides with the time of burning of the dry pasture lands and with brush fires, the general belief is that it is caused by smoke.

"This year the *calina* was particularly intense. From February to the end of May visibility was seriously impaired, and there were several grave consequences. Air traffic in the interior was hampered, with some airports closed for days at a time. A squadron of jet fighters flying from eastern Venezuela to its base in Maracay became dispersed and several aircraft were lost. Ships ran aground, and several automobile accidents were caused by the poor visibility. Many residents of Caracas, which lies in a narrow valley surrounded by mountains, lost the beautiful sight of Mount Avila, only four or five kilometers to the north [*see illustrations on opposite page*].

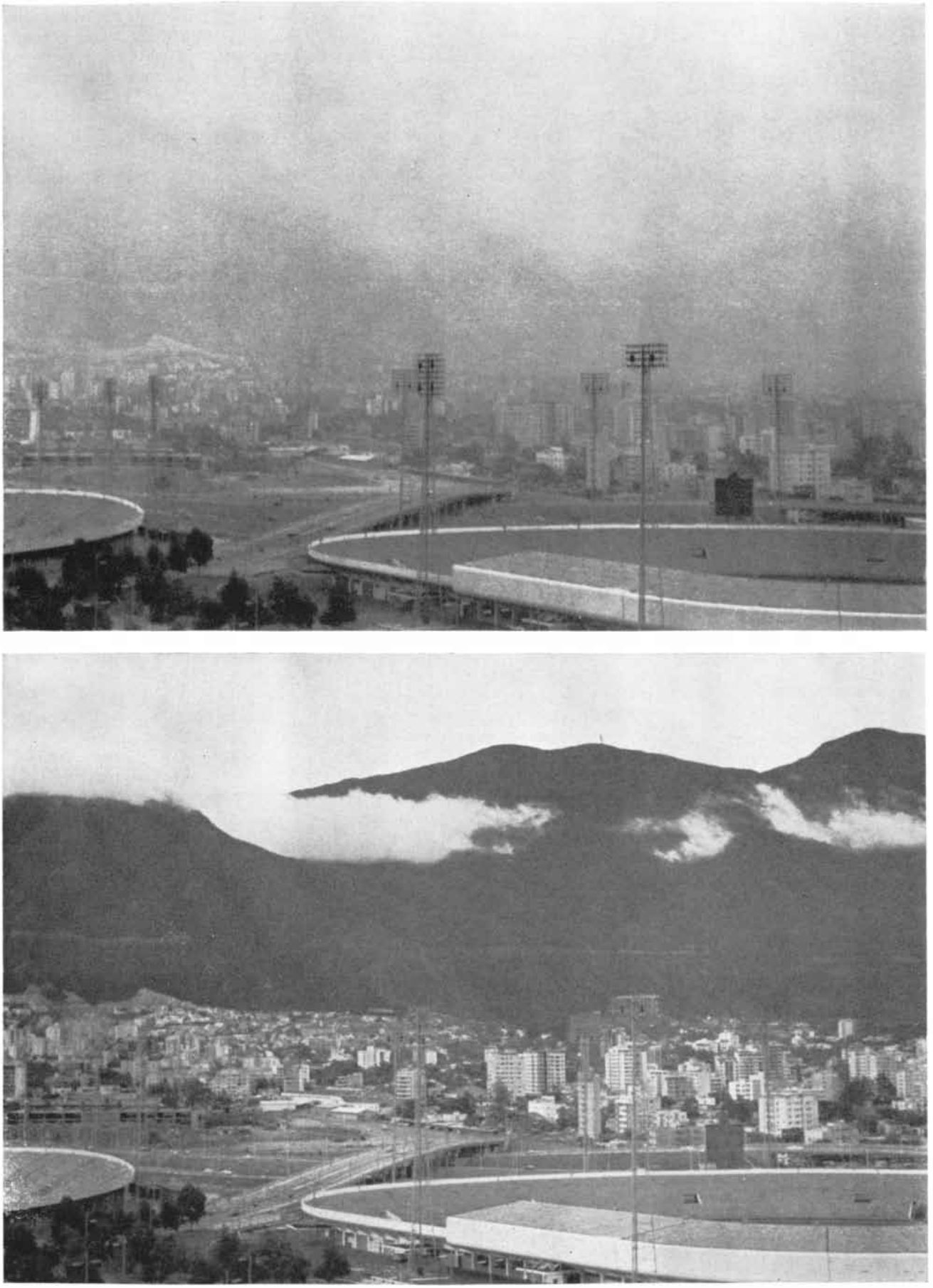
"For several years I have been observing this phenomenon and wondering what causes it. I noted first of all—as apparently no one had before—that it comes from the Caribbean Sea and is carried by the wind toward the interior of the country. In many flights I have found the *calina* visible as far as 100 kilometers out to sea north of the Venezuelan coast. The trade winds during the dry season blow steadily from the northeast toward the coast. If the *calina* were smoke, one would scarcely expect to find it upwind.

"As seen from the ground the *calina* is bluish, but as one looks down on it from a plane it appears brownish. The *calina* layer ends abruptly at about 9,000 feet and the upper level is remarkably flat, so that it makes a horizon. It appears to be absolutely independent of any clouds that move through it and it contrasts sharply with them in color and shape.

"Unlike ordinary fog, the *calina* is remarkable for its uniformity and constancy. It covers thousands of square miles for months at a time: the valleys and the mountains, the llanos (the great plains in the interior of Venezuela) and the marshes of the Maracaibo Basin. It even extends at times as far as Bogotá in Colombia, over 600 miles southwest of our Caribbean coast. For months on end we have spectacular red sunsets, and the moon looks yellowish when it is near the horizon. The *calina* seems more intense in the morning and evening and seems to disappear during the night; this is because it is more visible in lateral lighting. The air feels heavy; people complain of high humidity, whereas actually the air is abnormally dry.

"Puzzled by the *calina* and not finding any satisfactory description in the literature, I decided to carry out systematic observations to try to find its composition and to explain its origin. I cleaned up my old polarizing microscope, adapted a camera to it and set out to discover what sort of particles nucleate the *calina* droplets.

"My observation that the *calina* came from the sea naturally led me to believe that it should contain microscopic crystals of salt, and so my first efforts were aimed at capturing such crystals in the air. Previous attempts to do this, by workers at the Woods Hole Oceanographic Institution seeking to confirm the presence of salt in cumulus clouds, had been only partially successful. Being hygroscopic, the salt absorbed water during the plane's descent in the humid atmosphere and tended to redissolve. It occurred to me that the crystals could be collected on microscope slides that had been smeared with Canada balsam. This mounting medium, commonly used for mineral preparations, is anhydrous, and salt is therefore insoluble in it. I prepared the microscope slides by first placing a small drop of balsam in the center of the glass and spreading it to cover about one



Two views of Caracas, Venezuela, from the same point. The top photograph was taken during a calina, the lower one on a clear day

square centimeter. Crystals were collected simply by exposing the prepared slide to the air for a few seconds. The cover glass was then pressed over the specimen, so that the particles caught in the balsam were permanently preserved.

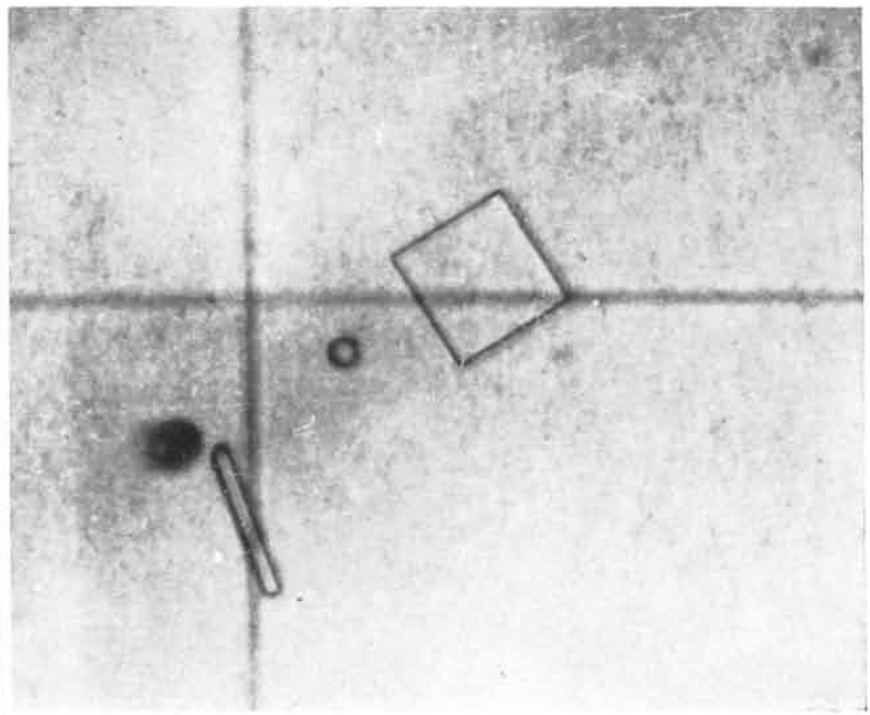
"When collecting from an airplane, I exposed four slides at a time by holding them with binder clips to a piece of ¼-inch glass about 12 inches long and the width of the microscope slides. I was able to hold them out a few inches into the slip stream even at speeds of 200 miles per hour. When working from an automobile, I clipped the slides to a piece of cardboard, which I then attached to a ventilator window opened to face the wind.

"Early in the study I found a few salt crystals and immediately concluded that I had hit the full explanation of the *calina*. My theory was simple: The strong, steady trade winds that blow over the Caribbean, whipping up whitecaps and the large waves that break along the Venezuelan shore, raise a cloud of droplets that make up the sea spray; this spray is carried inland by the wind in great volume; as the water evaporates from the droplets in the atmosphere, tiny salt crystals are formed that, being very small, float away with the wind. These crystals, I assumed, were the nuclei of the *calina* droplets.

"But, as usual in these cases, what at first appeared simple became more complex as I probed deeper into the problem. Careful examination of the slides soon disclosed that I was catching not only salt crystals and other things to be expected in the air, such as grains of pollen, dust, vegetable fibers and fragments of insects, but also a great number of tiny spherical particles evenly distributed on the slides and almost invisible in the Canada balsam. The particles were a few microns in size (a micron is one thousandth of a millimeter), too small for identification by ordinary optical methods. They were present on all the slides. My theory did not explain these particles.

"In an effort to gather more evidence I sought the help of friends who were flying or driving to the interior; I gave them slides, cover glasses and balsam and detailed instructions on how to collect the particles. I made two special flights over Caracas to gather more material, take pictures and record the temperature and relative humidity of the air in the thick of the *calina*. The temperature was between 28 and 30 degrees centigrade (82.4 to 86 degrees Fahrenheit), and the relative humidity was 40 to 45 per cent at 5,000 feet—much hotter and drier than normal. During the 'non-*calina*' portion of the year the average relative humidity in Caracas is 89 per cent at 7:00 a.m., 64 per cent at 1:00 p.m., 89 per cent at 7:00 p.m. and 93 to 98 per cent during the night.

"It turned out that even the hot, dry air over the llanos, near the ground, contained salt crystals in suspension. Slides



Two salt crystals, with two "calina particles," gathered in the llanos

FLYING MISSILE LAUNCHER. New Boeing B-52H missile bomber can take off faster, fly farther and strike harder than any previous B-52. It's shown here carrying models of four hypersonic Skybolt air-launched ballistic missiles, a 1000-mile range weapon now under development. The Strategic Air Command B-52, most versatile long-range weapon system in the U. S. Air Force arsenal, can also carry supersonic Hound Dog missiles for inflight launching, in addition to its regular bomb-bay load of gravity bombs.

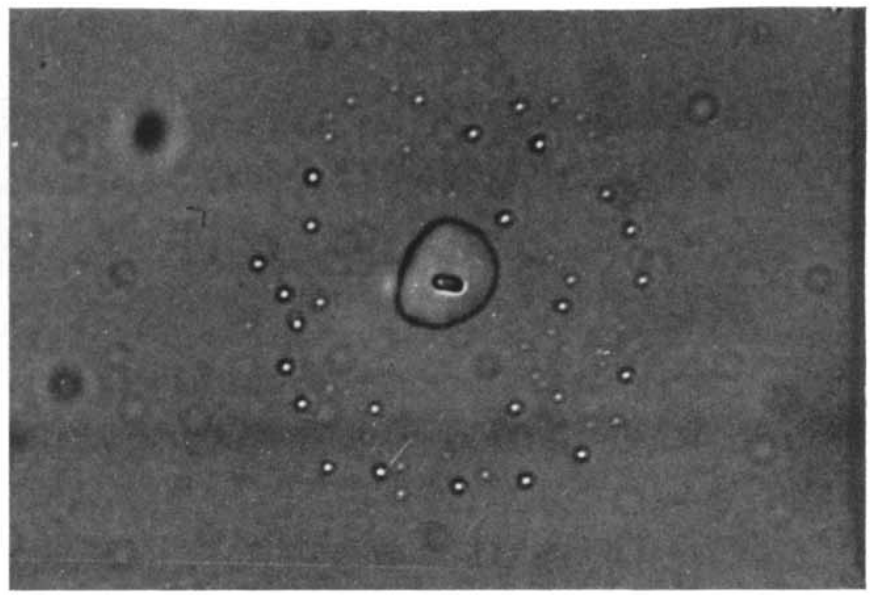
Capability has many faces at Boeing

THREE-ENGINE JET. Scale model of America's first short-range jetliner, the Boeing 727. Already, 117 Boeing 727s have been ordered by American, Eastern, Lufthansa and United airlines for delivery beginning in 1963.

MINUTEMAN, first U. S. Air Force solid-fuel intercontinental ballistic missile, scheduled to be operational in 1962, will be stored ready for quick launching in underground silos. Boeing is weapon system integrator for Minuteman.

MARS DEPARTURE. Artist's concept of 8-man space vehicle taking off from Mars for return to earth. This space transport system, based on a Boeing study, would enable explorer scientists to spend months on Mars with instruments and life-support equipment. Boeing scientists are at work on many phases of space flight.

BOEING



Satellite calina particles surround a droplet containing a salt-crystal nucleus

prepared at a ranch in the inland state of Cojedes contained small but perfect crystals [*see illustration on page 174*]. (Incidentally, if one square centimeter of balsam captured two or three crystals, then there must be millions of them in the ambient air, and these crystals must fall to the ground when the wind dies down or when it rains. What will this eventually do to the fertility of the soil?) The extremely low relative humidity appeared to be contrary to what one would expect with salt in the air, which I then thought should tend to increase the humidity.

"This was another indication that I had been jumping to conclusions. I had to be more systematic and start again. I began to keep records of the relative humidity and noted that it had dropped to levels never reported before: 50 per cent at 7:00 a.m., 30 to 40 per cent in the course of the afternoon. During the night we did not even approach the dew point, which in normal times is reached every night. Intrigued by all this, I decided to study the process of the formation of the *calina* from its very beginning: at the seashore.

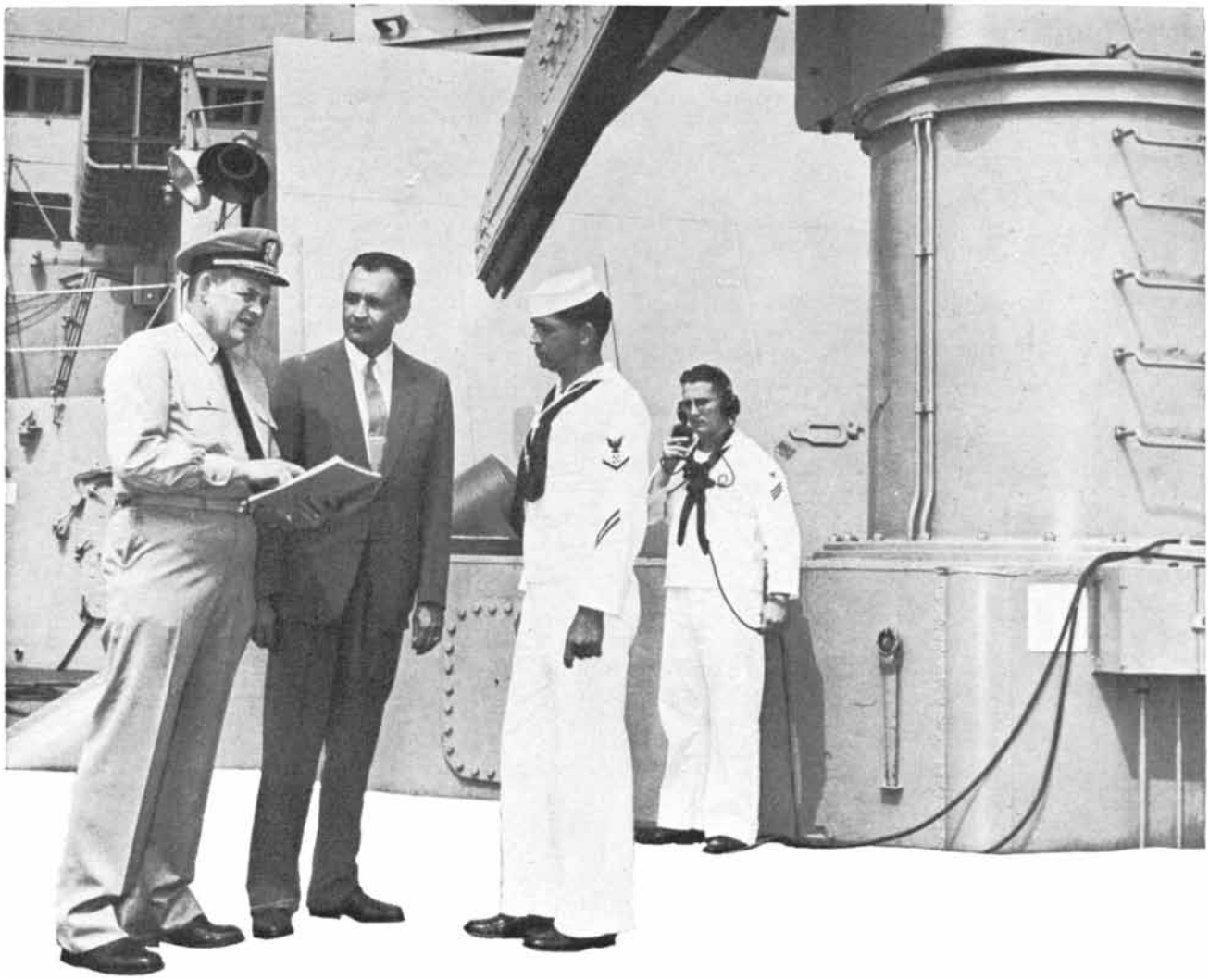
"At 7:00 a.m. on a Saturday I went down to the shore at Catia de la Mar (Caracas, although 1,000 meters above sea level, is only some 15 miles from the sea by a superhighway) and exposed some slides for five minutes to the sea spray: four without balsam and four with balsam. The temperature of the air was 30 degrees C. and the relative humidity three meters from the surf and two meters above it was only 77 per cent at 8:00 a.m. The trade wind from the northeast was blowing moderately, and the waves were normal.

"Then I took the road that goes east along the shore toward Playa Grande; here, over a stretch of about one kilometer and some 100 meters away from the water, I exposed another four slides while driving against the wind. Subsequently I went up the hill to the Playa Grande terrace, where I was 60 meters above sea level and some 200 meters from the water (500 in the direction of the wind), and exposed another four slides.

"From this high point there is a panoramic view of the shore, and I could see the *calina* coming from the sea and being blown up toward the mountains, blurring both the horizon and the profile of the coastal range. The temperature was 34 degrees C. and the relative humidity was 54 per cent.

"Then I exposed a number of slides along the *autopista*, the superhighway between Caracas and the sea. Relative humidity was between 40 and 45 per cent, the temperature was around 34 degrees C. The series gave me an excellent sampling of particles from the shore up to 1,000 meters.

"With great curiosity I went to the microscope to examine the slides. The first surprise came when I found some perfect salt crystals preserved in the balsam of slides exposed near the surf. How could they have crystallized out so soon? I found them again and again, associated with sea-water drops, in slides exposed on the road along the shore and in those exposed at the Playa Grande terrace. There was no doubt: the sea air, even close to the shore, contained salt crystals. It could be, of course, that air turbulence had brought these crystals from a great height or a long distance.



How the USS LONG BEACH became Mr. Hinkle's office-away-from-the-office

Charles J. Hinkle—38, an electronic engineer, and head of the experimental branch of the Navy's HERO (Hazards of Electromagnetic Radiation to Ordnance) program—has become a familiar figure on board the USS LONG BEACH, America's first nuclear-powered missile cruiser.

He is responsible for making sure that the shipboard environment of radio and radar transmitters will be compatible with the Terrier and Talos missile systems—that no RF energy output will adversely affect the sensitive electro-explosive components of these missiles under any operating condition.

Making sure starts with basic research, requires personal inspections and thorough laboratory and field tests by Mr. Hinkle and his associates. In setting up safe operating procedures for personnel aboard the Navy's latest ships, and in developing recommendations that will affect the design of future electronic and ordnance equipment, Mr. Hinkle spends a good deal of time away from his office—*on board the most advanced naval vessels in the world.*

His HERO compatibility studies represent just a fraction of the research, test and evaluation projects that carry Naval scientists and engineers to the very heart of technological creativity.

Seapower—the Comprehensive Science of Sea, Air and Space—requires the talents of vigorous people who can adapt to different environments and disciplines. If you are this sort of person, write to Thomas McKenna, Code 200, Room 1000, Main Navy Building, Navy Department, Washington 25, D. C.

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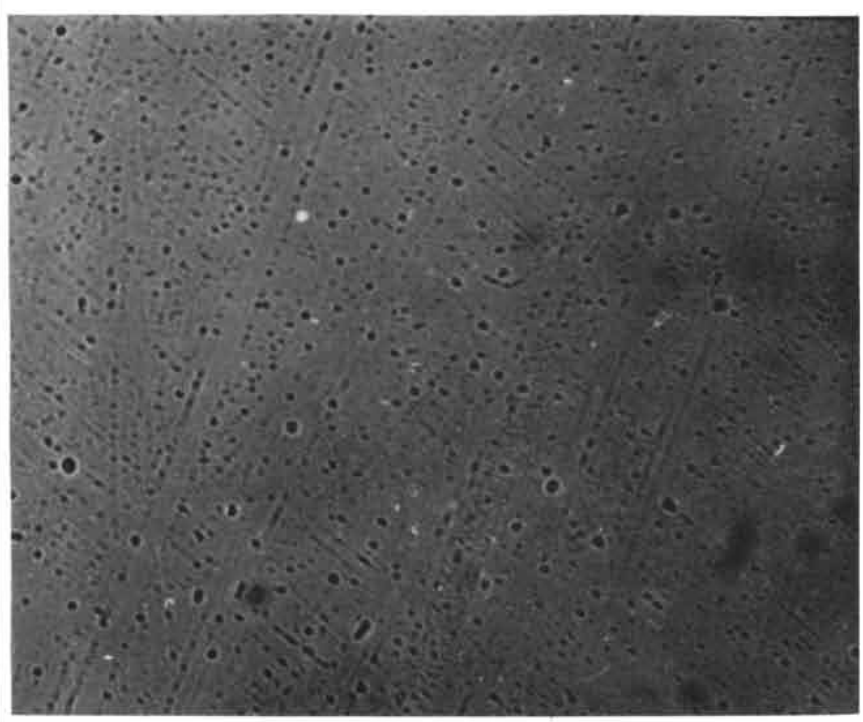
But their frequency made this unlikely. Apparently crystallization takes place over a very short distance—a sort of spray-drying caused by the atomization of the sea-water drops into a relatively dry atmosphere.

"Then, in the Playa Grande slides, I found a most interesting thing: all the stages of the process of formation of the salt crystals (which are perfect cubes) could be seen, starting with drops of sea water and moving through the intermediate steps. Furthermore—and this was particularly important—there were great numbers of small, spherical droplets around the large drops that contained the salt crystals. These small droplets resembled the mysterious spherical particles that universally accompanied the salt crystals on all slides of the *calina*. The resemblance was not only in shape but also in size. I was struck by one particularly fascinating detail that was difficult to photograph because of the extremely flat depth of field: the microdrops showed a tendency to cluster around both the crystals and the drops that were in process of crystallization [*see illustration on page 176*].

"Greatly encouraged by having found the characteristic way in which sea spray behaves during the crystallization of its salts, and intrigued by the curious sequence of associated events, I began to study the slides made along the *autopista*. They contained many dust particles, bits of carbon from the automobile exhaust and minute pieces of glass, all of which are to be expected in the vicinity of a highway that carries heavy traffic. I found little crystals of salt the same size as those of Playa Grande. They measured about two-hundredths of a millimeter across and weighed on the order of a milligram. In many cases the crystals were surrounded by microdrops.

"The more I observed this phenomenon, the more puzzled I was. At first I thought that the clusters were a 'splash' effect resulting from the impact of the crystal, or the drop containing the crystal, against the Canada balsam. But when I saw the phenomenon repeated time and again, I became convinced that even in the air the microdrops were clustered around the salt crystals like tiny satellites.

"Pondering on this curious phenomenon, it occurred to me that the particles might be charged with static electricity and so be attracted to a crystal nucleus of opposite charge. An obvious experiment was to charge the microscope slides by rubbing them with an electrifying agent. This I did on the roof of our office building, holding the slides with plastic tongs and rubbing some with a silk handkerchief and others with a camel's-hair brush. After 20 seconds of exposure to the air the electrified slides were protected with cover slips held in place by Scotch tape stuck along the edges. It was a hot, dry afternoon (30 degrees C. and 28 per cent relative humidity in the shade). The results were dramatic: not only had I captured the particles in great



Calina particles aligned on a slide electrified by camel's-hair brush strokes

HUMAN SKELETON

Functional Model

BY LEON SCHLOSSBERG

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Leon Schlossberg is Medical Illustrator at The Johns Hopkins Hospital and Instructor of Art as Applied to Medicine at The Johns Hopkins University School of Medicine.

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numbers, but also they had attached themselves to the slides in the very spots where the glass had been rubbed! On the slides electrified with the camel's-hair brush trails of microdrops actually traced the path of each hair [*see illustration on page 178*]. I had captured almost exclusively the microdrops, which, probably due to difference of charge intensity, had divorced themselves from the salt crystals.

"The dryness of the air again pointed up the question of the composition of the microdrops. How could they subsist, without evaporating, in such a dry, hot atmosphere?

"The season of the *calina* was now approaching its end and it was urgent to gather enough drops for chemical analysis. Some of my technical friends hurriedly built a small electrostatic separator, obtaining the necessary 15,000 volts from a television set. With this apparatus we were able to collect a few milligrams of the microdrop material before the *calina* disappeared. Spectrographic analysis of the metallic components, which is all that could be done on such a small sample, indicated the presence of sodium, magnesium and calcium —along with copper from the electrical apparatus and some aluminum, probably from clay in the dust collected with the *calina* particles.

"In the few remaining days of the season I prepared most of the slides without balsam by electrifying the glass with either the camel's-hair brush or with Saran Wrap, a plastic film [*see illustration on page 183*]. This gave me dry mounts of the particles. These particles were more visible than those embedded in balsam, and the salt crystals, simultaneously collected on the slides, lasted many days before absorbing humidity. In contrast with the behavior of the salt crystals, the microdrops grew considerably in size, indicating they were still able to absorb water from the air.

"What may be reasoned from the study of the slides? I have the impression that the chemical composition of the microdrops is that of a brine that remains after the crystallization from the sea water of the sodium chloride—a concentrated solution of sodium and magnesium chlorides, magnesium sulfate and calcium chloride, all quite soluble and hygroscopic salts. This might explain their resistance to evaporation. The metallic elements shown by spectrographic analysis to be present in the microdrops are those one would expect to find in the brine.

"It is, of course, possible that the salts in some of the droplets do crystal-

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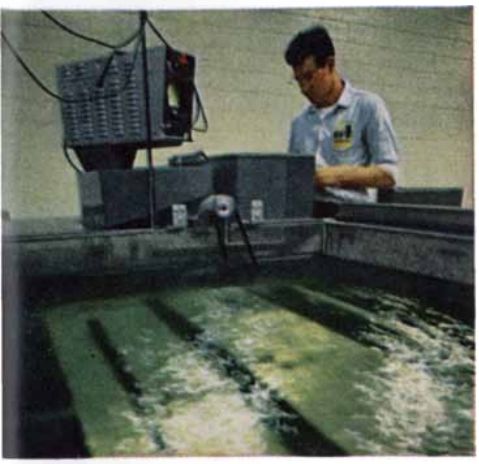

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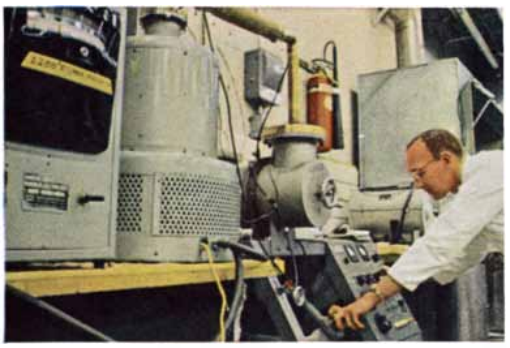

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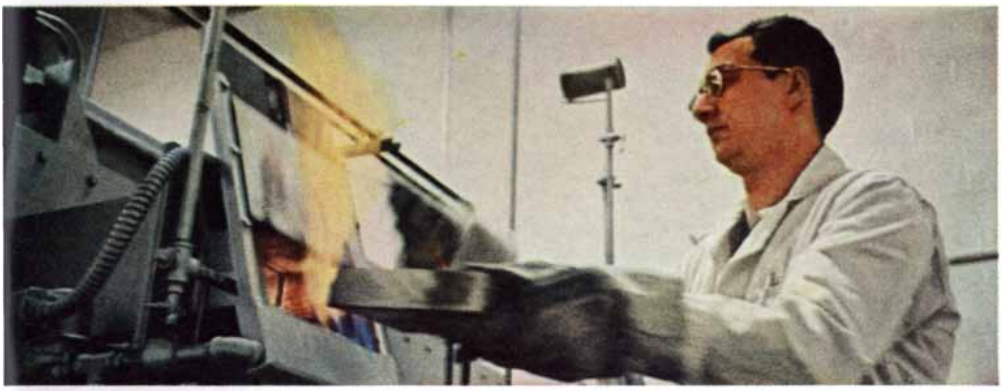

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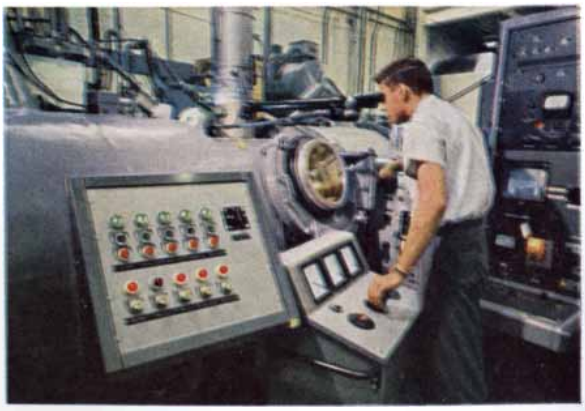

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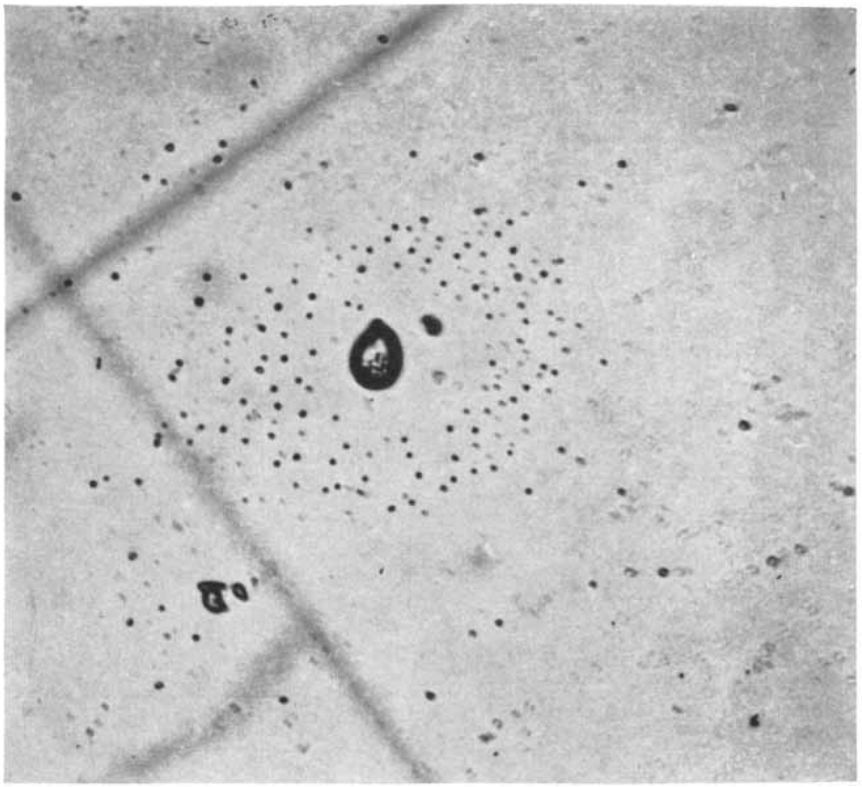


Calina particles around a nucleus on a slide uniformly electrified with Saran Wrap

lize out if they reach an exceedingly dry atmosphere. The probability, in this case, is that minute crystals of magnesium chloride hydrate ($MgCl_2$–$6H_2O$) would be formed—and this is a very hygroscopic salt that would again rapidly dissolve into droplets. We do not know, of course, what chemical reaction the droplets of brine actually undergo because of the action of the sun's rays during their travels with the wind.

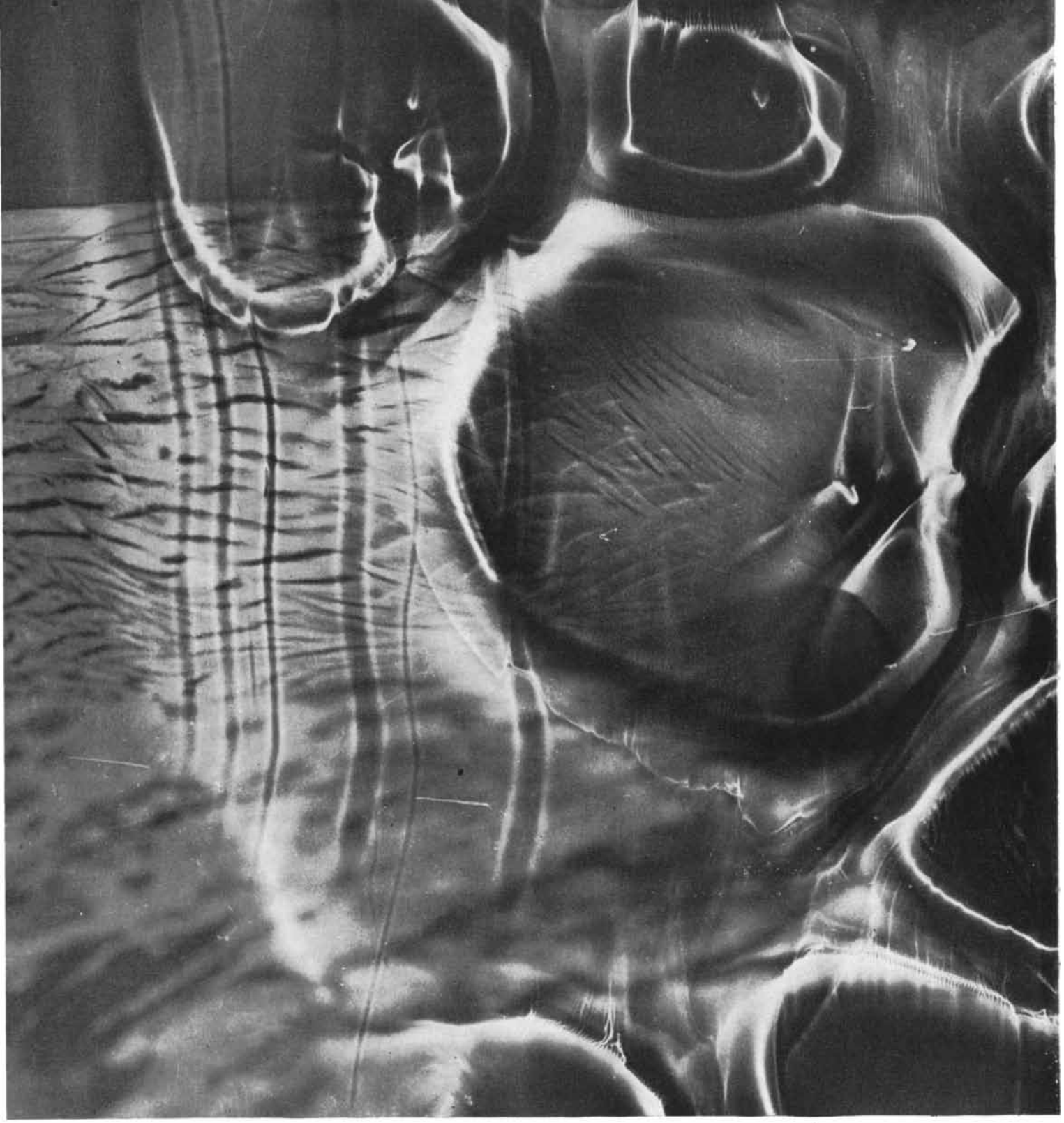
"There are other circumstances related to the *calina* that are also puzzling. Ordinary fog is supposed to start by condensation of water in the atmosphere around small particles of hygroscopic salts (or dust, or sulfur from fires) even when the air is unsaturated. But for condensation to continue, the relative humidity has to *increase* above the value at which condensation started. Since the effect of condensation is normally to dry the air by removal of water vapor, thereby decreasing the relative humidity, condensation cannot ordinarily proceed unless somehow the relative humidity increases by evaporation of more water into the air or by cooling of the air.

"But in the case of the *calina,* persistent fog and dryness of the air appear to go together. Could it be that the *calina,* made up as it is of hygroscopic crystals of sodium chloride and those droplets containing particularly thirsty salts, is one factor contributing to the dryness? At least this year the *calina,* an intense and prolonged dry season (the worst in 40 years), and excessive heat have coexisted. There may be a relationship of cause and effect. Stronger trade winds would produce more spray and hence more *calina,* which would tend to dry the air and retard the rains. It will take further studies to confirm or prove wrong all this theorizing.

"Venezuela is south of the hurricane zone of the Caribbean Sea, and as a general rule we do not have the big changes in atmospheric pressure observed at higher latitudes. We have instead a remarkably uniform diurnal pressure tide of small magnitude. This stability of atmospheric pressure may be one of the reasons why the *calina* stays in the air for such long periods.

"One last point of some industrial interest: the *calina* particles seem to be a cause of short circuits on high-voltage lines in Venezuela, not only near the shore but in the interior. The high voltage attracts the particles, and the insulators get covered with them. There has been a serious increase of this kind of accident this year.

"Now, at last, it is raining on the parched soil of Venezuela. Between showers the air is clear again and I can enjoy the beautiful view of Mount Avila from my office window."



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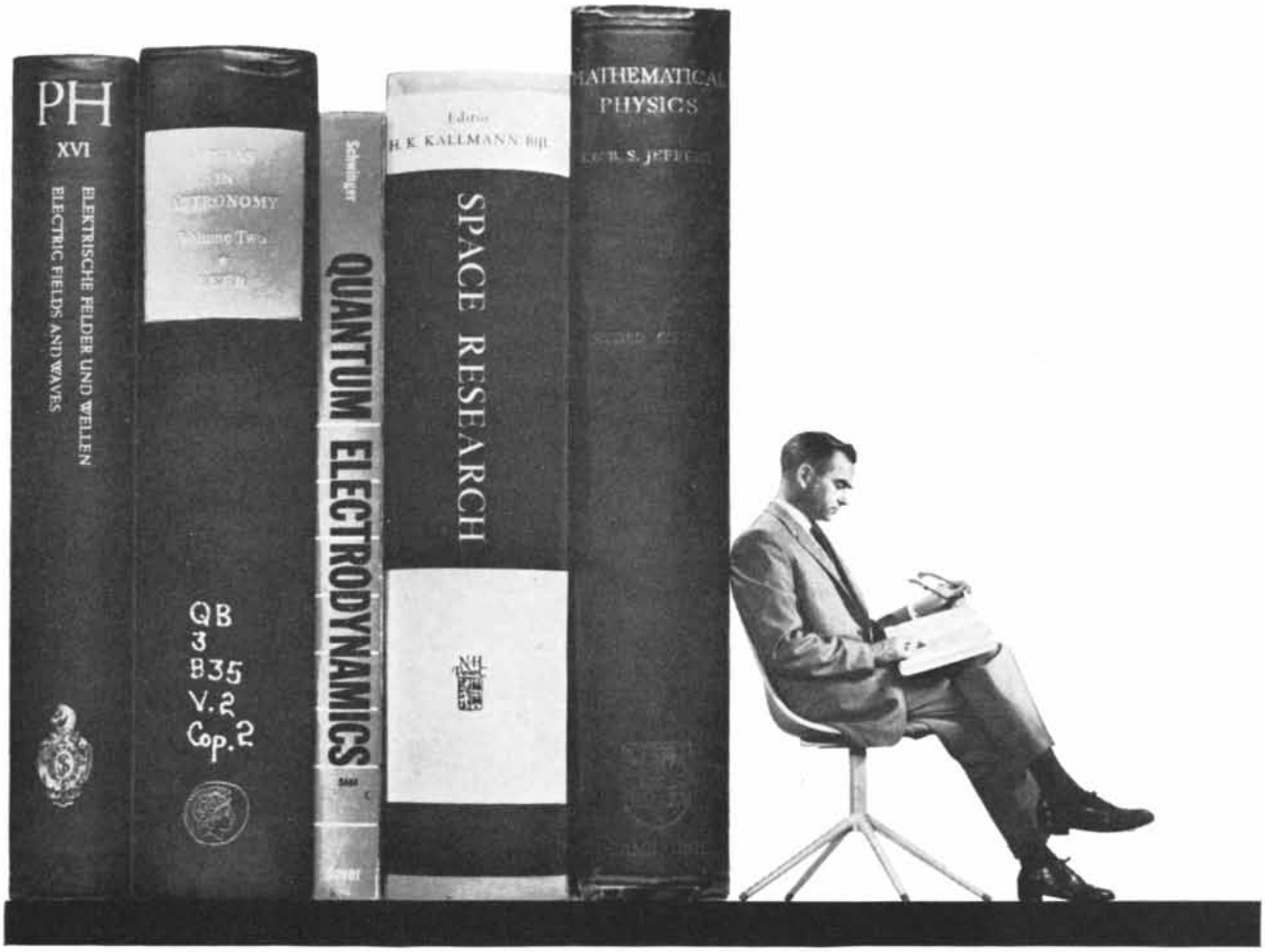

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BOOKS

How people lived during the flowering of Florence

by James R. Newman

DAILY LIFE IN FLORENCE IN THE TIME OF THE MEDICI, by J. Lucas-Dubreton. The Macmillan Company ($4.50).

Stupidity has its uses. Be not too brave is a sound maxim; be not too keen may be another. A certain degree of stupidity, Walter Bagehot argued, is needed if a nation is to have a good and stable government. Exuberance, imagination, vigor in a people are to be admired. But patience, phlegm, self-possession, the siesta. tending one's own garden are not to be despised. Government is a chancy thing. It must rule and preserve freedom; it must command obedience and nurture independence; it must encourage and restrain; above all, it must keep itself in being. A people too docile and apathetic invites encroachments on its liberties; but a people mercurial, impatient, ever ready to rise, to break the cake of custom before it is half-baked, is even easier prey for tyrants. History affords many examples. The republic of Florence was one.

The "City of Flowers" at the foot of the lovely Fiesole hills, lying in the fertile plain of the Arno, was, it is thought, an old Etruscan city. Julius Caesar rebuilt it as a Roman military camp, divided into four quarters with a capital and a forum. Under the Carolingian emperors the Florentines prospered and established a commune. For a time they were great warriors, but they got over this. Their métier lay elsewhere. The Florentines established themselves early as superb traders. They were artisans, merchants, bankers; their handicrafts, industries and commerce flourished; trade and banking brought the city into closer and closer relations with France, the Papacy and southern Italy.

It must not be imagined, however, that this intensive economic development ran a placid course. There were factional fights and sanguinary rivalries. Adherence to the Papacy gradually waned as self-interest and patriotism came to the fore. The feudal lords in their castles surrounding the town—the men "of the towers"—lost their position at the top of the social order. A new class took their place: the wealthy merchants. The aristocracy of the counter marked the advent of capitalism.

But other powerful forces came in time to check the merchants. These were the *arti,* or trade guilds, the principal art being the finishing and dyeing of woolen fabrics. In 1293 an important step was taken in Florentine politics. There were promulgated the *Ordinamenti della Guistizia,* which required every citizen to enroll in a guild. If one did not enroll one became a *scioperato,* a second-class plebeian. No one was exempt from this decree, not even the nobleman. If he refrained from joining, he remained a noble but had no right to the title of citizen, was excluded from government and had no vote in the council. "To degrade a man, Florence left him his social rank."

Thus the Guelphs and the Republican spirit triumphed, and the Ghibellines—usually identified with the aristocrats and the emperor—were cast down.

Nothing, however, was truly settled. The city thrived and became more splendid. Grand churches, palaces and libraries were built. By 1338 Florence possessed more than 200 factories which produced annually more than 80,000 pieces of cloth. A silk industry sprang up; the weaving of tapestry, an art introduced by French and Flemish workmen, was perfected. Florentine merchants traveled through Europe, visiting their warehouses and founding banks. The Florentine florin was the strongest and most sought-after currency. The pleasances of pure art—painting, goldsmithing, architecture and jewelry design—were cultivated. A college, the Studio, was founded. Florence was altogether an Eden of civilization.

But the serpent was there. Discord, strife, feuding, periodic convulsions accompanied the growth of the city. Every private dispute was a potential public riot. A joyous festival might in a moment be interrupted and turn into a bloody brawl and panic. Conspiracies, assassinations, insurrections were common. The small artisans revolted against the merchants. The patricians drew swords against the wealthy burghers. Rival factions in subject towns had monthly wars. Constitutions were drawn up and then burned before the ink on them was dry. To be a member of the government was to be halfway to the gallows: the Florentines thought stringing up an official was the most fun one could have. (The chief of police was a favorite victim.) A stranger who once visited Florence heard shouting and saw people running along the street with drawn swords. "What is happening?" he asked. "Oh, nothing serious. They are simply sharing out the magistratures and other public offices." The Republic "grew weaker and distrustful of itself" even as her commerce expanded and she became pre-eminent in intellectual and artistic works. It is said that a house divided against itself cannot stand. Florence flouted this assertion. Perhaps government is less important than men are taught.

In 1434 the Medicis came to power. For almost a century they held sway while Florence "attained the summit of its magnificence." It is with this period that Lucas-Dubreton's book is primarily concerned. First published in French in the Hachette "Daily Life" series, it is now offered in a capable English translation by A. Lytton Sells. It is a discursive, popular survey which deals with Cosimo and Lorenzo the Magnificent, culture and violence, the city and the countryside, home life, the ways of whores, intellectuals, gamblers, astrologers and sorcerers, notable churchmen, the keeping of journals, the problems of burghers, artisans and taxpayers, festivities and hangings, the theater, artists and their works, Savonarola, manners and morals, vicissitudes of public life, warfare and sieges, food and dress, connubial bliss, treachery, famine, superstition, the crimes of princes.

Under the Medici dictatorship Florence gained several decades of compara-

tive tranquility. Cosimo was "a grim old merchant" who knew how to hold power, how to play his enemies off against each other, how to compromise, when to be tightfisted, when to be liberal and generous—at public expense. He gave the Florentines both circuses and bread. He founded the first public library. He was a Maecenas to scholars, thinkers, literary men and to the artists from Brunelleschi to Donatello.

What Cosimo began, his grandson Lorenzo perfected. He was a more complete tyrant than his grandfather, more unscrupulous and ruthless, and an even more lavish patron of art and letters. Kindness and gentleness were not in his complexion, but he was intelligent, well educated, refined in his tastes and most skillful in his dealings with men at every level. There were murderous conspiracies against him (one in which his brother Giuliano was assassinated was a very tight squeak), but he survived them. He burned his candle at both ends. Politics, holding the lid down on the caldron of domestic discord, financial high jinks, women—all consumed his energies. At 44 he was a decrepit old man. Sinister omens heralded his death: a furious hurricane during which the Medici escutcheon was shattered; a lion in the Magnifico's private zoo devoured by others; an ox "breathing fire through its nostrils . . . pursuing a woman." He lay in torment with severe stomach pain. His physician, Pier Leoni of Spoleto, ministered to him in the style of the day. (Science was not a Florentine strong point.) He gave him a beverage containing powdered diamonds—thought to be a proper remedy for a great financier—thus speeding Lorenzo on his way. He died on April 8, 1492. It was a national calamity. His successors were not his equals. Under them Florence declined. Never again was it to attain the heights, the renown, the prosperity and the comparative domestic peacefulness it had enjoyed under the Magnifico.

Let us try to catch glimpses of what Florence was like in its golden age. It was a city of walls with square towers rising from crenelated ramparts. In the Middle Ages there had been many more towers, a crown standing out "in a jagged silhouette," but as the republic was gradually swallowed by the principate they were broken down and the structures below turned into dwelling houses. Four fine stone bridges spanned the Arno, among them the famous Ponte Vecchio, covered with shops and houses. The streets were fairly wide, nearly all paved with flagstones and fitted with gutters to carry off the rain water. This kept the city clean, but in the summer the flagstones radiated the heat, and if one could manage it, one stayed indoors from noon to evening enjoying the cool of the usually spacious ground-floor rooms of the houses. Florence had its famous gates and fortified barbicans; magnificent palaces, of which no less than 30 were raised between 1450 and 1478; hundreds of hospitals where men and women were lodged and treated free of charge; fine hostelries to which citizens came for relaxation and amusement; playgrounds and a stadium where young men practised jumping and played at *palla al calcio,* or football. Horse racing was a favorite spectator sport, the course running through the entire city from the Porta al Prato to the Porta Santa Croce.

The busiest center of this city of some 80,000 or 90,000 inhabitants (though well versed in accountancy and statistics, the Florentines kept no accurate record of births and deaths, so that there is considerable uncertainty as to population) was the Mercato Vecchio, now the Piazza della Repubblica. Here one could see the greengrocers with their movable booths, the butchers and their open stalls, the fishmongers and touting innkeepers, the barbers shaving their clients in the open (except on Sundays, when barbering had to be performed in shops). The din was like "that of a poultry yard; people hailing each other or quarreling, and the barber threatening the apothecary whom he looks on as a competitor." On surrounding streets were printing presses, the palace of the wool merchants, shops where silk and textiles and secondhand clothes were sold, where money-changers conducted their affairs, hosiers' establishments, goldsmiths' parlors and workrooms. Under the Medicis the streets became "more open and ornate," buildings were replaced with "a constant eye for beauty," and the older fortress dwellings made way for houses in Renaissance style, designed by Brunelleschi, Alberti and their pupils. But there were also "sombre spots" such as the well-named *Stinche,* the state prison, described by Machiavelli as "a stinking gaol where the walls harbour vermin so huge and swollen that you might compare them to butterflies."

The normal Florentine way to live was in the open. One conducted business out of doors, talked politics, hatched conspiracies (*combinazioni*), ogled nice girls and negotiated with tarts. In good weather, which was abundant, the citizen sat in the street, which served as the outer room of the house, and played at chess or dice, with bystanders breathing down his neck and offering the immemorially unwelcome advice. In this teeming, excitable, pullulating crowd any unusual incident or rumor might occasion a panic. To have an old mare break loose and trot off with its screaming owner in pursuit was enough to turn a peaceful scene into a riot. Men, women and children went flying in all directions. Merchants hastily closed their shops, stalls and counters were overturned, drapers threw their rolls of cloth into the shelter of their booths, the doors of the palace were bolted—obviously another revolution had broken out—and the public executioner, thinking that, if he survived, his services would be much in demand, discreetly hid himself. But soon after the squall was over everyone resumed his place, and what passed for peace and order was restored.

The city stretched far beyond its walls and there life, whether that of the peasant or the prosperous farmer or merchant prince in his villa, was less hectic. The landscape was pleasant, the view from the encircling hills enchanting, the water pure and wholesome. Cereals and vegetables were cultivated; the country farm also provided cheese, wine, oil, forage and wood. Gentlemen had dogs and falcons and hunted hares and roebucks. A philosopher such as Machiavelli (who, when dismissed from his post in a political upheaval, rusticated for some years in a modest house) might go for long walks, talk to wayfarers, listen to gossip, take his ease at the local inn playing cards or backgammon and in the evening renew his mind and spirit by reading the classics. Peasants lived as peasants always have: laboring, complaining, conniving—"professors of distrust." The burgher held the peasant in low esteem, although he did not regard him with "the perfect scorn of a French lord for his villein." But the *villano* did not care a rap; he was as much a citizen as anyone else, and he could, so long as the harvest did not fail, take care of himself. One of his simple amusements, only mildly sadistic, appeals to me. At a country fete he would bring out a donkey with cymbals tied to its back and a thistle fixed under its tail, which would tickle the creature, make it fidget and so provide music for dancing.

In medieval Florence a girl married at the age of 20 or more. By the 15th century she did not wait so long. Marriage was arranged by the *sensale,* a go-between, and there had to be a dowry (3,000 florins, say, in the middle class), which was officially recorded in the "Great Book." The fiancé gave a ring as

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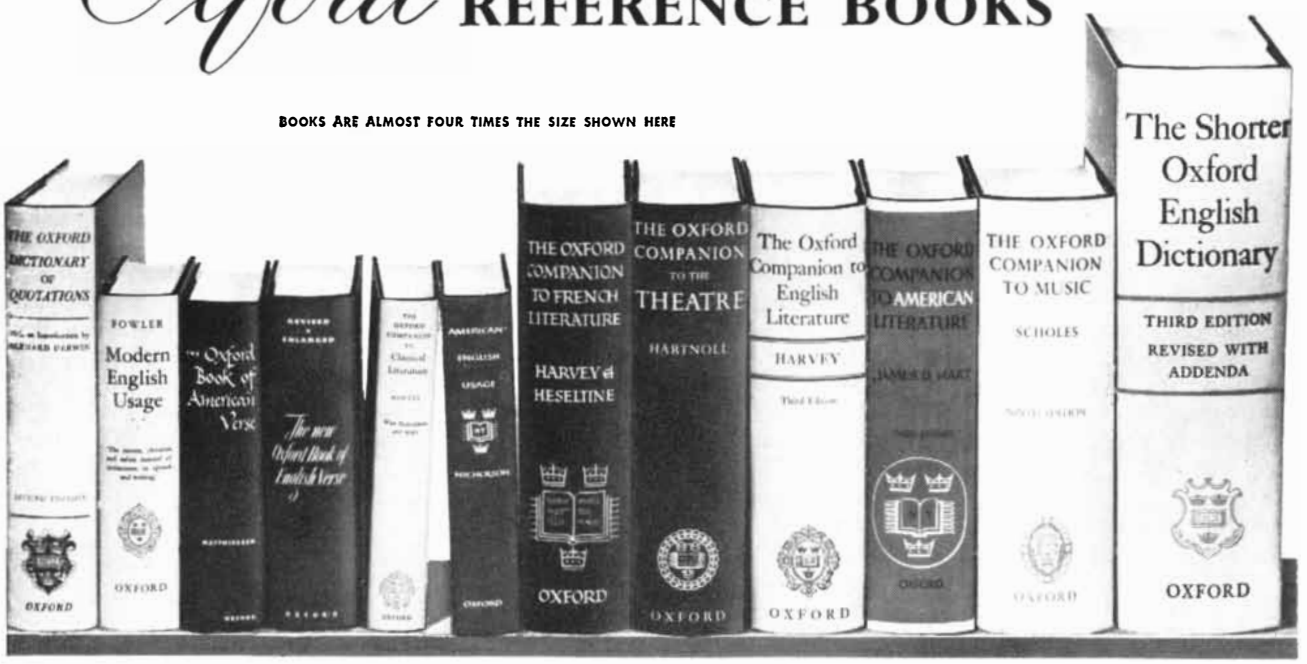

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a symbol of engagement, and other presents were exchanged. On the wedding day there was a charming ceremony in which the young men stretched a ribbon or a garland of flowers across the street, the handsomest offered the bride a bouquet, and the bridegroom then broke the obstacle. The marriage banquet was as grand as one could afford. When a minor Medici was wed, a succession of guests were served for three days running in a garden surrounded by new silk tapestries; 200 calves were consumed, as well as kids, hares, capons, geese, pheasants, peacocks and every other kind of poultry.

All sorts of regulations attended the running of a house. The servant was often a slave, purchased in the market at Venice for a price from 6 to 87 ducats, according to age and ability. Slave or not, she was treated like a slave. "Don't give her any leisure," the young wife was told; "as long as you keep her on the go, she will not remain leaning out of the window." There was much for the servant to do, particularly with the new elegance and refinement that accompanied Florence's prosperity. Whereas formerly, even in the higher social circles, the bones of game or fish were thrown under the table, the room was cleaned only on Saturday and people lived among their animals, now daily house cleaning was in order, and the animals, which included house dogs and geese (the former to keep an eye on the latter, and both to guard against burglars), fallow deer and chamois, ostriches and porcupines, were confined to the gardens and courtyards, or, if one's purse permitted, in specially built menageries. Florentine houses were equipped with large beds for several persons, and one slept naked. Tapestries covered the walls; vases stood on sideboards; there were big chests decorated with genre paintings or marquetry. The Florentine, "who regarded the German as the very type of a dirty sloven," changed his personal linen on Saturdays—which in that climate could hardly have been too often—and went to the public baths, of which the city boasted four.

Mothers were expected to nurse their own children, but if a wet nurse had to be hired she could under no circumstances "belong to one of those savage peoples, like the Tartars or Saracens." A child was left as much as possible out of doors. If he cried he should be left to cry. Education was, as always, a subject of controversy. Some sages held that there was no point in teaching a child under seven anything other than essentials of language and the names of things: *babbo* (papa), *mamma, pappo* (bread), *bombo* (wine), *fare la nanna* (to sleep); others felt that small infusions of knowledge were not positively harmful, so that by the time the child was 11 and handed over to a master, the latter would not be tempted to throttle it as a dunce. Use of the rod was not encouraged. "Only donkeys should be beaten," it was said, for beating leads to resentment and withers "the natural affection of the heart"—except, presumably, in donkeys.

The schoolmaster taught either in a private home, where he was paid, or in a public school, in which case the State paid him. In neither case, however, was he paid very well. "He was usually a poor devil of a pedant, with his little bonnet and his threadbare gown which had seen at least five jubilees." His property often consisted of a bag containing two shirts, four handkerchiefs and a few books—Donato's grammar, the *Cornucopia* and the *Doctrinal*, together with some other Latin or Italian works. Disdained, his trade considered the lowest of all, characterized by satirists as at once conceited and incurably stupid, the teacher could be expected to give back as good as he got.

Grammar, geometry and Latin were administered to the young Florentine. Ovid and Plutarch were staples. Many hours were allowed for recreation and gymnastic exercises. It was better, I dare say, to be a rich man's son than a poor man's son; still, it is surprising to learn that in the time of the Medicis 8,000 to 10,000 children were learning reading, 1,000 to 2,000 arithmetic and 600 grammar and logic. Even girls, formerly instructed only in spinning and sewing, were now taught to read and write, and they were exposed to a bit of Latin to add to their charms. The hour of emancipation, as Lucas-Dubreton remarks, had indeed struck.

It was no longer required of a maiden that she wear a topaz to quell her love passions. Gloom and confinement were not held to be essential in a female's upbringing. "Before long, people would be saying the riskiest things in the presence of 'nice, respectable girls'; they would be telling stories that would make a gargoyle blush." *Honi soit qui mal y pense*—or whatever the Italians say to cover the circumstance.

A word about higher education. Bologna and Padua had universities well ahead of Florence, but in the 14th century a Florentine university was established, supported by an annual subsidy. A staff of readers lectured on law; on medicine, surgery and anatomy (for these specialists was reserved the regular supply of corpses taken down from the gallows); on logic and philosophy; and, of course, on rhetoric, a most highly regarded subject. The point is worth making that the readers' salaries, though wretched, came entirely from the State and not the Church.

Home life in Florence deserves further attention. The first family meal was taken between 9 and 10 in the morning, the second before nightfall. Husband and wife ate from the same dish and drank from the same cup. Bread, herbs, jam and fruit frequently made the menu. The new elegance brought variety. Boiled kid or peacock were served, followed by colored scented jellies, made of almond milk and other ingredients, in the shape of little men or animals. At table the fork was used (Florence was ahead of France in this amenity), and one was not to dip one's fingers in the gravy. At the rich merchant's board slices of melon were served, all kinds of boiled meats, sausages, stews, roasts, fowl, fish, cakes. The average Florentine did less to appease the weakness of the flesh, but he dined well, nonetheless, on salad, perhaps a small pigeon, liver sausage, goat's-milk cheese, fruit and *pasta*. Wine was drunk, of the local vintages. It was recommended by an eminent contemporary leech as an aid to the digestion, an improver of the blood, a calmer of the intellect, a stimulator of the appetite and a sovereign expeller of wind. Florence liked its food and drink, but drunkards and gluttons were not in favor. Most people practised "a delicate epicureanism," much to the amazement of foreign visitors (in particular an English churchman who was accustomed to seeing his fellow countrymen swilling and gourmandizing at the table for four hours).

Rules of courtesy and good manners were set forth in a manual, the *Galateo*, by Giovanni della Casa. One was to masticate quietly, not to crouch over food as if one "were blowing a trumpet," not to hiccup, not to rub one's teeth on the napkin, not to scratch or spit (at least only "reservedly"), not to sniff at another's glass or plate, not to walk about with a toothpick in one's mouth ("which makes you look like a bird carrying a twig to its nest"), not to wear a toothpick in one's collar (which, I confess, would not have occurred to me), not to wave one's fork in affected expression (*favellar in punto della forchetta*), not to give long descriptions of one's dreams or forever talk of one's children, not to nudge people with one's elbow and not to look in one's handkerchief

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after blowing one's nose "as if pearls or rubies had been deposited in it." Also, if you were to pass as a gentleman, you were not to be seen in public wearing your nightcap, not to put on your garters in front of other people, not to leave your office with your pen behind your ear, not to cock your leg on the table, not to spit on your hands. "Your dress should be neither so pretty nor so elaborate as to make people remark that you are wearing Ganymede's hose and Cupid's doublet."

Cultured, refined, moderate (in all except politics), skeptical, "tepid" in their Christianity (though chapels, oratories and churches abounded), but full of fears, highly suggestible and certainly not above superstition—these were the Florentines. Palmists were consulted even by the well-informed. Astrologers had influence and proclaimed days of good and evil omen for grand undertakings. Sorcery had many adherents. Yet when one was sick, one sent for a physician, not a palmist—though the wisdom of the choice was not always unequivocal. The medical art, which included the art of "drugs and groceries," had impressive practitioners. They wore long and capacious robes that were trimmed with squirrel fur and bands of scarlet; they adorned themselves with heavily gemmed rings and gilded spurs. In 1479, 66 doctors are recorded as practicing in Florence. They mainly prescribed "simples": cabbage, for example, which they regarded as a panacea. Still, this was better than the merciless potion lavished on Lorenzo by his physician. Men sent for doctors but, with some justification, did not take them very seriously. When things went wrong, the doctor might suffer as grievously as his patient: the learned Pier Leoni was found dead at the bottom of a well the day after Lorenzo died, either *felo de se* or dispatched by the Magnifico's admirers.

In dress, fashions and entertainment the period of the Medicis brought many changes. The austere garments of Dante's time gave way, despite sumptuary laws, to variety and color. Men wore long gowns, hoods or bonnets with ribbons. A gilded youth might be decked out in a pink cape edged with a broad band of velvet, white velvet hose with silver lacework, velvet shoes, a velvet cap with feather, scented gloves, a gold medal, a dagger, a sword and a profusion of rings. Hair was now cut short and beards were coming into favor.

Women's dresses were gorgeously and densely embroidered with flowers, parrots, dragons, pagodas, in crimson,

green, red and scarlet. Preachers and moralists railed at the clothes, the jewels, the high-heeled sandals, the cosmetics, the curls and ringlets, the low-cut dresses ("well below the arm-pits"), but it did no good. Even Savonarola, who managed to impose reforms in other matters, got nowhere when he asked for laws curbing excesses in feminine attire.

Music, always beloved of the Florentines, increased its sway. Instruments were improved and diversified: organ, harpsichord, violin, lute, lyre, cello, harp, horn, trombone. A school of harmony grew up in the entourage of Lorenzo. Painters and sculptors who were also musicians were included in this academy. Recitals were given. Several orchestras were formed and music was allied to the drama, which it supported and developed. For a long time exclusively religious, the stage now became "definitely secular, pagan and realistic." A most successful play was Machiavelli's *Mandragora*, presented in 1526 by the "Company of the Trowel"; it dealt with the troubles of a cuckolded husband, a casuistical monk and a wife of "half-hearted virtue." No less successful were the ecclesiastical festivals and the popular spectacles, which were brought off in magnificence and splendor and included such features as great gilded towers borne on wagons, many-colored standards and sundry ingenious mechanisms to produce motion in the displays.

The spectacles, festivals and other delights and comforts that the citizens of Florence enjoyed in such profusion cost money, and when the State paid the State had to collect. Never was a people more taxed. There were sales taxes, municipal tolls collected at the city gates and tithes of all kinds. Personal property as well as real estate was subject to levies. Taxation was used as an instrument of policy—"as a dagger and a stick," in Guicciardini's phrase—often to soak the rich and so gain the applause of the small burghers and the artisans. Income taxes were introduced, accompanied inevitably by "fiscal inquisition." Florentines were known to cheat on their taxes unless a close watch was kept over their finances. The *decima scalata* was graduated from 10 per cent to 33⅓ per cent, which would not have been unreasonable were it not for the practice of reimposing the tax two or three or more times in a single year. A man with an income of 300 ducats, which was high, might thus be forced to pay as much as twice this amount in annual taxes. The lower class thought this was dandy, but the rich felt themselves "cut to the

quick." Recurrent crises in public finance were closely linked with the general instability of the Florentine government.

It would be well to end on a less melancholy note. The Renaissance in general and Florence in particular raised the status of women. In the Middle Ages a woman was widely regarded as having the morals and rationality of a child. Her task was to bear children, tell her beads, mend the linen, cook, look after the keys and keep her mouth shut. The Florence of the Medicis liberated her from this thralldom. Women had warm advocates and "the old-fashioned type of husband was thoroughly well trounced." It was now said that a woman did not in mind and soul compare unfavorably with a man. The ladies of Florence became conversant with moral and natural philosophy and with logic and rhetoric. They read Petrarch, Ariosto and such "light-minded" authors as Aretino. They cultivated and supported the arts. Extremists went so far as to argue that it would not be a bad thing to let women govern cities, make laws and control armies.

Ideals of feminine beauty were well defined. The hair should be fair and gold-tinted; blonde was the "queen of colours" and could be obtained by artifice (Venetian women were said to be expert in this process). The eyes should be large, "slightly protuberant," and the white of the eye slightly bluish. Eyelashes should be "not too long or too thick or too dark." The nose should be slender. The mouth should be small and "should not display more than six teeth when the lips... are half open." The neck should be long. The legs should be long and slender, the feet small but not thin. Fingernails should shine and not extend beyond the fingers "by more than the breadth of the back of a knife." The bosom must be "ample and shining, and not show any bones." Altogether reasonable.

To keep the skin white, almond oil with white wax and a little camphor were recommended. A well-bred lady was to wash herself completely every day with warm pump water in which sweet-smelling herbs had been boiled. Cleanliness was important for itself, not only for show. "There is nothing worse," it was said, "than to look clean where you are visible, and cross yourself as regards the rest." Exercise was considered good for women; playing ball every day was encouraged.

Women were to be modest and reserved; yet it was proper to show a little of one's wares—especially those worth showing. One wore gloves but displayed

the hand, if pretty, while playing chess or cards. One gave a glimpse of the leg when walking, fishing, hunting or "leaping some small ditch." Be neither provocative nor too timid nor prudish was the accepted maxim.

Love was most important. Without love nothing mattered. Conjugal fidelity was held desirable but not essential. The experienced matron Raffaella advised that a little "backsliding" now and then is a safety valve against the "despair [which] will deliver you bodily to the devil." Honor, after all, rests on public esteem, so it is important to avoid scandal and to give no reason for gossip. "Sin if you can't resist, but maintain your good reputation." In choosing a lover avoid young men of 20 "like the devil," because they are apt to be indiscreet and boast of their conquests. Old men are no better, because they are prone to jealousy and backbiting. Stay away—if possible—from married men. Pick an "honest and discreet fellow," says Raffaella, "whom you have opportunities of meeting secretly."

A final point. If the upper-class Florentines hadn't been such political windbags, their wives might have been more faithful. Winter and summer the husbands remained in the Council till the early hours of the morning, quarreling and yapping at each other. What were their wives to do, deprived of their rightful bliss and afforded the opportunity of wrongful bliss? One of the inconveniences, says Lucas-Dubreton, of a democratic regime.

"What I want," said Mr. Gradgrind in *Hard Times*, "is Facts...Facts alone are wanted in life." It could be said, not unjustly, that this book has too many facts and too little interpretation. The author is more mason than architect. These passionate, sharp-witted, volatile, greedy, immensely gifted people remain inherently enigmatic. Once there was an Athens, once a Florence; perhaps that is all that can be said. At any rate, one cannot fault Lucas-Dubreton for failing to provide the particulars, the minutiae, the color, the incidents, the personalities, the anecdotes. He contrives a living picture —explain it as we may—of a marvelously tumultuous and creative city and period.

Short Reviews

FIGHTS, GAMES, AND DEBATES, by Anatol Rapoport. The University of Michigan Press ($6.95). A provocative study, by a mathematician who has focused his interest on social and biological questions, of the sources, nature and possible control of human conflict in all

its forms. It will be appreciated, especially in today's uneasy world, that this is a large, hideously complex subject, second to none in importance, and that anyone persevering and bold enough to tackle it deserves the thanks of everyone. The book divides into three parts, each concerned with a different phase of man's propensity to engage in what the author somewhat unhappily calls "debates," a catchall name comprising conflicts ranging from mass-murder wars to ticktacktoe.

The first section examines the approach to social behavior associated primarily with the work of Lewis F. Richardson, the British meteorologist who devoted many years of his life to the mathematical treatment of the dynamics of "fatal quarrels" on a large scale; and considers related inquiries by the mathematical biologist Nicolas Rashevsky. To this work Rapoport gives the name "social physics," not because it is concerned with finding analogies to physical laws in social behavior but because the basic method, which is theoretical, deductive and makes use of certain quantitative relations which may underlie social behavior (for example, frequency of wars and arms expenditures), resembles the method of mathematical physics.

The second part of the book, and in many ways the most rewarding, is a primer of the mathematical theory of games, explaining the origins of the theory, the concept of strategy, the mixing of strategies, games with collusion, coalitions, the possible application of the theory to nongame conflicts. This is a brilliant performance, and anyone who wishes to understand what this subject is about, its uses and limitations, its true potentialities as well as the pretensions of some of its overenthusiastic proponents, is strongly advised to read this refreshingly lucid exposé. The concluding section, dealing with the "ethics of debate," presents a critical examination of the bases of disagreement, the dangers of blind involvement, prejudice, the deliberate and unconscious misuses of language, the ways of rational persuasion. Men disagree about many things, and disagreement may breed fear, hatred and violence. It is not difficult to show that much disagreement, particularly between large social groups and nations, arises out of an inability to communicate and a failure to understand the opponent's views, convictions, fears, objectives and the like. Many philosophers, psychologists, psychiatrists and students of society have studied and pronounced on this aspect

of conflict, and Rapoport in this section adds very little to what others have said. But even his general and discursive observations deserve attention, for he is a man of utmost good will, whose humanity and insistent searching for a way to use reason and scientific knowledge as solvents of social conflict make themselves felt throughout these pages. A set of differential equations, as he freely admits, is unlikely to explain an arms race or the outbreak of war fever; the theory of two-person games, even in its most sophisticated form, may not serve the diplomat so well as patience and an ability to perceive that a tight shoe may pinch his opponent as much as himself; and an analysis, however persuasive, of why masses of men come to hate each other blindly may not overnight produce world fraternity. Yet this book makes the case strongly that the use of these and other rational methods is certain to broaden our outlook, to make us aware of how often we take refuge in dangerous clichés and platitudes, how feebly we draw on our intellectual resources in meeting man-made crises. The sons who were told to dig for buried treasure in the vineyard found no treasure, but they improved the soil. This, at least, as Rapoport reminds us, is the reward to be hoped for from a systematic study of conflict.

MARCO POLO'S ASIA, by Leonardo Olschki. University of California Press ($10). In 1271, when Marco Polo was 17, he set out from Venice with his father and uncle on one of the most prodigious journeys of all time. They traveled for four years, down the Adriatic, across the Mediterranean and the Black Sea, through Armenia, Persia, Afghanistan, Turkestan, Tibet, over the great desert of Gobi to Tangut, thence probably to Shangtu, where in 1275 they found Kublai Khan in his summer residence. The father and uncle had on an earlier journey, for commercial purposes, met the Great Khan, had been well received and had been sent by him, armed with golden tablets of imperial command (which rendered their person inviolable, under pain of death and terrible reprisals, against any who in the Khan's vast kingdom should disregard them), to the Pope with a request for 100 educated men to instruct his subjects in Christianity and the arts of the West. Their embassy was not altogether successful, for they were unable to persuade the Pope to supply the instructors, but the Khan received the Polos well, and Marco in particular soon rose to high place in the court. He

was widely used as an emissary, as an observer, as a reporter; he had the opportunity to see and to get to know lands and peoples that no Westerner had ever encountered before. He spent 17 years in China and finally, in 1292, laden with priceless gifts and other marks of imperial favor, left with his father and uncle for Venice, where he arrived three years later. Taken prisoner in 1298 in a battle between the Venetians and the Genoese, he was detained for a time in Genoa, and while there he dictated to a fellow prisoner his recollections of his travels and adventures. This writing, known in Italy as *Il Milione*, is a wonderful account of the immensely varied life of man and nature in the vast regions of the East. It became enormously popular and it underwent, in many different manuscripts, "renowned for their incongruity," a wide variety of changes. For centuries scholars have attempted to reconstruct the authentic text; to ascertain not only what Marco said about nature, about Asiatic civilization, medicine and learning, about Asiatic politics, religion and history, about historical and legendary figures; but also to distinguish between those portions of his account based on his personal experience and those resting on hearsay. Critical editions of *Il Milione* have appeared, the critical apparatus vying in bulk with the text; translations have been made; the resources of Western and Oriental learning have been pressed into service. The result is bewildering even for the trained scholar. In Olschki's book we have an admirable and often fascinating review of what is now known about Marco Polo; the book is both a summary and a critical evaluation that readers of every kind will find to their taste. *Il Milione*, as Olschki makes clear, was much more than a great travel book, just as Marco was more than a brilliantly observant traveler. The man and the book have often been misunderstood; the present volume will help to dispel this misunderstanding. Excellent illustrations and a map.

THE BASIC WRITINGS OF BERTRAND RUSSELL, edited by Robert E. Egner and Lester E. Denonn. Simon and Schuster ($10). This compilation by a teacher of philosophy and an attorney (described as the "appointed bibliographer of Lord Russell") consists of 81 essays and excerpts from the works of Bertrand Russell. Anyone bold enough to attempt such an epitome perhaps deserves a small salute, if for no other reason than that he will almost certainly fail if his object is to give an adequate portrait of the extraordinary mind and extraordinary range of interests of this extraordinary man. The editors, let it be said directly, have failed. Even with Russell's guidance they have been unable to bring the thing off. They have failed, partly because within the limits set the task is intrinsically too difficult, partly because they lack the requisite skill. It is not enough to have a burning desire to be first chef at the Waldorf; one must also know how to cook. It would be unjust to assert, to be sure, that the collection lacks first-rate reading matter. Russell is here in many moods and capacities: personal reminiscences, his "Outline of Intellectual Rubbish," the famous essay "A Free Man's Worship," writings on the uses of language, epistemology, the history of philosophy, moral philosophy, education, politics, economics, religion, science, international affairs. But there are too many bits and pieces and hurried glimpses, like a half-hour tour of a great museum. Inexcusable is the treatment of Russell's splendid achievement in mathematical logic. This is represented by a series of prefaces, summaries and introductions to *Principia Mathematica*, which are all but incomprehensible to the ordinary reader and nonsensical for the specialist. The editors have not taken the trouble even to attend properly to the footnotes. For example, the excerpt on mathematics and logic from *Introduction to Mathematical Philosophy*, written in 1919, has a footnote which says: "The importance of 'tautology' for a definition of mathematics was pointed out to me by my former pupil Ludwig Wittgenstein, who was working on the problem. I do not know whether he has solved it, or even whether he is alive or dead." The editors know; Russell knows. Wittgenstein died more than a decade ago. To leave the note as it stands is absurd. A sorry business.

CLASSICS IN PSYCHOLOGY, edited by Thorne Shipley. Philosophical Library, Inc. ($20). This jumbo of a book contains 36 selections from writings of leading psychologists and psychiatrists of the past 150 years. Included are excerpts from the writings of Johann Friedrich Herbart, Wilhelm Wundt, Hermann von Helmholtz, Ernst Mach, William James, Edward B. Titchener, J. M. Charcot, Eugen Bleuler, Morton Prince, Hughlings Jackson, Charles Sherrington, Sigmund Freud, Alfred Adler, Carl Gustav Jung, Ivan Pavlov, John Watson, Alfred Binet and G. Stanley Hall. There is a brief biographical

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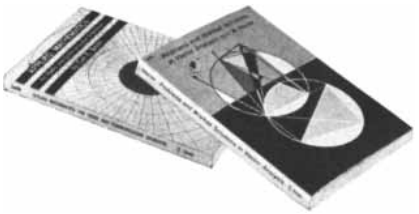

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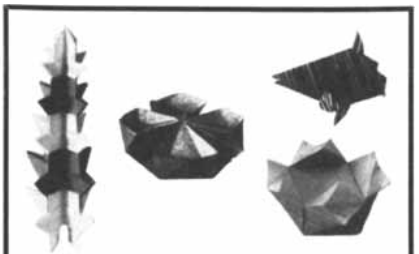

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GALAXIES, edited by Harlow Shapley. Harvard University Press ($5). Revised edition of a book based on Shapley's Harris Lectures at Northwestern University. The author takes cognizance of the advances in the study of galaxies since the first edition. The book does not include, as he points out in the preface, information gained from radio telescopes, new spectroscopic analyses and certain other recent developments, on the grounds that "these fields are being so busily developed at present that a statement of today may be out-dated tomorrow." He has confined himself to the material which will "better stand the erosion of time." Illustrations.

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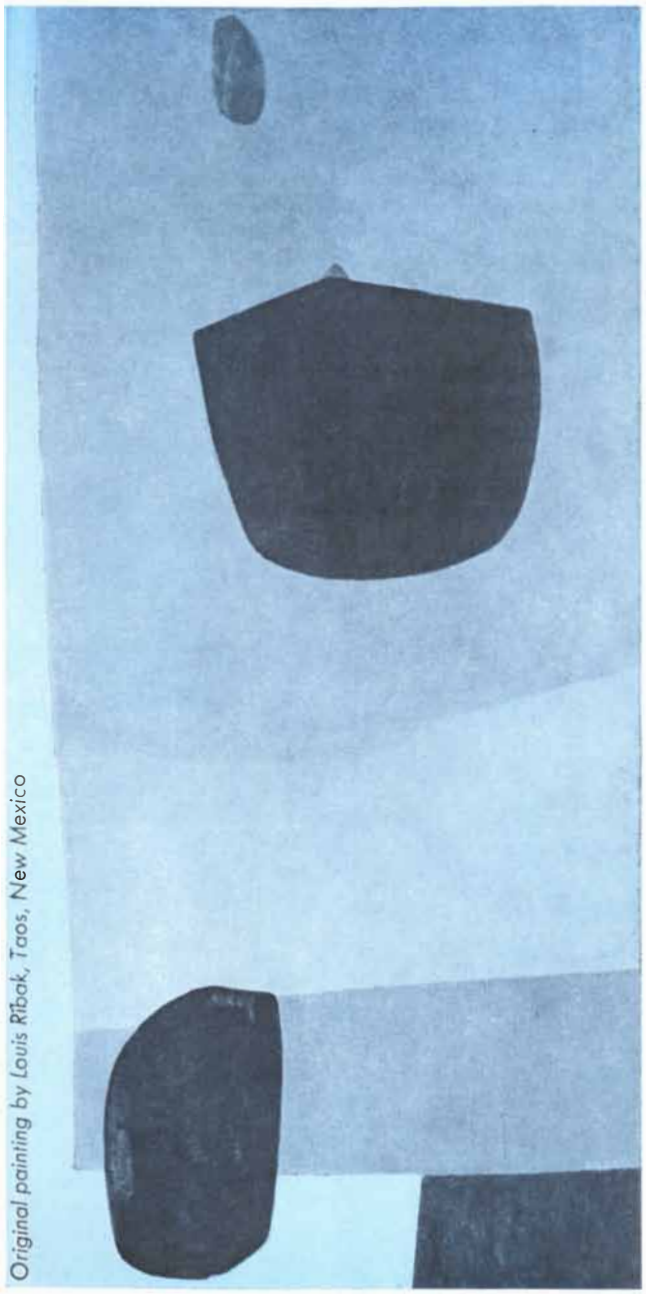

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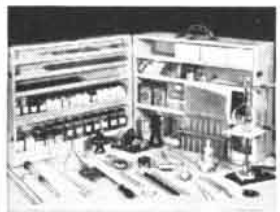

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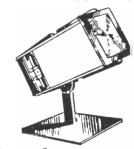

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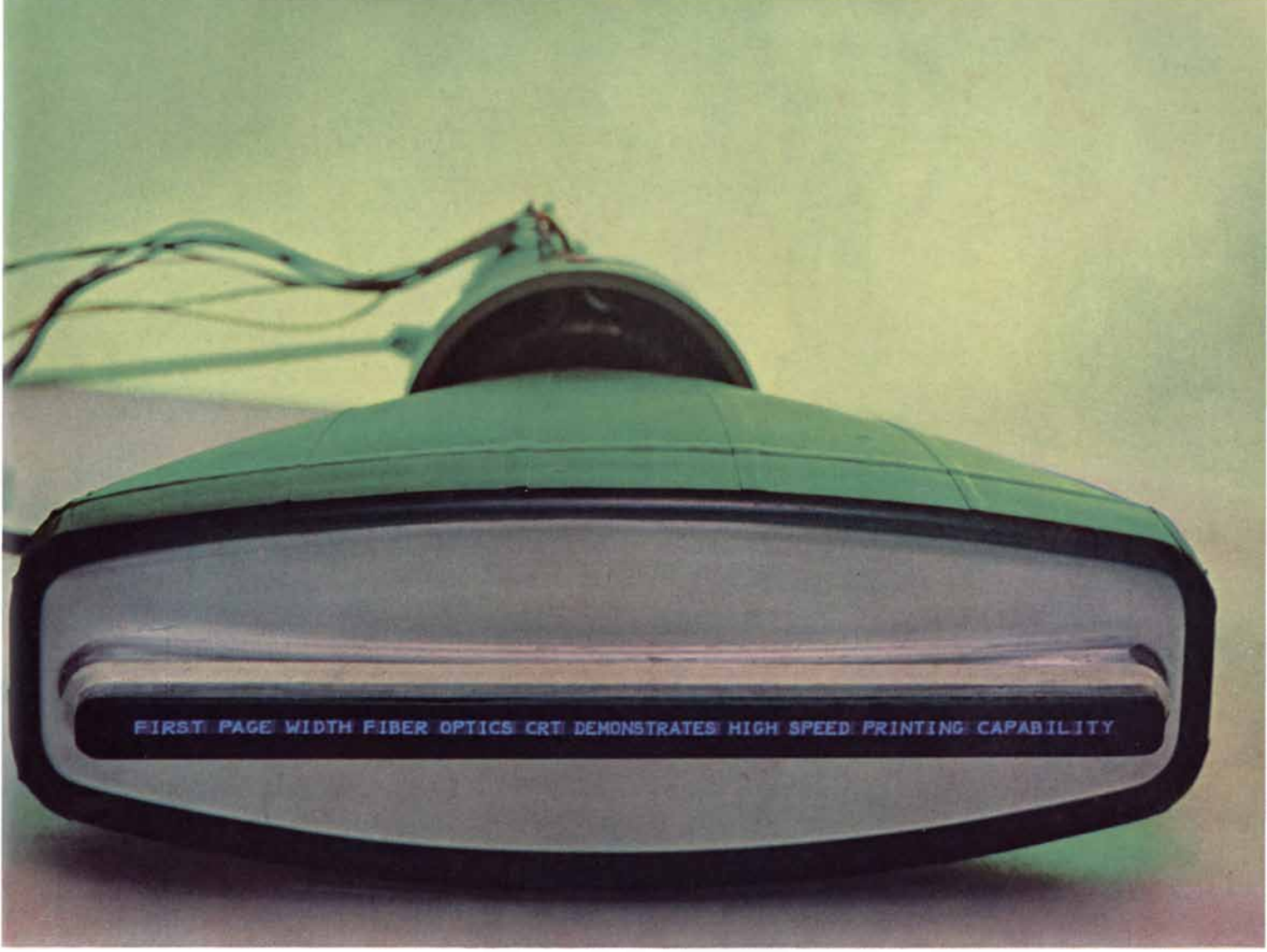

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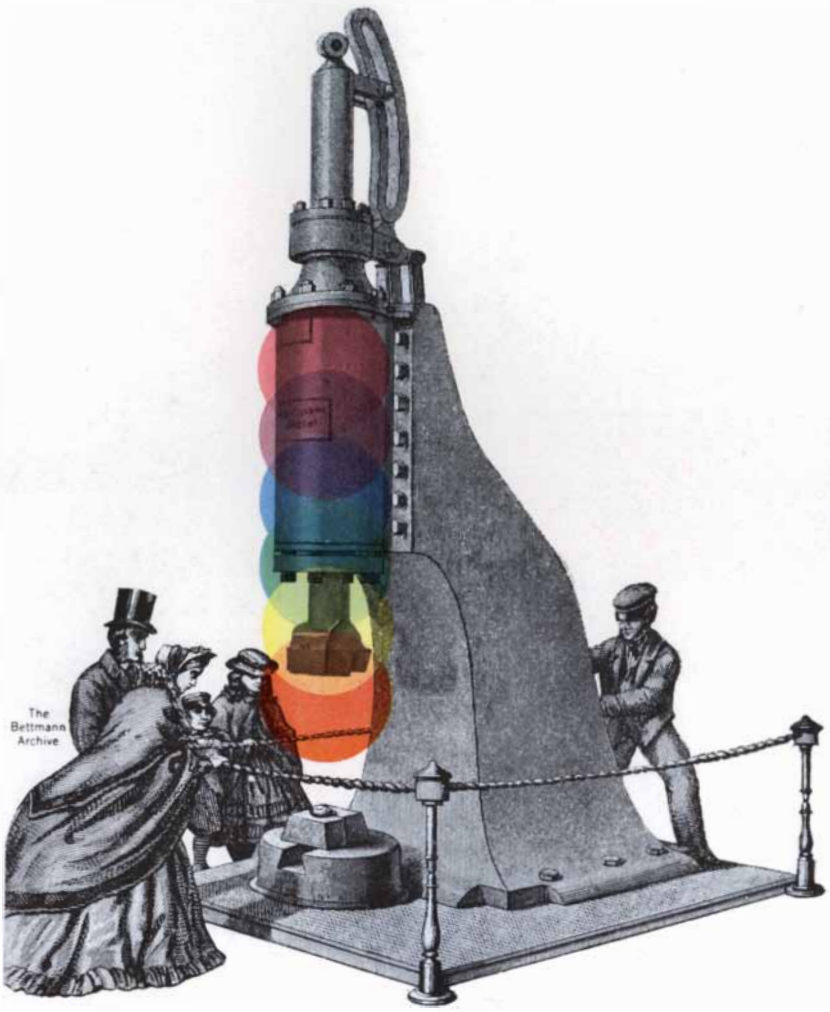

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