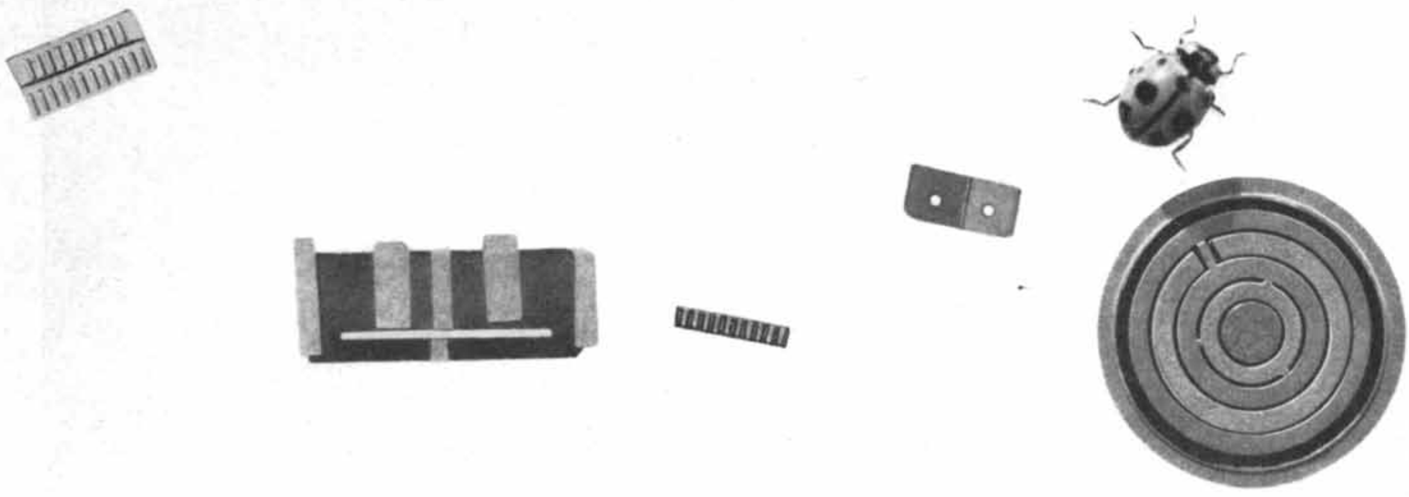
SCIENTIFIC AMERICAN

FRIENDLY VIRUSES

FIFTY CENTS

August 1960

FROM WESTINGHOUSE AT YOUNGWOOD



ENLARGED THREE TIMES—shown left to right are examples of Westinghouse functional electronic blocks: multiple three-terminal p-n-p-n switch; bistable multivibrator; multiple two-terminal p-n-p-n switch on dendrite; pulse generator; two-stage power amplifier.

Functional electronic blocks: a new design concept in molecular electronics

Functional electronic blocks perform complete circuit or sub-system functions within single semiconductor wafers or blocks. The functions are accomplished without the use of individual active or passive components, or inter-connections. The only connections to the blocks are those required for input and output terminals in power supplies. Thus, the functions are performed with great reduction in sub-system size and weight, and, as a result of the radical decrease in number of parts and inter-connections, it is reasonable to expect that system reliability will be improved.

Feasibility established

The Westinghouse Semiconductor Department has made a broad attack on the problem of the development of functional electronic blocks. Their feasibility has been demonstrated in the general categories of amplifier, computer, and switch functional electronic blocks. Low-level amplifiers in numerous designs, high-level amplifiers in two- and three-stage equivalents have been made to provide broad experience in development of amplifiers with a range of input and output impedances, voltage, current and power gains. In computer blocks; monostable, bistable and astable multivibrator equivalents of cross-coupled transistor, p-n-p-n switch and tunnel junction types have been developed to cover a frequency range from fractions of a cycle to three mc. per second. Multiple three-terminal p-n-p-n switches and multiple two-terminal p-n-p-n switches on dendrites are being developed.

Samples now available

In order to expedite the adaption of the functional block concept to systems design, Westinghouse is making available, on a developmental sample basis, the following functional electronic blocks: Two-stage power amplifier/Three-stage power amplifier/Bistable multivibrator/ Pulse generator/ Ten-position multiple three-terminal switch.

The available types of functional electronic blocks will be extended in the coming months to include a variety of low-level amplifiers, additional multivibrators and switches. Your inquiries on the blocks now available as samples and on the development of other functional electronic blocks for your specific needs are invited. Call, or write: Westinghouse Electric Corporation, Semiconductor Department, Youngwood, Penna. SC-1003

Westinghouse

Established 1845 **SCIENTIFIC AMERICAN** August, 1960 Volume 203 Number 2

ARTICLES

DEPARTMENTS

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THE COVER

The painting on the cover is a closeup of part of an experiment on how infection with a virus affects the feeding habits of an insect (see "Friendly Viruses," page 138). In the small cage at upper left four corn leaf-hoppers feed on a corn leaf, the sap of which is normally their sole diet. In the cage at bottom center four other corn leaf-hoppers shun the leaf of an aster plant. In the cage at upper right leaf hoppers of the same species feed on the leaf of an aster plant that is infected with the virus disease known as aster yellows. Curiously the aster-yellows virus enables the corn leaf-hopper to feed on the aster plant, and after ingesting the virus the insect can feed on a variety of other plants. At bottom right is the tip of a glass-marking pencil. Just above the point of the pencil is the edge of a small disk-shaped magnet that is used to attach the insect cage to the leaf.

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Cover painting by John Langley Howard

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HEDGEHOPPING AT MACH 1
Lockheed radar shows pilot how to miss what he can't see

When a pilot hugs the deck traveling a mile *every four seconds,* his route is the world's most dangerous obstacle course. Hills, bridges and other hazards can be in his lap before he has time to maneuver safely over them. He needs information well in advance, particularly in poor visibility or at night.

And now he gets it—from Lockheed Electronics terrain avoidance radar. A compact display shows him obstacles, his position in relation to them, and the maneuvers necessary to avoid them—in time.

Lockheed Electronics systems engineers have created in one group of modules the most versatile airborne radar in flight test today. Equally effective as a mapping, bombing or navigational radar, this lightweight, transistorized unit is typical of the sophisticated equipments developed by Lockheed Electronics to help strengthen the nation's defense.

CAPABILITIES—MILITARY SYSTEMS/STAVID DIVISION

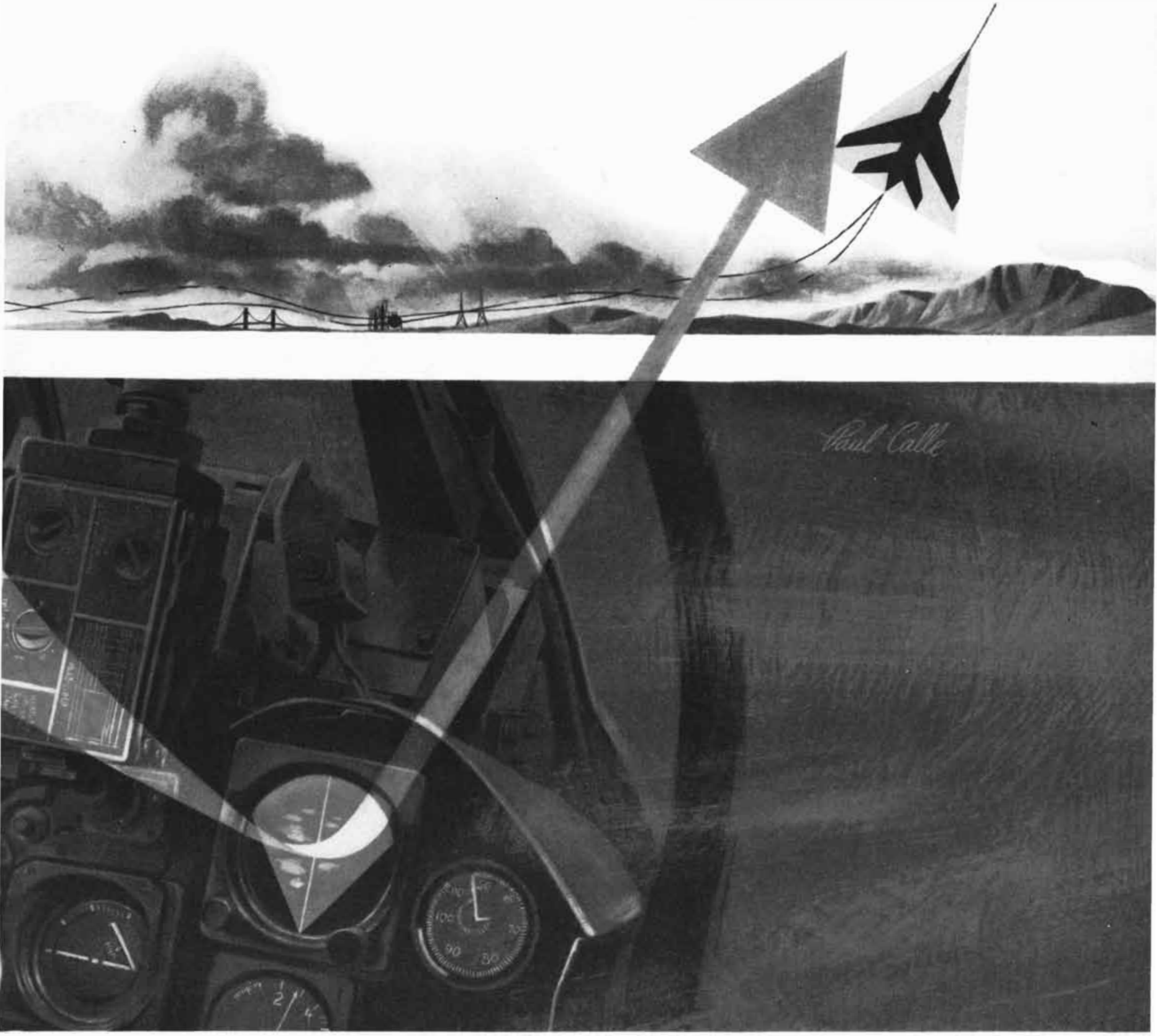
RADAR SYSTEMS—search, bombing, navigation devices and displays, missile guidance and control, automatic detection and data processing

COUNTERMEASURES—ECM, ECCM, active and passive

UNDERSEA WEAPON CONTROL AND DETECTION—ASW, electromagnetic detection, location and communication

SIMULATION AND TRAINING DEVICES

OPERATIONS ANALYSIS—offensive and defensive systems, war operations, undersea warfare, electronics in space



MINDING THE FUTURE

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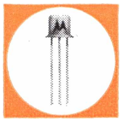
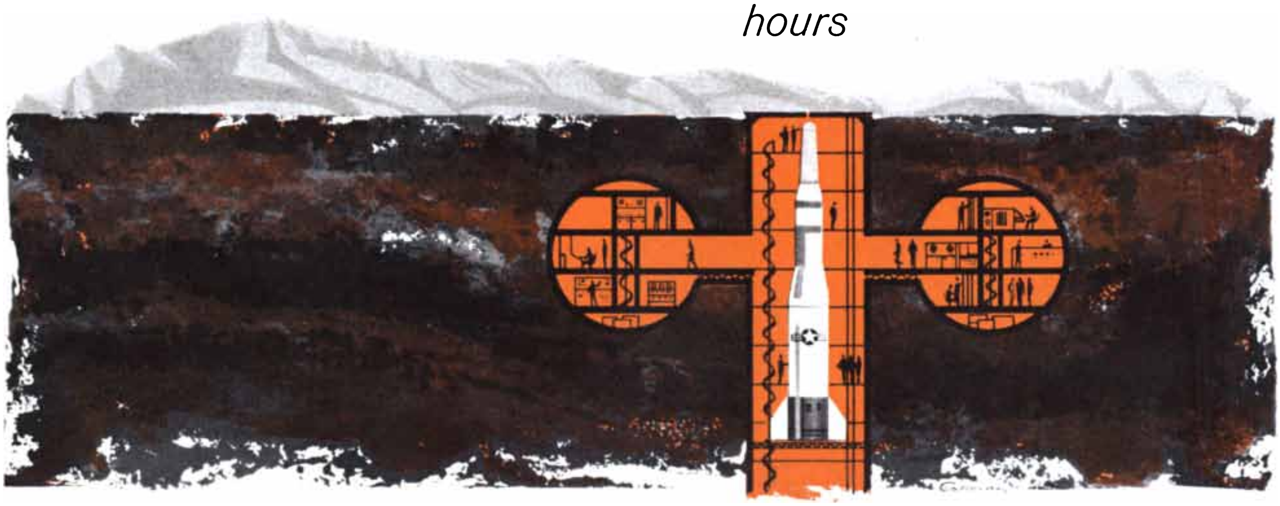




A DOOR IS OPENED... TO COST SAVINGS IN INSTRUMENT-AIR CONTROL

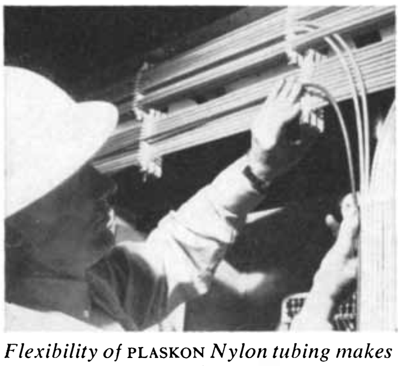
Some wit has said, "Air is free; it's *breathing* that costs money." The same can be said about instrument-air control systems. Miles of expensive tubing are needed to convey air impulses between control panels and field instruments. Until lately, copper was king in this area—particularly in chemical processing, petroleum refining, and in school and office heating and conditioning.

Now, however, a new plastic offers to do the job cheaper—and often better. It's extrudable PLASKON® Nylon, a special form of polycaprolactam (nylon-6) marketed by our Plastics and Coal Chemicals Division. Available in a flexible grade (without sacrifice of tensile strength), it is ideally suited for instrumentation tubing.

Installing PLASKON Nylon instrumentation tubing at Allied Chemical's Hopewell, Virginia plant. Note the 1000-foot, continuous, light-weight coils held by workman.

Supplants copper

Very logical reasons account for the fact that nylon tubing is supplanting copper. It costs less as a material—averages *half* as much in sizes under ¾ of an inch. Its flexibility reduces installation time by eliminating costly bend-



Flexibility of PLASKON Nylon tubing makes even right-angle bends easy.

ing and drawing—achieves complex bends where copper might kink. It comes in continuous lengths, avoids the joining of short sections. Connections, when needed, can be made with conventional fittings. It's adaptable to many installation methods, including factory- and job-made bundles. It's light—⅛ the weight of copper. It's color-codable. And nylon, of all the common flexible plastics, is the strongest, toughest and most heat-resistant, with unique surface hardness and resistance to abrasion.

Proved by use

About now, some cynic is sure to ask, "If the stuff's so darn good, why don't you use it yourself?" We do. We do indeed. In our Edgewater, N. J., plant it has given us nearly two years of trouble-free service. More than 125,000 feet of PLASKON Nylon tubing are installed in our Hopewell, Virginia, plant. Besides saving us more than a few coppers in installation costs (30%, in fact), it serves both as a test and demonstration of nylon instrumentation tubing. You can't help but learn a lot about tubing when you put in nearly 25 miles of it. We'd like to pass on our findings to you.

Allied Chemical

BASIC TO AMERICA'S PROGRESS

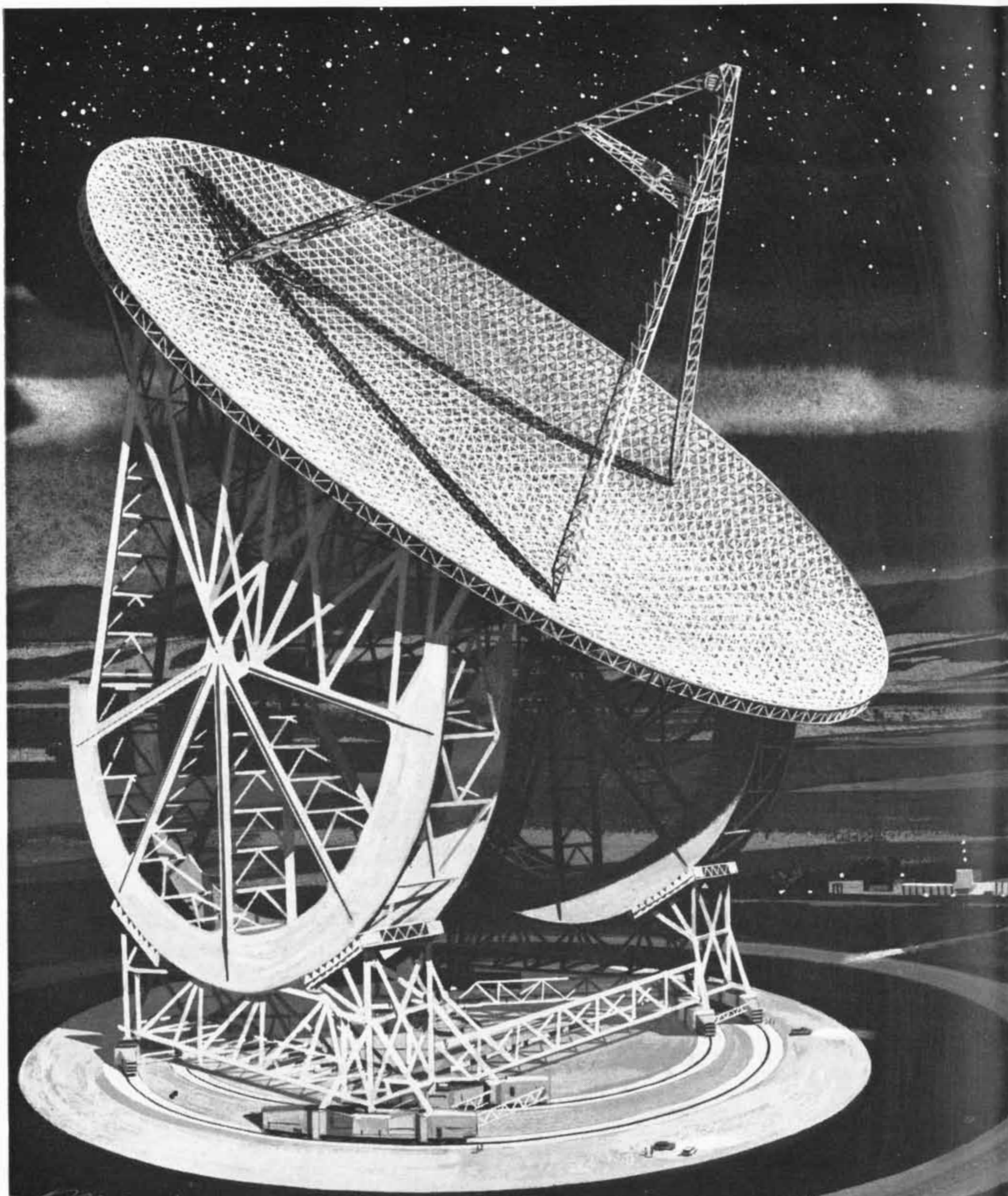
Limitations? Some, to be sure, but more than offset by the advantages. A few chemicals attack nylon, and where these are present, it should be protected. The melting point is 420 F. And nylon can burn—but with reluctance, and it tends to be self-extinguishing.

Wide applications

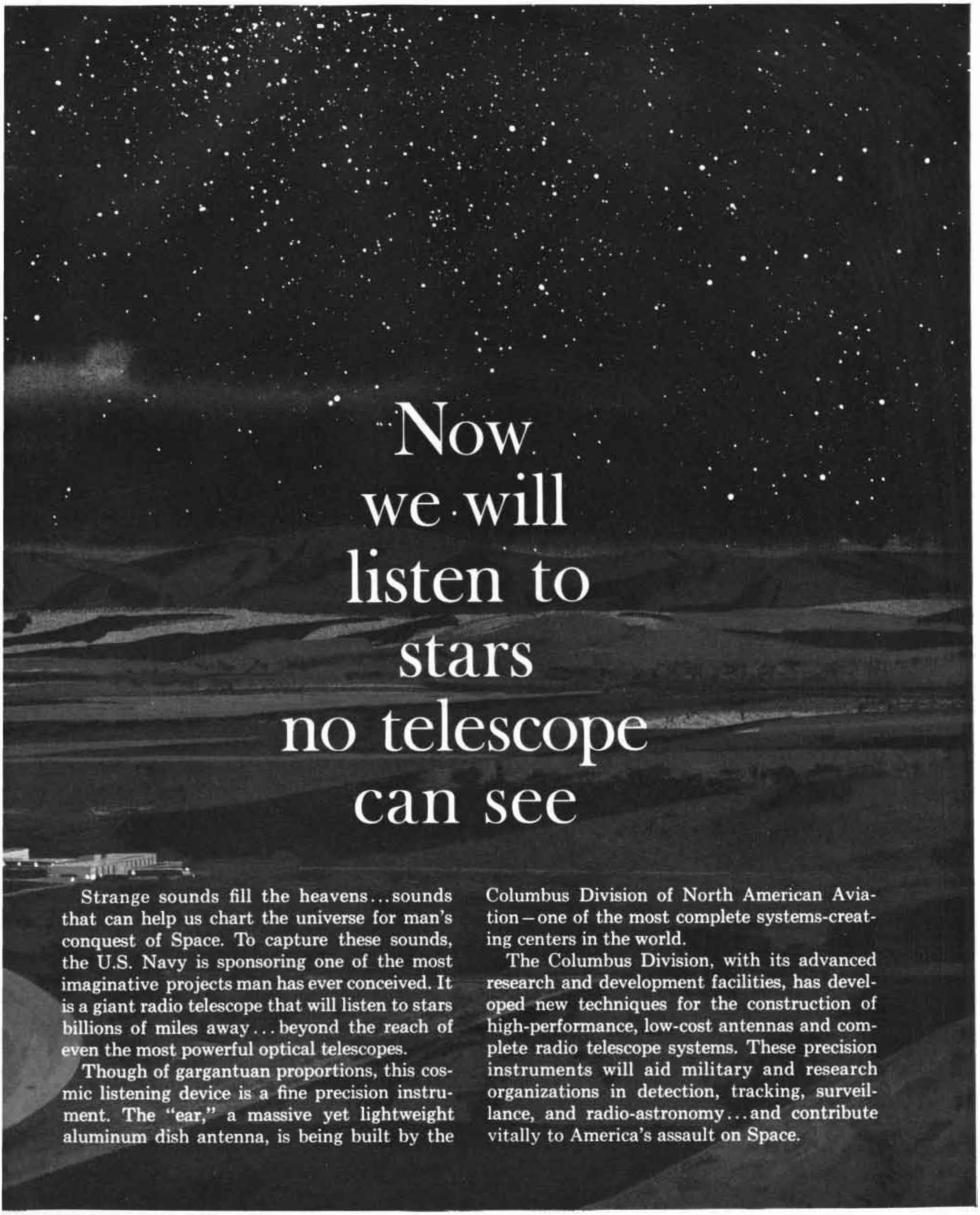
You'll find many other uses for nylon tubing besides instrument-air control: high-pressure hydraulic and air, lubricating and gasoline, hot water, paint spraying and solvent conveying. And, of course, pipe, tape and complex shapes can be extruded from PLASKON Nylon for a multitude of applications.

Free booklet

To bring you the whole story of PLASKON Nylon tubing, we have prepared a booklet describing both the advantages and installation methods. Included is a detailed cost analysis of our Hopewell installation, showing in actual figures how it can save money. For a copy, just write, on company letterhead, to Allied Chemical Corporation, Dept. 86-S, 61 Broadway, New York 6, New York, or phone HAnover 2-7300.



THE BIG "EAR"—The world's largest radio telescope is being built at the U.S. Naval Radio Research Station in Sugar Grove, West Virginia. It will tower to the height of a 60-story building. The movable reflector, directed by an inertial-guidance system, is 600 feet in diameter and more than seven acres in area. The 10-foot thick reflector, with a potential range of billions of light years, will be built by the Columbus Division of North American Aviation.



Now we will listen to stars no telescope can see

Strange sounds fill the heavens...sounds that can help us chart the universe for man's conquest of Space. To capture these sounds, the U.S. Navy is sponsoring one of the most imaginative projects man has ever conceived. It is a giant radio telescope that will listen to stars billions of miles away... beyond the reach of even the most powerful optical telescopes.

Though of gargantuan proportions, this cosmic listening device is a fine precision instrument. The "ear," a massive yet lightweight aluminum dish antenna, is being built by the Columbus Division of North American Aviation—one of the most complete systems-creating centers in the world.

The Columbus Division, with its advanced research and development facilities, has developed new techniques for the construction of high-performance, low-cost antennas and complete radio telescope systems. These precision instruments will aid military and research organizations in detection, tracking, surveillance, and radio-astronomy...and contribute vitally to America's assault on Space.

THE COLUMBUS DIVISION OF NORTH AMERICAN AVIATION, INC.
Columbus, Ohio

LETTERS

Sirs:

L. Pearce Williams, in his article "Humphry Davy," [SCIENTIFIC AMERICAN, June] has done a fine job in presenting the biographical facts. It was surprising, however, to read in the caption for the celebrated Gillray etching that "the flatulent individual inhaling the gas has not been identified." His identity has long been established, as has that of almost everyone in the caricature. The flatulent gentleman is the 52-year-old Sir John Coxe Hippisley, a relatively important patron of science in the early 19th century, and, in particular, a friend and patron of Humphry Davy's.

The caricature has been discussed in several places. Perhaps the most exhaustive treatment is in Cohen's *Das Lachgas*, published in 1907. Cohen presents a good case for establishing that the intent of the cartoon was political castigation of Count Rumford. Reliable identification of the figures represented can be found in two separate works: *The Illustrative Description of the Genuine Works of Mr. Js. Gillray* (1830), and Thomas Wright and R. H. Evans's *Historical and Descriptive Account of the Caricatures of James Gillray* (1851). In the first work the following identifications are made:

"The coterie thus immortalized by Gillray is composed of characters who were well known at these fashionable lectures. The unfortunate gentleman experimented upon, who is exhibited as having taken too great a draught of natural philosophy for his weak stomach, is Sir J. C. H-p-s-y. The operator is understood to be either Dr. Garnet or Dr. Young. The bellows are held by Mr. Davy. . . . To his left is Count Rumford, and, in the semicircle, tracing the heads by the course of the sun, may be recognized, Mr. D'Israeli, in spectacles; Earl Gower (now Marquess of Stafford); the late Earl Stanhope; Earl Pomfret; Sir Henry Englefield; Miss Lock (now Mrs. Angerstein); Mr. Southey; Mr. Denys, in spectacles (who married the sister of Lord Pomfret), and his little boy; the back-front view of the said Lady Charlotte Denys; and Mr. Tholdal, a German gentleman, in the suite of a foreign minister. The other figures are not portraits."

The second work identifies the figures in the same way, with the exception of the operator, who is identified positively as Dr. Garnet, and the gentleman between Miss Lock and Mr. Denys, who is said to be Mr. Sotheby.

Gillray's scene is remarkably close to an actual incident described in the journal of the sprightly, keen-witted (and acid-tongued) Lady Holland. On March 22, 1800, she wrote:

"This Institution of Rumford's furnishes ridiculous stories. The other day they tried the effect of the gas, so poetically described by Beddoes; it exhilarates the spirits, distends the machine. The first subject was a corpulent middle-aged gentleman, who, after inhaling a sufficient dose, was requested to describe to the company his sensations; 'Why, I only feel stupid.' This intelligence was received amidst a burst of applause, most probably not for the novelty of the information. Sir Coxe Hippisley was the next who submitted to the operation, but the *effect* upon him was so *animating* that the ladies tittered, held up their hands, and declared themselves satisfied."

Sir John Coxe Hippisley (1748-1825) was primarily a political figure. Educated at Hertford College, Oxford, he was admitted to the Inner Temple and subsequently called to the bar in 1771. He lived in Italy intermittently from 1799 on, engaging in confidential negotiations for the British Government with the Vatican and with the Italian Government. Lord North recommended he be appointed to the East India Company (with which Sir Joseph Banks had such strong connections) and in 1786 he was made paymaster at Tanjore in India. He served there in the war of 1789 with Hyder Ali and Tippoo Sahib. His baronetcy came to him in 1796 for his negotiation of the marriage between the Duke

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of Würtemberg and the Princess Royal of England; he was made a trustee of the royal marriage settlement. Earlier he had entered Parliament, where he strongly supported Roman Catholic emancipation. After his retirement from the House of Commons in 1819, he wrote on the elimination of the use of treadmills, suggesting, instead, the use of the hand-crank mill. Sir John died in London. He was buried in Temple Church, and a tablet, with a long inscription to his memory, was erected in the Parish Church of Stone Easton, Somerset.

Sir John's connections with Davy were in three separate areas. For a long time Sir John supported the Literary Fund Society, one of the principal promoting agents for the literary institutions of Bath and Bristol. Young Davy, together with Beddoes, Southey and Coleridge, participated actively in the movement. Southey's *Annual Review*, one of the first fruits of the literary renascence, contained several of Davy's early poems. In addition, Sir John was closely connected with the first managers of the Royal Institution. The Manager's Minutes for April 20, 1799 (six weeks after the founding of the Institution) show that he presented to the library a copy of Lord Sandwich's *A Voyage round the Mediterranean*. Finally, Davy's work on agricultural chemistry (begun on the suggestion of Sir Joseph Banks) coincided again with the interests of Sir John, for he also enjoyed the vice presidency of the West of England Agricultural Society.

J. Z. FULLMER

Department of Chemistry
Newcomb College
Tulane University
New Orleans, La.

Sirs:

I should like to comment on one point brought out in the fine article on Humphry Davy by L. Pearce Williams.

The assignment of credit to Davy for the discovery of chlorine neglects the excellent work of an outstanding Swedish chemist of the 18th century, Karl Wilhelm Scheele. Granted that Davy showed the elemental nature of chlorine, still it was Scheele who had noted, isolated and determined the properties of chlorine over a quarter of a century before Davy.

In a paper published in 1774 Scheele reported his observations on the gas evolved in the reaction between manganese dioxide and hydrochloric acid. It was a remarkably complete and accurate statement of the preparation and properties of chlorine.

THEODORE PERROS

Department of Chemistry
George Washington University
Washington, D.C.

Sirs:

Professor Perros is quite right in stating that Scheele discovered chlorine, and mention should have been made of this in the article. I do think, however, that credit for the discovery of chlorine *as an element* should go to Davy. Like so many other discoveries in the history of science, Scheele's could not be properly appreciated when it was made, and it was gradually forgotten until the problem of the composition of muriatic acid emerged as one of fundamental importance to the structure of chemical theory. Davy's attack on "oxymuriatic acid" was made without knowledge of Scheele's work, and the analyses of this substance and their meaning resulted from Davy's own views on the criteria for the definition of elementary substances. Scheele produced an interesting gas; Davy put forward a new substance whose existence, he knew, must cause a rethinking of a basic axiom in chemical theory. In this difference, I believe, can be seen the valid claim for discovery by Davy.

L. PEARCE WILLIAMS

Oxford, England

Sirs:

No one can disagree with the comments in "Science and the Citizen" for February regarding the superb performance of the CERN group in bringing their 24-billion-electron-volt machine into operation with such spectacular initial performance. However, there are some errors in the data you presented for comparison with the Bevatron at the University of California.

The Bevatron accelerates a pulse of protons to 6.2 billion electron volts every 5-6 seconds (not minutes). Normal high beam intensity, regularly achieved, is now 200-300 billion particles per pulse (not 20 billion). . . .

W. W. SALSIG, JR.

Lawrence Radiation Laboratory
University of California
Berkeley, Calif.


wherever there's electronics...
there's Transitron
Within the next few years, a major portion of America's chief deterrent force will consist of solid fuel intercontinental Minuteman missiles. These missiles can be fired from underground launch silos, or railroad cars constantly on the move. Their crucial accuracy will rely in part on Transitron's semiconductors. At Transitron, more than 5,000 skilled employees work exclusively to develop high quality silicon and germanium semiconductors. In missiles, rockets, radar, atomic subs, communications, jets and thousands of other commercial and military applications — wherever there's electronics, there's Transitron, leading the field in advanced semiconductor reliability.
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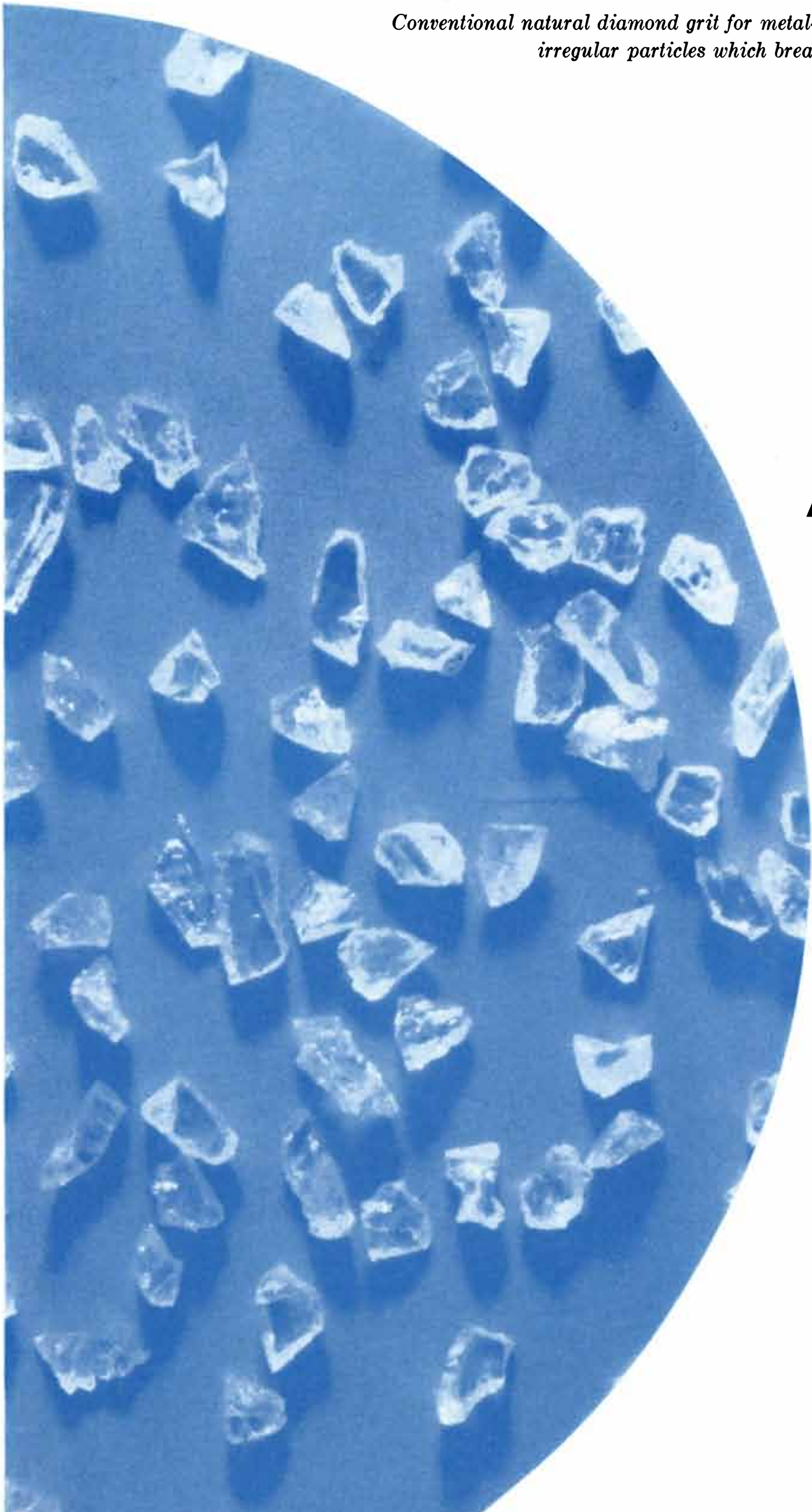
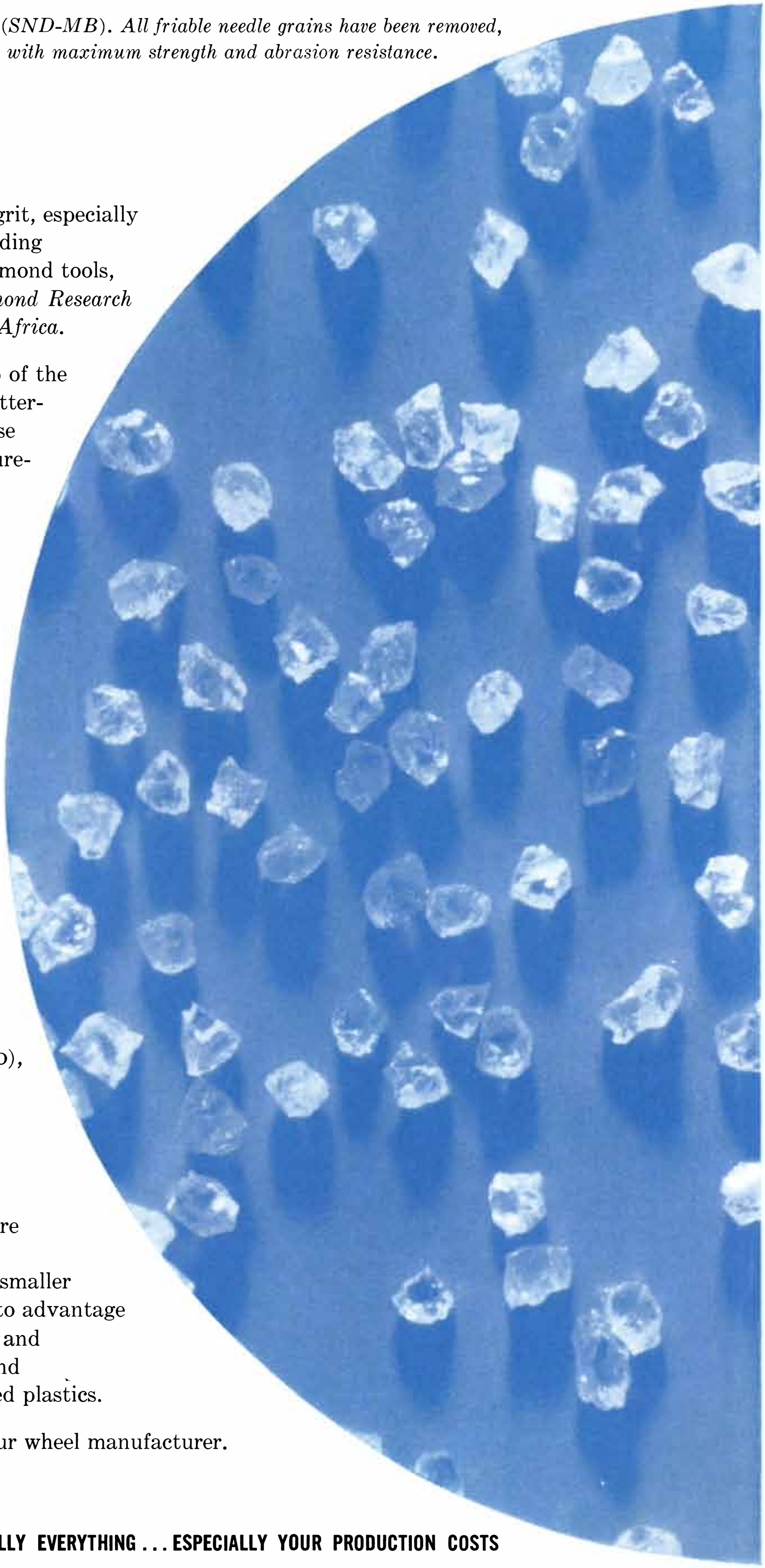
Conventional natural diamond grit for metal-bond wheels and saws. Note the friable irregular particles which break down under heavy pressure grinding.



New Selected Natural Diamond Grit (SND-MB). All friable needle grains have been removed, leaving only the blocky, cube-like grit with maximum strength and abrasion resistance.



A new type of natural diamond grit, especially suited for use in metal-bond grinding wheels and other metal-bond diamond tools, has been developed at the *Diamond Research Laboratory, Johannesburg, South Africa.*

This new natural grit is made up of the strongest, most abrasion and shatter-resistant diamond particles for use in metal matrixes. A new pressure-testing and selecting process removes friable particles from the grit. Thus, the inherent strength of the natural diamond particle is ideally presented for the heavy-duty cutting done with metal-bond wheels and saws.

The new grit has been found stronger than any diamond grit available to date. In tests with concrete, marble, and tile, the new grit permitted a 30 to 50 per cent faster cutting rate than was previously possible. Further tests are under way in actual production set-ups.

Known as SND-MB (SELECTED NATURAL DIAMOND-METAL BOND), the new grit will be offered in a production range of mesh sizes from Tyler screen 16 to 325 mesh at present. The larger sizes will be used in metal-bond saws and thin-wall core drills, which are used in cutting concrete, stone and other rugged materials. The smaller cube-like diamonds will be used to advantage in metal-bond wheels for cutting and grinding of materials like glass and ultra-hard ceramics and reinforced plastics.

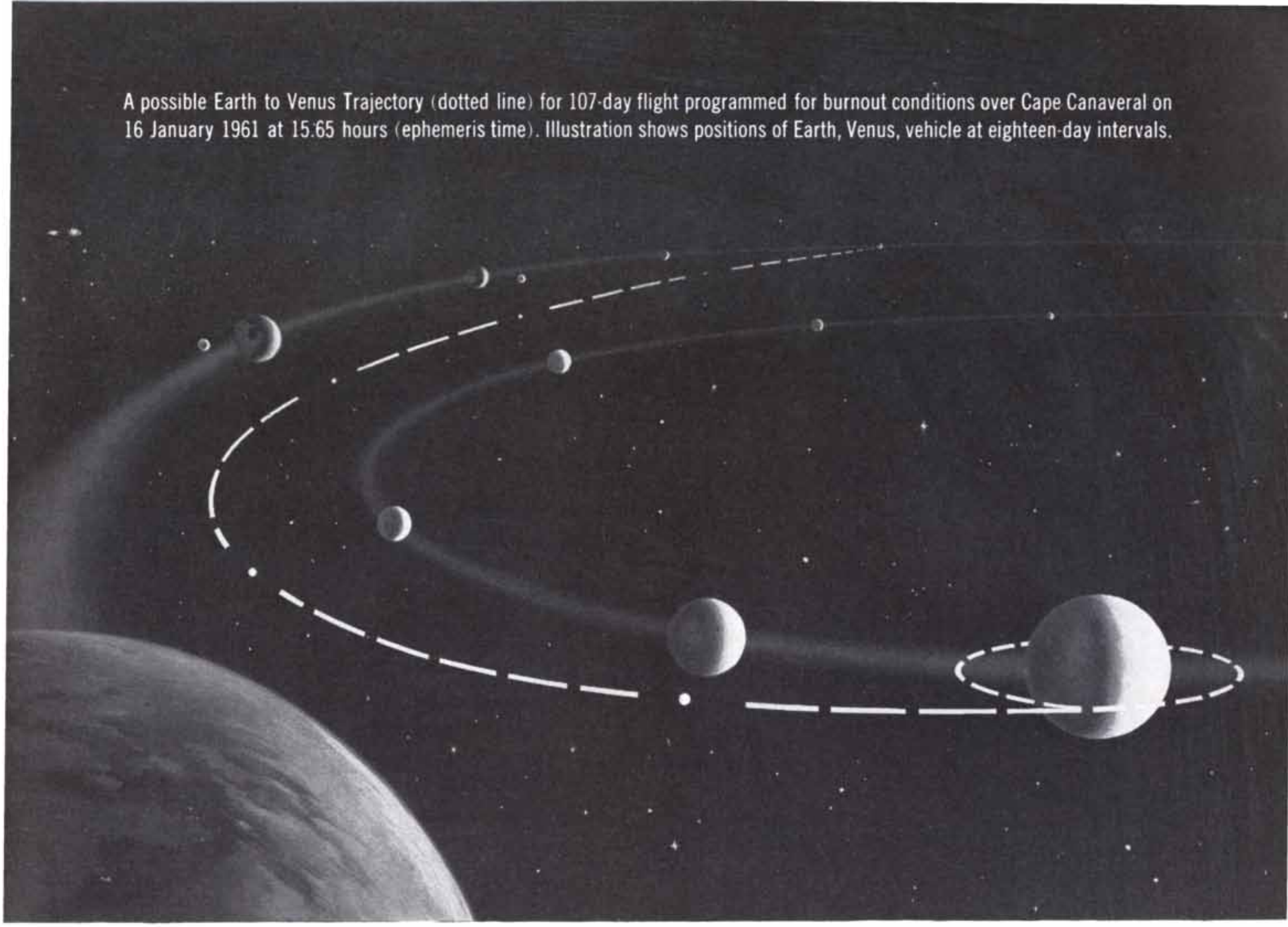
SND-MB is now available to your wheel manufacturer. Ask him about it.

INDUSTRIAL DIAMONDS CUT PRACTICALLY EVERYTHING ... ESPECIALLY YOUR PRODUCTION COSTS

supporting your computing investment...

THE INDUSTRY'S MOST EXTENSIVE LINE OF ANALOG COMPUTING COMPONENTS

EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*



A possible Earth to Venus Trajectory (dotted line) for 107-day flight programmed for burnout conditions over Cape Canaveral on 16 January 1961 at 15:65 hours (ephemeris time). Illustration shows positions of Earth, Venus, vehicle at eighteen-day intervals.

MISSILE AND SPACE VEHICLE DEPARTMENT

...center for missile and space technology research and development at General Electric

Progress in defining space trajectories

Astrodynamicists at General Electric's Missile and Space Vehicle Department are currently mapping space . . . determining trajectories for flights from the Earth to other bodies of our solar system.

Under these funded studies, MSVD has recently completed a program of error analysis of trajectories to the Moon involving the four-body gravitational system, as well as a study of flight paths to Venus.

From consideration of the total gravitational field, specific space missions are computed when date of departure, trip time and launch site are specified. The exact launch burnout conditions are determined for the time of day which maximizes the additional boost caused by the Earth's rotation. Employing new techniques, MSVD scientists have made these determinations with as few as three corrective computer runs. These methods also can be applied to flights to other planets of our solar system.

In addition, the Department is developing methods to determine orbital parameters of earth satellites using only Doppler information. This MSVD experience in tracking techniques and computer programs permitted analysis of the Russian Lunik III trajectory.

For more information about MSVD's progress in all phases of space technology, write for the new Department Bulletin, Section 160-92A, General Electric Co., Missile and Space Vehicle Department, Philadelphia 1, Penna.

GENERAL ELECTRIC

MISSILE AND SPACE VEHICLE DEPARTMENT

A Department of the Defense Electronics Division

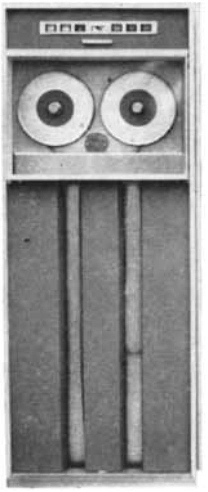
Scientists and Engineers interested in career opportunities in Space Technology, contact Mr. T. H. Sebring, Dept. 160, MSVD

The advantages of vacuum capstans in the high-speed manipulation of magnetic tape

by DR. RICHARD B. LAWRANCE, *Manager*
Magnetic Tape Transport Department, Minneapolis-Honeywell, Datamatic Division

The magnetic tape units used with the Honeywell 800 and Honeywell 400 electronic data processing systems have a clean, unencumbered appearance that has more than aesthetic significance. In addition to providing high information processing rates, these tape units embody unique design features that yield in-service tape system reliability of an exceptionally high order. The tape is handled so gently that we are the first in the data processing industry to guarantee to replace any tapes worn out or damaged by our mechanisms.

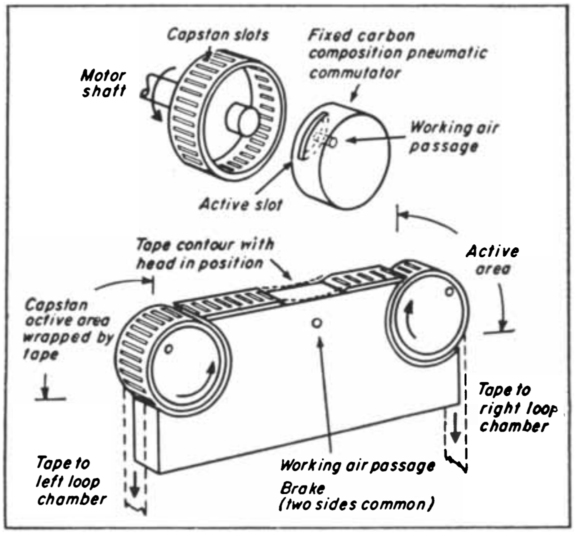
A quick look at the basic performance specifications of these units is a logical prelude to a discussion of their design. The instantaneous read-write data transfer rate is 96,000 four-bit decimal digits per second. This is achieved through the use of ¾-inch wide magnetic tape moving at 120 inches per second and recorded with eight parallel information channels at a density of 397 bits per inch. Two additional parallel channels are recorded with a clock signal and with parity information, respectively.



Writing takes place with the tape moving in the forward direction; reading, with the tape moving in either direction. Rewind speed is 360 inches per second.

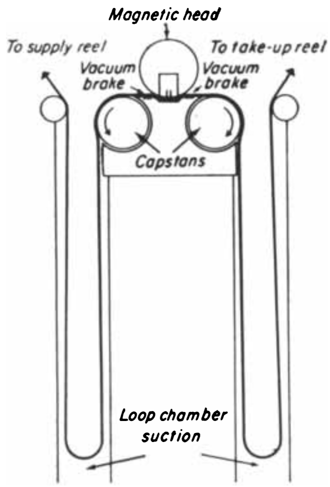
Vacuum Capstan Method of Tape Transport

The most distinctive design feature of Honeywell magnetic tape units is the use of vacuum capstans to produce and control the motion of the tape past the read-write head. The vacuum capstan assembly and details of one capstan are shown schematically in the figure below.



The two capstans rotate continuously in opposite directions, with a surface speed of 120 inches per second. Each capstan has a working air passage in its fixed pneumatic commutator, by means of which suction or compressed air can be communicated via the capstan slots to the underside of the tape. The active area is the 90-degree arc wrapped by the tape. For driving tape, suction of one-half atmosphere is supplied to the working air passage of the appropriate capstan causing the tape to engage to the capstan surface and be driven without further slipping as long as suction is provided. Typical figures for the acceleration process are acceleration to full speed, subsequently constant, in less than three milliseconds, with approximately one-eighth inch acceleration distance.

A Cushion of Air Protects the Tape



The inactive capstan is supplied with compressed air of approximately two psi (gauge) so that the tape rides over it on a very-low-friction air bearing.

The left and right portions of the brake (lying between the normal head location and the two capstans) are internally connected to a common working air passage that is supplied appropriately with medium suction, strong suction or air at atmospheric pressure. When the tape is at rest, it is held to the brake by medium suction and both capstans, being inactive, are disengaged from the tape by flowing compressed air. The design of the capstan assembly provides unbroken guiding for both edges of the tape.

The configuration of a mounted tape is shown in the schematic above. The loop chambers which control tape tension and give additional edge guiding are relatively conventional, although the method of controlling the supply and take-up reels is not.

Minimum Contact with Oxide Surface of Tape

A feature of greatest importance is the fact that the information-bearing oxide surface of the tape never comes in contact with any fixed or moving parts of the mechanism with the exception of the magnetic head. By preventing all unnecessary rubbing contact and by avoiding all sources of rolling pressure contact, a new order of tape longevity is achieved.

Extensive measurements have been made of head wear on Honeywell's operating DATAmatic 1000 tape mechanisms which have been in service for several years. These units use the same tape and head configurations as Honeywell 800 and Honeywell 400 tape units. The average loss of material from the magnetic head is quite uniform and unexpectedly low, amounting to 0.0001 inch per year (two-shift operation). Headwear is concentrated in a small area whereas wear of the tape is distributed over its entire surface; consequently, the observed small figure for wear of the head is very reassuring as concerns tape life. A part of this favorable performance is undoubtedly due to the fact that no pressure pads are required for adequate contact between tape and head.

Tape Rewinding at High Speed

The magnetic head, which is shown in information transfer position in the figure above, is eccentrically pivoted and rotates automatically out of contact with the tape when either computer-controlled rewinding or manually controlled tape changing is in process. Head wear and tape oxide wear during rewinding are thus eliminated.

All tape rewinding takes place at 360 inches per second, regardless of the amount of tape to be rewound. The tape rewind speed is controlled by the left-hand capstan whose motor speed is automatically tripled to 3600 rpm. The tape remains in both vacuum loop chambers and accordingly receives the benefit of controlled tension and complete edge guiding. The object of a rewind instruction is to move the entire magnetically active portion of the tape onto the left-hand reel, leaving the head positioned over the beginning clear leader which is made of heavier gauge Mylar permanently welded to the magnetic portion of the tape. Upon rewinding past this junction, as sensed by a photoelectric arrangement, the mechanism speed shifts down from 360 to 120 ips. This latter speed endures for a fraction of a second and the tape is then stopped in normal fashion by pneumatic disengagement from the capstan and engagement to the brake. The head, which has been automatically moved out of contact with the tape during rewind, now rotates back into contact with the tape, and through the closing of a switch, signals the computer that the tape unit is again ready for instructions.

Tape Changing

When it is desired to change tape, a centrally located manual switch on the control panel is thrown to the Tape Change position. If the tape is not already rewound, a rewind is automatically effected as the first part of the tape change cycle. The tape then proceeds a few feet further down the clear leader until a short, centrally placed slot in the leader is sensed by an orifice and pressure switch associated with the upper end of the right hand loop chamber. The pressure transient caused by momentary venting through the slot is sensed, the loop chamber vacuum and capstan vacuum are turned off, and the tape is stopped ready for removal with only two or three turns remaining to be manually unwound from the right-hand reel.

Since a partial vacuum (about one-half atmosphere absolute) is provided within the equipment for use in the clutch, it is quite natural to use this vacuum for holding the reels onto the reel mounts. Advantageous features include the lack of metal-to-metal contact between reel and reel mount, the fact that the reel hub is not subjected to hoop stress, and the provision of a large flat reference surface on the reel mount, which insures wobble-free rotation and accurate positioning of the reel relative to the back reference surface.

Suction is similarly used for attaching the free end of the tape leader to the right-hand reel whenever a tape is loaded on the machine, as well as for initially attaching the inner end of the tape to the left-hand supply reel. It is worth mentioning that vacuum attachment of the tape to the reel makes it unnecessary to perforate the reel flanges for finer access to the hub during loading. The unperforated flanges are helpful in protecting tape from dirt and mechanical damage while in storage or during handling. Hazard to the operator is also reduced materially.

One net result of these design features is a tape changing procedure that is simple, straightforward and essentially foolproof. A complete tape changing operation requires less than 30 seconds of the operator's time.

Why vacuum capstans are superior to pinch rollers

The advantages of using the pneumatic principle as opposed to the pinch roller principle can be readily appreciated by experienced users of electronic data processing systems.

1. Only the mass of the tape itself requires acceleration, thus minimizing the forces transmitted to and by the tape.
2. The tape accelerating forces are distributed over a typically fifteen-fold larger area, whose length may equal or exceed one-fourth of the capstan circumference. The vacuum capstan can be made conveniently large since it does not accelerate.
3. Symmetrical engagement of the tape to capstan or brake is automatically achieved by symmetrical design of pneumatic passages. Engagement always commences along tape center line, minimizing skew. Transverse variation in tape thickness does not add to skew.
4. Free from dirt embossing. No material body need touch the oxide surface of the tape (although usually the magnetic head is made to do so).
5. No restriction on interval between successive commands. Moving parts of mechanism are offset from tape path, are completely covered, and cannot touch tape. No danger to tape from tug-of-war.
6. Air lubrication of tape is a built-in feature.

For additional information

These and additional features and details of the fail-safe Honeywell 800 tape mechanism are discussed in reprints of a paper presented before the Eastern Joint Computer Conference. Also available are descriptive brochures on Honeywell 400 and Honeywell 800 transistorized data processing systems. If you would like copies of any or all of these documents, write: Dept. SB, Minneapolis-Honeywell, Datamatic Division, Wellesley Hills 81, Mass.

HONEYWELL 800

75th YEAR PIONEERING THE FUTURE

HONEYWELL 400

Honeywell

Electronic Data Processing

50 AND 100 YEARS AGO

AUGUST, 1910: "By his wonderful high flight at Atlantic City on July 9th, Walter Brookins broke by a wide margin all previous records of this kind and brought to the Wrights new laurels by showing the splendid climbing ability of their biplane. After a steady ascent of 53 minutes in circles, he reached a height of 6,175 feet. His fuel gave out, and he was obliged to descend in gliding flight from this tremendous altitude. This he did successfully in 10 minutes at a rapid rate. He was chilled through despite warm clothing. His flight won him a $5,000 prize, and he broke by 1,236 feet his former record made at Indianapolis and by 1,560 feet Latham's European record."

"It is gratifying to learn that twice during the past three months the Bureau of Public Health of Philadelphia has been able to report that no deaths occurred from typhoid fever in a whole week. During the month of June there were but 13 deaths from this scourge as compared with 669 deaths during the corresponding month of 1906. Philadelphia has reason to be proud of the results gained through the adoption of filtered water, the deaths from typhoid having decreased steadily from 72.4 per 100,000 in 1906 to 21.2 per 100,000 in 1909. The indications are that the present year will show a still more striking fall in the death rate of this disease."

"Four years ago Mr. Burbank received from North Africa a poppy plant of strange species. He crossed it with the 'Shirley' poppy and the tulip. The last result is a new variety of the Papaver family, but longer, brighter and possessing greater contrasts of color. He has also just matured an evening primrose, pure white and five inches in width, nearly double the diameter of any known species. These are the horticulturist's latest productions."

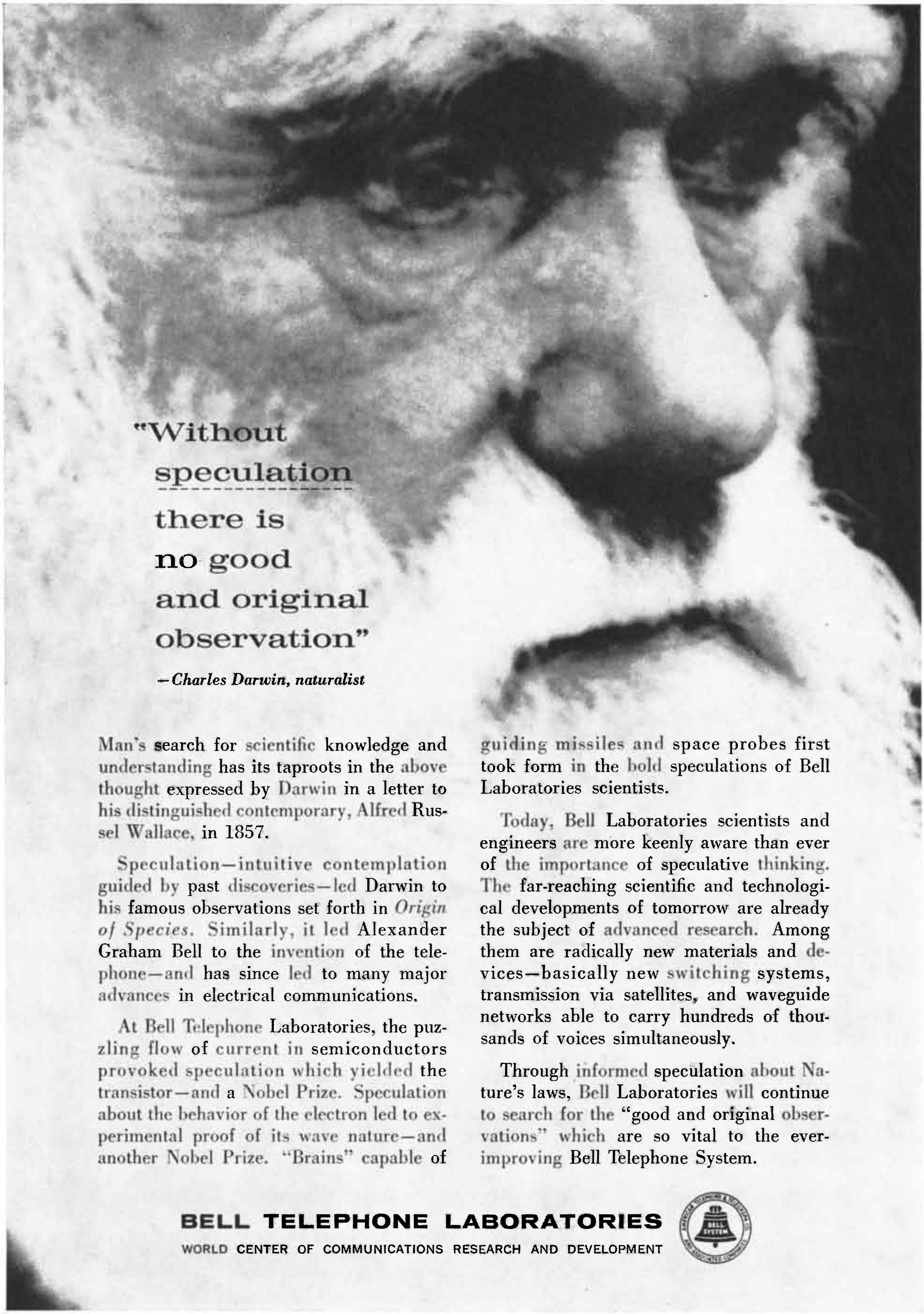
"Probably the most important and difficult construction executed by the corps of engineers of the United States Army is the Panama Canal. When the task was committed to their care, there was serious doubt whether even this body of men could succeed where so many had failed. When the chief engineer, Col. Goethals, announced that the canal would be ready for opening by January, 1915, the statement was received with considerable incredulity. But strict discipline, well-thought-out organization and high professional ability, have proved more than equal to the task; and, if recent progress is an indication of future accomplishment, the Canal will surely be completed by January 1st, 1915."

"When she died this month at the age of 90, Florence Nightingale had lived to see the adoption of her hospital methods by most of the world's armies, methods which have undoubtedly brought about a most salutary improvement in the conditions of the wounded in the field of battle. Her work dates from the beginning of the Crimean War, a conflict which was discreditably mismanaged both from a military and from a medical standpoint. With 40 companions, Miss Nightingale left London for Turkey, where she worked wonders. Totally disregarding military red tape, she reorganized the entire system of military hospital management, brought order out of chaos and saved thousands of lives. What is more, she gave us our modern system of hospital management. During her whole life, she advocated the systematic education of nurses, and with funds contributed after the Crimean War she established an institution for the training of nurses."

AUGUST, 1860: "The grand celebration of the successful laying of the Atlantic Telegraph Cable, two years ago, can never be forgotten, more especially as the whole affair afterwards turned out to be premature. In connection with this subject, although it was given out that Queen Victoria sent a message to President Buchanan by the cable, and that he in return had sent one to the royal lady by the same source, still many persons have not only doubted that such messages were ever sent, but a pamphlet was published last year in Boston containing very powerful arguments to prove that these messages came and went by a *steamship*, and that the whole of the reported cable telegraph was 'bogus.' This question has at last been fairly investigated and settled in England in favor of the Atlantic Cable having really exhibited some signs of speech."

"To give the Americans an opportunity of witnessing her sailing qualities, the directors of the *Great Eastern* steamship sent her on a short excursion down the coast to Cape May. She left New York on Monday afternoon, July 30th, and arrived at Cape May Tuesday morning. Spending the day at Cape May, she returned Tuesday night, arriving at New York Wednesday morning. She had about 2,000 passengers. The trip, so far as the sailing qualities of the ship are concerned, was successful. The navigation of the vessel by the officers, the discipline of the crew and the working of the huge oscillators that drive the paddle wheels, as well as of the four smaller engines that propel the screw, were all admirable. But the arrangements for the care and comfort of the passengers were unsatisfactory. Notwithstanding the impossibility of getting meals served in the style of our Fifth Avenue Hotel, and the absence of such conveniences for washing as are found in our modern city houses, we returned more than ever convinced that the *Great Eastern* is the eighth wonder of the world."

"It is stated that, during this season, Mr. McCormick has sold 4,000 reapers. Therefore, the gross receipts of his sales this year will reach $600,000, out of which he will realize a moderate fortune, say $100,000. McCormick is undoubtedly one of the wealthiest men in the North-west; and he not only has an interest in reapers, but he is a liberal supporter of religion, having not long since given $100,000 to endow the Presbyterian Theological Seminary, at Chicago. Apparently he is endeavoring to mix politics with these affairs, for, according to a recent announcement, he hoped to run the race for the mayoralty at Chicago with the accomplished 'Long John' Wentworth, but owing to an unexpected shuffle on the boards, the great reaper man was cut down. It is reported that McCormick did not quite like the manner in which he had been left out of the political race; and he straightway bought out the Chicago *Herald* for $5,000, and afterwards purchased up claims against the Chicago *Times,* whereby he obtained a summary control over it. Thus equipped with the power of two newspapers combined, and an exchequer overflowing with the profits of his valuable patents, there is no knowing what he may yet attain."


"Without speculation there is no good and original observation"
—Charles Darwin, naturalist
Man's search for scientific knowledge and understanding has its taproots in the above thought expressed by Darwin in a letter to his distinguished contemporary, Alfred Russel Wallace, in 1857.
Speculation—intuitive contemplation guided by past discoveries—led Darwin to his famous observations set forth in Origin of Species. Similarly, it led Alexander Graham Bell to the invention of the telephone—and has since led to many major advances in electrical communications.
At Bell Telephone Laboratories, the puzzling flow of current in semiconductors provoked speculation which yielded the transistor—and a Nobel Prize. Speculation about the behavior of the electron led to experimental proof of its wave nature—and another Nobel Prize. "Brains" capable of guiding missiles and space probes first took form in the bold speculations of Bell Laboratories scientists.
Today, Bell Laboratories scientists and engineers are more keenly aware than ever of the importance of speculative thinking. The far-reaching scientific and technological developments of tomorrow are already the subject of advanced research. Among them are radically new materials and devices—basically new switching systems, transmission via satellites, and waveguide networks able to carry hundreds of thousands of voices simultaneously.
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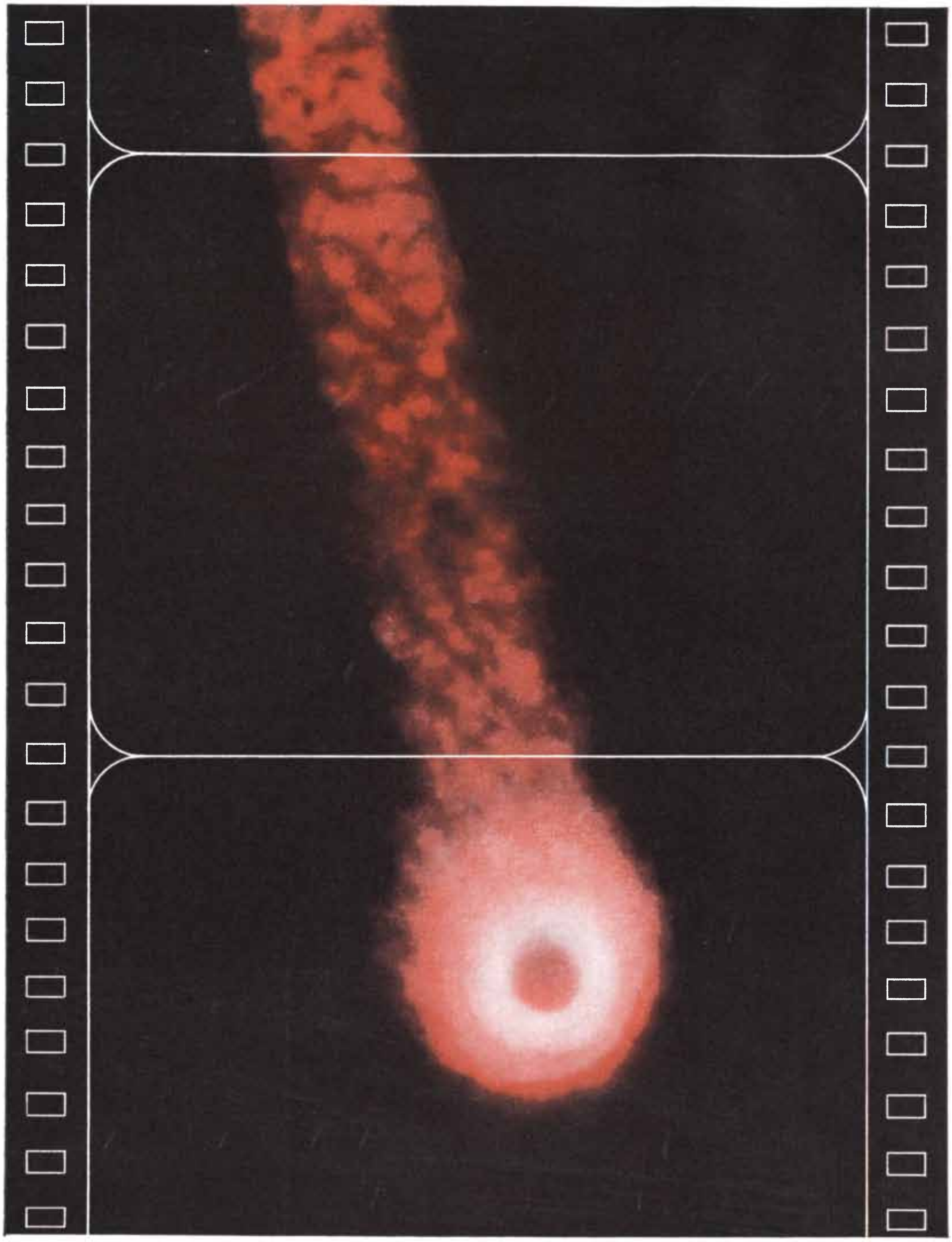

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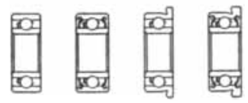

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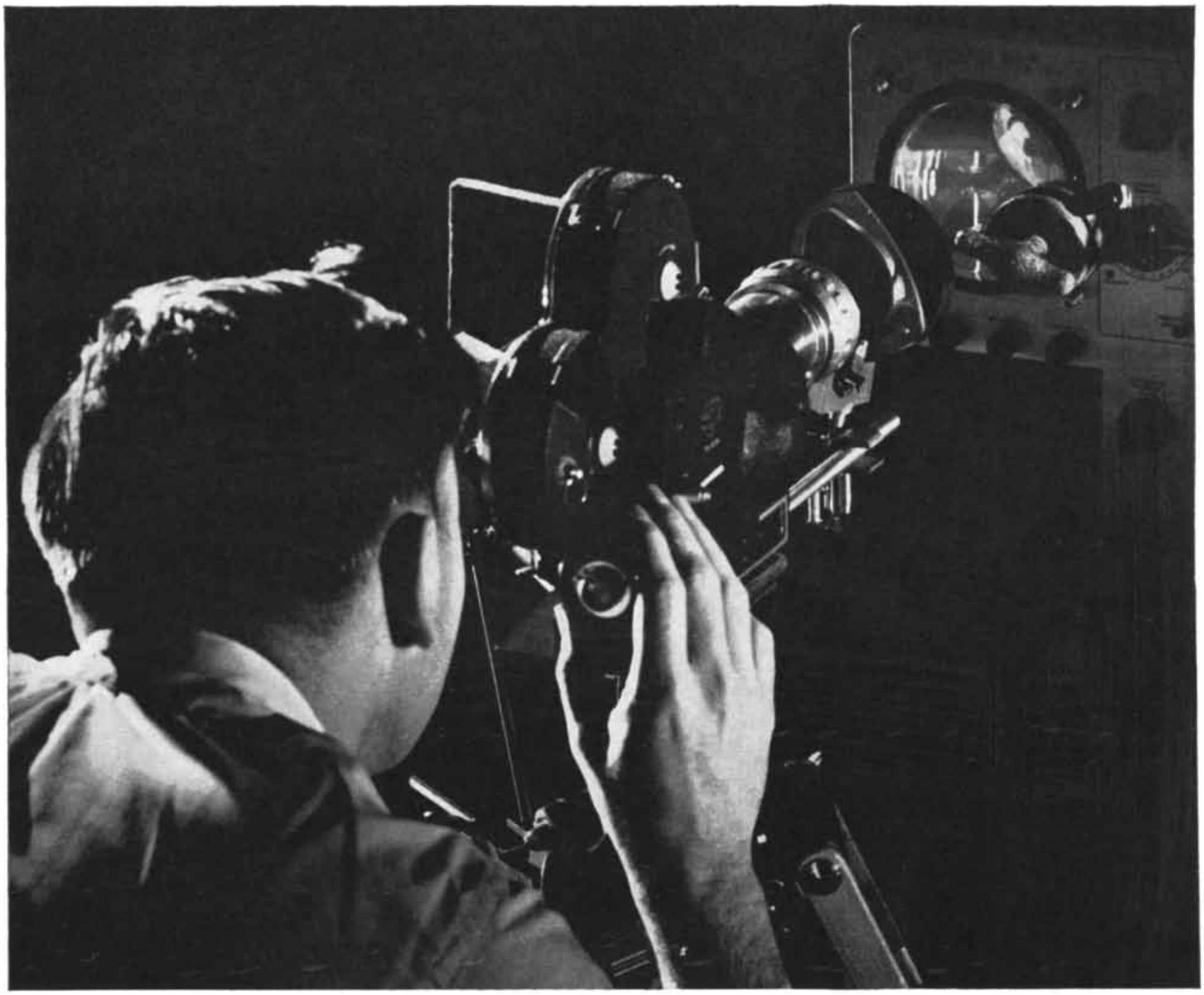

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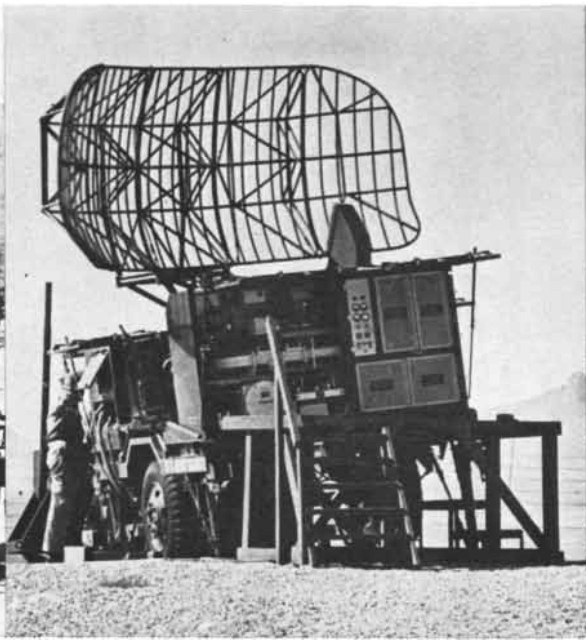

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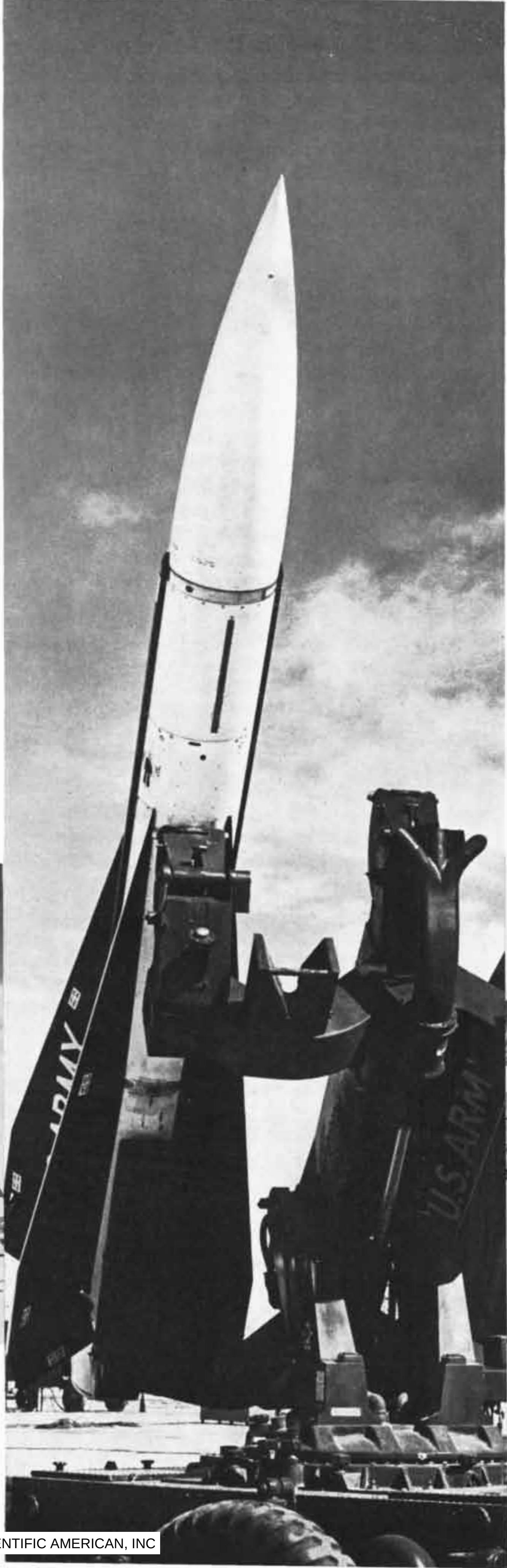

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THE AUTHORS

JOHN P. CAMPBELL ("Vertical-Takeoff Aircraft") is head of the Dynamic Stability Branch of the Langley Research Center of the National Aeronautics and Space Administration. He was born in Scottsboro, Ala., in 1917 and received his bachelor's degree in aeronautical engineering from Auburn University in 1939. He joined the National Advisory Committee for Aeronautics in the same year, and since then has been engaged in research with that organization and its successor, the N.A.S.A.

VON R. ESHLEMAN and ALLEN M. PETERSON ("Radar Astronomy") are both associate professors of electrical engineering at the Radioscience Laboratory of Stanford University. Eshleman, whose special fields are radio communication, radar astronomy and astronautics, was born in Ohio in 1924 and served in the Navy from 1943 to 1946. He acquired his bachelor's degree at George Washington University in 1949, and his M.S. and Ph.D. at Stanford in 1950 and 1952 respectively. For the past six years he has been in charge of research contracts between the Air Force and Stanford for studies of meteor ionization-trails and their application to radio communication. The equipment used in this research is the basis of some of the studies described in the present article. Peterson, a native of California, was born in 1922. He acquired his degrees at Stanford, obtaining his Ph.D. in 1952. He has been a staff member of the Radioscience Laboratory since 1947, and is at present head of the Communication and Propagation Laboratory of the Stanford Research Institute. During the International Geophysical Year he was a member of the Aurora and Airglow Panel and consultant to the Ionospheric Physics Panel, whose responsibilities included planning and co-ordinating research programs in upper-atmosphere physics and related areas.

OLIVER G. SELFRIDGE and ULRIC NEISSER ("Pattern Recognition by Machine") are, respectively, a member of the staff at the Lincoln Laboratory of the Massachusetts Institute of Technology, and assistant professor of psychology at Brandeis University. Selfridge was born in London 34 years ago, and acquired his bachelor's degree in mathematics at M.I.T. in 1945. He pursued graduate work in mathematics there from 1947 to 1950, studied electronic countermeasures at Fort Monmouth in New Jersey for two years and then joined Lincoln Laboratory, where, he says, "my interests in communications techniques and information theory were soon supplemented by an interest in pattern recognition and other aspects of artificial intelligence." Neisser, born in Germany in 1928, took his B.A. in psychology at Harvard University in 1950, his M.A. at Swarthmore College in 1952 and his Ph.D. at Harvard in 1956. He held a postdoctoral fellowship from the National Science Foundation from 1955 to 1957, and then joined the faculty of Brandeis. He was a member of the summer research staff at Lincoln Laboratory in 1958 and 1959, and he is currently a consultant.

WILLARD BASCOM ("Beaches") is technical director of the Mohole project for the AMSOC Committee of the National Academy of Sciences, which he joined as a staff member in 1954. From 1945 to 1954 he studied waves and beaches as a research engineer for the University of California, first at Berkeley and then at the Scripps Institution of Oceanography. He has been a consultant to the Navy on amphibious warfare and has lectured on related subjects to Naval postgraduate classes in oceanography. This is his third article for SCIENTIFIC AMERICAN. His first, entitled "The Mohole," appeared in April, 1959; his second, "Ocean Waves," in August, 1959.

WERNER R. LOEWENSTEIN ("Biological Transducers") is associate professor on the Faculty of Medicine at Columbia University. Born in Germany and raised in Chile, he decided at the age of 19 to become a neurophysiologist. He obtained his doctorate in physiological science at the University of Chile in 1950, and came to the U. S. in 1953 to work at Johns Hopkins University and at the University of California at Los Angeles. After further research at the University of Chile in 1955, he returned to take up his present position at Columbia, where he has worked principally on nerve-impulse initiation.

SIDNEY W. MINTZ ("Peasant Markets") is associate professor of anthropology at Yale University. He acquired his B.A. in psychology at Brooklyn College in 1943, served three years with the Air Force and took his Ph.D. in anthropology at Columbia University in 1951. He has done field work in Puerto Rico, Jamaica and Haiti. Mintz has been at Yale since 1951, where he is also a Fellow of Saybrook College and editor of the Yale University Press's *Caribbean Series*. He recently published the life history of a sugar-cane worker in Puerto Rico entitled *Worker in the Cane*.

J. D. BERNAL ("The Structure of Liquids") has since 1937 held the chair of physics at Birkbeck College of the University of London. Born in Ireland and educated in England, he studied physics at the University of Cambridge, began his research work under Sir William Bragg, and later lectured at Cambridge, where he was assistant director of research in crystallography. He has done most of his research on the structures of both simple and complex substances, and is now directing a team of workers investigating the structure of proteins, liquids, viruses, magnetic materials and corrosion products. During the war he worked for the Ministry of Home Security on protection against bomb damage, and was later adviser to the Air Ministry and scientific adviser to the Chief of Combined Operations. He is a Fellow of the Royal Society, which awarded him a Royal Medal in 1945, and a member of the science academies of six other countries. He is also vice president of the World Federation of Scientific Workers.

KARL MARAMOROSCH ("Friendly Viruses") is a member of the faculty of the Rockefeller Institute. He was born in Vienna, and received his early training in Poland and Romania. He came to the U. S. from Sweden in 1947, acquired his Ph.D. at Columbia University in 1949 and then joined the Rockefeller Institute. For his demonstration of virus multiplication in aster leaf-hoppers [see "A Versatile Virus," by Karl Maramorosch; SCIENTIFIC AMERICAN, June, 1953] the New York Academy of Sciences awarded Maramorosch the A. Cressy Morrison prize. In 1958 he received the American Association for the Advancement of Science Campbell Prize and Medal for his work on plant-virus strains in an insect vector. His latest assignment has taken him to the Philippines, where he is working on a coconut-palm disease at the request of the United Nations Food and Agricultural Organization.

GERALD HOLTON, who reviews Max Caspar's *Kepler* in this issue, is professor of physics at Harvard University and editor-in-chief of *Daedalus,* the journal of the American Academy of Arts and Sciences. At present he is on leave of absence from Harvard and is doing research in high-pressure physics at the Centre National de la Recherche Scientifique near Paris.

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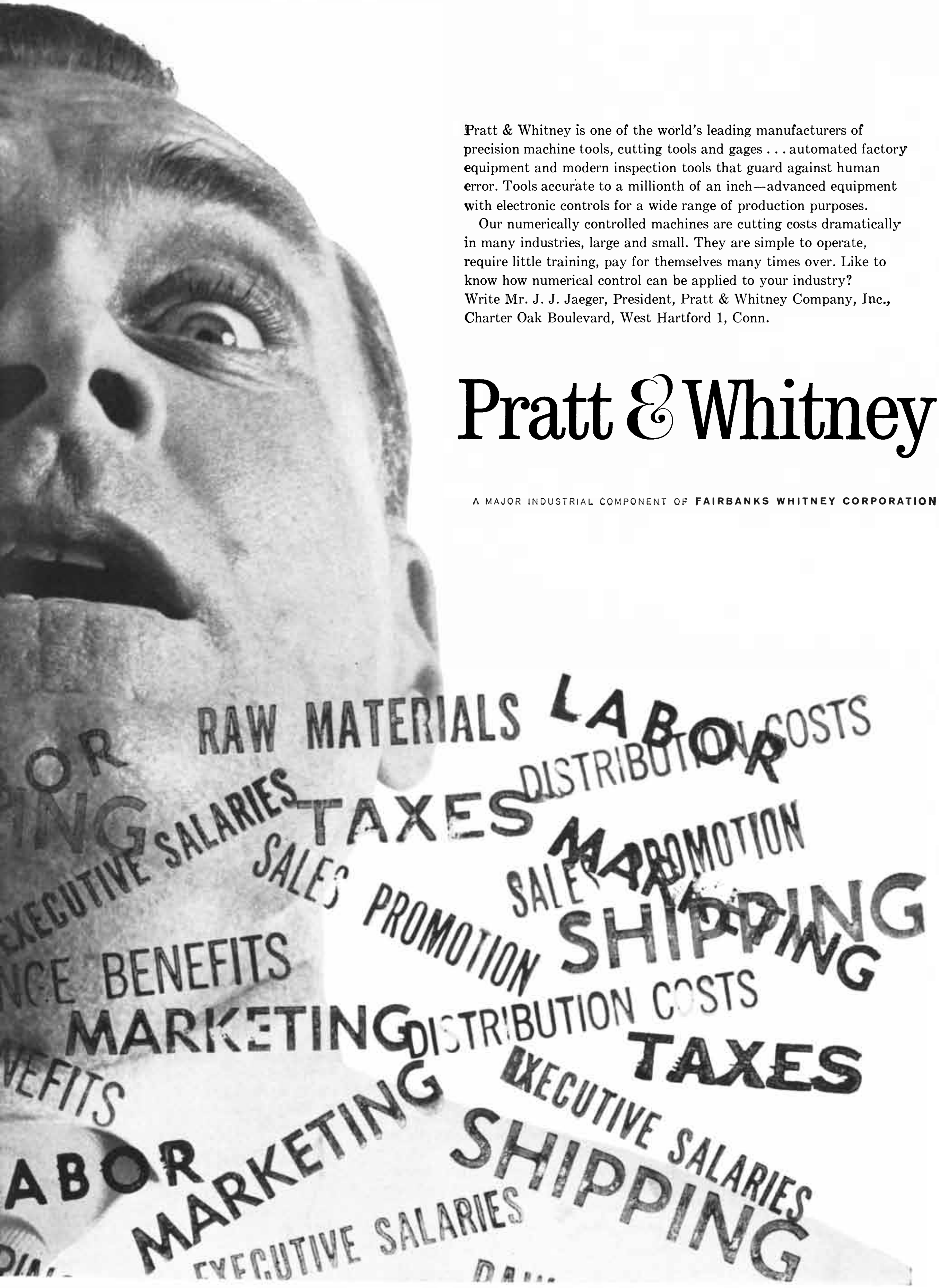

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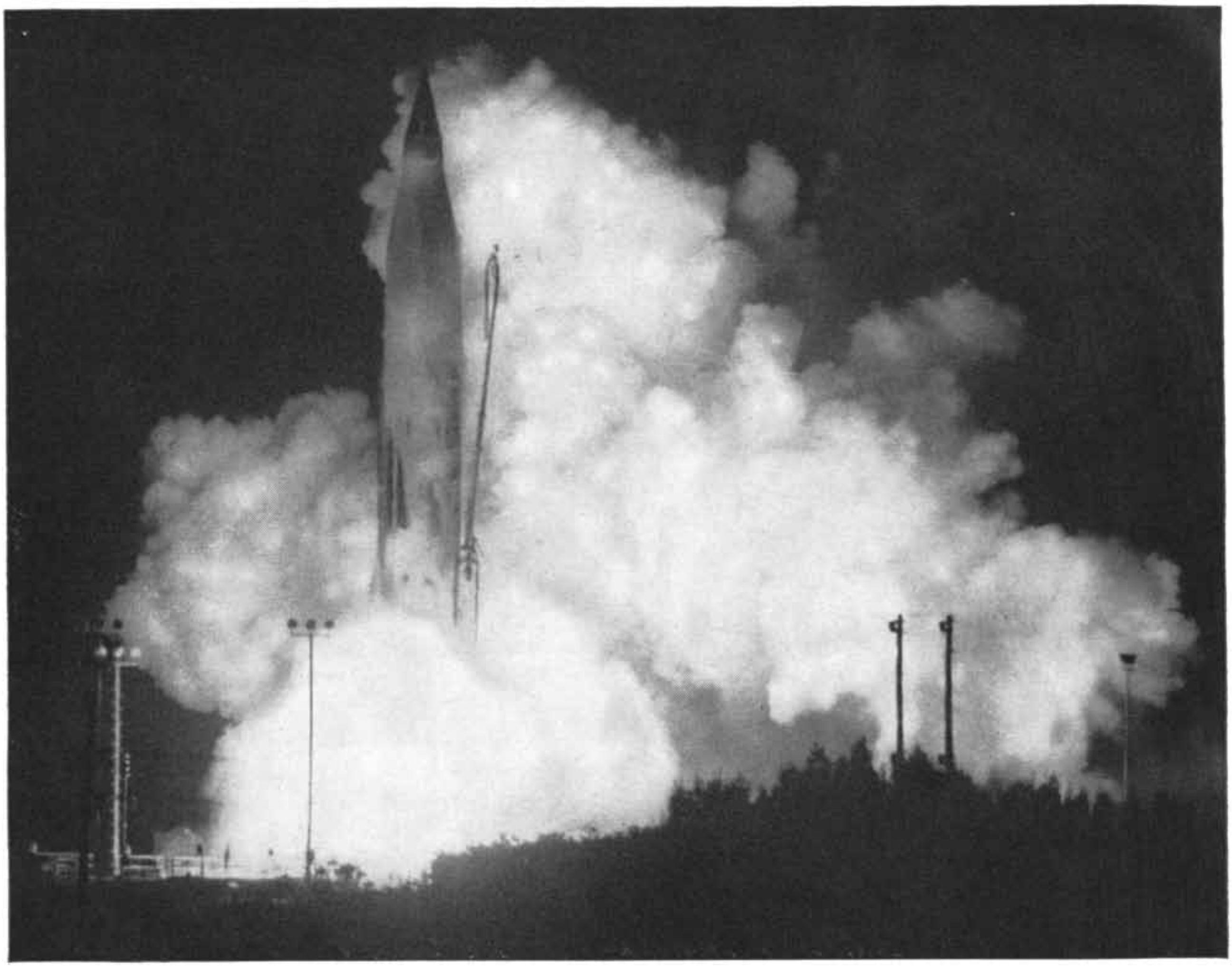

Record breaking Atlas missile billows flame and vapor as she launches 4¼-ton satellite into orbit. Constructed of Type 301 Nickel Stainless Steel, Atlas is built by Convair (Astronautics) Division of General Dynamics Corporation. *U.S. Air Force photo*

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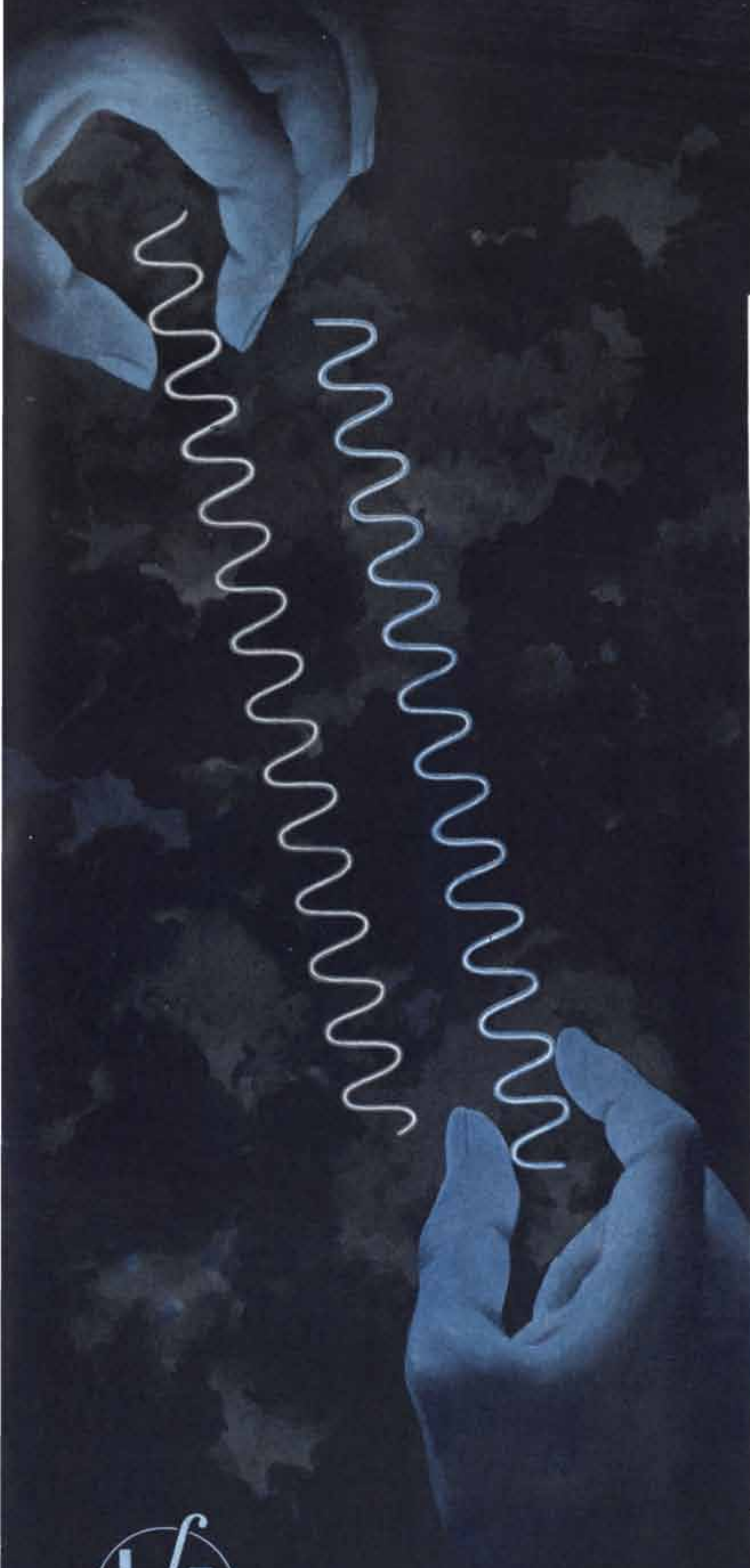
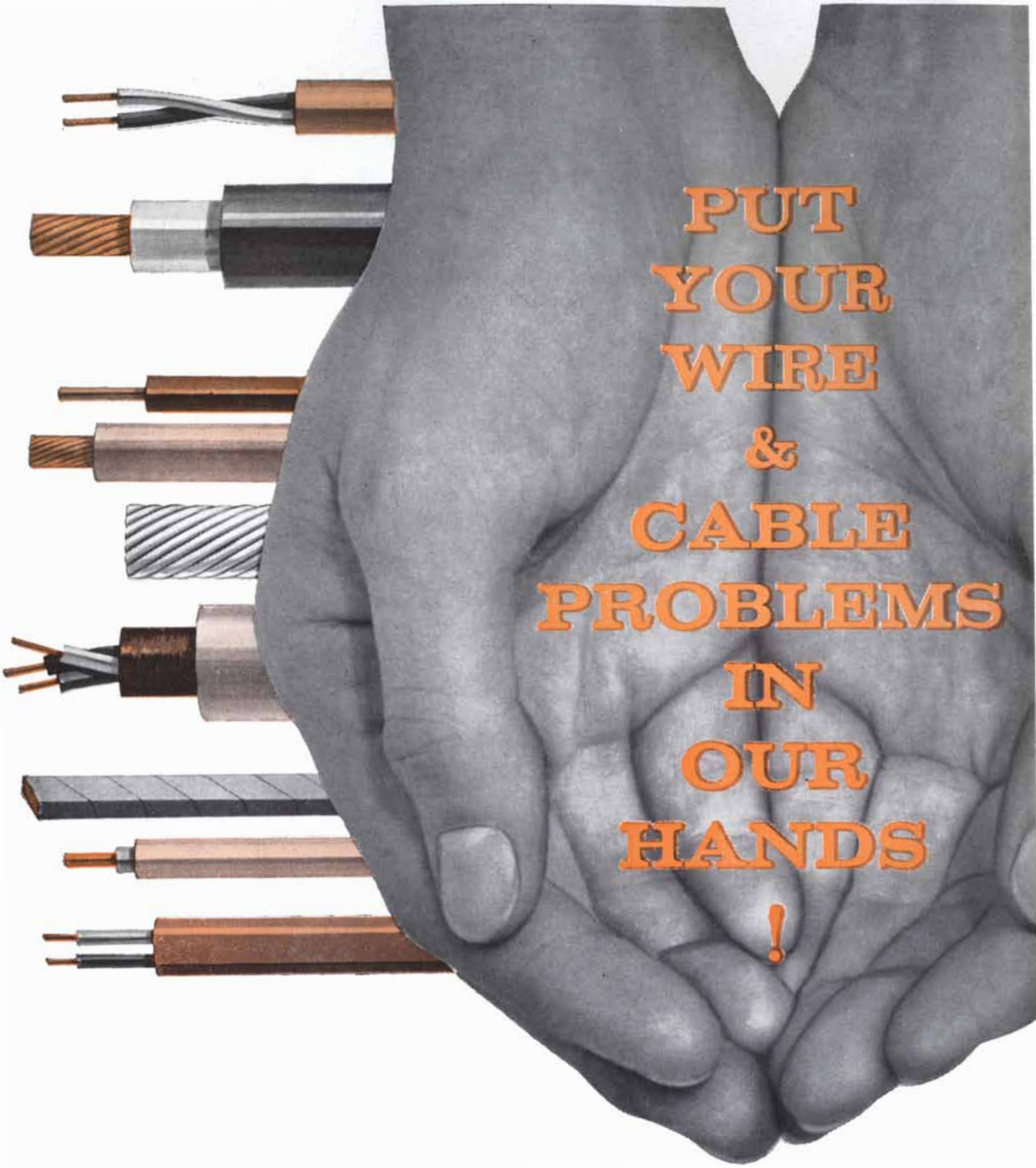




To help conquer extremes . . . from known to

Established 1845 SCIENTIFIC AMERICAN August, 1960 Volume 203 Number 2

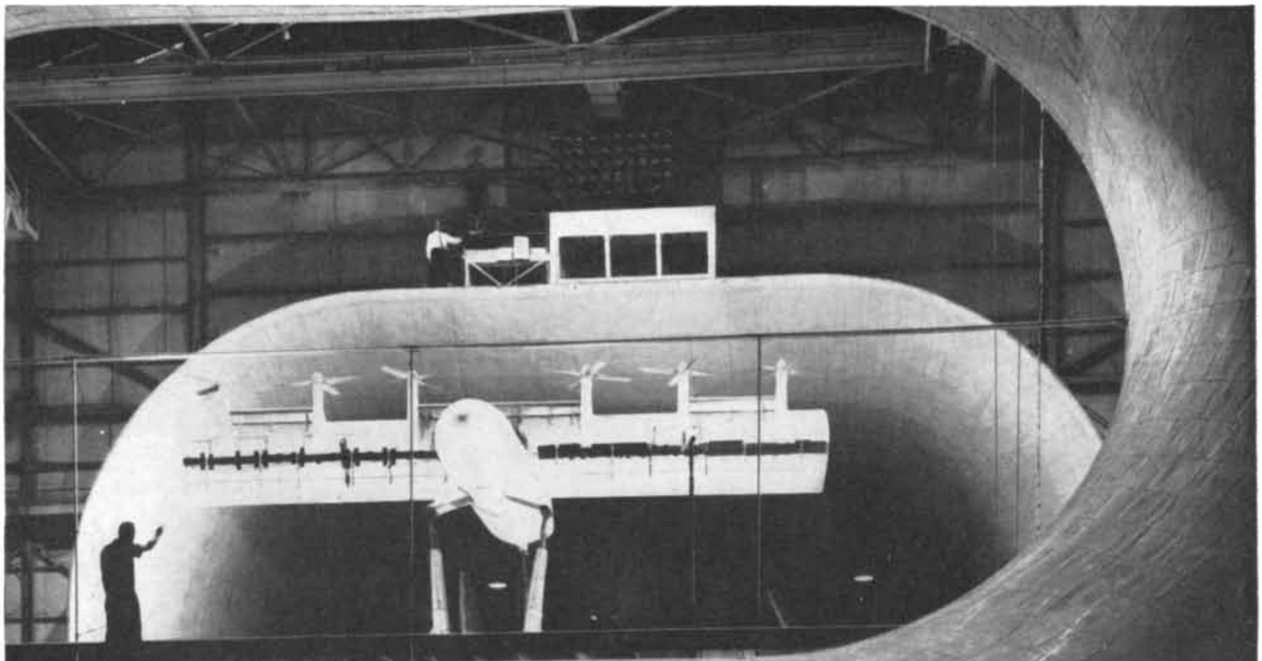
Vertical-Takeoff Aircraft

Turboprop and turbojet engines make possible a large variety of airplanes that can take off and land vertically. Many designs are being tested, and a few are going into production

by John P. Campbell

Advances in aviation have now made it possible for a traveler to spend as much time getting to and from airports as in flying halfway across the country. The situation is bound to get worse. The same airplanes that are eating up distance faster and faster need more and more room on the ground to take off and land. The next generation of larger airports, already overdue, will lie even farther from the centers of cities, beyond their widening suburban areas.

In some places helicopters are helping to bridge the gap. Their use as airport taxis will undoubtedly increase. For journeys up to a few hundred miles, however, a relay of three aircraft is hardly the ideal solution. What is wanted is an aircraft with the helicopter's ability to take off and land downtown, but with enough speed and efficiency in horizon-

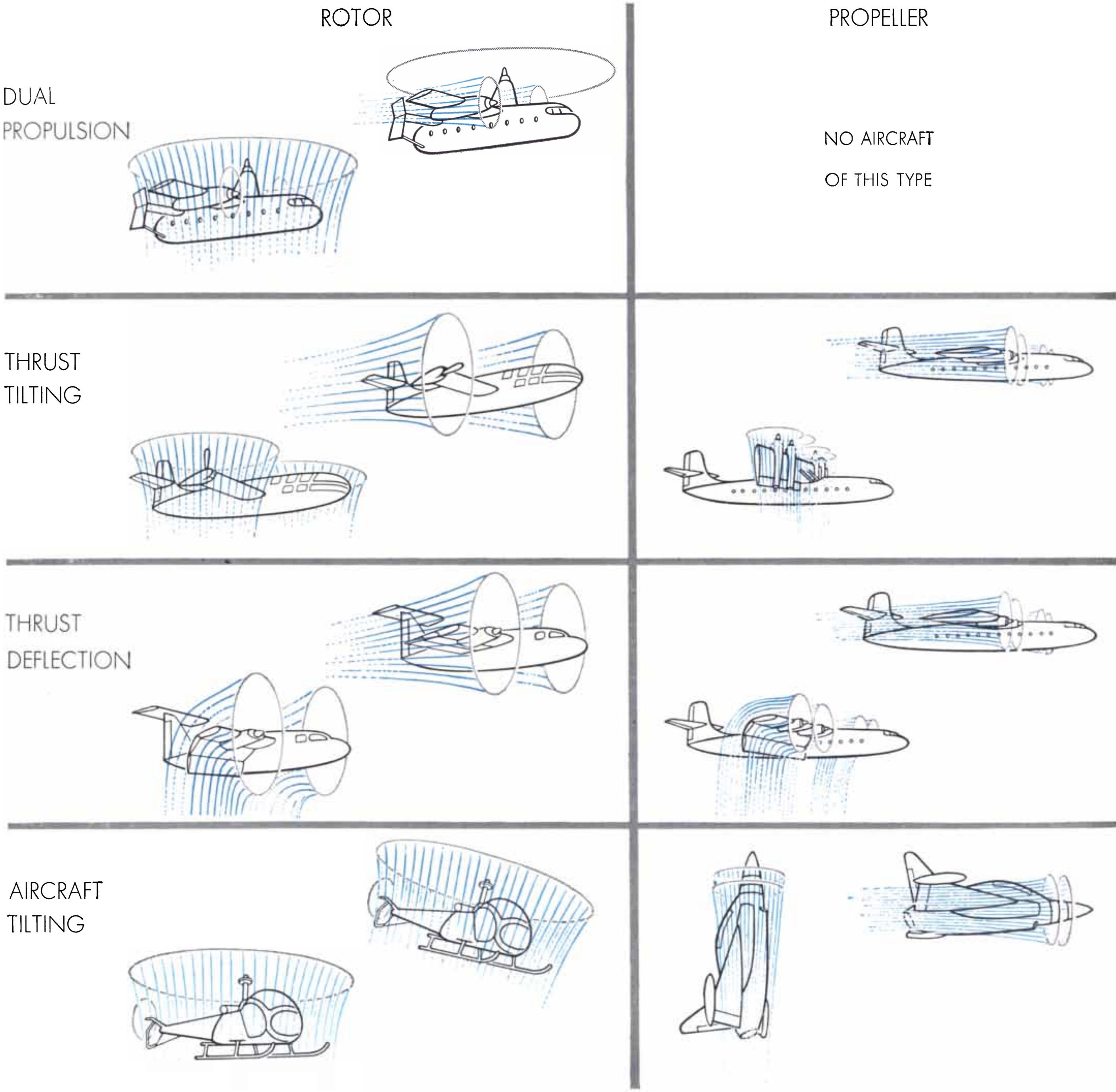


MODEL of tilt-wing vertical takeoff and landing (VTOL) airplane was photographed in the full-scale wind tunnel of the National Aeronautics and Space Administration at Langley Field. Six turboprop engines furnish thrust for vertical and horizontal flight.

tal flight to make the shorter interurban hops itself.

Active research on vertical takeoff and landing (VTOL) aircraft is in progress both here and abroad. In this country the program has been a three-way collaboration among the National Aeronautics and Space Administration, a number of aircraft manufacturers and the armed forces. The requirements of commercial passenger traffic are not the only, nor even the major, impetus behind the investigations. The Army, Navy and Air Force are interested in a variety of aircraft that could operate in forward areas without the need for prepared landing strips. Interceptor, reconnaissance and cargo types are all being studied. So far as freight carriers are concerned, they would obviously have both commercial and military applications.

Although true VTOL airplanes, well adapted to both horizontal and vertical flight, are only now becoming technically feasible, their advantages have long been obvious. In 1921 A. F. Zahm, a prominent aeronautical engineer, patented an airplane with a wing and flap that would deflect the propeller slipstream downward to provide lift for hovering. The airplane was never built, however, because the piston engines of the time (and, indeed, of the present) could not provide enough thrust through a conventional propeller to support the weight of the ship. Lacking power to do the job with propellers, designers had to find a more efficient approach.



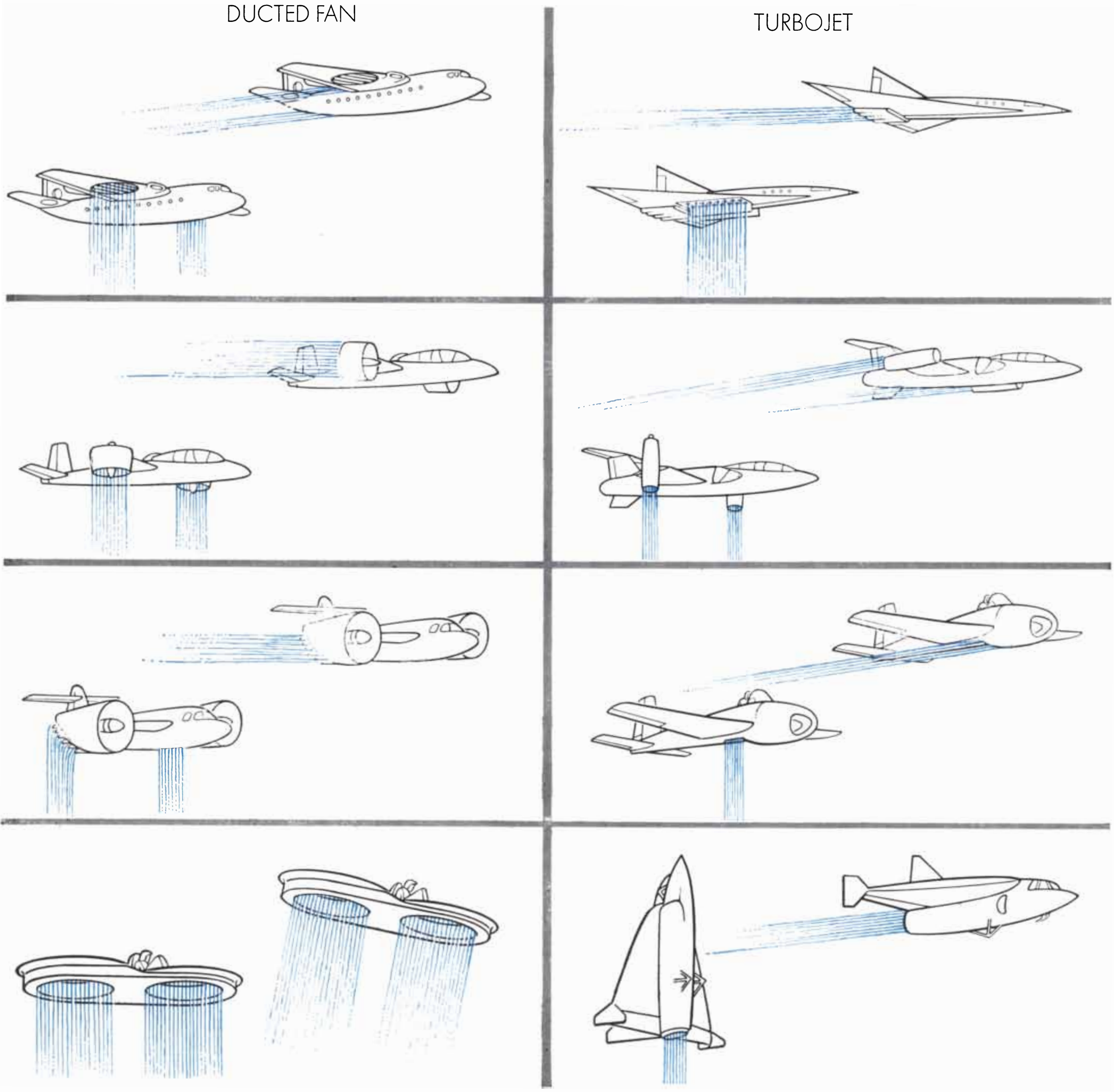
FAMILY OF VTOL TYPES can be classified according to the source of thrust (*left to right*) and according to the methods of converting from vertical to horizontal flight (*top to bottom*). In each section of the chart the configuration for vertical flight ap-

In essence the problem was simple enough. A VTOL aircraft must push a mass of air downward to produce the upward lift or thrust required for hovering flight. The amount of thrust is proportional both to the mass of air that is moved and the speed with which it is moved (mv). Thus the same thrust can be attained by moving a large mass at low speed, or a small mass at high speed.

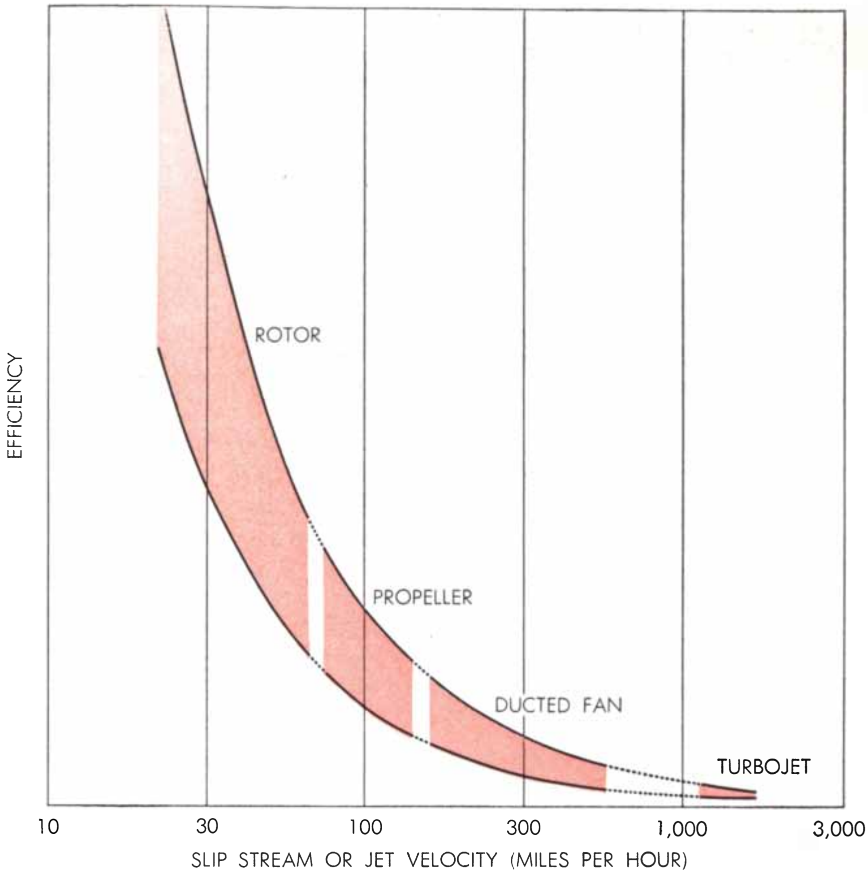
The power consumed, however, varies as the mass and the square of the speed (mv^2). Cutting the slip-stream velocity (and increasing the mass proportionately) leads to a net decrease in the power demanded of the engine. The logical approach for the early VTOL aircraft designer was therefore the large, slow-spinning rotor of the helicopter. By pushing down a column of air of large diameter at a moderate rate, it worked efficiently enough to obtain the necessary lift from the engines available.

It should be noted that efficiency is not the only advantage of a slow slip-stream. In rescue work, where people are lifted from the ground in the open air, it is essential. Furthermore it minimizes the considerable problems of ground erosion and flying dust and debris in operations from unprepared ground. Thus there are several reasons why the helicopter seems likely to retain a considerable range of utility despite certain drawbacks inherent in the design.

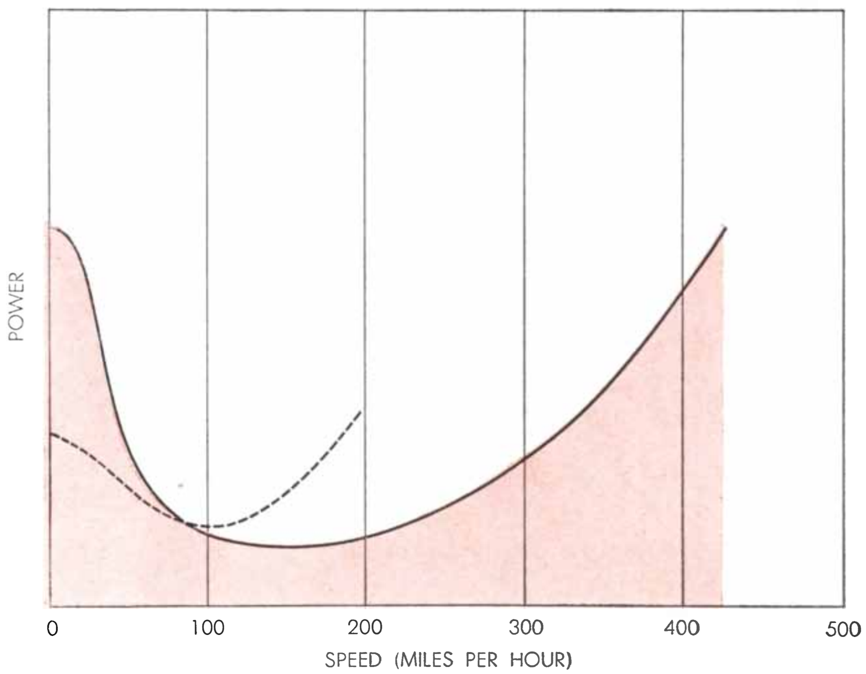
These difficulties include mechanical complexity and high maintenance cost, but the major limitation is that the helicopter cruises rather inefficiently and



pears at left and the configuration for horizontal flight at right. Colored lines represent slip stream from rotors, propellers or jets. All of the designs shown on these two pages have been seriously studied, and many of them have actually been built and tested.



HOVERING EFFICIENCY decreases with increasing velocity of the slip stream or jet exhaust that provides thrust. Graph shows relative ranges of efficiency for all thrust devices.



CRUISING EFFICIENCY of a helicopter is less than that of a VTOL airplane deriving horizontal thrust from propellers and lift from a wing. Curves show relative power demands on helicopter engine (*dashed*) and propeller engines (*solid*) at various cruising speeds.

slowly, with a top speed of less than 200 miles per hour. In order to fly forward the helicopter noses over slightly so that the slip stream has a small backward component. Now the rotor provides both the lift to support the helicopter and the thrust to propel it forward. Unfortunately, the rotor performs these two functions much less efficiently than do the wing and propeller of a conventional airplane in forward flight.

It would appear that the requirements for vertical and horizontal flight are contradictory. It is scarcely surprising that a machine designed to do one most efficiently is not very good at the other. Why not use both wing and rotor to obtain the advantages of each?

This is just what several designers are doing. One scheme employs a dual propulsion-system: a rotor for taking off, landing and hovering; propellers (and a wing) for faster and more efficient cruising. An experimental plane of this type, the XV-1 built by the McDonnell Aircraft Corporation, was flown successfully several years ago, but its development was not pursued. In England, however, the Fairey Aviation Co., Ltd., has been working intensively on a similar aircraft. The Rotodyne, as it is called, will soon be the first operational VTOL transport other than the helicopter. Carrying 48 passengers at a cruising speed of 160 miles per hour, it is expected to cut in half the present four-hour trip (by plane and bus) between London and Paris.

Another approach is to use the same rotors for vertical and horizontal thrust, tilting them from one position to the other as the need arises. Under the sponsorship of the Army and the Air Force, the Bell Aerospace Corporation has built a tilting-rotor "convertiplane," the XV-3. In tests by the Air Force and the National Aeronautics and Space Administration (NASA) the XV-3 has shown that it can easily make the transition from hovering to cruising and back.

In an effort to avoid the problems attendant on shifting the thrust unit itself, some researchers are experimenting with methods of bending the slip stream. Essentially this is done by directing the air across a wing with a large downward-slanting flap [*see top illustration on page 48*]. On the underside the stream has, so to speak, no choice but to follow the surface. It also tends to do so on the upper side, held by reduced pressure in the layer of air flowing over the surface. The wing-and-flap arrangement has proved capable of deflecting the stream efficiently through no more than

FAIREY ROTODYNE is a dual-propulsion VTOL airplane. The rotor above the fuselage provides thrust for vertical flight; the conventional propellers, thrust for horizontal flight. This British design, which is soon to go into operation, carries 48 passengers.

50 or 60 degrees. Thus for hovering, the wing, or the entire aircraft, must be tilted up 30 or 40 degrees. The Kaman Aircraft Corporation is building a thrust-deflection rotor aircraft, the K-16, for the Navy. The plans also call for tilting the wing, so that the fuselage will remain horizontal under all flight conditions.

The designs discussed thus far provide examples of the four possible ways to convert from vertical to horizontal flight: aircraft tilting (as in the helicopter), dual propulsion, thrust-tilting and thrust-deflection. They have in common the use of large rotors for taking off, landing and hovering.

Until the advent of the turboprop and turbojet engines there was no choice but to use rotors. Now the necessary vertical thrust can be obtained in other ways. A turboprop engine produces more than twice the power of a piston engine of the same weight. Either with a conventional propeller or with an arrangement known as a ducted fan, which we will discuss presently, it can deliver enough thrust to support the weight of an aircraft in hovering flight. Pure jets can also do this.

Because of their higher slip-stream velocities, propellers and jets are less efficient than rotors when they are operated vertically. A VTOL airplane would consume four times as much fuel as a helicopter would in supporting the same payload in hovering flight. A jet would consume 25 times as much as a helicopter. But if vertical operation is restricted chiefly to takeoff and landing, getting rid of the clumsy rotor may be worth the loss of efficiency.

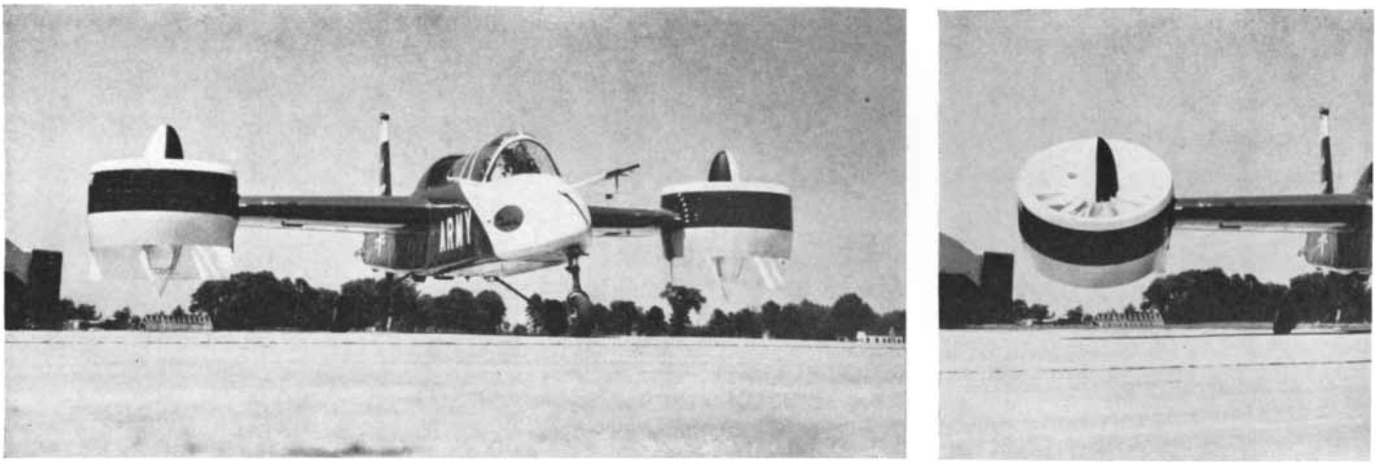
Much of the earlier research effort on VTOL designs in the U. S. went into propeller-driven aircraft-tilting types, where the entire airplane pointed straight up during the takeoff and landing. Both Convair and the Lockheed Aircraft Corp. built fairly sucessful examples of these "tail-sitters," but problems connected with their propellers and engines, as well as the general inconvenience of the vertical position of the fuselage, led to their abandonment.

More recently interest has centered on the tilt-wing design, in which propellers and wing move together from the vertical to the horizontal position, and on thrust deflectors. Vertol and the Hiller Aircraft Corporation have built tilt-wing airplanes; the Fairchild Engine and Airplane Corporation and the Ryan Aeronautical Co., thrust deflectors. To anyone who has not seen it before, a tilt-wing airplane making the transition from hovering to forward flight presents a startling sight. As forward motion begins, the wing is still tilted at a very steep angle to the horizontal. If a conventional airplane attempted to fly at such an angle, its wing would be completely stalled; that is, air would not flow over the surfaces in such a way as to generate lift. However, the effective "angle of attack" of a wing is determined not only by the relative horizontal motion of air across it, but also by the flow of the slip stream from the propeller. In a hovering, or nearly hovering, VTOL airplane the slip stream is necessarily faster than in a conventional craft, and so the wing can assume a much steeper angle without stalling. The tilt-wing airplane has demonstrated its ability to overcome wing-stalling, and it seems likely to prove a successful VTOL design.

The deflected slip-stream arrangement, on the other hand, has proved less well adapted to pure VTOL operation, primarily because of a substantial loss of thrust in turning the propeller slip-stream downward. However, it does appear suitable for an airplane that takes off and lands not vertically, but with a short horizontal run that substantially reduces the power required.

Perhaps the most promising configuration studied so far for transport aircraft is one that combines the tilt-wing and deflected slip-stream principles. It is essentially a tilt-wing airplane with a large wing flap to ease the stalling problem in transition flight. Although it could take off and land vertically, it might be used normally as a short takeoff and landing (STOL) airplane, expending less power and enjoying a greater margin of safety if the engines should fail.

A relatively new propulsion unit, the ducted fan, has attracted considerable attention from VTOL designers. It consists of a propeller surrounded by a ring, or duct, which alters the shape of the slip stream. Behind a conventional propeller the stream tapers down to

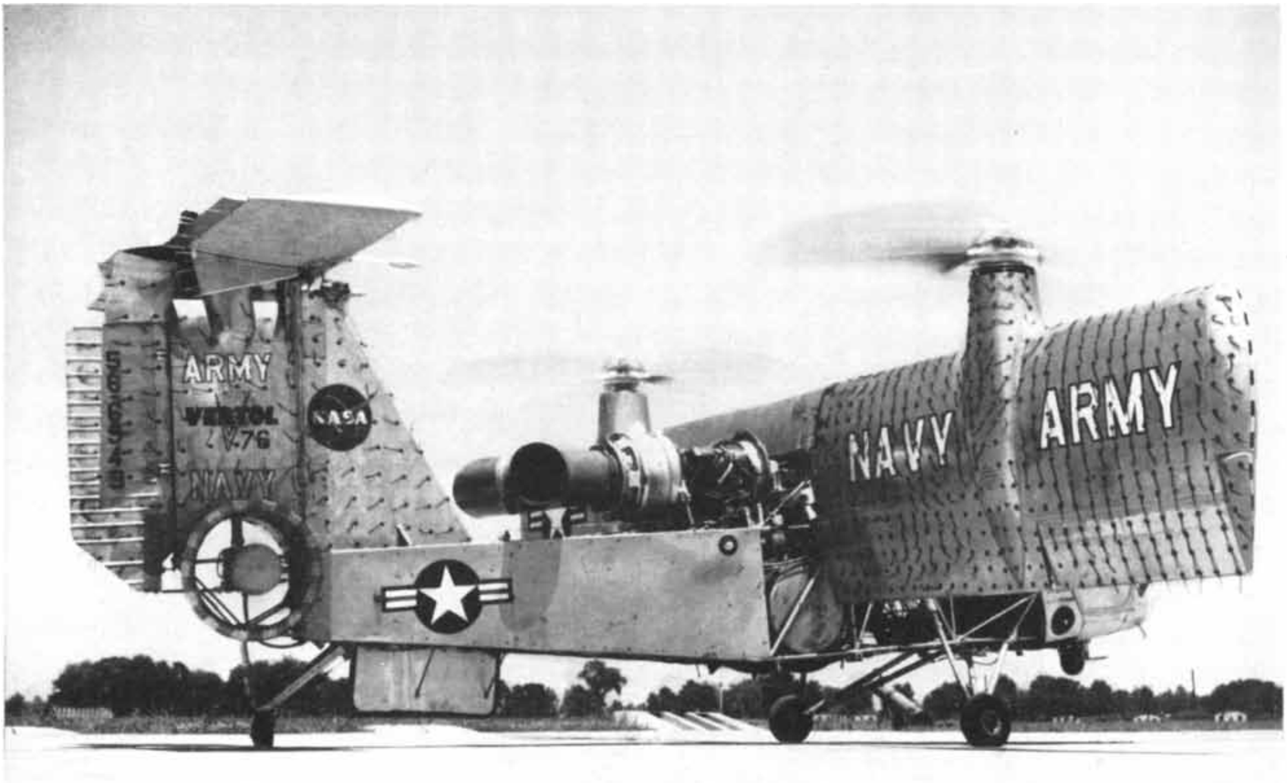


DUCTED-FAN AIRPLANE, built by the Doak Aircraft Co., was photographed at Langley Field. Fan units can be tilted straight up for vertical takeoff (*left*), diagonally for short takeoff (*middle*) and horizontally for cruising flight (*right*). The duct around

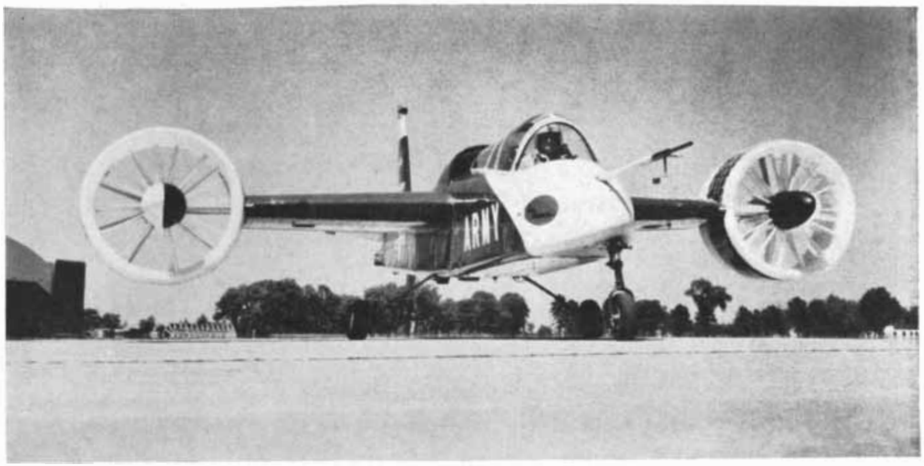
about half its original area, thereby reducing the effective thrust. The duct eliminates this effect, which means that a given thrust can be obtained with a fan of smaller diameter. However, the ducts have been found to aggravate the problem of stability and the ducts represent added weight and drag. It remains to be seen whether the advantages outweigh the disadvantages.

Of the many ducted-fan designs that have been considered, the most successful to date is a tilting-thrust airplane built by the Doak Aircraft Co. With a pair of rotatable ducts at its wingtips, this craft has already demonstrated its ability to perform the transition from hovering to forward flight. It is now undergoing further testing by the NASA.

The flying platforms and "aerial jeeps," which have received considerable publicity during the last couple of years, are ducted-fan designs of the aircraft-tilting type. As in the helicopter, their forward progress is accomplished by tilting the vehicle through a small angle. Simple in principle (the pilot of a flying platform merely leans in the direction he wants to go) they have proved somewhat more complicated in practice. The Hiller Aircraft Corp. has studied the flying platform, and the Piasecki Helicopter Corp., the Curtiss-Wright Corp., and the Chrysler Corp. have built and tested aerial jeep machines, but the results thus far are not particularly encouraging.



TILT-WING AIRPLANE, also photographed at Langley Field, was built by Vertol. At left the plane is photographed on the ground, ready to take off. The short lengths of cotton string covering the wing and tail show the direction of air flow over these



the fan prevents the slip stream from narrowing, as it does behind a conventional propeller or rotor. The fan can therefore have a smaller diameter for a given thrust. However, the additional weight and drag due to the duct itself partially offset this advantage.

As with conventional airplanes, the fastest VTOL designs, including some that cruise at supersonic speeds, obtain their thrust from pure jets rather than from propellers. Turbojet versions of all four basic types have been studied, dual-propulsion systems chiefly in England and the others in the U. S.

The British S.C.1, built and tested by Short Bros. and Harland, Ltd., has four special turbojet engines mounted vertically in the fuselage for lifting thrust and one conventional turbojet engine mounted horizontally. Used only for takeoff and landing, the lifting engines are light, simple and efficient. This lifting engine principle appears promising, particularly for transports.

Neither thrust-tilting nor thrust-deflection designs seem as well adapted to jet transports because the same engines supply vertical lift and forward propulsion despite the great disparity in the thrust required for the two purposes. In cruising flight, unless some of the engines are shut down, they will operate in the range of low thrust, where they are relatively inefficient. The simplicity of thrust-tilting and thrust-deflection arrangements in a jet, however, makes them attractive for small military aircraft. Bell built the X-14, a ship of the thrust-deflection type for the Air Force, and it is now being used in research by the NASA. Swiveling tailpipes beneath the wing direct the exhaust of two small

surfaces. At right the plane has risen vertically and is in the process of tilting the wing down to the horizontal position. The ability of the wing to generate lift while still at a very steep angle is due to the high speed of the slip stream typical of VTOL airplanes.

THRUST-DEFLECTION AIRPLANE was built by the Ryan Aeronautical Co. The large flaps, when turned downward, bend the slip stream from the propellers through an angle of 50 to 60 degrees. Such deflection, however, causes substantial loss of thrust.

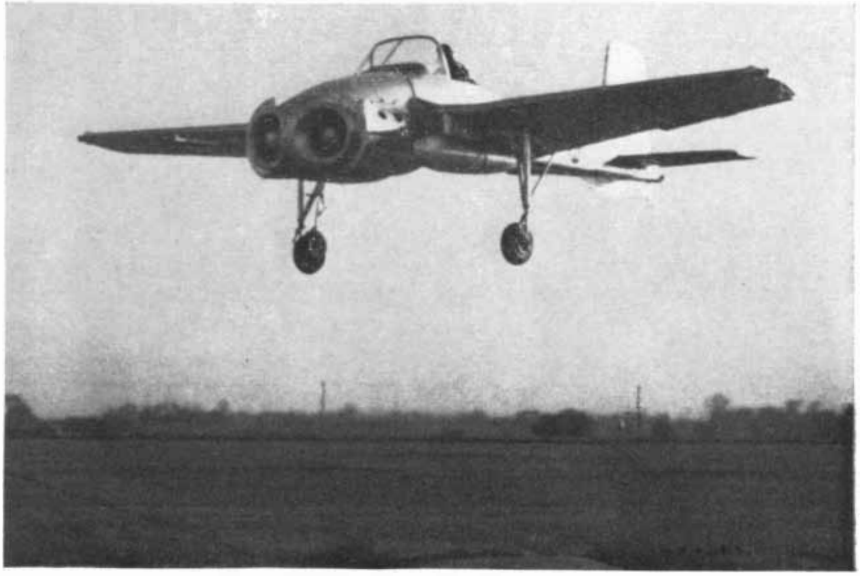
PIASECKI "AERIAL JEEP" derives thrust from ducted fans mounted rigidly to the air frame. To fly horizontally the entire craft is tilted slightly. This design is being explored because of its simplicity and its adaptability for flying at very low altitudes.

turbojet engines horizontally or downward. A similar concept has been embodied in a small transonic strike aircraft that is now being built in England by Hawker Aircraft, Ltd., for the Royal Air Force; this plane is scheduled to fly in the next few months.

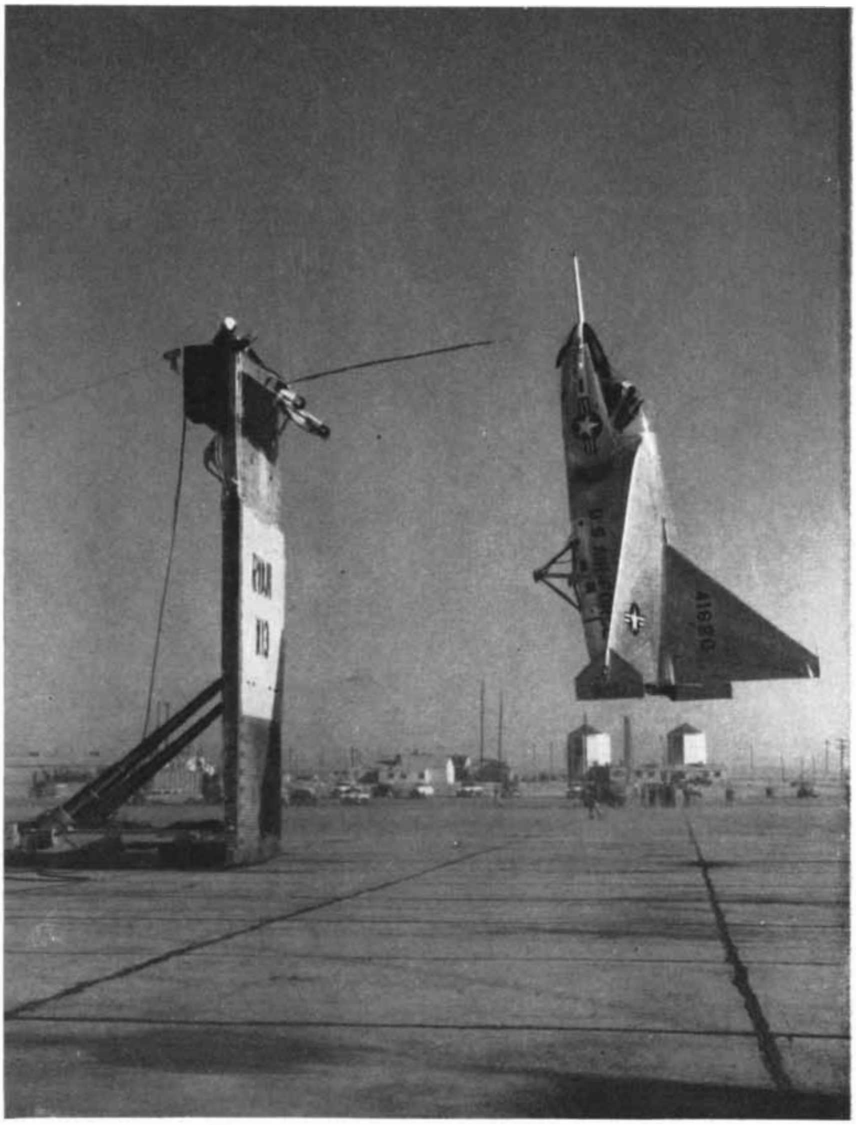
Perhaps the most impressive VTOL aircraft flown in the U. S. thus far is the Ryan X-13, a jet-powered tail-sitter built for the Navy. It took off and landed vertically, hooking to a cable on a special trailer. The entire fuselage tilted over in forward flight. Although flight tests were successfully completed in 1957, work was then discontinued because the services had come to favor designs in which the fuselage remains horizontal.

The fact that VTOL research is taking so many different directions is hardly surprising at this stage. Conventional aircraft experienced similar growing pains for a considerable period after the Wright brothers' first flight. In the beginning no one could have predicted that the monoplane would establish its superiority over the biplane and triplane, the tractor propeller over the pusher, or the tail-aft design over the tail-first.

Similarly, it is too early to predict accurately which VTOL designs will be most successful, but it is possible to foresee some general outlines. The helicopter will probably remain the first choice for short-range, low-speed operation and for applications that involve a large proportion of hovering time. Other rotor types—dual-propulsion and tilt-rotor—will provide somewhat greater speed and range, while retaining most of the helicopter's advantage for vertical operation. As has been mentioned, one of the most promising of all designs is the propeller tilt-wing with a fairly large flap. It is suitable for transport duty both in VTOL operation and in short takeoff and landing. Ducted-fan types have not appeared especially promising, but future advances may change the picture. As for turbojets, one small operational airplane is now being built in England for the R.A.F. The U. S. military is interested in supersonic VTOL fighters, but recent decisions indicate that they are not likely to be developed for another eight or 10 years. Nor is it yet clear which design will serve best. Turbojet VTOL transport airplanes with lifting engines appear technically feasible, but are not likely to be built soon. Whatever their actual form, VTOL aircraft are certain to bring about some revolutionary developments in both military and civil aviation during the next 10 or 20 years.



BELL X-14 is a turbojet design using thrust deflection to provide lifting force for takeoff and landing. The tail pipes beneath the wing can be directed horizontally or vertically.



RYAN X-13, also a turbojet plane, is a "tail-sitter," or aircraft-tilting type. It lands vertically on the special trailer at left, engaging a horizontal wire with a hook on its nose.

RADAR ASTRONOMY

In contrast to radio astronomy, which works with signals that are broadcast by objects in space, this new discipline investigates the solar system with the echoes of signals sent out from earth

by Von R. Eshleman and Allen M. Peterson

Are the "canals" of Mars long marshes or simply the scars of planetary evolution? Do the clouds that cover the face of Venus conceal oceans, continents and mountain ranges? Is it true that the sun has a highly variable atmosphere of charged particles that extends beyond the orbit of the earth? The electromagnetic radiations of the cosmos—the signals that nature happens to broadcast—do not necessarily supply clear answers to these and numerous other questions that men feel impelled to ask. Up to the present, light and radio waves reaching the earth from outside its atmosphere have been almost the only source of knowledge about the solar system and the universe beyond. Now, with the launching of man-made satellites and rocket probes, the exploration of the solar system has entered a more active phase. It may well be, however, that before fully instrumented space observatories make their journeys, many of the questions they are designed to answer will be answered by the use of radar in astronomy—that is, by the use of radio signals, but signals that man himself chooses to broadcast.

In radar astronomy powerful radio transmitters employ giant antennas to send out pulses of electromagnetic energy. These signals make direct contact with the objects of study and return to the sender. It is as though the astronomer could touch the objects as well as see and hear them. When the radar pulses encounter a solid body or a gaseous region, they are distorted in significant ways. Depending on the nature of the object they meet, they are in varying degrees scattered, absorbed, retarded, polarized, refracted and reflected. The minute fraction of the pulse energy that returns to the antenna can then be compared to the original signal, revealing new information about the body or region that distorted them.

The use of radar to detect distant objects has progressed rapidly in the past few years. Radar pulses were first used some 35 years ago to probe the ionized layers in the upper atmosphere. The continued investigation of these ionospheric layers with increasingly sensitive systems led naturally to studies of more distant targets. In 1946 workers of the U. S. Army Signal Corps (and at about the same time Z. Bay of Hungary) detected the return of a radar signal from the moon. Only 12 years later, in 1958, workers at the Lincoln Laboratory of the Massachusetts Institute of Technology employed a radar system 10 million times more sensitive to send a round-trip signal to Venus. In 1959 radar echoes from the sun were detected at Stanford University. The steps from the moon to Venus and the sun required tremendous increases in sensitivity, but with a similar additional improvement in equipment essentially all of the solar system can be studied by radar.

The special forte of radar is the accurate measurement of distance, which is vital to the planning of space probes. Radar studies of Venus have already brought considerable improvement in estimates of the "astronomical unit," the mean distance between the earth and the sun. Further advances in radar technology should make it possible to construct maps of the planets that will present their surfaces in detail approaching that of photographs of the moon. Because radar is expected to penetrate Venusian or Jovian clouds as readily as those of the earth, it will give man his first look at the surfaces of these planets. Radar will also, in effect, illuminate the dark side of Mercury and the interplanetary gas, which send little or no light or radio energy to earth. And with radar it will be possible to investigate at first hand regions such as the solar corona that cannot be probed by rocket.

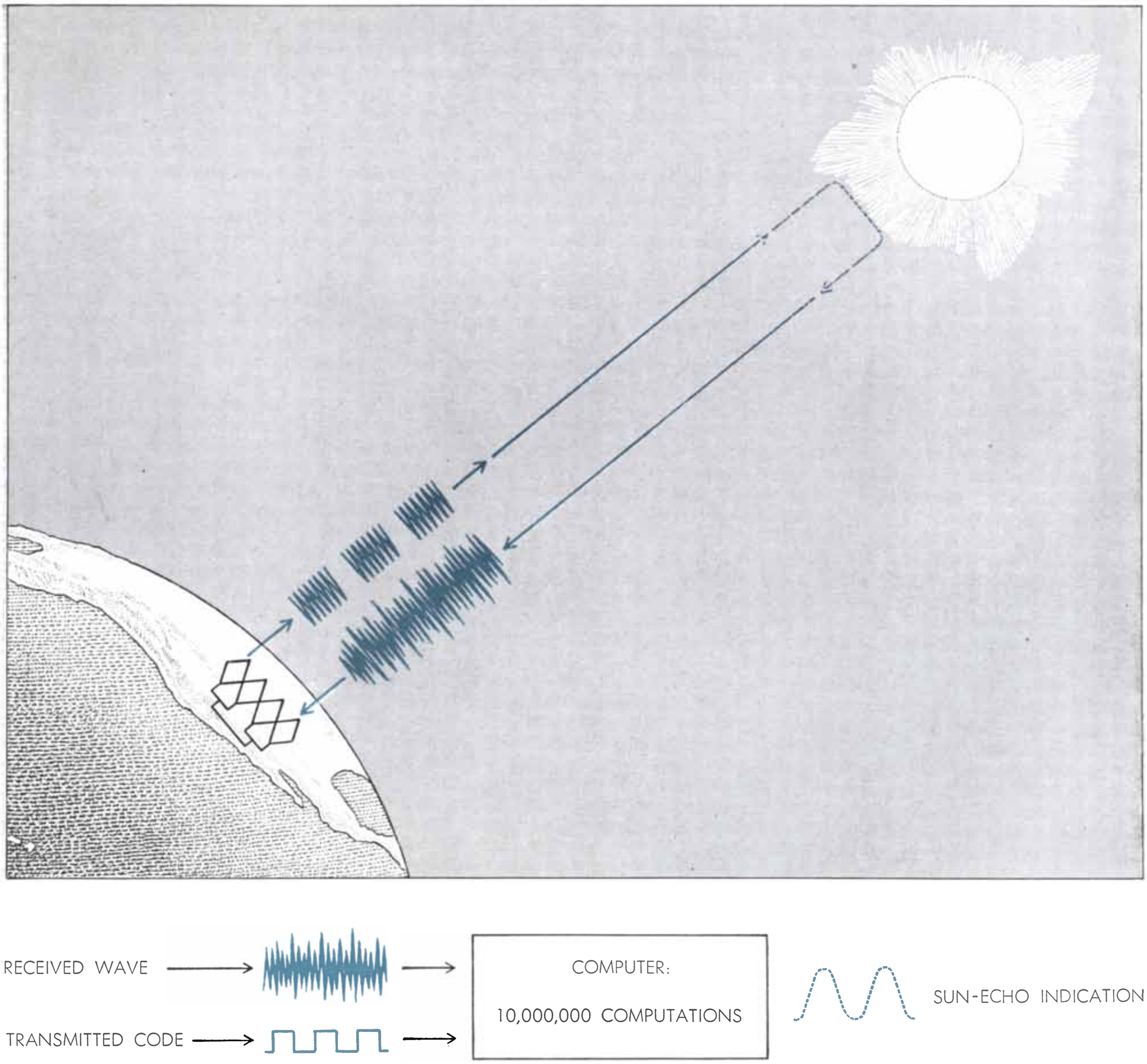
Radar astronomy will not, however, displace rocketry in the active exploration of space. Rather the one will complement the other. The collaboration of the two technologies is likely to be the closer because both are confined to operation within the limits of the solar system. While a rocket might be launched into the more distant reaches of space, it would be difficult to maintain radio contact with it much beyond the boundaries of the solar system, and it will remain quite impossible to secure a radar echo from even the nearest star.

Though new transmitters are converting greater amounts of energy with greater efficiency into radio signals, their output seems insignificant indeed when it is compared to cosmic sources. The second most intense radio "star" has been identified as two colliding galaxies some 500 million light-years away in the constellation Cygnus. This source emits about 10^{36} (one trillion trillion trillion) watts of electromagnetic energy. The sun has a total power output of more than 10^{26} watts, mostly in the visible and infrared regions of the spectrum, but with as much as 10^{13} watts at radio wavelengths. The largest transmitters now being built and planned for use in radar astronomy still have a power output averaging less than 10^{7} watts. A transmitter that has just been installed at Stanford University fills a barn-sized building with more than 50 tons of electronic equipment and yet puts out only 3×10^{5} (300,000) watts. Although much larger values can be achieved in short bursts to simplify certain measurements, the sensitivity of a radar system depends on its average power. It is unlikely that transmitters of more than two orders of magnitude greater power will be built for some time to come. At present the construction cost of large transmitters ranges from $1 to $5 per watt of power capacity. This cost must be considerably reduced before large increases in transmitter power can be justified.

Whatever the initial energy of a signal, it must fall off steeply. As a signal travels forward it spreads outward over an ever larger spherical surface, and so its intensity must vary inversely as the square of the distance from the source. The same rule of course applies to natural radiation, and reduces the huge output of Cygnus A to a whisper by the time it reaches earth. Because the radar signal must return to its source, it encounters the spreading effect on both legs of its journey, and so must be powerful enough to sustain a reduction in intensity as the fourth power of the distance it travels.

Radar technique can compensate in part for this loss of energy. First of all, the full power of the transmitter can be radiated in a very narrow band of wavelengths. The intensity of the signal in the chosen wavelength band may thus greatly exceed that of natural radiation in the same limited band. Secondly, the use of very large antennas will not only secure high efficiency in the radiation of the outbound signal, but will also provide maximum "light-gathering" power to pick up the attenuated echo.

Antennas come in a number of sizes and shapes. Probably the most familiar are the steerable paraboloidal antennas such as the 250-foot "dish" at Jodrell Bank in England. The Stanford Research Institute is now building two 150-foot



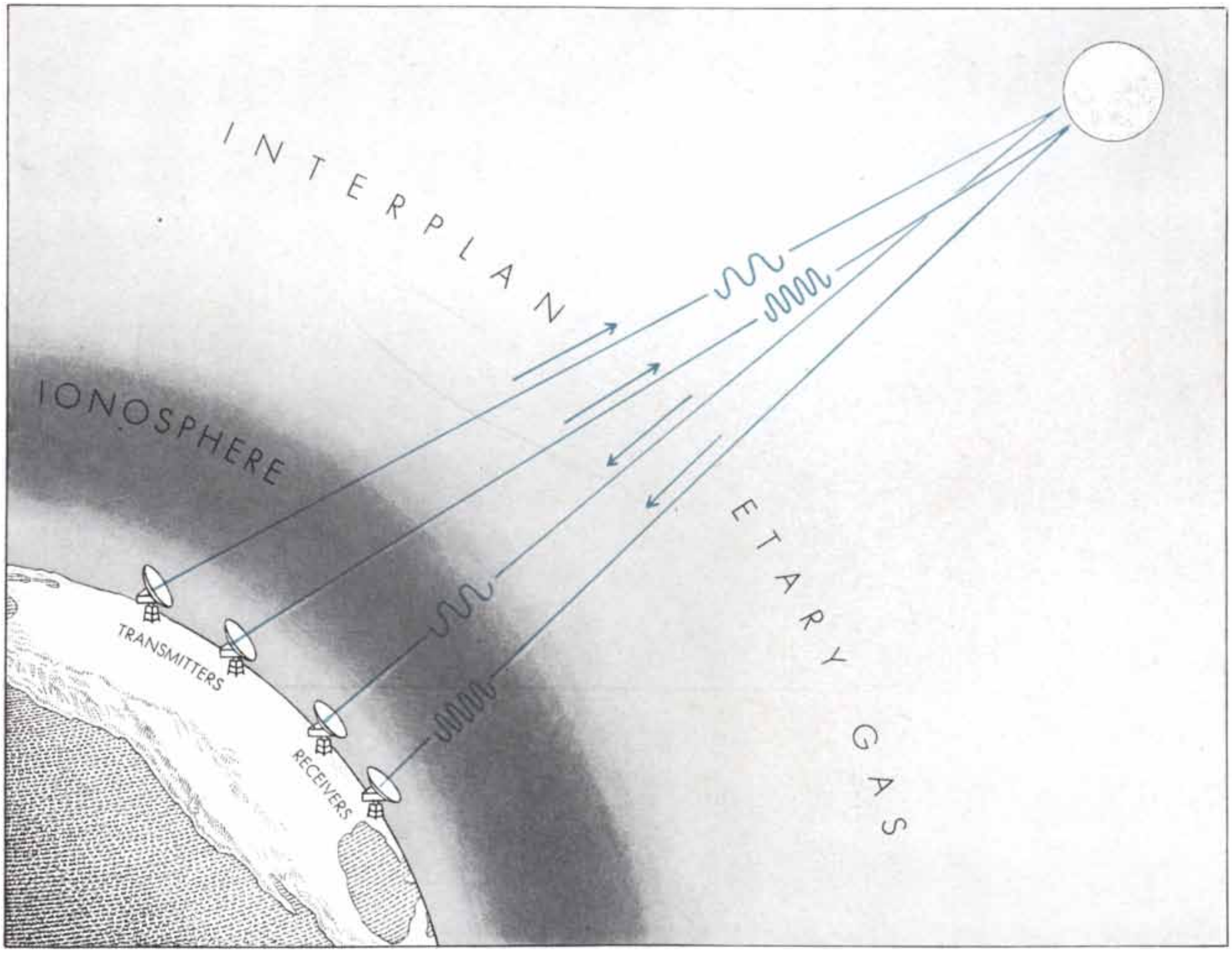
RADAR PROBING of the sun's corona in 1959 at Stanford University is depicted schematically. A 40-kilowatt transmitter and a 14-acre fixed antenna (*bottom left in top drawing*) were used to transmit signals (*three small colored areas*) at a wavelength of 11.5 meters. The sun's own radio noise masked the returning echo (*large colored area*). An electronic computer then compared the received wave (*bottom*) with known characteristics (*transmitted code*) of the original signals to detect the presence of the echo.

paraboloids. Australia will soon erect a 210-foot antenna, and construction is under way on the Navy's gigantic steerable antenna, 600 feet in diameter, in West Virginia [see "The 600-Foot Radio Telescope," by Edward F. McClain, Jr.; SCIENTIFIC AMERICAN, January]. The degree to which the surface of such an antenna approximates a perfect paraboloid determines the shortest wavelengths that can be focused. The U.S.S.R. has a 72-foot antenna, the surface of which does not deviate by more than a few millimeters from a perfect paraboloid; it can be used at wavelengths as short as eight millimeters. Of course it is more difficult to maintain such perfection in larger antennas. For work at wavelengths on the order of several meters, the Stanford Research Institute has proposed construction of a steerable antenna 800 feet in diameter. Since it need not have a smooth surface like that planned for the Navy's giant antenna, it will cost only $8 million, about a tenth the cost of the 600-foot structure. Some savings in cost can also be achieved by the sacrifice of steerability; a 1,000-foot "hole-in-the-ground" dish is planned for construction in Puerto Rico by Cornell University and the Air Force. Since operations at the longest wavelengths do not involve optical considerations, antennas for use in this range can be built by stringing wires and rods on poles. The antenna that made the first radar contact with the sun was spread over 14 acres, but it cost less than $30,000. Radar astronomy can also utilize the interferometer principle, hooking together a number of antennas to locate objects with high angular precision.

While there is no limit to how much a weak signal can be amplified, it does no good to do so if the signal is hopelessly confused with radio noise, since both will be amplified together. At wavelengths greater than about two meters the limiting noise comes from various sources in the cosmos, with intensity differing with direction. Cosmic noise also comes in at shorter wavelengths, but in the past the noise produced inside the short-wavelength receivers themselves has exceeded the noise from external sources. However, with the new solid-state devices (masers and parametric amplifiers), receiver noise is greatly reduced, so that much weaker signals can be detected at the short wavelengths.

But even if the radar echo is drowned in noise, it may still be resolved, providing it is sustained for a sufficient length of time. Techniques for wave analysis, employing electronic computers, can extract its regular pattern from a welter of noise hundreds of times greater in intensity. Such computational efforts made it possible to demonstrate the radar detection of Venus and the sun. On the other hand, if the echo strength is greater than the noise intensity, involved data-processing can be used to measure its characteristics with great accuracy.

In keeping with the established function of radar on earth, one of the first



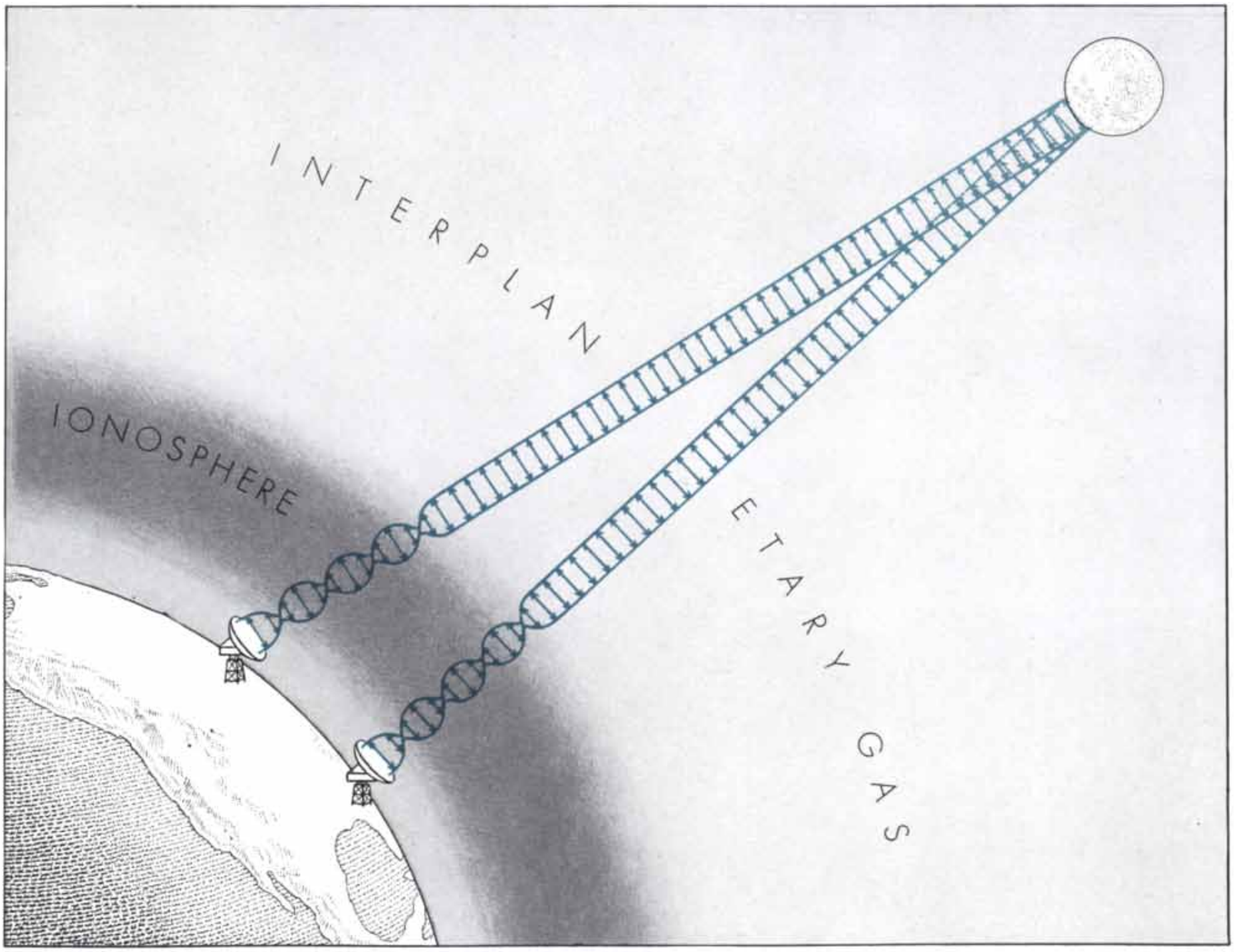
RADAR ECHOES from moon and planets can be used to measure density of interplanetary gas. The gas slows speed of long wavelength pulse more than it does that of shorter wavelength pulse sent simultaneously; difference in arrival time is a direct measure of average gas density along path. Ionospheric component can be subtracted from total to give true interplanetary-gas density.

functions of radar in astronomy is to refine the measurement of distances in the solar system. The astronomical unit, as determined by optical astronomy, is accurate to only one part in 1,000. Already the radar study of Venus appears to have reduced the error to one part in 100,000 and stronger radar echoes from Venus and other objects will provide even greater accuracy. The close passage of asteroids, if observed both optically and by radar, would provide the best opportunity for future measurements. New information might also be obtained about the size, shape, density and rotation of these interesting objects. Very small changes in the orbits of planets or asteroids may be detected; these would disclose the perturbations caused by other bodies and make it possible to check for minute effects predicted by the general theory of relativity. The extreme accuracy of radar range-measurement will show up slight departures from the spherical shape of both the target and the earth.

The planets, their satellites and the asteroids that revolve about the sun all represent "hard" objects that reflect radio waves in the same way that an airplane does. Radar can also be employed to detect and investigate "soft" objects, such as the clouds of gas in interplanetary space. The physical contrast between the two kinds of object calls for a corresponding difference in the kinds of radar technique that are employed to study them.

The most important soft object is the sun itself. Though the sun is nearly four times more distant than Venus, it is so much larger that a solar radar echo would be about 100 times more intense, if echo intensity were determined by size and distance alone. The successful short-wave Venus radar was not employed, however, in the first radar detection of the sun. The first radar return from the sun was secured last year by a long-wave system, corresponding to the difference between the two kinds of target.

The sun is made up primarily of hydrogen and helium, much of which is ionized. While gases normally have little effect on radio waves, the free electrons in an ionized gas do affect the waves and may cause reflection, retardation and absorption. These effects are proportional to the product of the number of electrons per unit volume times the square of the wavelength. Thus to secure an echo from a region of low electron-density, such as the solar corona, relatively long wavelengths must be used. Short wavelengths will penetrate almost to the photosphere (the visible surface of the sun) which is visible for the very reason that waves of visible light cannot penetrate it. But the denser the gas, the higher the absorption of incoming waves. Short radio waves consequently lose nearly all of their energy before they reach the reflecting level. Longer wavelengths, on the other hand, are reflected farther out in



POLARIZED ECHOES from the moon measure the electron density of the ionized layers (*ionosphere*) of the earth's atmosphere. The radar signal is transmitted as a polarized wave (*colored band*). The plane of polarization of the wave is changed by the earth's magnetic field when the wave passes through the ionosphere in both directions. Change in polarization is a measure of density.

FIXED ANTENNA ARRAY at Stanford University is used to study meteors, the moon and the ionized gas between the earth and the moon. The array consists of wires and rods strung on poles in two 2,000-foot sections, and operates at a wavelength of 13 meters.

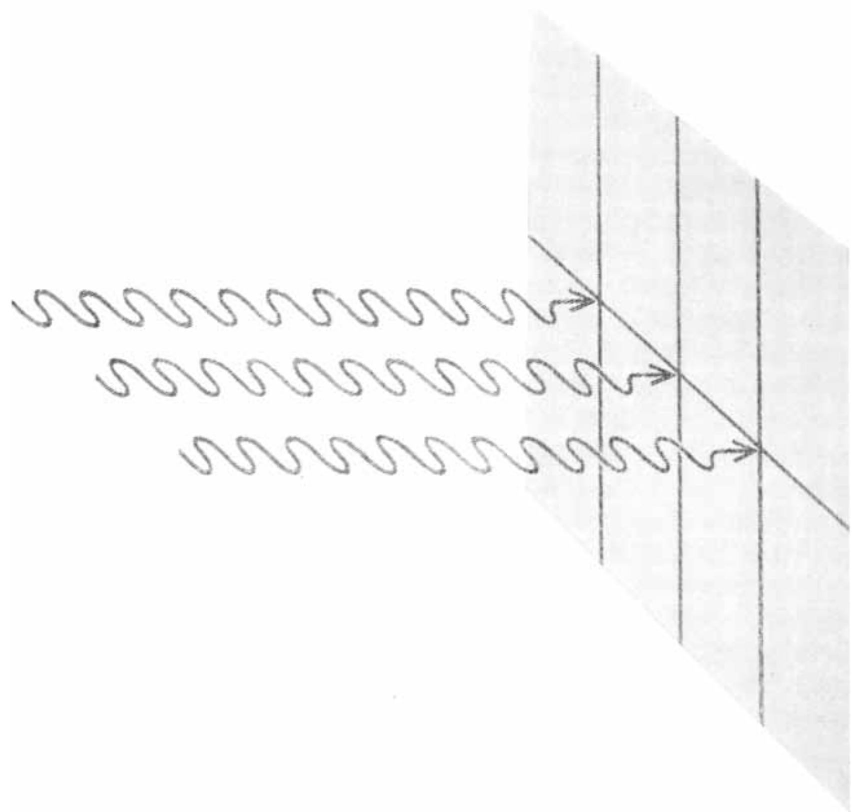
the corona before they have lost significant energy to absorption.

The radar system used to study the sun operated at a wavelength of 11.5 meters, 16 times the wavelength of the Venus radar. This wavelength is long enough to avoid absorption and to produce a detectable echo from the corona. But long wavelengths raise other problems. Very large antennas are needed to obtain high directivity; low-noise receiving devices, so important at short wavelengths, are of no benefit here because most long-wavelength noise comes from cosmic sources. The sun is an especially powerful source, radiating in a steady drone and also in unpredictable bursts. It is estimated that the solar noise was 50,000 times stronger than the echo, and the presence of the signal could only be established by extensive wave-analysis with an electronic computer.

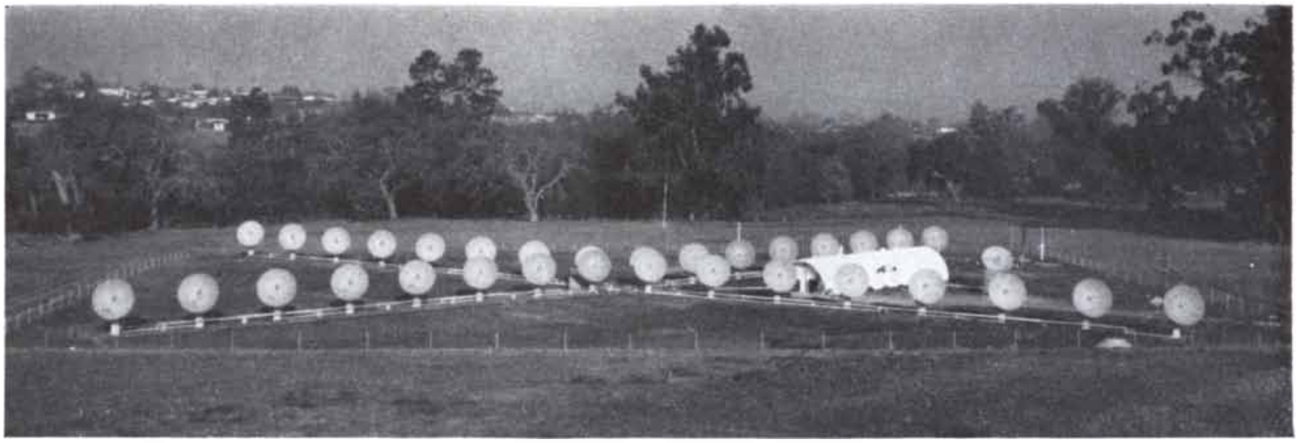
Although the first echoes from the sun were too weak to yield much new information, they did show that important solar studies can be made with the radar systems now being built. These investigations will involve a special adaptation of the technique that promises to yield detailed maps of the planets, and should provide a rather complete picture of the corona's changing structure. These studies may also tell us more about how the sun produces the great streams of ionized gas which envelop the earth and cause auroras, ionospheric and magnetic storms, communication blackouts and the outer Van Allen radiation belt.

Interplanetary space, which is far from empty, will also be an object of investigation. In the region between the planets it is estimated that there are between 10^7 and 10^9 ionized particles per cubic meter. Inside the solar streams the number may be 100 times larger. Even though there are more particles in the highest vacuum yet achieved on earth, it may still be possible to measure the density of the interplanetary medium by means of radar.

To make this measurement the transmitter will beam its signal at some hard object—most likely the moon—in order to secure a sufficiently strong echo for analysis. Simultaneous emission of long- and short-wavelength pulses promises to yield the most reliable result. The long-wavelength pulse will be slowed more than the short-wavelength pulse, the difference in arrival time being directly proportional to the average electron-density along the path. For the time difference to be large enough to measure, the path must reach at least to the moon and back. If the interplanetary density averages 10^8 electrons per cubic meter, the extra time delay of a moon echo at



RANGE-DOPPLER RESOLUTION of regions on a planet is explained in these two drawings. The incident wave (*gray lines in drawing at left*) is transmitted at one wavelength, and its wave front (*gray area*) is a plane. Since various parts of the wave must travel different distances, or ranges, to reach the target, the returning wave front (*circular broken*

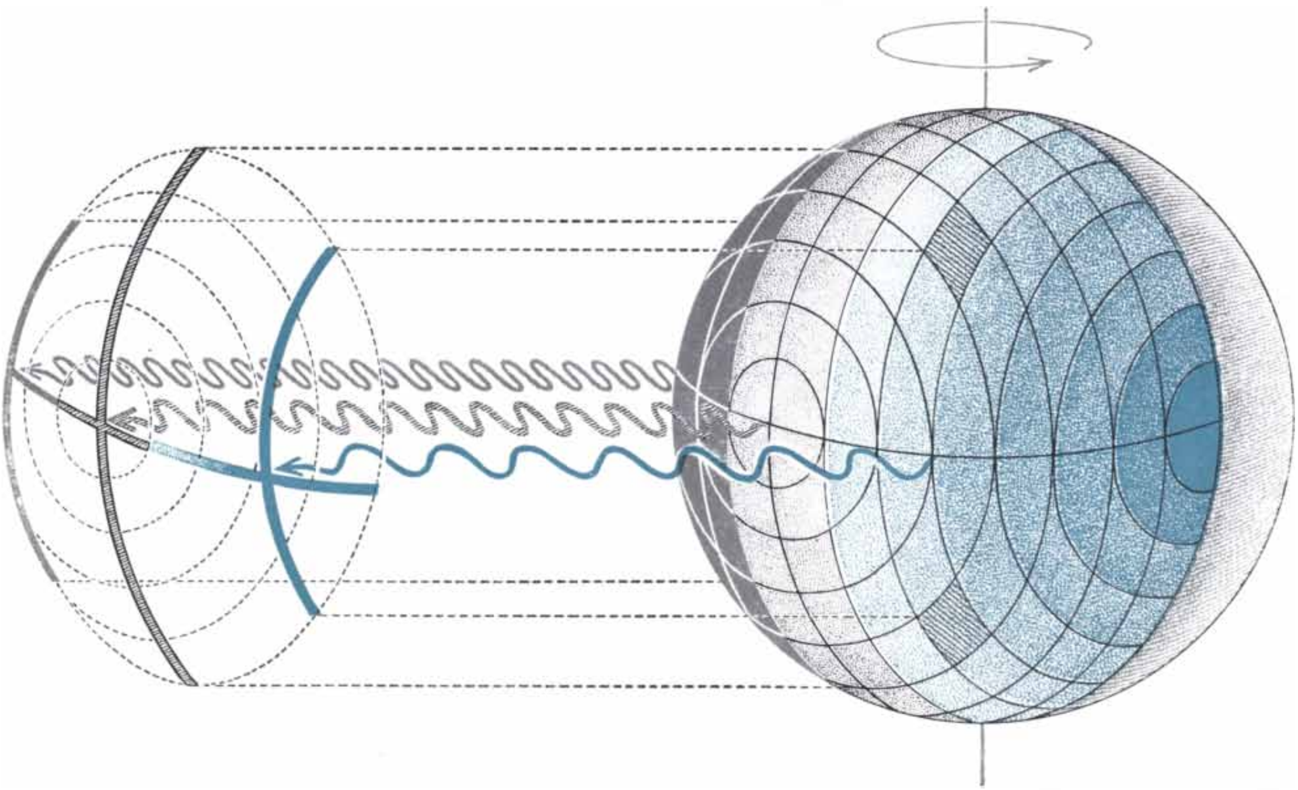


THIRTY-TWO ANTENNAS, each 10 feet in diameter, are used at Stanford University as a radio interferometer for studies of 10-centimeter radiation from the sun. Interferometers will be used in radar-astronomy research for obtaining high angular resolution.

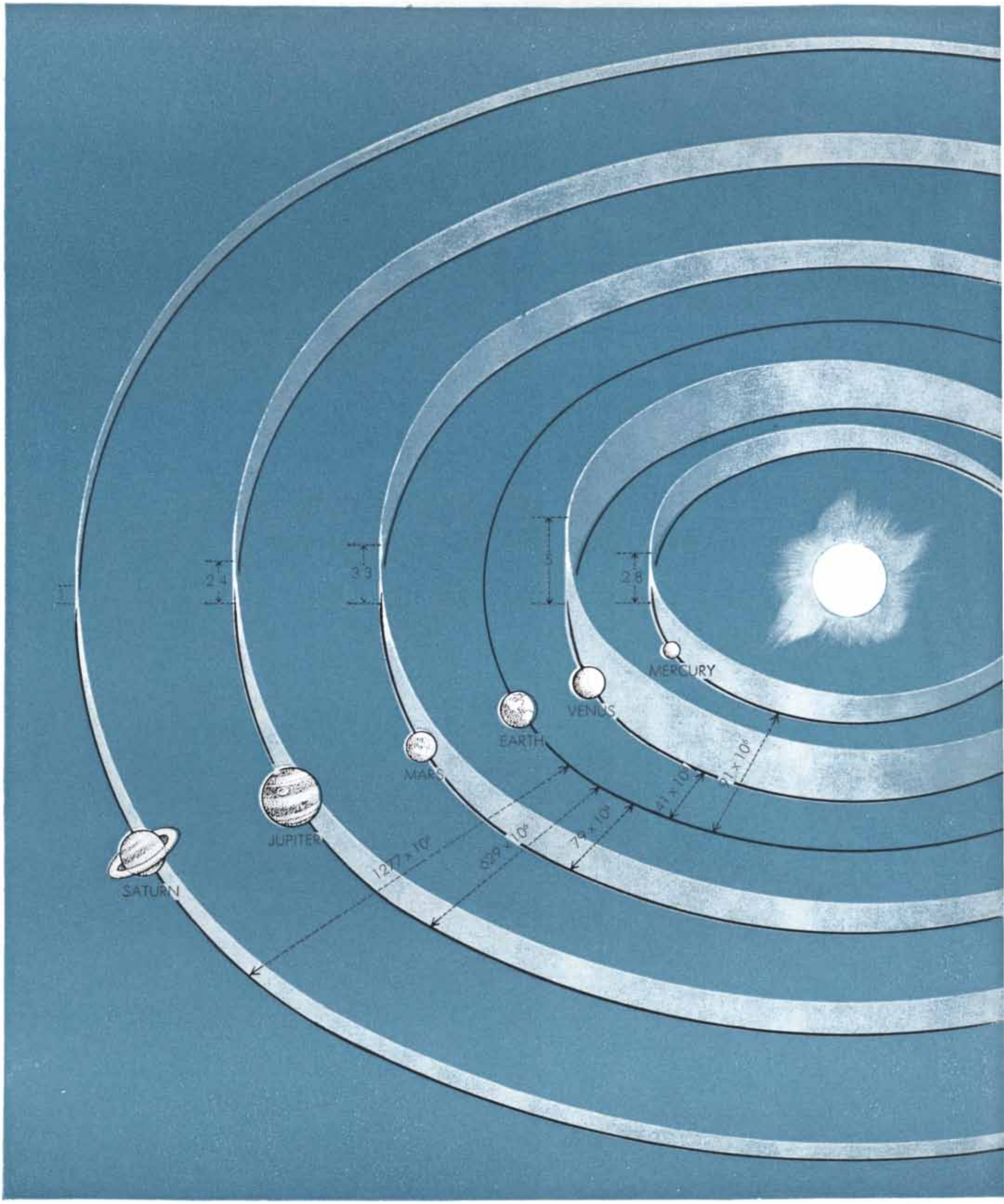
a wavelength of 15 meters, compared with an echo at a much shorter wavelength, is only .000025 second.

At present there are no long-wavelength radars with sufficient pulse power to make this measurement. But there are methods for making essentially the same measurement with lower powered radars that can transmit continuously at several discrete wavelengths. Such an experiment is now under way at Stanford, and it appears that it will indeed be possible to monitor the changing density of the interplanetary medium between the earth and the moon. With more sensitive systems, similar measurements could be made between the earth and Venus and between the earth and Mars. It would be especially interesting to observe the changing density of the interplanetary medium in different directions as the sun erupts and drives varying amounts of ionized gas away from its strong gravitational field.

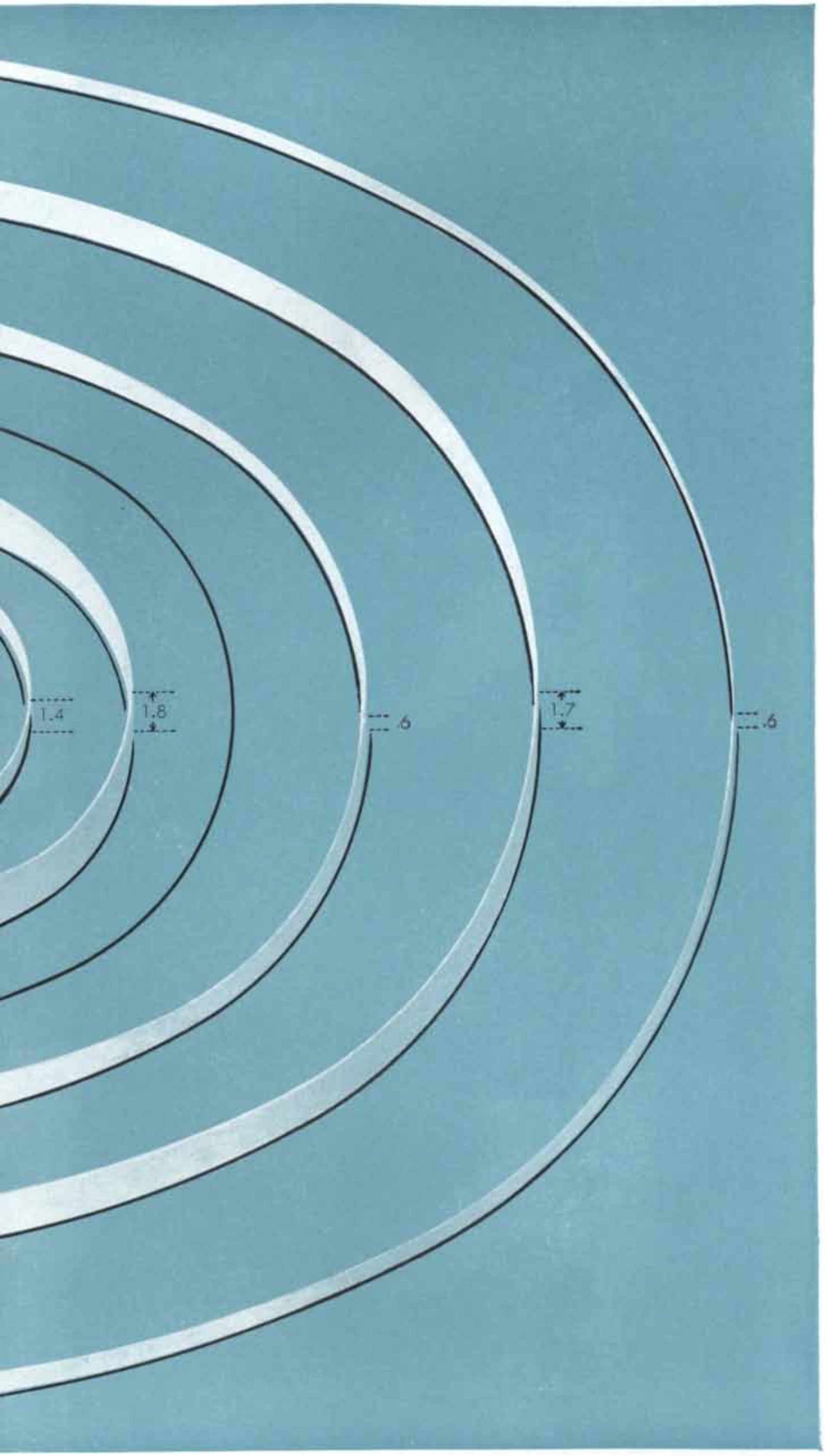
Moon echoes have already been employed to study signal distortions caused by the earth's ionosphere. In order to measure the density of the interplanetary gas between the earth and moon it will be necessary to measure the density of the ionosphere at the same time, so that it can be subtracted from the total to yield the true interplanetary density. A



lines at right) is correspondingly distorted. Wave energy reflected from portions of planet moving toward or away from the earth will return at shorter wavelengths (*upper wavy line*) or longer wavelengths (*colored line*). Wave energy from center (*vertical stippled area*) will not show this Doppler shift. Two small regions (*hatched areas*) are at the same range and show the same Doppler shift. By separating the echo into many range and Doppler wavelength portions, other small regions can be studied independently.



HEIGHT OF BANDS drawn on the orbits of five planets represents the echo intensity of those targets with respect to the moon. Relative reduction in intensity is obtained by subtracting band height from a reference intensity of 12 for the moon and raising 10 to that power. Venus, for example, has a band height of 5 at its closest approach to the earth; its echo intensity is thus 7 (12 minus 5) powers of 10 (10^7), or 10 million times, weaker than a moon echo. Band heights to left of sun are for planets at their closest ap-



proach to earth; to the right, for their farthest approach. Sun has a band height of 7. Computations are based on the assumption that echo intensity depends only on target diameter and distance, varying directly as the square of the diameter and inversely as the fourth power of distance. Figures at lower left give distance from the earth in kilometers.

variety of techniques for study of the ionosphere has been developed recently. One, which requires the moon as a reflector, measures the change in polarization of the waves caused by the earth's magnetic field during the two-way transit of the pulse through the ionosphere [*see illustration on page 53*]. A quite different procedure makes use of high-sensitivity radars operating at relatively short wavelengths. These waves are not reflected by the ionosphere, but a minute fraction of their energy is scattered back to the receiver by the individual electrons. The precise distribution of electrons with height can thus be measured, as well as the temperature and other aspects of the upper atmosphere.

Another use for radar is suggested by the results recently obtained from the study of very-long-wavelength (tens of kilometers) radio signals, or "whistlers," which propagate tens of thousands of miles out into space along the lines of force in the earth's magnetic field. The sources of these signals are the strong radiations from lightning strokes and magnetohydrodynamic waves formed by streams of particles from the sun. Man-made radar signals that propagate along the same magnetic paths may be employed to extend such investigation of various outer-atmospheric phenomena.

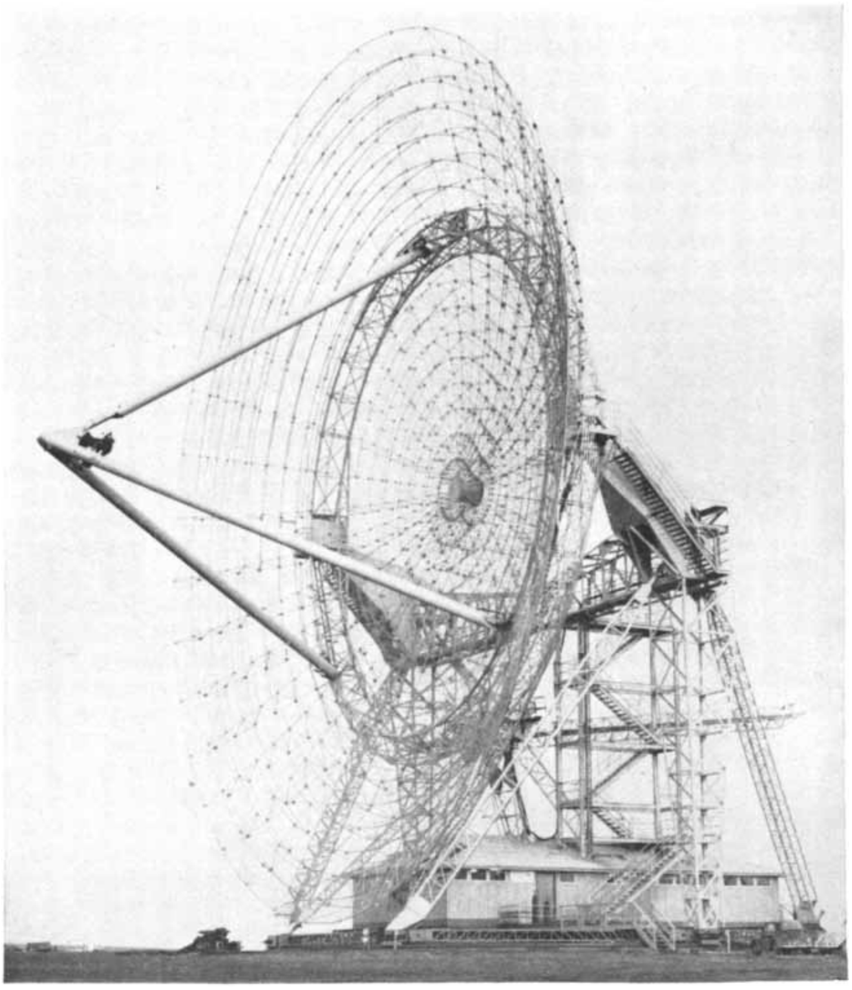
In many respects the investigation of the ionosphere bears upon what may be learned by probing deeper into space. For example, radar studies of the auroras, which are caused by the entry of solar particles into the atmosphere, show results that are related to solar events and changes in the radiation belts of the earth. Some 10 billion meteors plunging into the upper atmosphere each day streak the sky with trails of ionized particles. Radar echoes from these trails have laid the foundation for a new technique in long-distance radio communication. They have also produced significant information about the upper atmosphere and have helped determine the distribution of meteoritic dust between the planets. Studies of very small meteors indicate that most of these particles travel in bunches, in effect forming thousands of subvisual comets which collide with the earth each year. Meteoritic particles do not appear to be a serious threat to space craft, though little is known about particles in orbits that do not intercept the orbit of the earth. There are so many of these small dust particles between the planets that they scatter enough sunlight to be seen as a faint luminosity: the so-called zodiacal light. If the solar system were viewed from a position well outside the orbit of Pluto, this disk of luminosity, extending beyond the earth's orbit, would be a more striking feature of the solar system than are the planets themselves.

The ionospheres, radiation belts and auroras that may exist near other planets present another group of interesting subjects for investigation by long-wavelength radars of very high sensitivity. It may also be possible to obtain a direct echo from solar streams far from the sun, and from comets that pass near the earth. Radar reflections from the vicinity of a vehicle in space could be greatly enhanced by releasing a material such as sodium to form a large cloud that would be ionized by sunlight. Soviet workers used this technique to increase the visibility of their first circumsolar satellite.

The ultimate ambition of the radar astronomer is to map the surfaces of the planets. The most surprising feature of the radar signal is its resolving power, that is, its capacity to produce separate images of objects that are close together or to resolve the details in a small image. Even astronomers are surprised to learn that this power in radar astronomy is independent of distance. One second of arc is considered good angular resolution in photographs of objects in the solar system; this is the equivalent of two kilometers on the surface of the moon and 450 kilometers on the surface of Mars. The smallest angles measured in radio astronomy are of the order of 60 seconds, or one minute, of arc. The unaided eye has about the same resolving power. Thus radio astronomy and the human eye cannot resolve any detail within the tiny disk of Mars, which subtends an angle of 25 seconds, and they can resolve only the gross features of the lunar surface.

The angular resolution of radar astronomy is only slightly better than that of radio astronomy. But resolution in angle is not the only means of obtaining clear radar pictures of the planets. Because the wavelength and the timing of the transmitted pulse are under rigorous control, it is possible to measure with great accuracy the flight time required for various parts of the reflected pulse to return to the receiver and to measure with equal accuracy the changes in wavelength—the Doppler effect—caused by the relative motion of various parts of the reflecting object. For example, if the object is a planet, points on the spherical surface that are at the same distance (that is, the same range or flight time) from the transmitter will return echo energy at the same time. For any given flight time these points describe a circle concentric with the nearest point on the face of the planet. If the planet is rotating, those points on the planet that are moving toward the earth will return an echo with a wavelength shorter than that of the transmitted signal, and those points that are moving away will return an echo with a longer wavelength. For any given Doppler shift in wavelength such points describe an arc on the surface of the planet equivalent to that which would be formed by the intersection of a plane parallel to the planet's axis and to the line of sight from the earth. The two points that are marked by the intersection of a given range circle and a given Doppler arc will return echoes with the same flight time and the same Doppler shift and may thus be used to locate those points on the surface of the planet. Other combinations of flight time and Doppler shift will locate other pairs of points on the surface [*see illustration at bottom of pages 54 and 55*]. Since each point becomes paired with other points as the planet rotates, all points can ultimately be resolved to lay out a map of the planet's surface. The distinguishing feature of each point—whether sand, boulders, mountains, water or vegetation—can be determined by other changes in the echo, changes in the polarization and total energy of the returning signal, which will also vary with the changing angle of reflection from the rotating planet and with the choice of the signal transmitted. Such information will complete the planetary map.

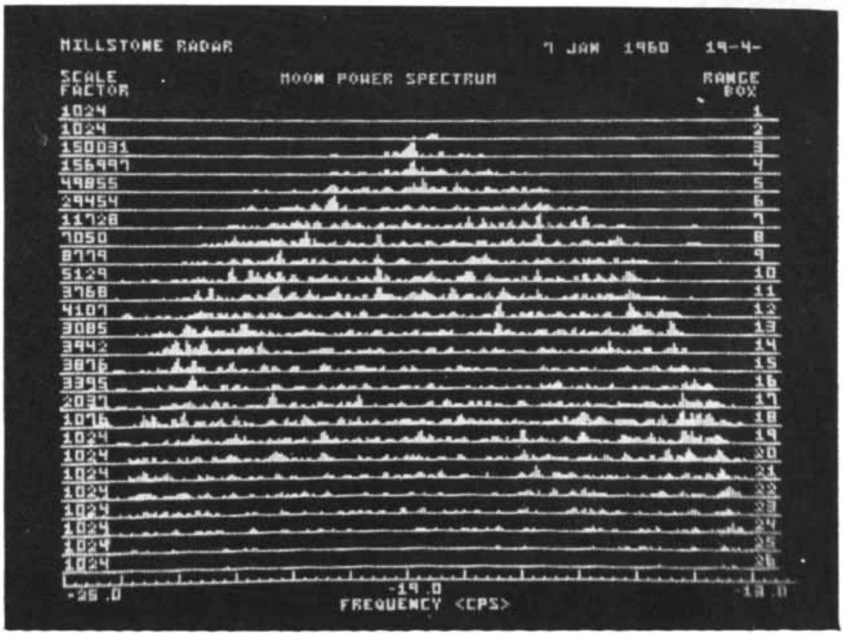
This technique, first described by workers at the Lincoln Laboratory, has been used by them to map the moon at a wavelength of 70 centimeters. With discrimination of flight-time differences of five ten-thousandths second and Doppler shifts of two ten-billionths wavelength, their radar system resolved re-



ANTENNA 142 FEET IN DIAMETER is the second largest steerable paraboloid in operation at the present time. The antenna was installed in Scotland by the Stanford Research Institute, and is being used for radar studies of the earth's ionosphere and of the moon.

gions as close as 100 kilometers. About 1,000 different areas were separately detected in this experiment. Of course photographs of the moon have much higher resolution. But the radar mapping experiment marks the first trial of this technique, and with more powerful radar systems there is almost no limit to the resolution that can be obtained. Since discrimination in range and in Doppler wavelength is independent of distance, a radar system of given power and sensitivity can resolve the surface of a planet in the same detail to which it can resolve the moon. Thus while the best optical systems resolve points on the surface of Mars no closer than several hundred kilometers, radar astronomy may some day bring the resolution of Mars and other planets down to a few kilometers. Radar systems are already being built that may begin to resolve relatively large regions on the nearer planets.

The moon will provide a convenient object for calibration of these new radar systems when they are turned on more distant targets. Range-Doppler resolution may be compared with fine optical detail on the moon as a guide for interpreting radar results. Moreover, the moon can be resolved in angle, providing another check on the range-Doppler technique. Since mapping—not to mention the mere detection of "hard" targets—calls for shorter wavelengths, receivers will employ the new low-noise circuits and will exploit the full geometrical precision that can be built into antennas. However, radar measurements of hard targets at longer wavelengths will provide other valuable information. By measuring changes in the echo that accompany changes in wavelength, in the polarization of the signal and in the angle at which the signal is reflected from the surface, it may be possible to determine the electrical and magnetic properties of the surface material, its average roughness (that is, whether it consists of sand, boulders, mountains or water waves) and the presence or absence of features of uniform orientation and length, such as vegetation.



RADAR MAP OF THE MOON was made in preliminary form from observations with the Lincoln Laboratory's 84-foot Millstone Hill antenna, operating at a wavelength of 70 centimeters. Semicircular boundary corresponds to the moon's edge as it would be seen from above by an observer facing the earth; the part of the moon nearest the earth is at top of map. As indicated by the frequency scale at bottom, right side of map corresponds to the part of the moon approaching the earth; left side, that moving away. Each line presents the echo data from a circle of equidistant points on the face of the moon. Each interval between lines represents a delay of .0005 second of radar echo-time. Further studies will be needed to perfect this radar map for comparison with visible features on the moon.

Once sufficiently sensitive radars are available, range-Doppler resolution could be used to measure surface features over relatively small areas. On Mars, for example, it should be possible to map in some detail the size and shape of the optically faint markings and to determine something about their electrical and physical characteristics. Since more is known about Mars than any other planet except the earth, there are many questions to be answered by careful radar studies.

Radar waves will penetrate the fog that envelops Venus and will return with information about that planet's surface. With only relatively coarse resolution in range and in Doppler wavelength, it should be possible to determine the large-scale surface features and to see if there are oceans, continents, polar icecaps or mountain ranges. The same measurements would also show the length of the Venusian day and the inclination of the planet's axis.

The more distant planets have less appeal because they appear much less hospitable as future goals of manned expeditions. But even Mercury, the smallest planet, has its interest to radar astronomy. At its closest approach to earth the hemisphere to be studied by radar is on the cold side, which is never illuminated by the sun and hence is never seen visually. When the planet is at greater range, the sunlit side could also be studied, especially in terms of the effects caused by the 600-degree-centigrade temperature-difference between its hemispheres.

With radar it should be possible to probe through the dense atmospheres of the major planets (Jupiter, Saturn, Uranus and Neptune) and to measure some of the surface characteristics of their presumably solid cores. Jupiter is the most interesting, partly because it is the largest planet, but also because radar may help determine the source of the tremendous outbursts of long-wave-length radio noise that it intermittently broadcasts. As for Pluto, it will be easier and more profitable to study some of the major satellites of the other planets before trying to bring the outermost planet under scrutiny.

Of course the final answers to many questions about the solar system will come only from highly sophisticated satellite probes. But radar astronomy will enhance the design and the planning of these enterprises by providing advance insights and will augment their results by continuity of observation. The radar installations will also play an important part in maintaining communication with far-traveling vehicles. Using only 5 per cent of the national expenditure for space exploration, very large-scale advances in the facilities for radar astronomy would be possible. One other fundamental ingredient is also badly needed, namely, young scientists of imagination and ability to work in this new discipline.

Pattern Recognition by Machine

There is not much doubt that computers can think, but they still cannot perceive. Recently, however, progress has been made toward enabling machines to recognize meaningful patterns such as letters

by Oliver G. Selfridge and Ulric Neisser

Can a machine think? The answer to this old chestnut is certainly yes: Computers have been made to play chess and checkers, to prove theorems, to solve intricate problems of strategy. Yet the intelligence implied by such activities has an elusive, unnatural quality. It is not based on any orderly development of cognitive skills. In particular, the machines are not well equipped to select from their environment the things, or the relations, they are going to think about.

In this they are sharply distinguished from intelligent living organisms. Every child learns to analyze speech into meaningful patterns long before he can prove any propositions. Computers can find proofs, but they cannot understand the simplest spoken instructions. Even the earliest computers could do arithmetic superbly, but only very recently have they begun to read the written digits that a child recognizes before he learns to add them. Understanding speech and reading print are examples of a basic intellectual skill that can variously be called cognition, abstraction or perception; perhaps the best general term for it is pattern recognition.

Except for their inability to recognize patterns, machines (or, more accurately, the programs that tell machines what to do) have now met most of the classic criteria of intelligence that skeptics have proposed. They *can* outperform their designers: The checker-playing program devised by Arthur L. Samuel of International Business Machines Corporation usually beats him. They *are* original: The "logic theorist," a creation of a group from the Carnegie Institute of Technology and the Rand Corporation (Allen Newell, Herbert Simon and J. C. Shaw) has found proofs for many of the theorems in *Principia Mathematica,* the monumental work in mathematical logic by A. N. Whitehead and Bertrand Russell. At least one proof is more elegant than the Whitehead-Russell version.

Sensible as they are, the machines are not perceptive. The information they receive must be fed to them one "bit" (a contraction of "binary digit," denoting a unit of information) at a time, up to perhaps millions of bits. Computers do not organize or classify the material in any very subtle or generally applicable way. They perform only highly specialized operations on carefully prepared inputs.

In contrast, a man is continuously exposed to a welter of data from his senses, and abstracts from it the patterns relevant to his activity at the moment. His ability to solve problems, prove theorems and generally run his life depends on this type of perception. We suspect that until programs to perceive patterns can be developed, achievements in mechanical problem-solving will remain isolated technical triumphs.

Developing pattern-recognition programs has proved rather difficult. One reason for the difficulty lies in the nature of the task. A man who abstracts a pattern from a complex of stimuli has essentially classified the possible inputs. But very often the basis of classification is unknown, even to himself; it is too complex to be specified explicitly. Asked to define a pattern, the man does so by example; as a logician might say, ostensively. This letter is A, that person is mother, these speech sounds are a request to pass the salt. The important patterns are defined by experience. Every human being acquires his pattern classes by adapting to a social or environmental consensus—in short, by learning.

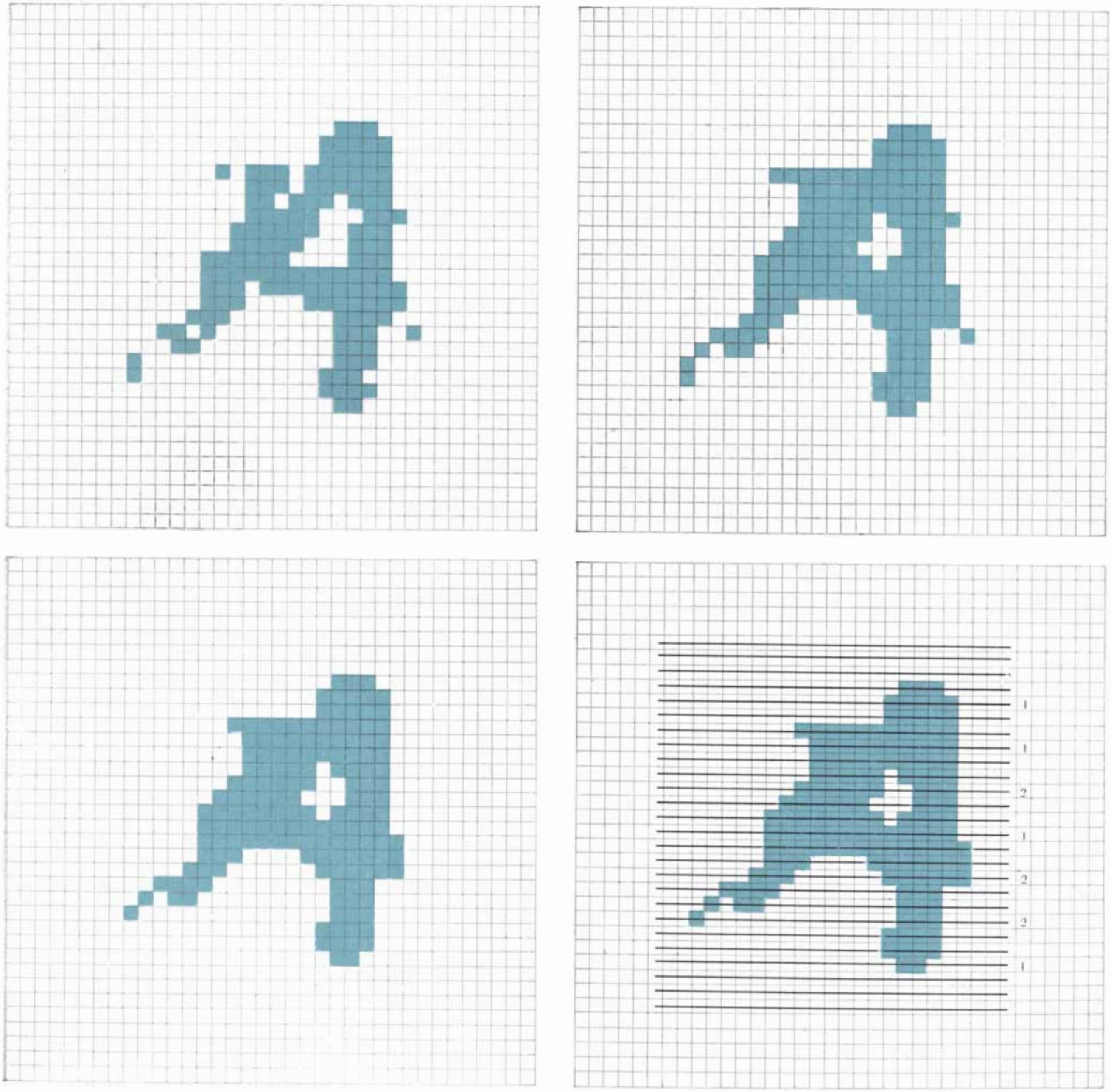
In company with workers at various institutions our group at the Lincoln Laboratory of the Massachusetts Institute of Technology has been working on mechanical recognition of patterns. Thus far only a few simple cases have been tackled. We shall discuss two examples. The first one is MAUDE (for Morse Automatic Decoder), a program for translating, or rather transliterating, hand-sent Morse code. This program was developed at the Lincoln Laboratory by a group of workers under the direction of Bernard Gold.

If telegraphers sent ideal Morse, recognition would be easy. The keyings, or "marks," for dashes would be exactly three times as long as the marks for dots; spaces separating the marks within a letter or other character (mark spaces) would be as long as dots; spaces between characters (character spaces), three times as long; spaces separating words (word spaces), seven times as long. Unfortunately human operators do not transmit these ideal intervals. A machine that processed a signal on the assumption that they do would perform very poorly indeed. In an actual message the distinction between dots and dashes is far from clear. There is a great deal of variation among the dots and dashes, and also among the three kinds of space. In fact, when a long message sent by a single operator is analyzed, it frequently turns out that some dots are longer than some dashes, and that some mark spaces are longer than some character spaces.

With a little practice in receiving code, the average person has no trouble with these irregularities. The patterns of the letters are defined for him in terms of the continuing consensus of experience, and he adapts to them as he listens. Soon he does not hear dots and dashes at all, but perceives the characters as wholes. Exactly how he does so is still obscure, and the mechanism probably varies widely from one operator to another. In any event transliteration is impossible if each mark and space is considered individually. MAUDE therefore uses contextual information, but far less than is available to a trained operator. The machine program knows all the standard Morse characters and a few compound ones, but no syllables or words. A trained operator, on the other hand, hears the characters themselves embedded in a meaningful context.

Empirically it is easier to distinguish between the two kinds of mark than among the three kinds of space. The main problem for any mechanical Morse translator is to segment the message into its characters by identifying the character spaces. MAUDE begins by assuming that the longest of each six consecutive spaces is a character space (since no Morse character is more than six marks long), and the shortest is a mark space. It is important to note that although the former rule follows logically from the structure of the ideal code, and that the latter seems quite plausible, their effectiveness can be demonstrated only by experiment. In fact the rules fail less than once in 10,000 times.

The decoding process proceeds as follows [*see illustration on page 63*]. The marks and spaces, received by the machine in the form of electrical pulses, are converted into a sequence of numbers measuring their duration. (For technical reasons these numbers are then converted into their logarithms.) The sequence of durations representing spaces



HAND-PRINTED LETTER A is processed for recognition by computer. Original sample is placed on grid and converted to a cellular pattern by completely filling in all squares through which lines pass (*top left*). The computer then cleans up the sample, filling in gaps (*top right*) and eliminating isolated cells (*bottom left*). The program tests the pattern for a variety of features. The test illustrated here (*bottom right*) is for the maximum number of intersections of the sample with all horizontal lines across the grid.

is processed first. The machine examines each group of six (spaces one through six, two through seven, three through eight and so on), recording in each the longest and shortest durations. When this process is complete, about 75 per cent of the character spaces and about 50 per cent of the mark spaces will have been identified.

To classify the remaining spaces a threshold is computed. It is set at the most plausible dividing line between the range of durations in which mark spaces have been found and the range of the identified character spaces. Every unclassified number larger than the threshold is then identified as a character space; every one smaller than the threshold, as a mark space.

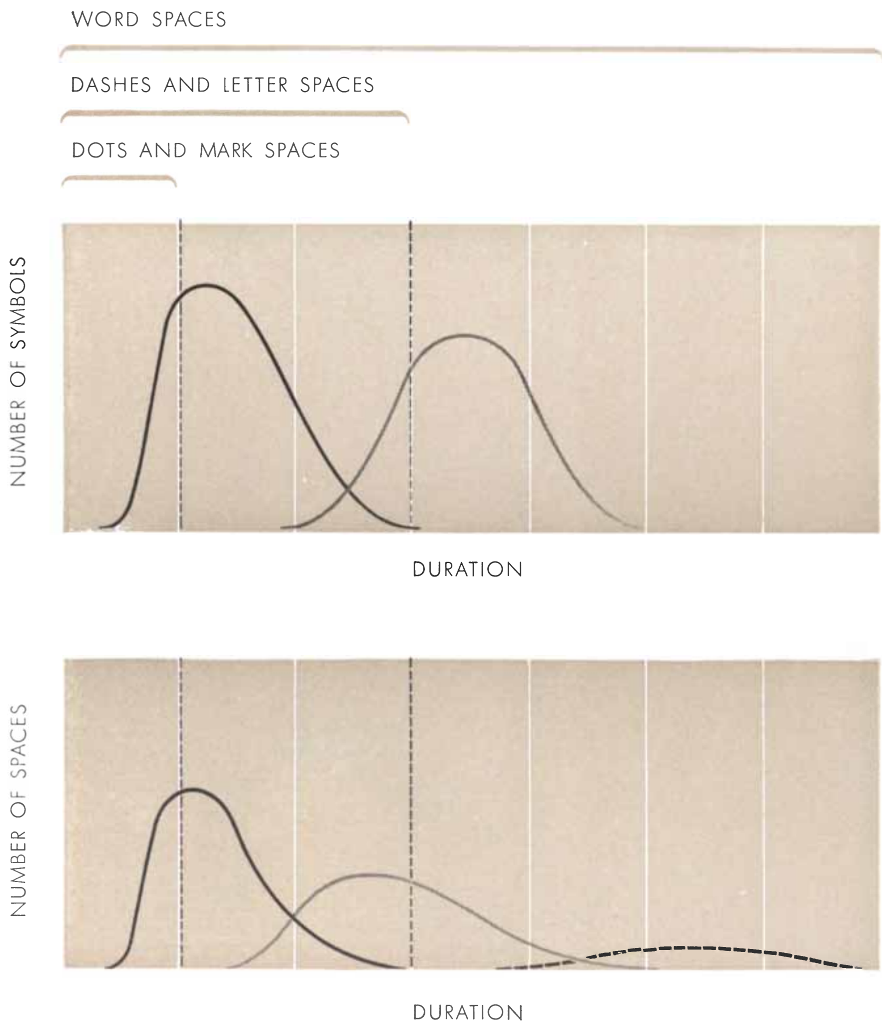
Now, by a similar process, the numbers representing marks are identified as dots and dashes. Combining the classified marks and spaces gives a string of tentative segments, separated by character spaces. These are inspected and compared to a set of proper Morse characters stored in the machine. (There are about 50 of these, out of the total of 127 possible sequences of six or fewer marks.) Experience has shown that when one of the tentative segments is not acceptable, it is most likely that one of the supposed mark spaces within the segment should be a character space instead. The program reclassifies the longest space in the segment as a character space and examines the two new characters thus formed. The procedure continues until every segment is an acceptable character, whereupon the message is printed out.

In the course of transmitting a long message, operators usually change speed from time to time. MAUDE adapts to these changes. The computed thresholds are local, moving averages that shift with the general lengthening or shortening of marks and spaces. Thus a mark of a certain duration could be classified as a dot in one part of the message and a dash in another.

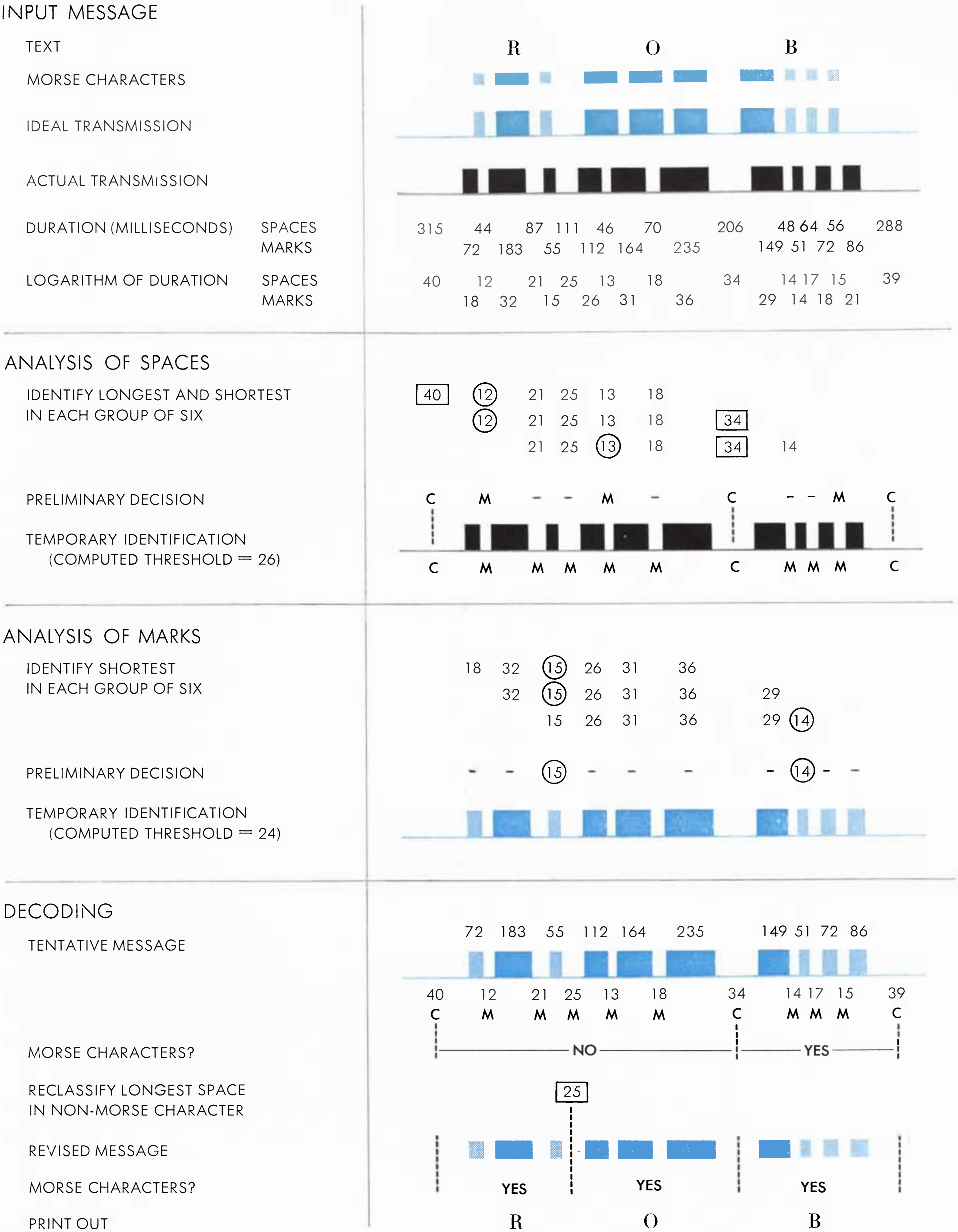
MAUDE's error rate is only slightly higher than that of a skilled human operator. Thus it is at least possible for a machine to recognize patterns even where the basis of classification is variable and not fully specified in advance. Moreover, the program illustrates an important general point. Its success depends on the rules by which the continuous message is divided into appropriate segments. Segmentation seems likely to be a primary problem in all mechanical pattern-recognition, particularly in the recognition of speech, since the natural pauses in spoken language do not generally come between words. MAUDE handles the segmentation problems in terms of context, and this will often be appropriate. In other respects MAUDE does not provide an adequate basis for generalizing about pattern recognition. The patterns of Morse code are too easy, and the processing is rather specialized.

Our second example deals with a more challenging problem: the recognition of hand-printed letters of the alphabet. The characters that people print in the ordinary course of filling out forms and questionnaires are surprisingly varied. Gaps abound where continuous lines might be expected; curves and sharp angles appear interchangeably; there is almost every imaginable distortion of slant, shape and size. Even human readers cannot always identify such characters; their error rate is about 3 per cent on randomly selected letters and numbers, seen out of context.

The first step in designing a mechanical reader is to provide it with a means of assimilating the visual data. By nature computers consider information in strings of bits: sequences of zeros and ones recorded in on-off devices. The simplest way to encode a character into such a sequence is to convert it into a sort of half-tone by splitting it into a mesh or matrix of squares as fine as may be necessary. Each square is then either black or white—a binary situation that the machine is designed to handle. Making such half-tones presents no problem. For example, an image of the letter could be projected on a bank of photocells, with the output of each cell controlling a binary device in the computer. In the ex-



VARIABILITY OF MORSE CODE sent by a human operator is illustrated in these curves. Upper graph shows range of durations for dots (*black curve*) and dashes (*gray curve*) in a message. Lower graph gives the same information for spaces between marks within a character (*solid black curve*), spaces between characters (*gray curve*) and between words (*broken curve*). Ideal durations are shown by brackets at top and vertical broken lines.



"MAUDE" PROGRAM, described in text, translates Morse code. Marks identified as dots are shown in light color; marks identified as dashes, in dark color. Unidentified marks are in black. Character spaces are denoted by C; mark spaces, by M. A circle around a number indicates that it is the smallest in a group; a rectangle means it is the largest. Analysis of spaces and marks proceeds by an examination of successive groups of six throughout the message. The table shows only the first three such groups in each case.

periments to be described here the appropriate digital information from the matrix was recorded on punch cards and was fed into the computer in this form.

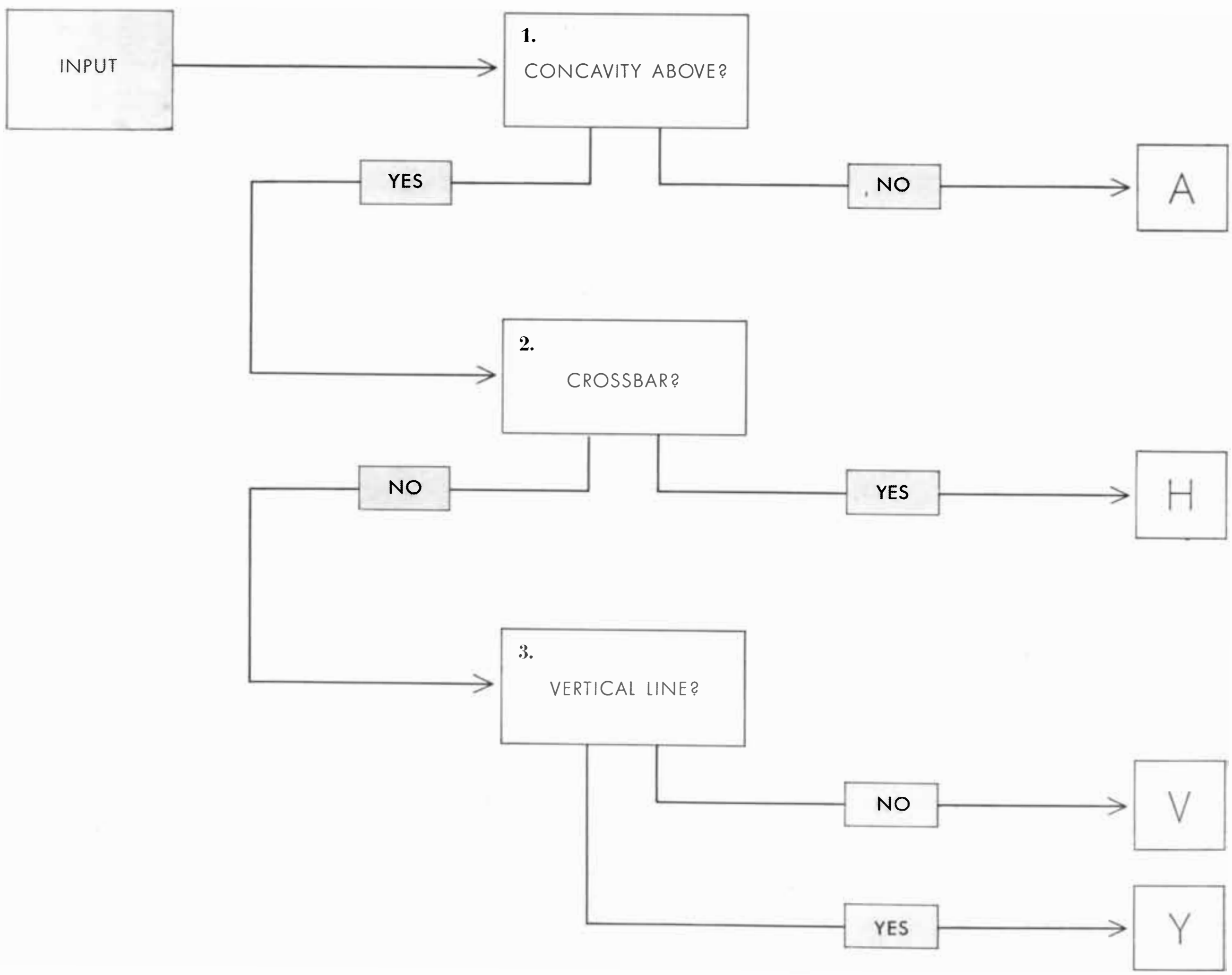
Once this sequence of bits has been put in, how shall the program proceed to identify it? Perhaps the most obvious approach is a simple matching scheme, which would evaluate the similarity of the unknown to a series of ideal templates of all the letters, previously stored in digital form in the machine. The sequence of zeros and ones representing the unknown letter would be compared to each template sequence, and the number of matching digits recorded in each case. The highest number of matches would identify the letter.

In its primitive form the scheme would clearly fail. Even if the unknown were identical to the template, slight changes in position, orientation or size could destroy the match completely [*see top illustration on page 68*]. This difficulty has long been recognized, and in some character-recognition programs it has been met by inserting a level of information-processing ahead of the template-matching procedure. The sample is shifted, rotated and magnified or reduced in order to put it into a standard, or at least a more tractable, form.

Although obviously an improvement over raw matching, such a procedure is still inadequate. What it does is to compare shapes rather successfully. But letters are a good deal more than mere shapes. Even when a sample has been converted to standard size, position and orientation, it may match a wrong template more closely than it matches the right one [*see bottom illustration on page 68*].

Nevertheless the scheme illustrates what we believe to be an important general principle. The critical change was from a program with a single level of operation to a program with two distinctly different levels. The first level shifts, and the second one matches. Such a hierarchical structure is forced on the recognition system by the nature of the entities to be recognized. The letter A is defined by the set of configurations that people call A, and their selections can be described—or imitated—only by a multilevel program.

We have said that letter patterns cannot be described merely as shapes. It appears that they can be specified only in terms of a preponderance of certain *features*. Thus A tends to be thinner at the top than at the bottom; it is roughly concave at the bottom; it usually has two main strokes more vertical than horizontal, one more horizontal than vertical, and so on. All these features taken together characterize A rather more closely than they characterize any other letter. Singly none of them is sufficient. For example, W is also roughly concave



SEQUENTIAL-PROCESSING program for distinguishing four letters, A, H, V and Y employs three test features: presence or absence of a concavity above, a crossbar and a vertical line. The tests are applied in order, with each outcome determining the next step.

at the bottom, and H has a pattern of horizontal and vertical strokes similar to that described for A. Each letter has its own set of probable features, and a successful character recognizer will determine which set is the best fit to an unknown sample.

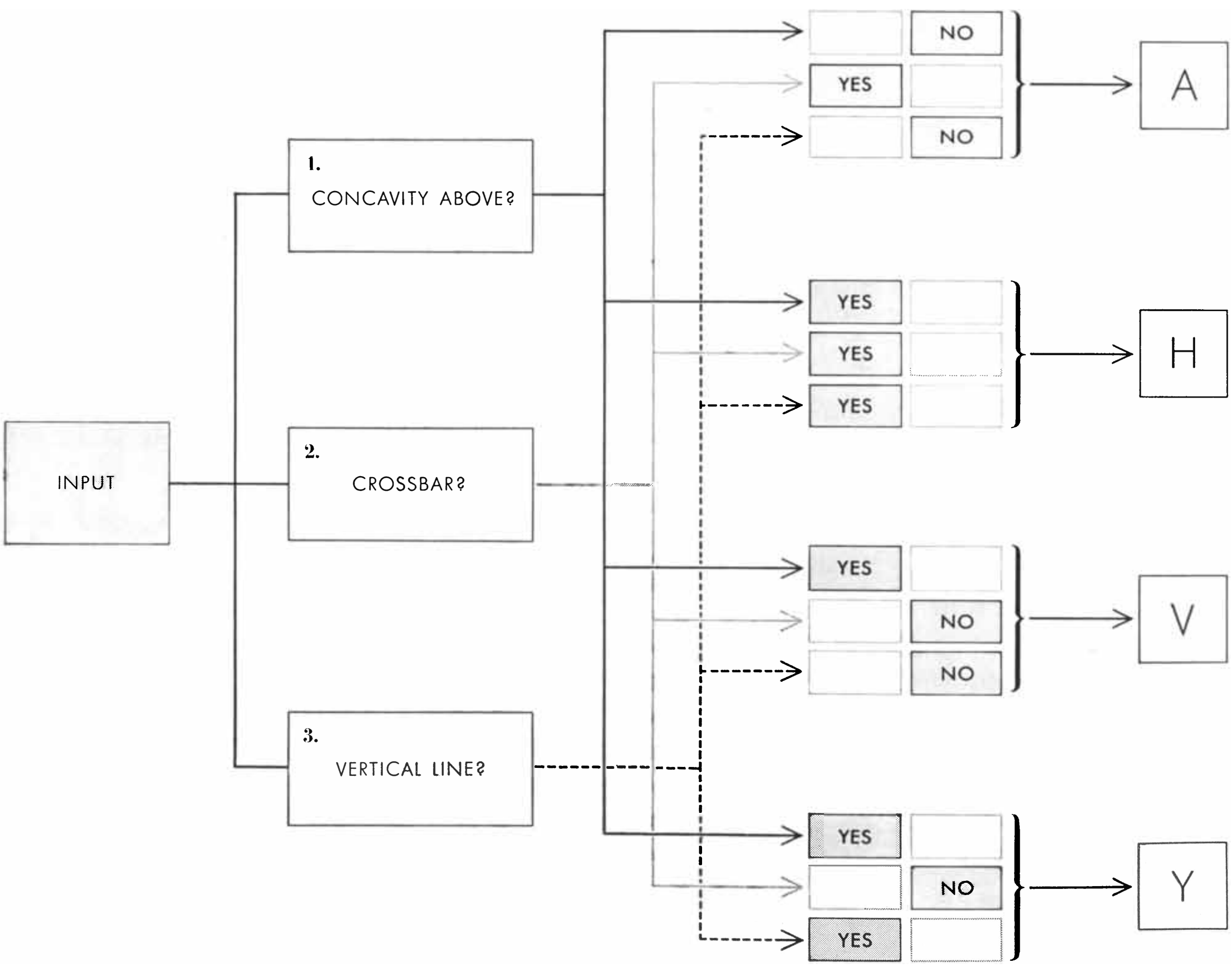
So far nothing has been said about how the features are to be determined and how the program will use them. The template-matching scheme represents one approach. Its "features," in a sense, are the individual cells of the matrix representing the unknown sample, and its procedure is to match them with corresponding cells in the template. Both features and procedure are determined by the designer. We have seen that this scheme will not succeed. In fact, any system must fail if it tries to specify every detail of a procedure for identifying patterns that are themselves defined only ostensively. A pattern-recognition system must learn. But how much?

At one extreme there have been attempts to make it learn, or generate, everything: the features, the processing, the decision procedure. The initial state of such a system is called a "random net." A large number of on-off computer elements are multiply interconnected in a random way. Each is thus fed by several others. The thresholds of the elements (the number of signals that must be received before the element fires) are then adjusted on the basis of performance. In other words, the system learns by reinforcing some pathways through the net and weakening others.

How far a random net can evolve is controversial. Probably a net can come to act as though it used templates. However, none has yet been shown capable of generating features more sophisticated than those based, like templates, on single matrix-cells. Indeed, we do not believe that this is possible.

At present the only way the machine can get an adequate set of features is from a human programmer. The effectiveness of any particular set can be demonstrated only by experiment. In general there is probably safety in numbers. The designer will do well to include all the features he can think of that might plausibly be useful.

A program that does not develop its own features may nevertheless be capable of modifying some subsequent level of the decision procedure, as we shall see. First however, let us consider that procedure itself. There are two fundamentally different possibilities: sequential and parallel processing. In sequential processing the features are inspected in a predetermined order, the outcome of each test determining the next step. Each letter is represented by a unique sequence of binary decisions. To take a simple example, a program to distinguish the letters A, H, V and Y



PARALLEL-PROCESSING program uses the same test features as the sequential program on opposite page, but applies all tests simultaneously and makes decision on the basis of the combined outcomes. The input is a sample of one of the letters A, H, V and Y.

LETTER	SAMPLES	OUTCOME			
		1	2	3	4
A	39		33	6	
E	46	6	35	5	
I	25	25			
L	24	7	17		
M	24			18	6
N	28		2	25	1
O	34		27	7	
R	33		28	4	1
S	38	8	30		
T	39	10	22	7	
TOTAL	330	56	194	72	8

"CENSUS" represents information learned by letter-recognition program during training period. This table summarizes the outcomes of the test for maximum number of intersections with a horizontal line, applied to a total of 330 indentified samples in the learning process.

might decide among them on the basis of the presence or absence of three features: a concavity at the top, a crossbar and a vertical line. The sequential process would ask first: "Is there a concavity at the top?" If the answer is no, the sample is A. If the answer is yes, the program asks: "Is there a crossbar?" If yes, the letter is H; if no, then: "Is there a vertical line?" If yes, the letter is Y; if no, V [*see illustration on page 64*].

In parallel processing all the questions would be asked at once, and all the answers presented simultaneously to the decision-maker [*see illustration on preceding page*]. Different combinations identify the different letters. One might think of the various features as being inspected by little demons, all of whom then shout the answers in concert to a decision-making demon. From this conceit comes the name "Pandemonium" for parallel processing.

Of the two systems the sequential type is the more natural for a machine. Computer programs are sequences of instructions, in which choices or alternatives are usually introduced as "conditional transfers": Follow one set of instructions if a certain number is negative (say) and another set of instructions if it is not. Programs of this kind can be highly efficient, especially in cases where any given decision is almost certain to be right. But in "noisy" situations sequential programs require elaborate checking and back-tracking procedures to compensate for erroneous decisions. Parallel processing, on the other hand, need make no special allowance for error and uncertainty.

Furthermore, some features are simply not subject to a reasonable dichotomy. An A very surely has a crossbar, an O very surely has not. But what about B? The most we can say is that it has more of a crossbar than O, and less than A. A Pandemonium program can handle the situation by having the demons shout more or less loudly. In other words, the information flowing through the system need not be binary; it can represent the quantitative preponderance of the various features.

Still another advantage of parallel processing lies in the possibility of making small changes in a network for experimental purposes. In typical sequential programs the only possible changes involve replacing a zero with a one, or vice versa. In parallel ones, on the other hand, the weight given to crossbarness in deciding if the unknown is actually B may be changed by as small an amount as desired. Experimental changes of this kind need not be made by the programmer alone. A program can be designed to alter internal weights as a result of experience and to profit from its mistakes. Such learning is much easier to incorporate into a Pandemonium than into a sequential system, where a change at any point has grave consequences for large parts of the system.

Parallel processing seems to be the human way of handling pattern recognition as well. Speech can be understood if all acoustic frequencies above 2,000 cycles per second are eliminated, but it can also be understood if those below 2,000 are eliminated instead. Depth perception is excellent if both eyes are open and the head is held still; it is also excellent if one eye is open and the head is allowed to move.

A Pandemonium system that learns from experience has been tested by Worthie Doyle of the Lincoln Laboratory. At present it is programmed to identify 10 hand-printed characters, and has been tested on samples of A, E, I, L, M, N, O, R, S and T. The program has six levels: (1) input, (2) clean-up, (3) inspection of features, (4) comparison with learned-feature distribution, (5) computation of probabilities and (6) decision. The input is a 1,024-cell matrix, 32 on a side. At the second level the sample character is smoothed by filling in isolated gaps and eliminating isolated patches [*see illustration on page 61*].

Recognition is based on such features as the relative length of different edges and the maximum number of intersections of the sample with a horizontal line. (The computer "draws" the lines by inspecting every horizontal row in the matrix, and recognizes "intersections" as sequences of ones separated by sequences of zeros.) No single feature is essential to recognition, and various numbers of them have been tried. The particular program shown here [*see illustration on opposite page*] uses 28.

Every letter fed into the machine is tested for each of the features. During the learning phase a number of samples

RECOGNITION PROGRAM for hand-printed letters applies the 28 feature tests listed by code name at left. Names represent such features as maximum intersections with horizontal line (HOMSXC), concavity facing south (SOUCAV) and so on. Figures in right-hand section of table are relative probabilities of all letters for each test outcome. The program decides on the letter with the largest total of all probabilities. In the example shown here the decision is for the letter A, with a probability total of 4.579.

TYPE OF TEST AND DESIGNATION		OUTCOME	A	E	I	L	M	N	O	R	S	T
HORIZONTAL AND VERTICAL CROSS-SECTIONS	HOMSXC	3	.083	.070			.250	.347	.097	.056		.097
	VEMSXC	3	.073	.339			.040		.008	.194	.258	.089
	HORUNS	2111111		.500						.500		
	VERUNS	2111111						1.000				
STROKES	HORSTR	1	.132	.006	.125	.125	.125	.146	.016	.057	.016	.203
	VERSTR	2	.178	.007			.170	.207	.229	.207		
EDGE LENGTHS AND RATIOS	SEDGE	1	.267	.007		.014	.158	.115	.007	.165		.266
	WEDGE	1	.083	.071	.024	.024	.035	.012		.047	.318	.389
	NEDGE	2	.259	.024	.153	.024	.106	.106	.071	.059	.189	.012
	EEDGE	4	.232		.161		.214	.286	.107			
	NO:SOU	4	.513				.205	.077		.128		.077
	EA:WES	1	.055	.400		.309	.018	.036		.163		.018
PROFILES	SOUCAV	3	.150				.800	.050				
	WESCAV	2	.047	.094	.023	.012	.023	.035	.035	.059	.412	.259
	NORCAV	1	.133	.177	.100	.092	.004		.133	.108	.116	.137
	EASCAV	1	.155	.005	.115	.095	.105	.130	.170	.010	.050	.165
	SOUBOT	220	.268	.106		.068	.159	.167	.008	.220	.008	
	WESBOT	221	.030	.030	.061						.364	.515
	NORBOT	121	.290	.145					.354	.042	.042	.125
	EASBOT	121	.326				.020	.102	.266	.020	.245	.020
INTERNAL STRUCTURE	SBOTSG	2	.250	.008		.016	.125	.141	.219	.203	.039	
	WBOTSG	1	.161	.076	.090	.099	.108	.121	.063	.081	.045	.157
	NBOTSG	1	.119	.190	.111	.102	.013	.018	.089	.040	.159	.159
	EBOTSG	1	.147	.058	.098	.103	.103	.121	.062	.071	.076	.061
	SOUBEN	20					.333	.167				.500
	WESBEN	10	.198	.143	.011	.022	.121	.132	.011	.099	.022	.241
	NORBEN	10	.169	.180		.135	.079			.146	.247	.045
	EASBEN	10	.211	.012	.012	.118	.176	.106		.176		.188
TOTAL SCORE			4.579	2.648	1.084	1.358	3.490	3.622	1.945	2.851	2.606	3.823

of each of the 10 letters is presented and identified. For every feature the program compiles a table or "census." It tests each sample and enters the outcome under the appropriate letter. When the learning period is finished, the table shows how many times each outcome occurred for each of the 10 letters. The table on page 66, which refers to maximum intersections with a horizontal line, represents the experience gained from a total of 330 training samples. It shows, for example, that the outcome (three intersections) occurred 72 times distributed among six A's, five E's, 18 M's, 25 N's, seven O's, four R's, seven T's and no other letters. The other possible outcomes are similarly recorded.

Next the 28 censuses are converted to tables of estimated probabilities, by dividing each entry by the appropriate total. Thus the outcome—three intersections—comes from an A with a probability of .083 (6/72); an E, with a probability of .070 (5/72), and so on.

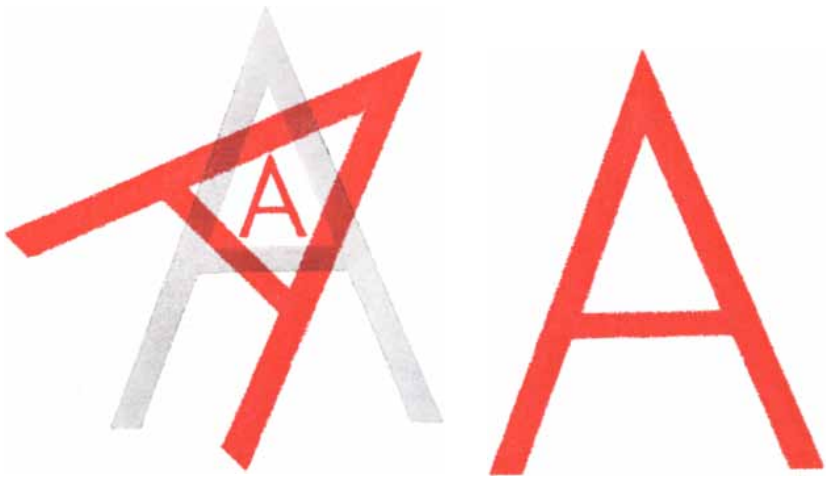
Now the system is ready to consider an unknown sample. It carries out the 28 tests and "looks up" each outcome in the corresponding feature census, entering the estimated probabilities in a table. Then the total probabilities are computed for each letter. The final decision is made by choosing the letter with the highest probability.

This program makes only about 10 per cent fewer correct identifications than human readers make—a respectable performance, to be sure. At the same time, the things it cannot do point to the difficulties that still lie ahead. We would emphasize three general problems: segmentation, hierarchical learning and feature generation.

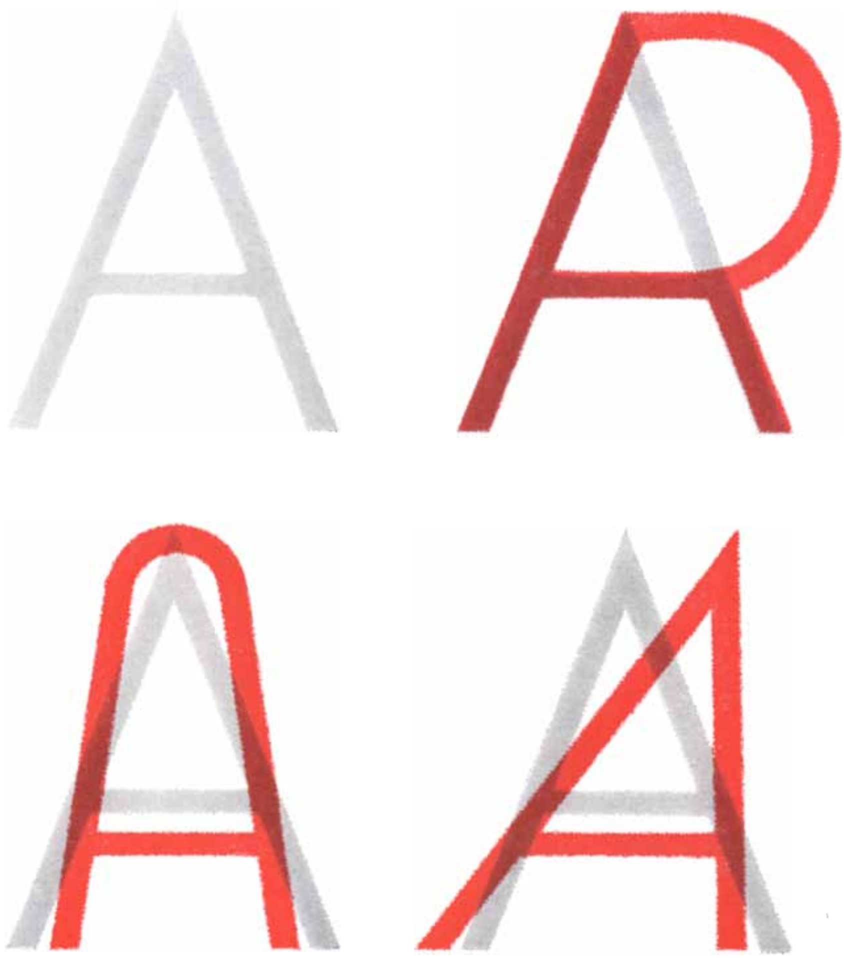
Characters must be fed in one at a time. The program is unable to segment continuous written material. The problem will doubtless be relatively easy to solve for text consisting of separate printed characters, but will be more formidable in the case of cursive script.

The program learns on one level only. The relation between feature presence and character probability is determined by experience; everything else is fixed by the designer. It would certainly be desirable for a character recognizer to use experience for more general improvements: to change its clean-up procedures, alter the way probabilities are combined and refine its decision process. Eventually we look to recognition of words; at that point the program will have to learn a vocabulary so that it can use context in identifying dubious letters. At the moment, however, neither we nor any other designers have any experience with the interaction of several levels of learning.

The most important learning process of all is still untouched: No current program can generate test features of its own. The effectiveness of all of them is forever restricted by the ingenuity or arbitrariness of their programmers. We can barely guess how this restriction might be overcome. Until it is, "artificial intelligence" will remain tainted with artifice.



TEMPLATE MATCHING cannot succeed when the unknown letter (*color*) has the wrong size, orientation or position. The program must begin by adjusting sample to standard form.



INCORRECT MATCH may result even when sample (*color*) has been converted to standard form. Here R matches A template more closely than do samples of the correct letter.

Kodak reports on:

new dimensional stability in recording film . . . tinging the stream

He has always thought a pick was the tool with which the Erie Canal was dug.

He thinks "D Max" is the name of a guy who might have been called "Dave" but wanted a classier handle.

Dr. F. W. Spangler (left) meets R. C. Hilton, senior geophysicist in charge of geophysical data processing for Shell Oil Company, Houston. Purpose of the visit is to familiarize Dr. Spangler directly with the ideal characteristics which Shell desires in a polyester recording film for use in the Reynolds Plotter. Dr. Spangler is an assistant superintendent of Kodak's Film Emulsion Division.

With the switch to thin, rugged Estar Base that eliminates troublesome dimensional change, Fred Spangler had to decide what inherent maximum density to give the **new Kodak Linagraph Recording Film.** Dick Hilton needs more from a film than that it shouldn't be troublesome. He doesn't talk Fred's "D Max" language. He seeks a certain appearance to which his perceptual process best responds in picking a "pick" from the corrected cross-section of the deep geological formation which the Plotter puts on the film. Spangler learned plenty from him and from others with other instrumentation and other perceptual patterns of translating photographic images into technical intelligence.

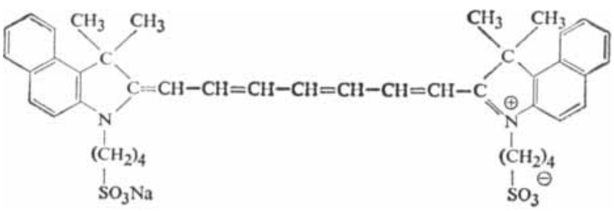
Eastman Kodak Company, Photorecording Methods Division, Rochester 4, N. Y., will be glad to write you a letter answering practical questions about the new Kodak Linagraph Recording Film (Estar Base), *such as who sells it and how to handle it, but we see no purpose in spilling a lot more words about it when all you have to do, if you are interested, is get some and see whether it suits you.*

Dye for the heart

We make a dye that has an absorption peak where the absorption curves cross for oxygenated and reduced hemoglobin. The strange consequence of this bit of trivia is that lives are being saved. Bad hearts are rebuilt.

Though the art of heart surgery is hard to teach through advertising columns, we hope some unforeseeable good might come from mentioning the dye to a wider scientific circle than knows it now.

Its molecule was constructed like this



by an interesting man who admires cats, writes warmly and well of the music of Brahms, and has supervised the synthesis of an average of one new dye a day during the 30-odd years we have enjoyed the good fortune to retain him in our employ.

When a certain distinguished medical investigator asked for a dye that peaks sharply at 8000A in the infrared, our man went to work and produced indocyanine green.

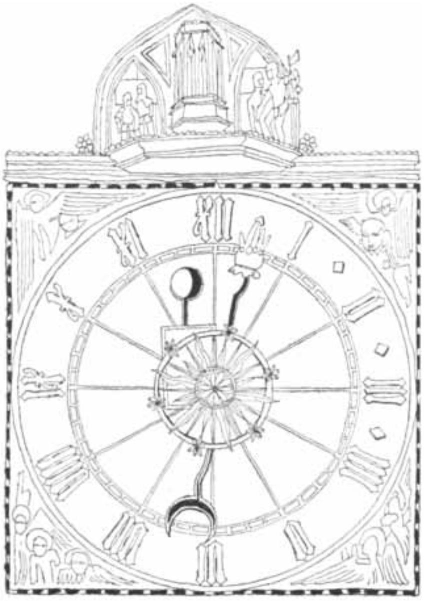
Before these heart men undertake a repair job, they must know what's wrong with the way the blood streams. Dyes are sometimes used to trace underground streams of water. Blood is already colored. Moreover its color depends on where it has been last. To add another color at a given point in the circuit, to measure this color automatically at some other point, and to calculate blood volume from the dilution of the color require the heart men to back their incredibly talented fingers with a little optical physics and adult habits of mathematical thought. It was clever to simplify the equations and raise sensitivity by centering dye absorption and photocell response at a wavelength where arterial and venous blood absorb light equally and weakly—cleverer even than the previous choice of Evans Blue, which just *looks* different from blood.

Things happen fast. A quick shot of indocyanine green at safe dilution goes in. A few seconds later the 8000A absorption, as a galvanometer plots it on photorecording paper, changes for a few more seconds. The shape of the plot tells the story to a man who has learned how to figure it out.

No toxic penalties have been noted. The patient does not change color. The dye appears to be rapidly and completely bound to blood albumin. It is quickly taken up by the healthy liver and all excreted in bile. The unhealthy liver takes significantly longer. Therefore there is a prospect of eventually using it to detect unhealthy livers.

Under the trademark "Cardio-Green" our indocyanine green is prepared for medical use and distributed by the pharmaceutical house of Hynson, Westcott & Dunning, Inc., Baltimore 1, Md. If you ask us anything more, we shall just pass your inquiry on to them, so you might as well write direct.

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

The UN Surveys Science

An increasing role in science for the United Nations and its family of specialized agencies is forecast in a report prepared by Pierre Auger, a French physicist and former director of the department of natural sciences of UNESCO. Entitled *Survey on the Main Trends of Inquiry in the Field of the Natural Sciences, the Dissemination of Scientific Knowledge and the Application of Such Knowledge for Peaceful Ends,* the paper was prepared at the direction of the UN General Assembly to mark out steps that the UN, its specialized agencies and the International Atomic Energy Agency might take in "encouraging the concentration of [research] efforts upon the most urgent problems, having regard to the needs of the various countries."

The survey is an encyclopedic analysis of world-wide trends in current research in fields ranging from mathematics and theoretical physics to cancer and motor-car suspensions. In the list of recommendations that follow, Auger urges increased aid to such bodies as the International Council of Scientific Unions and the European Committee for Nuclear Research (CERN), expansion of the activities of the International Atomic Energy Agency and other UN technical units, establishment of regional institutes for training specialized scientific personnel and the creation of an entirely new agency within the UN to carry on technical research for the purpose of speeding the development of backward areas. In addition he calls for specialized international programs in the exploration of the earth and space, in astronomy, oceanography, meteorology and cloud physics, wildlife conservation, digital computing, standardization of measurements, plasma physics, nuclear power, solar energy, electric-power transmission, molecular biology, neurophysiology, immunology, genetics, radiobiology, land utilization, agriculture and many areas of medicine and public health. Auger's report was presented to the UN Economic and Social Council at its July session in Geneva.

Farthest Galaxy

With the aid of the 200-inch telescope, Rudolph Minkowski of the Mount Wilson and Palomar Observatories has photographed a spot of light that appears to originate six billion light-years from the earth, and thus represents by far the most distant celestial object yet detected. Thought to be either a single galaxy or two galaxies in collision, the object exhibits a red-shift indicating that it is receding from the earth at a velocity of 90,000 miles a second—almost half the speed of light.

At distances of much more than two billion light-years most astronomical light-sources are undetectable. Their red-shift is so great as to put most of their light into the infrared portion of the spectrum, where it is drowned out by the infrared radiation of the earth's atmosphere. To photograph more distant objects it is necessary to find ones with bright emission lines far enough into the ultraviolet to remain in the visible spectrum after the shift. It has been found that strong sources of radio waves frequently have such emissions. Minkowski enlisted the aid of the radio observatories at the University of Cambridge and the California Institute of Technology, both of which are equipped with interferometers capable of high accuracy in locating small radio sources. Training the telescope on a source not associated with a previously visible object, Minkowski succeeded in making a spectrogram of the distant galaxy in a four-and-a-half hour exposure. He is now attempting to check the distance estimate by measuring the brightness of the object.

According to the evolutionary, or "big bang," theory, the universe originated in a vast explosion six to 12 billion years ago. Thus the light now recorded by Minkowski may have started out near the very beginning of time.

Biggest Canyon

A deep gash in the ocean floor, probably the largest canyon yet discovered on the earth's surface, was found in the South Atlantic last June by the Columbia University research ship *Vema*. Centered at 43 degrees 30 minutes South and 57 degrees 30 minutes West—roughly halfway between Buenos Aires and the Falkland Islands—the canyon is half a mile to a mile deep, nearly a mile wide at the bottom, five to 12 miles wide at the top, and at least several hundred miles long. Together with an Argentine oceanographic vessel also equipped with precision depth-recording equipment, the *Vema* made nearly 40 crossings of the cut, exploring about 70 miles of it in detail.

At first it appeared that the gorge might be an oceanic trench, since it runs parallel to the South American coast for 45 miles. At that point, however, it turns abruptly seaward. Cores taken from the bottom show that it is a river canyon. Pebbles characteristic of river beds were found beneath a layer of recent sediments. W. Maurice Ewing, director of Columbia's Lamont Geological Laboratory and chief scientist on the *Vema*, believes the canyon was part of an ice-age river system in what is now central Argentina. At that time the oceans were several hundred feet lower than at present, and the Argentine coast extended well beyond its present location. Presumably sediment carried to the old shore line piled up there and eventually slid down the continental slope, generating powerful turbidity currents that carved out the canyon.

The cruise was marked by another notable event. When the ship was southwest of Australia, it fired a series of 50-pound underwater bombs, and the explosion was heard by hydrophones at the Lamont field station in Bermuda, 12,000 miles away. The vibrations reached Bermuda via a "sound channel" in the vast stretches of the Indian and Atlantic oceans between Australia and Bermuda. Until now, the longest transmission through such a channel was 3,000 miles. The new record will stand for all time, since no other pair of points on the earth offers a longer deep-sea path free from intervening land masses.

Engineering Enrollment

A sharp decline in the number of students entering U. S. engineering schools, which began in 1958, may have halted by this fall. In 1957, according to figures compiled by the Engineering Manpower Commission of the Engineers Joint Council, freshman classes totaled 78,757. The number was 70,029 in 1958, a drop of 11.1 per cent; and 67,704 in 1959, a further decrease of 3.4 per cent. The most recent survey by the Commission shows applications for this fall's entering class running ahead of last year.

A study at one private engineering school suggests that the drop was due in part to a shift of students from engineering to pure science. Measures to increase the over-all enrollment in science and technology have as yet had little effect. In this school, the Commission notes, the number of students registered in pure science rose from 1,511 to 1,983 between 1956 and 1959. Total enrollment in the school increased only from 5,217 to 5,422 during the same period, while engineering enrollment dropped from 3,706 to 3,439.

Sweet Dreams

Even a bad dream is better than no dream at all. This is suggested by some recent experiments of William Dement, a psychiatrist at Mount Sinai Hospital in New York.

Evidence accumulated in recent years by the University of Chicago physiologist Nathaniel Kleitman and a number of other investigators, that everyone dreams several times each night, led Dement to wonder what would happen if an individual were deprived of the opportunity to dream at all. During several nights in succession, he awoke sleeping volunteers each time their eye movements and increased brain-wave activity signaled the start of a dream.

In *Science* Dement reported the results on the first eight volunteers, all males between the ages of 23 and 32. One quit the study after only three nights in "a flurry of obviously contrived excuses." Two lasted for four nights, and five were able to go through five to seven nights of dream interruption. All showed a steady increase in the number of attempts to dream. One started seven dreams on the first night and 24 on the seventh. Moreover, all exhibited anxiety, irritability, difficulty in concentrating and other signs of psychological disturbance during the period of the experiment. There were no such disturbances when, in a control experiment, the volunteers were awakened between dreams. All the subjects felt better as soon as allowed to resume dreaming. Dement suggests that his results show "that a certain amount of dreaming each night is a necessity. It is as though a pressure to dream builds up."

The Photo in Photosynthesis

Of all the mysteries in the complex process of photosynthesis the hardest to crack has been the role of light itself. Daniel I. Arnon, plant physiologist at the University of California, has suggested that the primary action of light is to produce the energy-rich compound adenosine triphosphate (ATP), and that it has nothing to do directly with the assimilation of carbon dioxide or the release of oxygen.

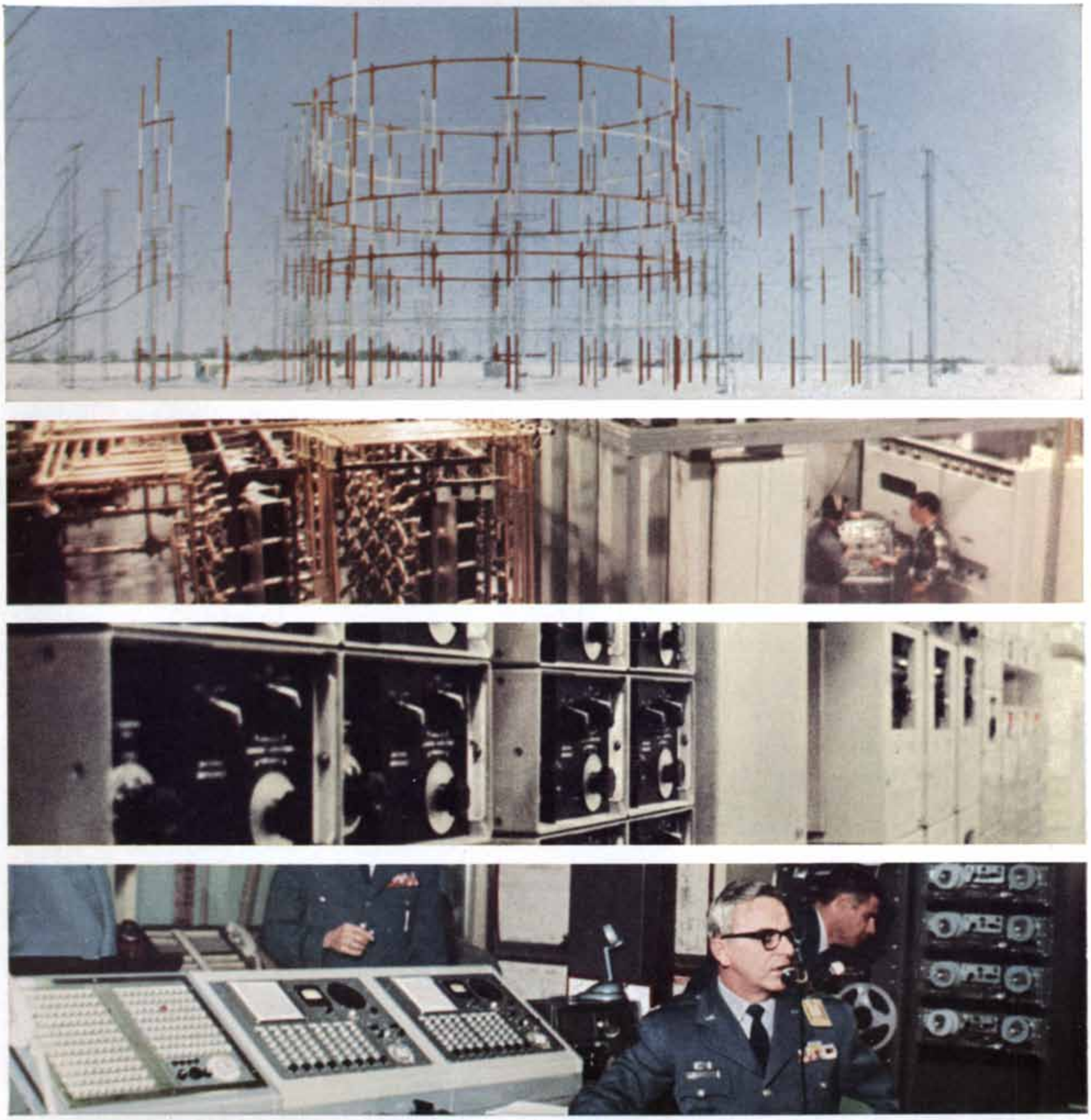
In a recent article in *Nature* Arnon and his colleagues report new evidence for this idea. A photosynthetic bacterium, *Chromatium,* which normally requires light to grow, can assimilate carbon and grow in the dark when supplied with ATP. The carbon comes not from carbon dioxide, but from acetate, and no oxygen is evolved in the process of its assimilation.

The authors suggest that this is the primitive type of photosynthesis. Only later did carbon dioxide and oxygen enter the picture. "It would thus appear," they conclude, "that oxygen evolution, which gave Priestley almost 200 years ago the first clue to the existence in this planet of what we now call photosynthesis, is, in the evolutionary time scale, the most recent aspect of the process."

Splat Cooling

A process that cools molten metals at the rate of two million degrees Fahrenheit per second has made it possible to produce metals and alloys with wholly new internal structures. The technique, called splat cooling, was developed by Pol E. Duwez, professor of mechanical engineering at the California Institute of Technology, and his students Ronald H. Willens and William Klement, Jr. Droplets of hot metal are shot against the copper rim of a rapidly spinning wheel, cooled to minus 300 degrees F. by liquid nitrogen. They flatten into pieces of thin foil half a square inch in area.

New alloys produced by splat cooling include copper-silver, germanium-silver and gallium antimonide-germanium,



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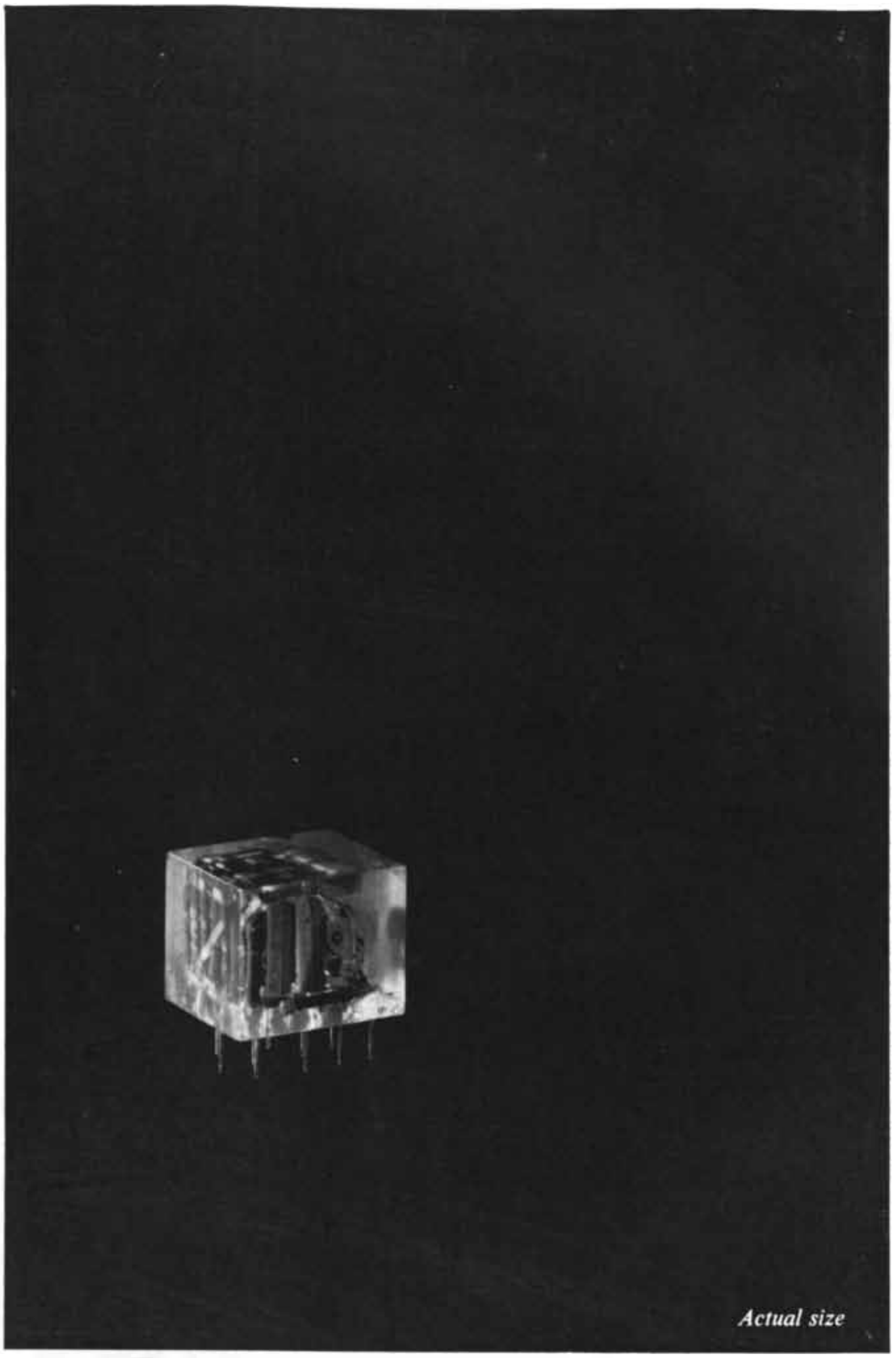

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Division of General Motors • Kokomo, Indiana with the component metals intermixed within ultramicroscopic grains. In normal alloys the metals segregate in different grains. In a splat-cooled gold-silicon mixture the atoms rearrange themselves into a novel and complex pattern 24 hours after cooling. The new materials are expected to have unusual electrical and magnetic properties, which may find applications in fields where the small size of the pieces is no handicap. Splat cooling, Duwez believes, may also offer a means of producing new superconducting and semiconducting alloys.

Genetics of Immunity

Successful tissue grafts between virtually unrelated strains of mice have been accomplished at the Roscoe B. Jackson Memorial Laboratory in Bar Harbor, Me. The method requires only that the animals have a single specific gene in common.

Elizabeth B. S. Russell and her associates made the discovery while seeking to treat a hereditary anemia in laboratory mice. They tried to transplant blood-manufacturing tissue from embryos of healthy animals into anemic adults. Of various purebred strains used as donors, only one served as the source of successful transplants. The injection of liver cells (or other blood-manufacturing tissue) from this strain not only cured the anemic adults, but also enabled them to accept grafts of other tissues from embryos or even adults of the donor strain.

The experimenters identified a single gene, the so-called histocompatibility, or "H," gene, as the crucial factor in determining the acceptability of the liver tissue to the host. Apparently blood-manufacturing tissues have less tendency to call forth tissue-rejecting antibodies in host animals than do other tissues such as skin. The latter cannot be grafted, even when the H genes are compatible. But once the liver cells have been accepted by a host, the animal becomes able to accept other tissues from donors of the same type.

Quivering Earth

The earthquake that devastated southern Chile last May will be remembered by seismologists as the first one demonstrated to have set the earth vibrating as a whole. Such an effect was predicted by 19th-century theoreticians. They expected three types of free oscillation: a so-called spheroidal mode, in which the earth behaves as if it were being alternately squeezed and released

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This project is part of the over-all Bendix space-systems development program which includes satellite communication, satellite navigation, radiation-resistant electronics, magnetohydrodynamics, plasma shock tubes, and infrared reconnaissance.

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by a giant with his hands on the poles, a torsional mode (in which the giant twists his hands in opposite directions) and a radial mode (uniform dilation and contraction of the earth).

The oscillations were difficult to detect because of their long period: up to an hour or more. Equipment capable of recording them did not come into use until about 20 years ago. Inconclusive evidence of free oscillation was obtained from the Kamchatka earthquake of 1952. During and after the Chilean quake, however, free oscillations were clearly registered on special long-period seismographs and a strain seismometer at the Lamont Geological Observatory. The oscillations displaced the earth's crust by several inches in the New York area—more than enough to have caused a distinct shock if it were not for the long period of 15 minutes and more. Both spheroidal and torsional oscillations were identified, according to Jack Oliver, head of the seismology department at Lamont, and the radial mode may turn up in records still awaiting analysis. The oscillations, distinct from aftershocks also accompanying the Chilean quake, continued for five days after the main shock.

City-Supported Research

With the ultimate objective of investing $1 per resident per year in medical research, the City of New York has appropriated $1.3 million to finance 32 medical research units and 21 investigatorships in the city during the fiscal year 1960 and 1961. The appropriation is a down-payment on a total commitment of $5 million to be paid out over the next five years. By 1962 the rate of annual expenditure is to rise to a round $8 million. (The City's population is estimated at 7,795,000.)

New York is thus the first municipality in the country to undertake regular appropriations in support of medical and health research in privately supported and public facilities. The grants—made in major part to the six medical schools in the city—are allocated by a volunteer Health Research Council appointed by Mayor Robert F. Wagner. According to George S. Mirick, scientific director, the Council seeks to emphasize research into "medical and health problems that are associated with life in the country's largest city." The present appropriations will support, among others, three investigations into the cost, quality and availability of medical care in the city and two investigations into the problem of narcotics addiction.

NEWS ABOUT

PRODUCT DESIGN

AND

MATERIALS

From the technical development laboratories at Dow comes a steady stream of new applications for versatile Dow plastics materials . . . new applications that accent beauty, function and strength . . . new applications that stimulate ideas for new designs of the future. The products described on these pages are just a few of the latest interpretations from America's plastics designers and manufacturers . . .

BLENDING FOOD OR FUN . . . PLASTICS PACE MODERN LIVING

Some plastics are meant to be seen, others to do their jobs under cover, but all are selected by designers and manufacturers because they add an important plus to the products designed for living. Here are some Dow plastics materials on the job, at home and at fun. Some you see, some you can't . . .

This modern built-in blender is an example of how Dow plastics materials serve in the home attractively and efficiently. The latest in handy appliances for the housewife, this blender mixes, chops, and liquefies in a matter of seconds. It has a host of other time-saving accomplishments, too.

To combine rugged, efficient performance with pleasing appearance, the designer specified clear Tyril® for the blending jar. Tyril—a Dow thermoplastic material – gives this appliance part the toughness to withstand the high-speed mixing and churning action of the knife blades . . . the chemical resistance to shrug off attacks by food acids and cooking ingredients . . . the temperature resistance to protect the jar whether it's being used to mix boiling liquids, or to crush ice. Washing presents no hazards,

either. Detergents won't harm Tyril, and it withstands normal abuse.

Tyril is currently serving consumers as the material in such products as tumblers (shown), cutlery handles, bristles, filter bowls, rigid food containers, closures, pen barrels, medical equipment components, and sprayer heads.

Away from home, on a family outing to the beach, this quartet of Dow plastics materials (right) lend their very special talents to cool beverages, protect fishing tackle and fishing reels, and to provide an extra measure of water and underwater fun.

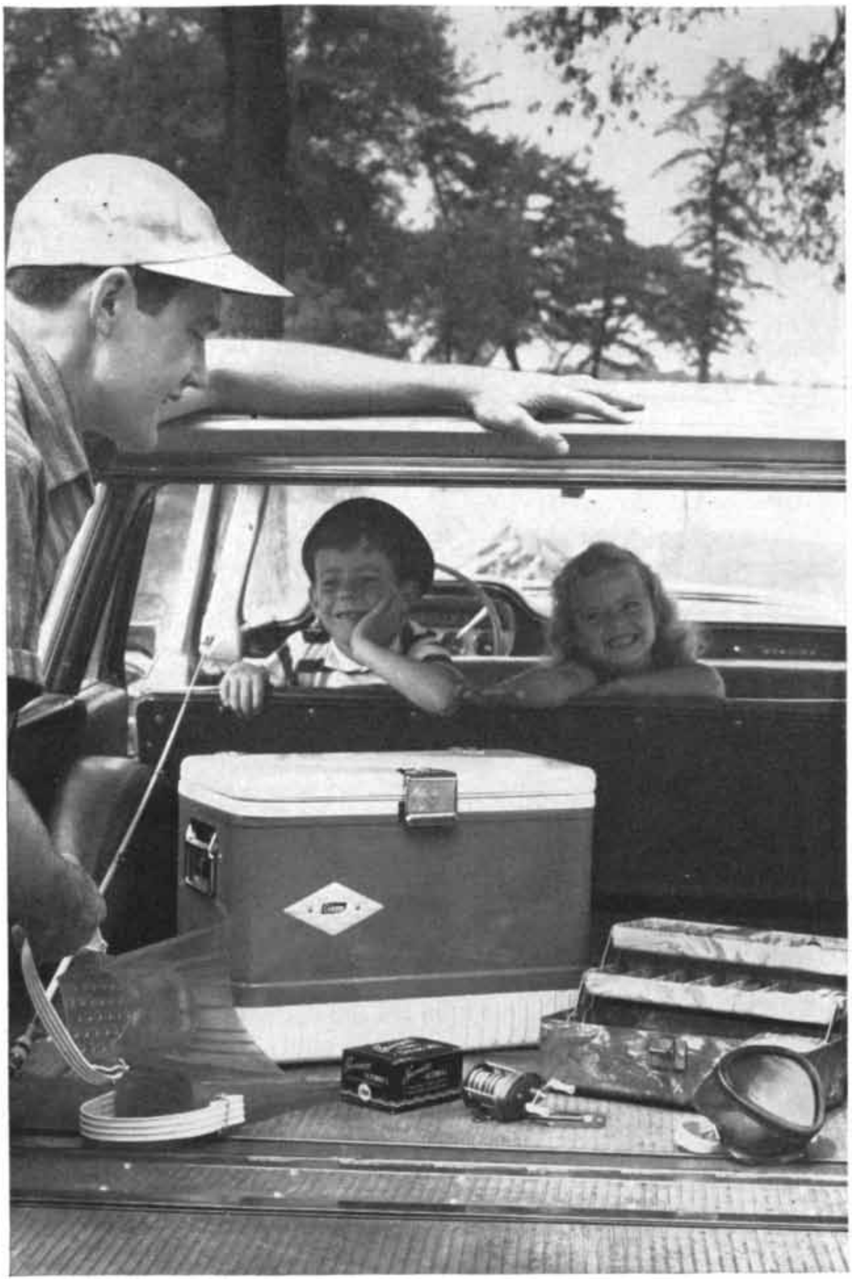
An undercover Dow thermoplastic that is making a name for itself, Pelaspan® – Dow expandable polystyrene beads–serves as the insulation for this beverage cooler. At one time, to insulate a product, designers were forced to adapt the shape of the product to include the added bulk and weight of the insulation. Today, designers have solved this problem with Pelaspan. Foamed in place by the manufacturer, Pelaspan provides thermal insulation with minimal bulk and weight for this attractive beverage cooler.

Built to last for a lifetime of fishing, the tackle box is molded of economical Styron® 480, a Dow super-high impact plastic formulation, with a green and white marblized color effect. In addition to the toughness to withstand a fisherman's hard knocks, Styron 480 has the high heat resistance to endure the blazing sun without softening or warping. The unique tongue and groove design molded along the edge of the box makes it watertight when closed–even allows it to float!

When there's a big one fighting the line, this casting reel can take the strain. The end caps and knobs are molded of Styron 475–a high impact polystyrene formulation. It will resist salt water deterioration, and possesses excellent chemical resistance. Its fine molding characteristics reproduce sharp details faithfully.

For fishermen who want to be part fish, or for just plain water fun, the underwater face mask and swim fins of Dow polyvinyl chloride resin (PVC) will give many seasons of wear. PVC permits the mask to fit snugly and comfortably across the swimmer's face, with a sealing lip around the edge to prevent water seepage.

The PVC fins are lighter, stronger, and will last longer than conventional materials. What's more, sun and water (even salt water) will not fade or rot PVC. Dow PVC is available in a wide selection of formulations, permitting a broad number of compounds to fit end-use applications.



IDEAS UNLIMITED

If any of the applications of Dow plastics materials described above have sparked an idea for a new-product design . . . an old-product rejuvenation . . . or a time-saving, money-saving new production technique, we'd be happy to discuss it with you. Please write THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Merchandising Department 1757EQ8.

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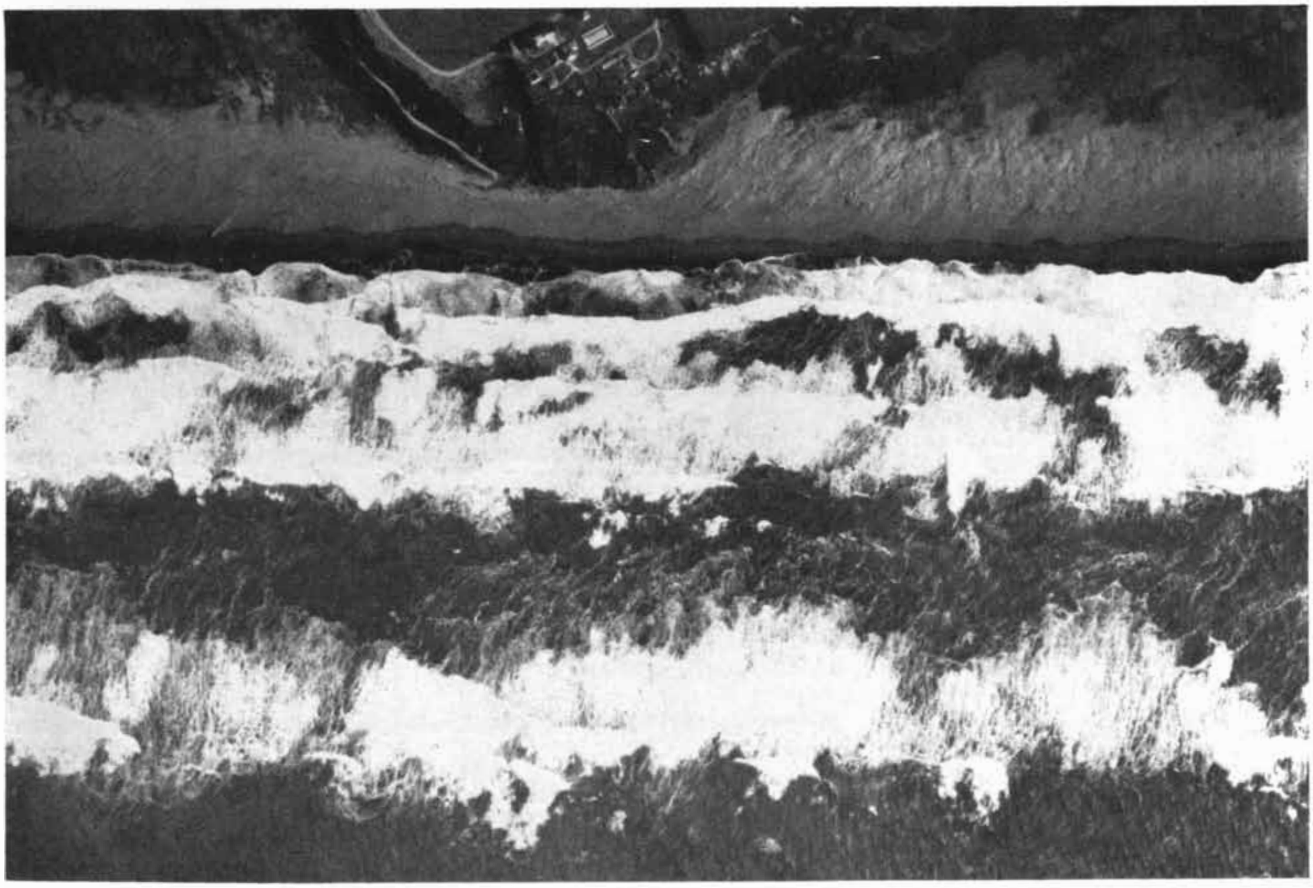


TWO VERTICAL AERIAL PHOTOGRAPHS show the beach at Table Bluff, Calif., during a light surf (*top*) and during a heavy surf (*bottom*). The first light band below the beach in the top photograph is waves breaking on the beach; the second light band is waves breaking on a sand bar. The light band at the bottom of bottom photograph is larger waves breaking on a deeper bar farther out.

BEACHES

Where the land meets the sea, the waves usually lay down a strip of sand or other uniform material. The constant shifting of this material has created a conservation problem for beach-loving man

by Willard Bascom

Beaches are natural playgrounds partly under the sun and partly under the sea where people can swim and surfboard, sun themselves and study other people. This human activity tends to obscure the fact that the beach itself is constantly in motion, quietly changing its configuration and restlessly shifting its position, grain by grain, until huge masses of sand have been moved. On a small scale and in a matter of hours the sand castles disappear and the footprints are erased; on a large scale, after days and months, the height of the sand around the rocks changes, the waves break in new places and the beach becomes broader or narrower. Indeed, over a period of years large quantities of sand may arrive or depart, posing complex problems of conservation for the people who want to enjoy the beach. This dynamic quality was incorporated by the late Columbia University physiographer Douglas W. Johnson into a definition: "A beach is a deposit of material which is in transit either alongshore or off-and-on shore." Thus three elements make a beach: a quantity of rocky material, a shore-line area in which it moves and a supply of energy to move it.

Most of the beach material along the coasts of the U. S. consists of light-colored sand—the product of the weathering of granitic rock into its two main constituents, quartz and feldspar [see "Sand," by Ph. H. Kuenen; SCIENTIFIC AMERICAN, April]. Americans therefore tend to think of beaches as stretches of white sand. But white sand is no more required to make a beach than is the sun or sun bathers. Many Tahitians and Hawaiians think that a proper beach is made of black sand—the result of the disintegration of dark volcanic rocks. Along much of the coast of England and much of the French Riviera the beach is composed of small flat stones called shingle. The word beach may originally have meant shore lines made of this shingle. In parts of Labrador, Alaska and Argentina the beaches consist of large cobbles from four to 12 inches in diameter. The beach of the Pacific Coast of Lower California is made of two materials: a flat sandy portion that is exposed only at low tide, while above and behind the sand great cobble ramparts rise in steep steps to a height of 30 feet or more. Nor are stones and sand the only beach materials. At Fort Bragg, Calif., a small pocket beach consists entirely of old tin cans washed in from the city's nearby oceanic dump and arranged by the sea in the usual beach forms. It seems that a beach can be made of almost any material of reasonable size and density that is present in quantity. Because the principles involved in the motion of beaches are much the same regardless of the material, the word sand will be used in this article for all beach materials.

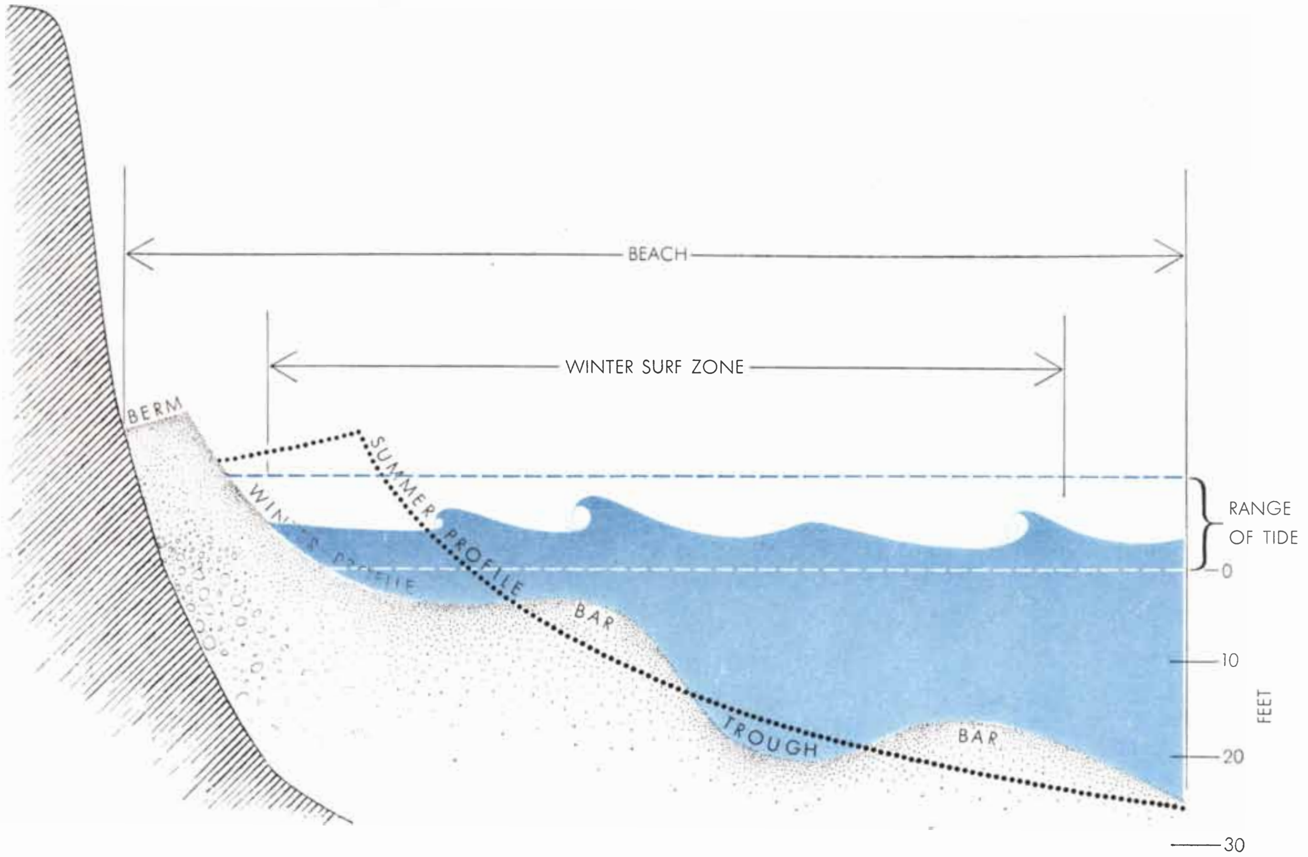
The Work of the Waves

A casual observer thinks of a beach as the sandy surface above water. The student of beaches takes a broader view and includes all of the area in which the sand moves. For him the beach extends from a depth of 30 feet below the water level at the lowest tide to the edge of the permanent coast. The latter may consist of a cliff, sand dunes or man-made structures, none of them really permanent, but all more enduring than the beach as seen at any one time. The offshore boundary of 30 feet below the low-tide water level is the depth beyond which ordinary water motion does not have sufficient energy to move the sand. A beach also has limits in the alongshore direction. A point of land or a stream may make such a boundary.

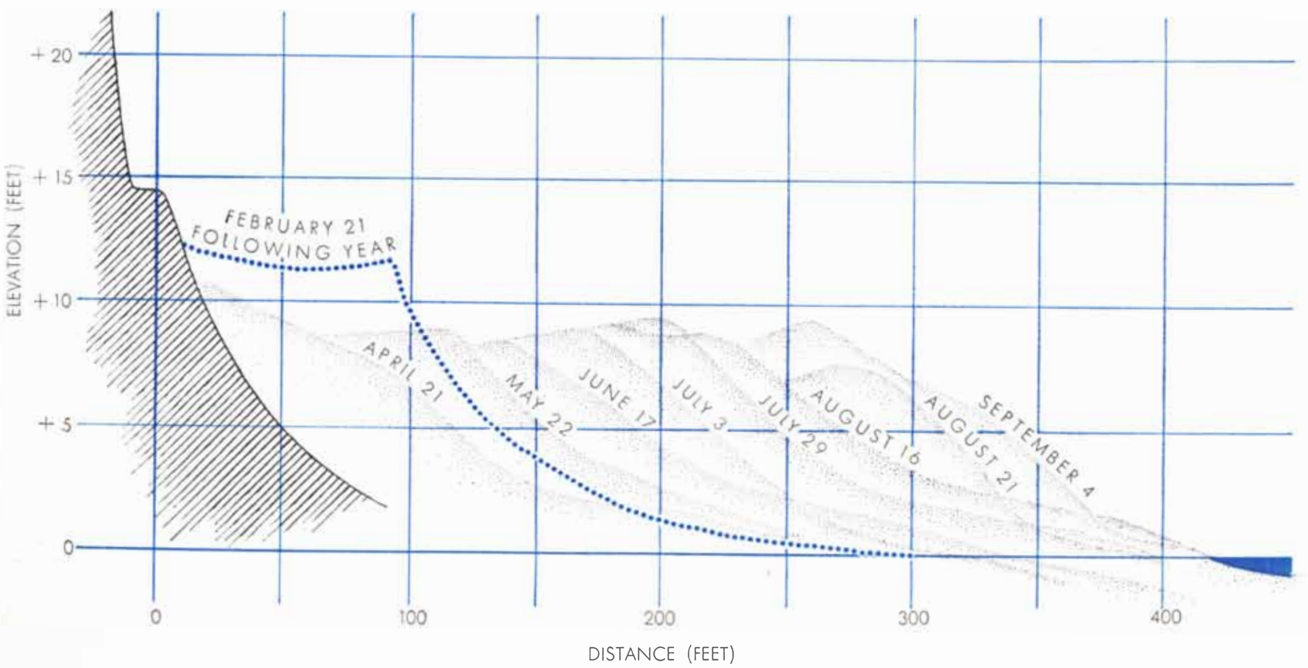
The waves and currents of the water provide the third element that must be present to make a beach: the energy to keep the sand in transit. At some beaches the wind also moves quite a lot of sand, but its direct effects will be ignored here. Of course it is the wind blowing on the surface of the sea that creates the waves, and so the wind ultimately causes all the movement of beaches. The waves rolling in on the beach may have originated far out at sea. The faster the wind, the longer it blows and the greater the distance over which it blows, the larger the waves it raises. If the storm is near the shore, the waves will be steep and may very quickly change the configuration of the beach. Normally, however, the waves that shape the beach have moved out from under the winds that generated them and are longer, lower and more regular than the wind waves. Such waves are called swell, and they travel away from the storm in all directions with very little loss of energy. Since a storm is almost always taking place somewhere at sea, the swell is constantly molding all the beaches around an ocean.

Swell is described by its height (the vertical distance between the trough and the crest of a wave), by its length (the horizontal distance between crests) and by its period (the time in seconds between crests observed at a given point). As swell moves into shallow water a remarkable change occurs. When the depth equals half a wavelength, the waves are said to "feel bottom." The velocity and length decrease, and the height increases; only the period remains the same. Rolling farther inshore, the waves rise higher and finally topple over and break. The result is surf—a turbulent mass of water [see "Ocean Waves," by Willard Bascom; SCIENTIFIC AMERICAN, August, 1959].

It is the action of waves in shallow



PROFILE OF A BEACH is characterized by a berm (the deposit of material at the top of the beach) and bars. In winter heavy surf removes sand from the berm and deposits it on the bars; in summer, light surf builds the berm. Vertical scale is exaggerated 25 times.



GROWTH OF THE BERM at Carmel, Calif., during the spring and summer is indicated by this series of dated slopes, based on actual measurements. Vertical dimension is exaggerated 10 times. The dotted line shows how berm was cut back during following winter.

water that changes the beach. The basic mechanism is simply the lifting of the sand grain by the turbulence that accompanies the passage of a wave and the free fall of the grain to the bottom as the wave loses its lifting force. Since a sand grain is lighter under water than in air by an amount equal to the weight of water it displaces, the water does not need great energy to lift it. Moreover, the grain settles back rather slowly because of the viscosity and turbulence of the water. While in suspension, a sand grain tends to move with the water, and currents of very low velocity will displace it. Each time a grain is lifted it lands in a slightly different location. Because uncounted millions of sand grains are continually being picked up and relocated, the beach shifts its position.

AMPHIBIOUS TRUCK, the Army "duck" of World War II, rides a 12-foot breaker during a University of California survey of beaches. By piloting the duck straight toward the shore the workers aboard it were able to sound the profile of the beach. This beach is at Carmel.

The Measurement of Beaches

During the years 1945 to 1950 John D. Isaacs, now of Scripps Institution of Oceanography, and I were employed on the "Waves" project of the University of California to study the beaches of the U. S. Pacific Coast. Under the direction of Morrough P. O'Brien, dean of engineering and a member of the Beach Erosion Board of the Army Corps of Engineers, we spent virtually all our time, winter and summer, observing the interaction of waves and beaches. To measure the height and period of the waves, we installed a dozen or so ocean-wave meters offshore, connected by armored submarine cable to recorders on the beach. With radio-controlled cameras we made photographs of the surf simultaneously from the beach, from nearby cliffs and from an aircraft directly above. We threw dye into the surf to determine the nature of its currents.

We spent most of our time, however, making repeated "profiles" of various beaches. This involved going out in an amphibious vehicle, the DUKW, or "duck," of World War II, to beyond the 30-foot low-tide depth and making numerous soundings as we came in to the beach face. Moving at three knots, we would keep the duck lined up with two marker poles set at right angles to the shore line. At short intervals I would heave the sounding lead, read the depth and call the results into a radio transmitter. Isaacs would be listening on shore, about 1,000 feet down the beach from the poles and watching the duck's progress through a surveyor's transit. The poles, the duck and the transit made a right triangle, with Isaacs sighting along the hypotenuse. When he saw the lead weight splash, he would read the angle on the transit and call it to an assistant who recorded depths and angles together. By plotting the depth at each distance from the shore line, we could draw a profile of the beach.

Somewhat surprisingly we obtained good profiles even in rough surf, partly because the duck is a fine beach-and-surf craft. It is 32 feet long, has six wheels and was originally designed for moving cargo from ship to shore and inland during amphibious operations. In breakers the front wheels tend to "hook" the crest of the wave, hanging down in front of the shoreward-tumbling water so that the vehicle is carried in like a surfboard. In the zone where it is only partly afloat the wheels and the propeller may drive it at the same time. The air pressure of its big tires is controlled from the cab, and when the vehicle reaches the steep beach-face, the pressure can be adjusted to achieve enough traction for the vehicle to grind its way upward.

On the northern California beaches in winter we often surveyed beaches where the breakers were 12 feet high, and occasionally, having misjudged the waves before starting out, we found ourselves amid breakers half again as high—a remarkable experience in a relatively small craft. Using the reliable duck we recorded changes in beach profiles from winter to summer on more than 30 West Coast beaches. We also kept a record of the ease with which the duck could move about on the part of beach above water. On the hard beaches north of the Columbia River it could travel as fast as it could on a highway—if the beach was being eroded. A day later, however, when the waves had altered the delicate balance of sand transport and deposited a new layer of soft sand, the duck could not exceed 10 miles per hour. We found that the beach face in the zone between high and low tide seemed to be the only place that retained its hardness and its degree of slope over relatively long periods.

Later we correlated our slope and wave measurements with the results of elaborate samplings of sand-grain size. This showed, as even a casual observer will note, that steeper beaches are usually composed of larger sand grains. Our studies also showed that factors not quite so apparent enter into the picture. For example, beaches that are partly protected from the swell will be steeper than beaches composed of sand of the same size that are exposed to it.

The Underwater Beach

The underwater slopes are quite different from those of the beach face, and are usually described in a different way to take account of the substantial irregularities between the waterline and the seaward boundary. In this scheme of classification a flat beach has an average underwater slope with a vertical rise of less than one foot in 75 feet of horizontal distance; a steep beach has a gradient steeper than one foot in 50 feet.

A large part of the movement of beach

material consists in an exchange between offshore underwater ridges, or bars, and the berm, the nearly horizontal deposit of material at the top of the beach onshore [*see top illustration on page 82*]. Bars may be considered as products of erosion, since they appear when violent wave action cuts back the berm and deposits the beach material in neat ridges offshore. Because they are associated with storm conditions, and since more storms occur in winter than in summer, bars are regarded as a normal feature of the beach profile in winter. All beaches exposed to the ocean swell (as well as beaches on such large bodies of water as the Great Lakes) have them, and beaches with a slope of less than one foot in 50 frequently have two or more. Essentially continuous bars 10 to 20 miles long are commonplace on the Pacific Coast north of Cape Mendocino.

Beach investigators do not know exactly how bars are formed. They have noted that the creation of bars is somehow related to wave steepness. Using an experimental wave-channel, J. W. Johnson of the University of California found that bars always formed on model beaches when the ratio of wave height to wavelength was steeper than .03, and that bars never appeared when the ratio was less than .03. In nature the numbers seem to be different, but the principle is undoubtedly the same. Since the tiny forces that cause differential motion of individual sand grains are hard to detect amid the general turbulence, the exact manner in which variations in steepness cause the sand to move landward or seaward remains elusive.

The bars in their turn have a decided effect upon waves. The outer slope of a bar is relatively steep, and this abrupt rise of the bottom causes the larger waves to break. The waves often re-form in the trough between bars and proceed toward shore as smaller waves, breaking on the shallower inner bars or on the beach face. The smaller waves in a train of waves of irregular heights will not break on the outer bar. Thus a bar tends to act as a wave filter, breaking and reducing the higher waves and passing waves that are below a certain height. On Pacific Coast beaches that are exposed to the full force of the waves, the top of the innermost bar is usually about a foot below the low-tide water level, the top of the second bar is at a depth of seven feet and the third bar is 13 feet deep. Large swell from a nearby storm will produce violent breakers as high as 30 feet on the outermost bar. On a beach with a gentle slope and a series of bars the waves will re-form and break again and again as they move in, creating a surf zone as much as a mile wide.

After the storm season the steepness of the waves decreases and they begin to move the sand toward the shore. The material from the outer bars fills in the troughs, and soon the beach profile shows no bars. The material from the inner bar migrates to the berm, building it seaward. Except on very flat beaches the berm usually has a well-defined edge, or crest, and its method of growth can be readily observed. As each wave reaches the beach face, it uses up its remaining energy in a thin swash of water that runs up the beach face carrying sand with it. Depending on how permeable and how saturated the sand is, a certain amount of the water sinks into the beach and does not return to the sea as backrush. Thus the transport capacity of the returning water is less than that of the uprushing water, and sand is added to the berm. When conditions are precisely right, a

RIP CHANNELS are marked by the dark lanes in the surf in this aerial photograph of a beach near Monterey, Calif. The channels are formed when a series of waves raises the level of the water inside a bar, and the outrushing water cuts a series of notches in the bar. The water in such channels can flow as fast as four knots. A swimmer can escape them by moving parallel to the beach.

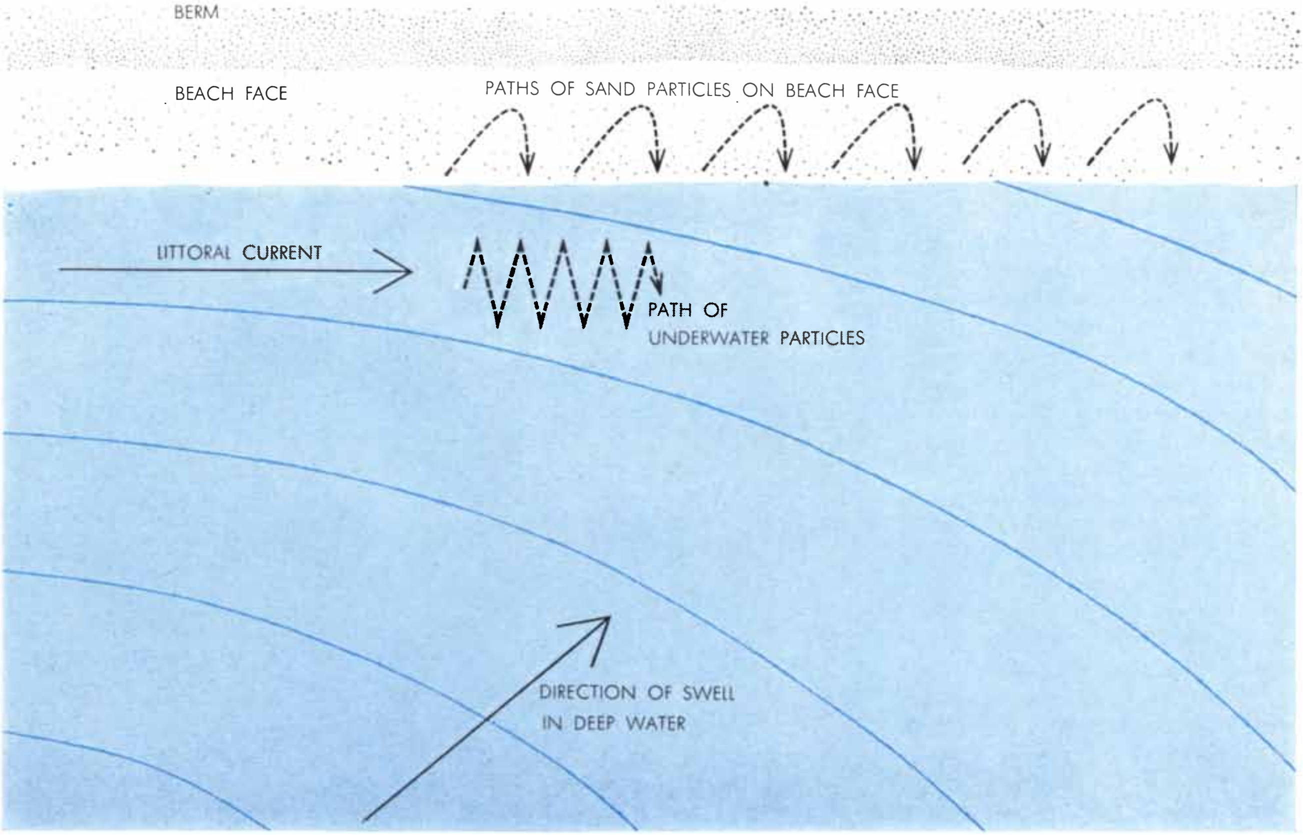
berm may grow as much as six inches an hour, or 10 feet a day. The berm of the beach at Carmel, Calif., which we studied for several years, is about 300 feet wider in September than it is in April, the months which respectively mark the end of the calm season and the storm season.

Large waves build a higher berm than small ones do. At Monterey Bay, Calif., the crest of the berm on the exposed beach at Fort Ord has reached 16 feet above the low-tide water level, whereas the berm of the beach a few miles away, which is protected by a headland from large waves, is six feet lower. Paradoxically the storm seas that remove the summer berm often leave a higher berm of their own at the back of the beach. This berm may remain clearly visible throughout the summer.

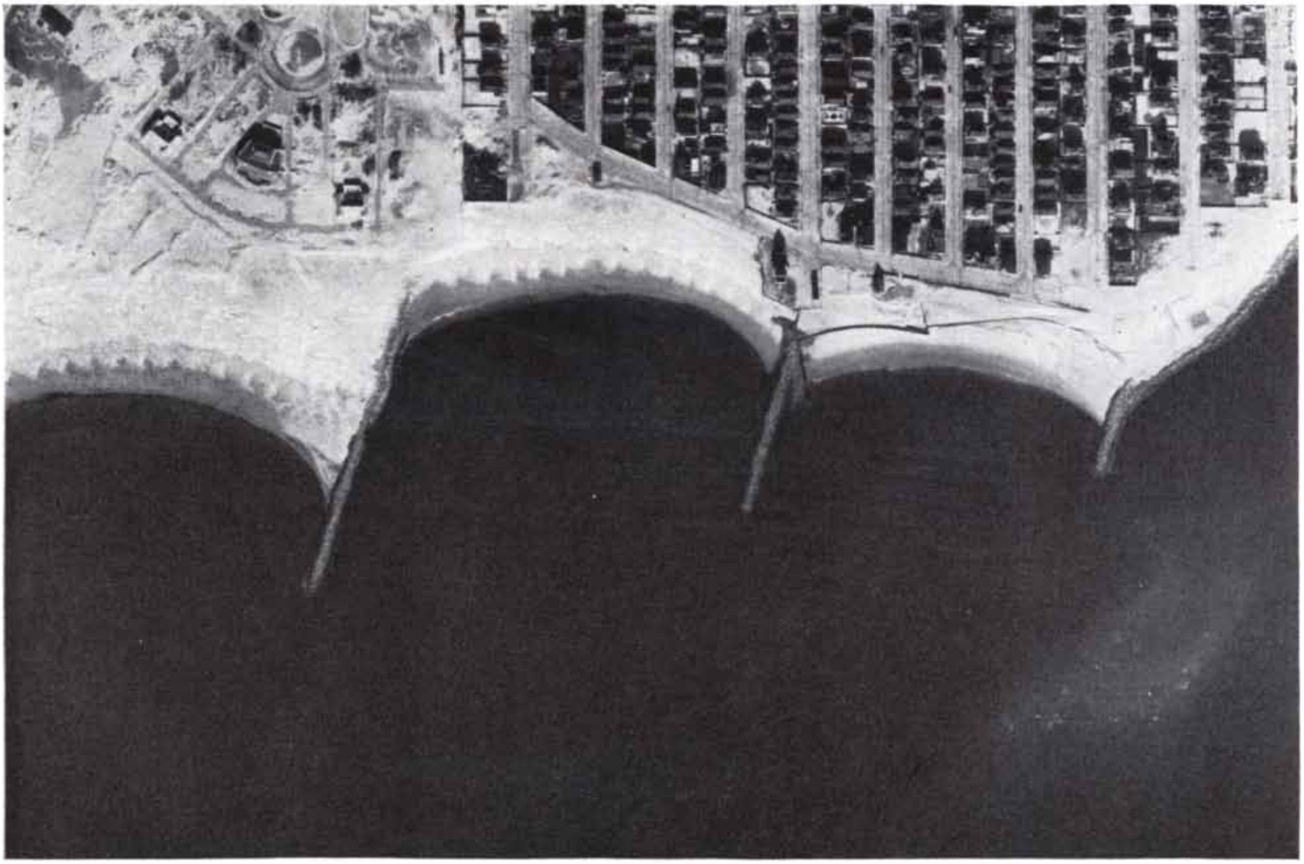
The material that stormy seas remove from the berm ordinarily returns during calm seasons. However, an occasional very large storm or a tsunami (a "tidal" wave) may strip a beach face of sand and carry the material to depths so great that the normal waves cannot reach it and return it. At Long Branch, N.J., and Santa Barbara, Calif., the Beach Erosion Board of the Army Corps of Engineers dumped mounds of sand at depths of 38 and 18 feet in the hope that waves would move the sand onto the berm. Unfortunately the sand, like that removed by a great storm, was too deep for normal waves to pick up.

When higher-than-average waves break in quick succession and raise the water level inside a bar, the water rushes back so energetically to sea that it sometimes breaches the bar at a narrow place, producing a so-called rip channel. From then on much of the excess water hurled over the bar by the breakers moves along the beach until it reaches the channel, where it flows out as a rip current [*see illustration on opposite page*]. The current can be dangerous, since it flows directly out to sea with a velocity as high as four knots, considerably faster than a man can swim. Fortunately rip currents are confined to relatively narrow channels, and the bather can get out of them simply by swimming a short distance parallel to the shore. On some beaches the lifeguards mark rip currents (they flow on the surface and can be seen from shore by a trained observer), often moving the warning signs several times a day to keep up with the migration of the currents along the beach.

The rip current appears in popular mythology as the fearsome "undertow," which is otherwise a pure invention of the imagination. The undertow is said to



LITTORAL CURRENT, a current running parallel to the beach, is set up when waves move toward the beach at an oblique angle. Under such conditions sand grains lifted by the surf, normally moved at right angles to the beach, are transported with the current.



GROINS, dams of stone or wood jutting out from the beach, are widely used to retard the erosion of beaches by littoral currents. The groins in this photograph are on the Atlantic Coast at Point Lookout on Long Island. The current moves from left to right.

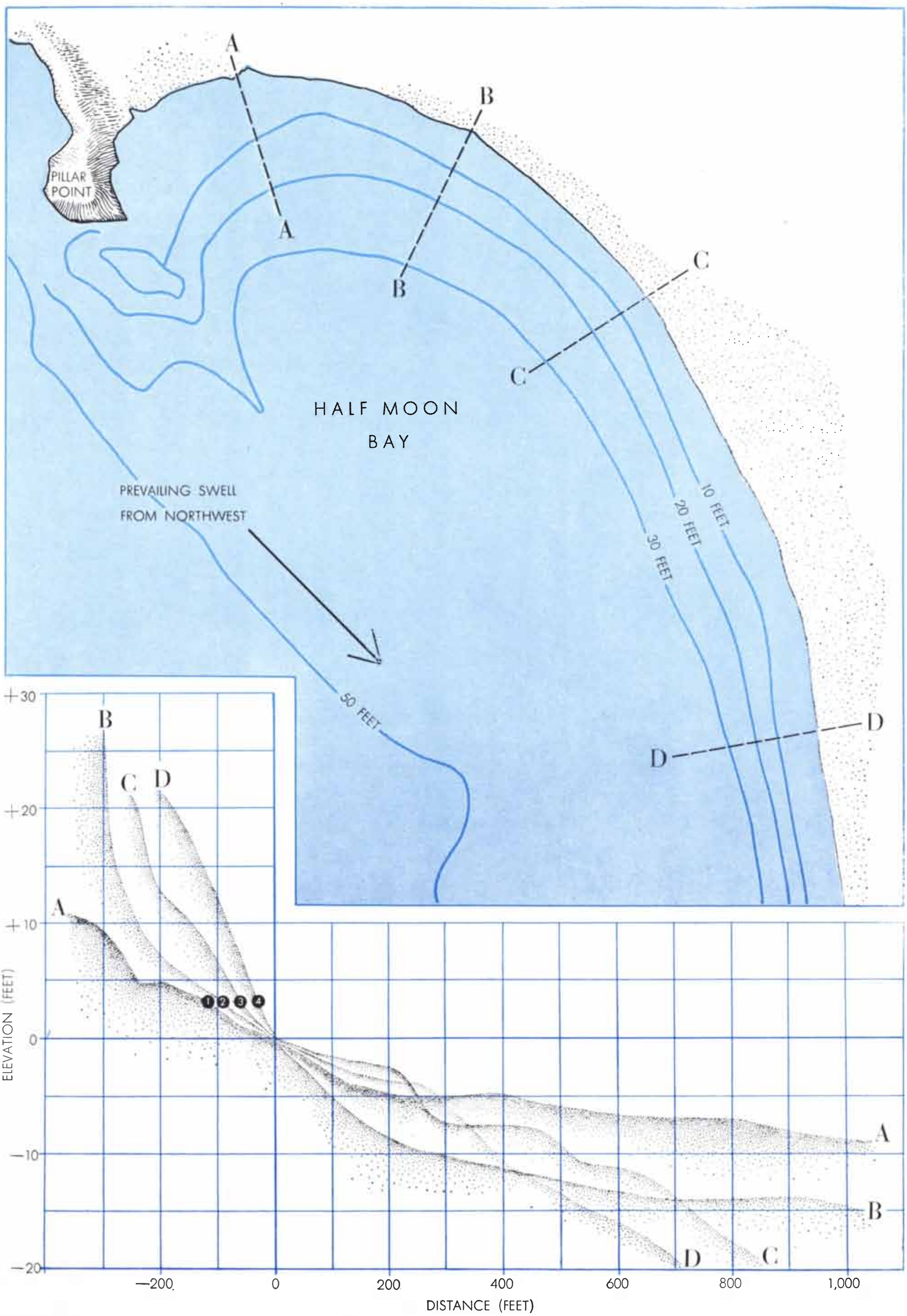
flow outward beneath the surf and so pull swimmers out to sea. Experiments with dye markers at beaches marked with undertow warning signs have repeatedly shown that no such current exists. The water does, of course, move in and out along the bottom with every wave, but anyone being pulled seaward would be carried shoreward after six seconds or so by the other half of the cycle. Unlike rip currents, undertow can be dismissed as a danger to swimmers.

Cusps and Ripple Marks

A beach feature that offers intriguing problems for the investigator is the cusp. This is a crescent-shaped depression that occasionally forms in regularly spaced series along the beach face. The triangular apex (the horn) at which two crescents join points seaward. A "bay" of sand, which may be deep and narrow or broad and shallow, lies between the horns. Cusps vary in length from a few feet to hundreds of feet and their relief may exceed six feet or be so shallow that they are barely discernible. Although investigators have studied these curious beach forms for years and have constructed many hypotheses about them, no one has produced a generally accepted explanation of how they begin, why they are so regular and why they have the dimensions they have. These factors are almost certainly related to the character of the waves that form them. Perhaps cusps develop when the waves have a "balanced" steepness, so that neither erosion nor deposition of the sand occurs.

Ripple marks, or sand ripples, are roughly parallel arrays of wave-shaped ridges and troughs that are formed in the sand on the sea bottom by the action of the water. Ordinarily their "wavelength" is three or four inches, and they are about an inch deep, but giant ripples something like desert sand dunes and with wavelengths of more than 10 feet have been observed under the surf. Since ripple crests are usually parallel to the wave crests, paleographers have used fossil ripples in sandstone to establish the orientation of ancient beaches.

Ripple marks may begin to form around a pebble or any other small prominence on the bottom. The oscillating wave-motion creates horizontal vortices first on one side of the pebble, then on the other, and a small ridge of sand begins to accumulate. At a certain distance on either side of the original ridge the vortex currents diminish and deposit sand so that another ridge forms and the ripple pattern grows. Water motion due


PILLAR POINT
A
A
B
B
C
C
D
D
HALF MOON BAY
PREVAILING SWELL FROM NORTHWEST
10 FEET
20 FEET
30 FEET
50 FEET
+30
+20
+10
0
−10
−20
ELEVATION (FEET)
−200
0
200
400
600
800
1,000
DISTANCE (FEET)
1
2
3
4

entirely to waves produces symmetrical ripples, but if a current is superimposed on the wave motion, the sides of the ripples are steeper on the lee side. Ripple marks come and go with the changing wave conditions, and they migrate with the currents. Although they, too, have been extensively studied, the relationship between current velocity, sand-grain size and the dimensions of the ripple marks remains unexplained.

The Preservation of Beaches

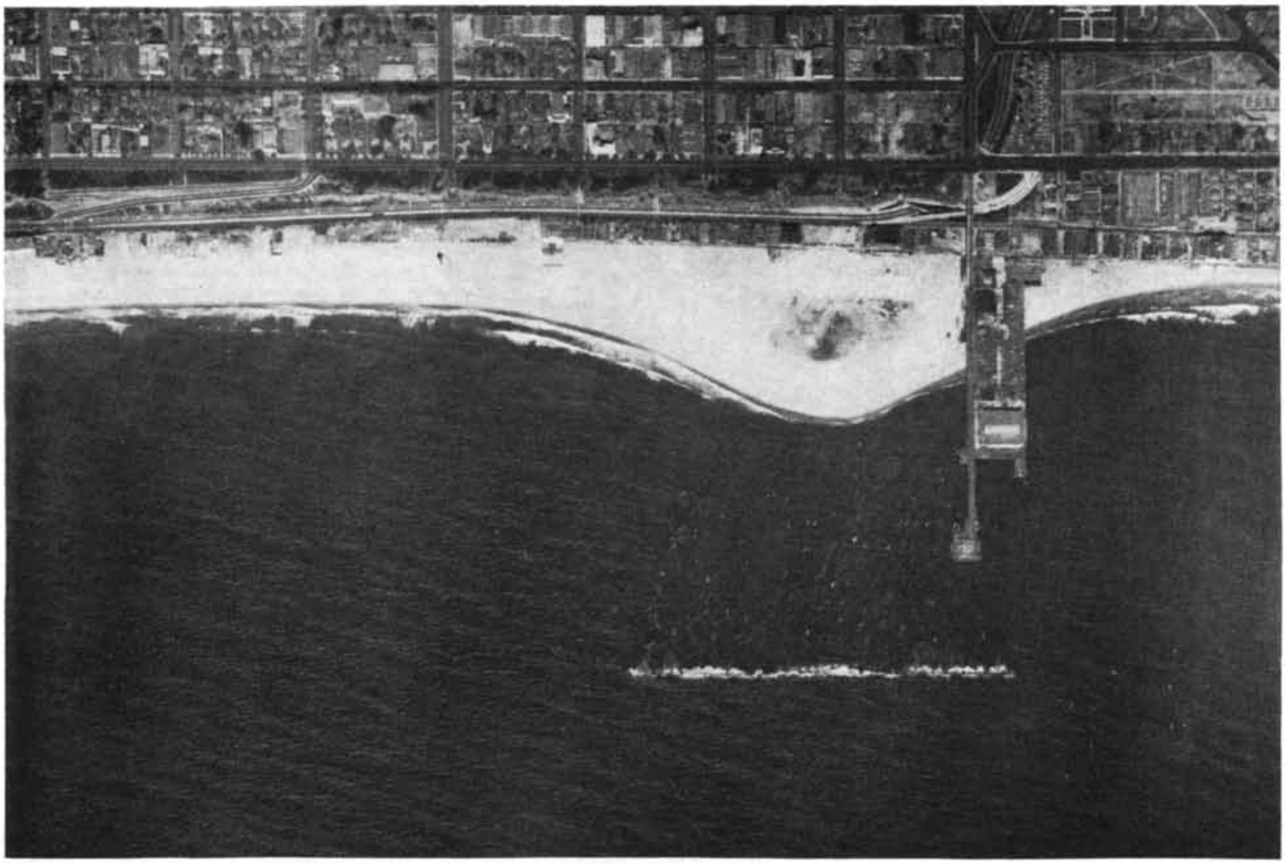
The major problems of beach conservation are created not by the seasonal movement of sand onshore and offshore, but by the motion of sand parallel to the shore. On some coasts, alongshore or littoral currents, which arise when waves strike the shore at an angle, annually transport millions of tons of sand, eroding one beach and building up another. The largest waves create the strongest littoral currents because they contain the most energy. They "feel" bottom well out from shore, and if they approach shore at an angle, they tend to be refracted or bent by the underwater contours so that the wave front becomes parallel to the shore line. Waves are often incompletely refracted, especially if the angle between the deep-water wave fronts and the shore line is great, or if the water becomes shallow abruptly. Consequently waves often strike the shore at an angle.

Along coasts where the prevailing waves arrive in this way, a littoral current flows constantly. These currents usually flow too slowly to move the sand grains by themselves. Turbulence in the

EFFECT OF A HEADLAND on a beach eroded by a littoral current is depicted in this chart made by the University of California "Waves" project. The headland is Pillar Point and the sheltered area is Half Moon Bay. The profiles of the beach at the locations marked on the map at the top of the opposite page are traced in the graph below the map. The average size of the sand grains at each location and the slope of the bottom are listed in the table below.

REFERENCE POINTS	SAND SIZE (MILLIMETERS)	SLOPE
❶	.17	1:41
❷	.20	1:30
❸	.39	1:13.5
❹	.65	1:8

BREAKWATER AT SANTA BARBARA, CALIF., causes sand transported by a littoral current running from west to east (*i.e.,* from left to right) to deposit in the sheltered water. A dredge in center of harbor moves sand beyond the large pier at right.



BREAKWATER AT SANTA MONICA, CALIF., runs parallel to the shore (*bottom right*). Originally it was thought that the littoral current running inside the breakwater would carry sand past it, but instead the sand was deposited in the quiet water.

surf zone, however, keeps the sand in suspension, and even a low-velocity alongshore current is able to transport large quantities of material. On the beach face the sand particles carried by the uprush describe an arc in the direction of the alongshore current so that each wave moves them along the beach a little way. In shallow water, where the waves can lift sand and move it back and forth, the littoral current gives the sand grains a saw-toothed motion [*see top illustration on page 86*]. With every oscillation the sand moves sideways, and there is no force to return it to its original position. As a result the sand travels downstream as on a conveyor belt, the belt having the width of the surf zone and the velocity of the littoral current.

Many seaside areas afflicted with littoral currents have serious problems of beach erosion. The California coast north of Point Conception faces west, directly into the Pacific Ocean winds and swell, and there is no appreciable alongshore current. But south of this point the shore line turns abruptly to the east, so that these same winds and waves strike the shore at an angle. As a result an almost continuous current moves sand to the east. Any structure that interrupts the flow acts like a dam, and the beaches immediately to the west grow while those to the east are stripped of sand by the waves and currents. Of the several structures that produce this effect, the most interesting is the breakwater at Santa Barbara, for there the amount of sand carried along the coast can be measured. Sand moving from the west past the end of the breakwater abruptly encounters the deeper, quiet water that the breakwater was built to create. There the cessation of turbulence causes all the suspended particles to be deposited just inside the end of the breakwater [*see top illustration on opposite page*].

Frequent surveys of the changes in the volume of sand in the spit have revealed the rate of deposition, which equals the rate of transport of sand along the shore. On an average day about 800 cubic yards of sand are dumped in the harbor and under storm conditions four times that much will arrive. To keep the sand from filling the harbor and to prevent damaging erosion on the shore beyond, a dredge pumps the sand from the spit across the quiet water to the downstream beach. Once again it is exposed to wave action, and the littoral current carries it along the coast until eventually it reaches Santa Monica.

That city also needed quiet water for a yacht harbor. Because of the difficulties associated with the damming of the sand by a conventional breakwater, the city built a wave barrier consisting of a straight line of rocks parallel to the shore and several hundred yards out [*see bottom illustration on page 90*]. The sand was expected to flow past in the wide space between the breakwater and the shore. It did not. The sand simply stopped moving in the quiet water, and the beach started to build outward toward the rock wall. Downstream from the structure the beaches retreated. Now Santa Monica must also employ a dredge to put the sand back into circulation.

A similar littoral sand-transport system operates along the southern shore of Long Island on the East Coast. Prevailing winds and the unrefracted waves from the North Atlantic sweep the sand along the shore from Montauk Point at the island's eastern tip to the Rockaway spit at the entrance of New York Harbor. Montauk is rapidly eroding, and Rockaway spit is (or was for a considerable period before the present shore-line structures were built) building at the rate of 200 feet a year.

If no action is taken on erosion problems, everyone shares the erosion. But as soon as one part of the shore is protected, the remainder of the shore must supply the sand. Nevertheless for many years the customary way to stop the retreat of a beach was to build groins, that is, dams made of rocks or wooden piling a few feet high and a few hundred feet long, jutting out from the beach face to stop the passing sand.

Along some coasts groins have been constructed at regular intervals for many miles, each supporting a curving beach that spills over its end, giving the beach a cuspate appearance. The sand still flows, but it is retained temporarily on each little segment of beach. Groins can hold sand if they are properly engineered, but their effect is local and temporary. They are no longer the preferred means of maintaining a beach, for it has been found that they are usually less effective and more expensive than a "beach-nourishment" program. In such programs new sand is supplied to the system from inland dunes or from the

CUSPS are a series of crescent-shaped depressions along a beach. The cusps in this aerial photograph are at El Segundo, Calif.; they are 60 feet across. There is no satisfactory explanation of how cusps are formed, though they are undoubtedly related to wave action.

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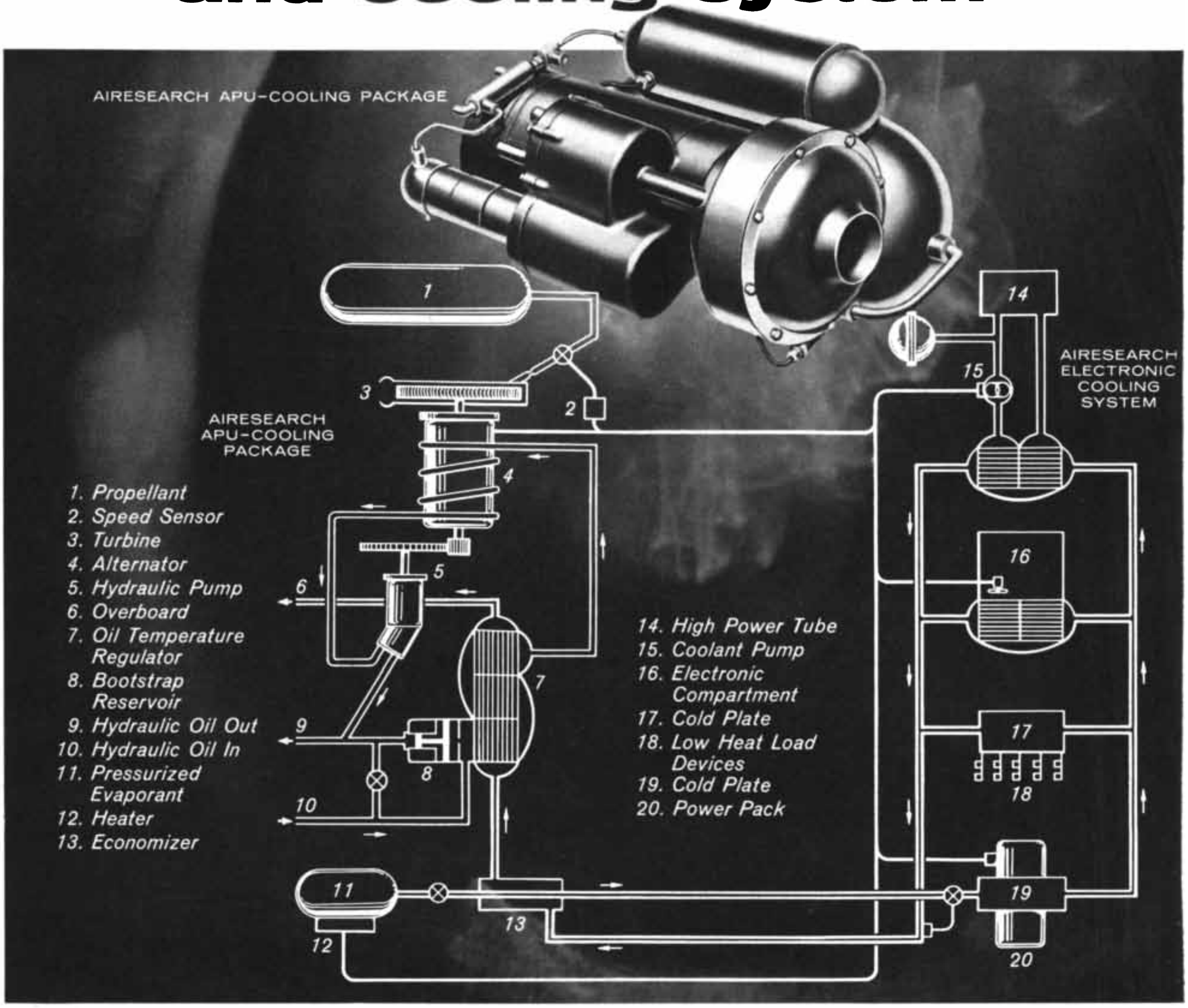

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Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS bottoms of nearby lagoons. For example, the famous Waikiki Beach in the Hawaiian Islands was recently rebuilt with sand that was trucked in from dunes 14 miles away.

This change of opinion about the best way to maintain beaches is illustrated by the problem now facing the state of New Jersey. The configuration of the coast is such that refracted Atlantic Ocean swell strikes heavily on the New Jersey coast's most prominent point, near Barnegat Inlet. Littoral currents move the sand away from the point in both directions, and the point is eroding rapidly. In the past 50 years nearly $50 million has been spent on shore works in an attempt to stabilize the shore line. The present annual rate of expenditure is more than $2 million, and the results are not entirely satisfactory. Some parts of the shore have long since been stripped of sand; others are still retreating.

The Beach Erosion Board has studied the New Jersey problem and has proposed a project to develop adequate recreational beaches and to prevent further erosion. This project would nourish all the beaches along the coast by supplying new sand to the beaches in the vicinity of Barnegat Inlet. The sand would come partly by truck from inland locations and partly by pumping from Barnegat Bay; wave action and littoral currents would be relied upon to distribute it along the coast. The initial investment would be $28 million, but the program would require less than $1 million per year to maintain the beaches thereafter.

Sixty-six other shore-line construction projects, costing a total of over $100 million, have been planned for the shores of the U. S., and about half are completed or are well under way. The preservation of valuable coastal land, the maintenance of usable harbors and the development of recreational activities require an understanding of the ways of moving sand. In these enterprises the knowledge gained by the scientific study of beaches will play a central role.

RIPPLE MARKS appear in the sand at the bottom of two experimental wave-tanks of the Beach Erosion Board in Washington, D.C. The tank at left contains fine sand; the tank at right, coarse sand. After the sand had been subjected to wave action for 60 hours, the tanks were drained and the configuration of the sand was photographed. Three sand bars have formed in the tank at right.

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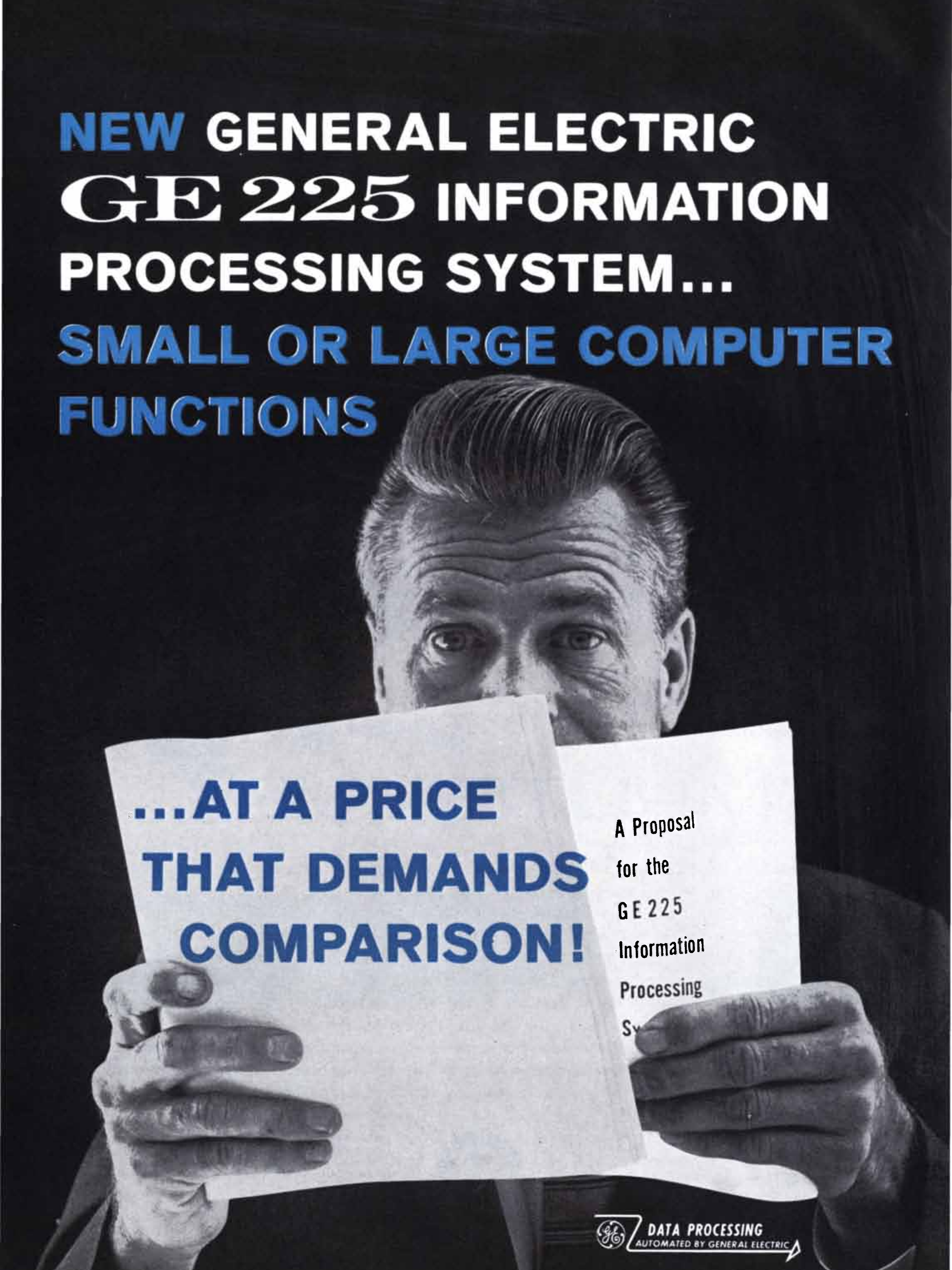
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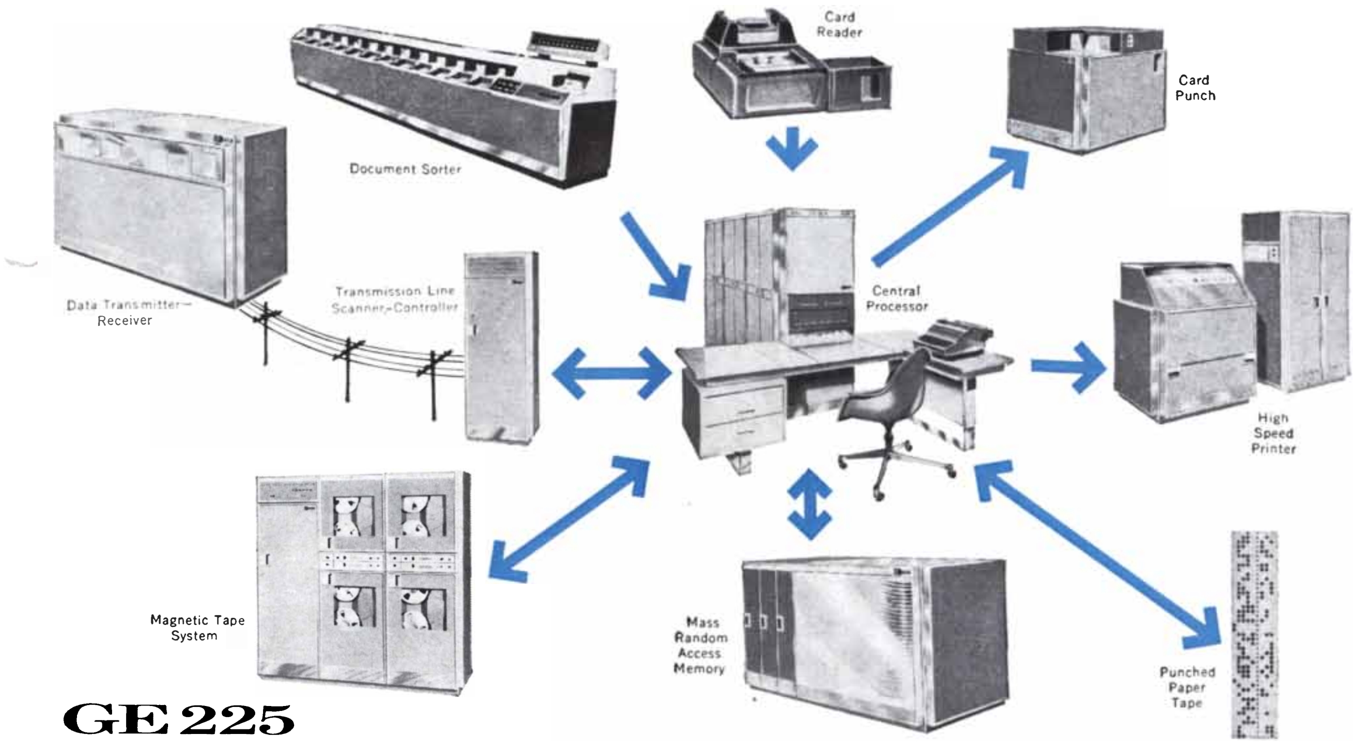

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PACINIAN CORPUSCLES are small ellipsoidal bodies, three of which are visible at the lower left side of the dark area in the center of this photograph. Here the corpuscles are located in the mesentery (a thin membrane attached to the intestine) of a cat. They are enlarged some four diameters. In actual size each corpuscle is about one millimeter long and .6 millimeter thick.

Biological Transducers

How are stimuli such as light and pressure converted into nerve impulses? The answer is sought by experiments with the Pacinian corpuscle, a specialized ending of the nerves of the sense of touch

by Werner R. Loewenstein

Aristotle's maxim "Nothing is in the mind that did not pass through the senses" is questioned by some schools of philosophy. If "brain" is substituted for "mind," however, and the statement is made a physiological rather than a philosophical one, it then becomes literally true. For higher organisms the sensory receptor furnishes the only means of gaining information about the surrounding world.

This is not the case with primitive one-celled organisms; the cell is directly excited by the environmental stimulus and responds through movement, secretion and so on. But as organisms became more complex in the course of evolution, many of their body cells lost direct contact with the outside world. Certain cells appeared that specialize in the reception of external stimuli. They are, in general, attuned to a single type of stimulus: the rods and cones in the retina respond to light, the thermal receptors in the skin respond to heat and cold, and the mechanoreceptors in muscle respond to mechanical stimuli such as stretching and pressure. The specialized receptor is an outgrowth of a nerve cell, or is in intimate contact with one. Environmental stimuli of the appropriate kind excite the receptor, and the excitation is conveyed to other parts of the organism along nerve circuits of varying complexity.

From the physical point of view the sensory receptors are transducers, that is, they convert one form of energy into another. The various types of receptor convert the particular form of energy to which each is attuned into the electrical energy of the nerve impulse. One may compare them with the transducer devices which modern technology has developed in great variety for automatic control of machines and factories—devices that measure temperature, pressure, rate of flow and so on, and feed their measurements into the artificial nerve-circuits of the control system. The biological transducers that nature took somewhat longer to develop have remarkable sensitivity and efficiency.

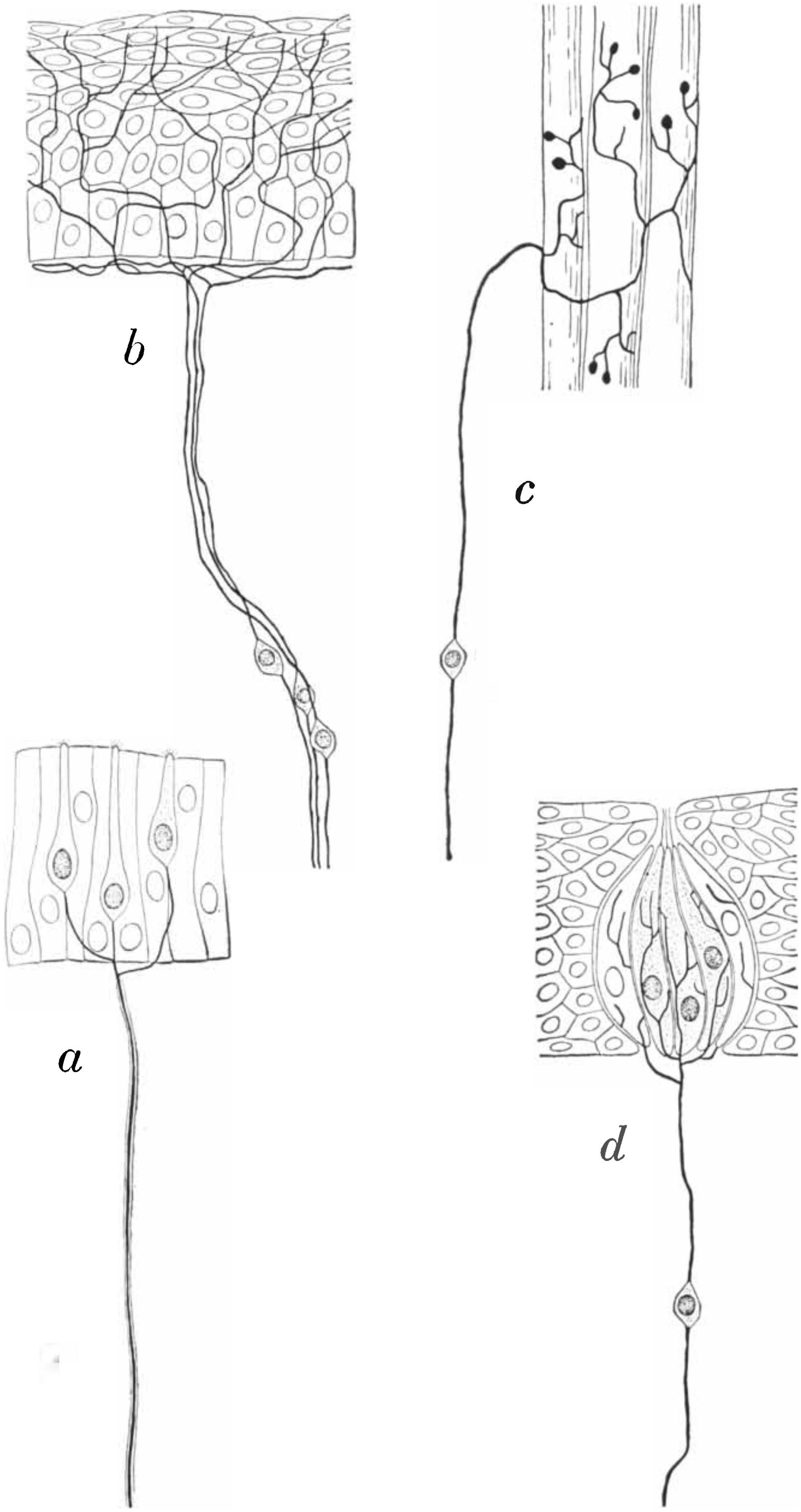
The mechanoreceptors were among the earliest to evolve; they enabled primitive marine animals to maintain their orientation with respect to gravity, to detect obstacles and to sense vibrations produced by other animals. The evolution of life on land brought the development of mechanoreceptors sensitive to vibrations of the air; with the growth of specialized internal organs and the need for fast regulatory mechanisms came the development of receptors sensitive to internal mechanical stimuli. Vertebrates possess mechanoreceptors in all organs in which active or passive movements occur, including the digestive tract, the lungs, the heart and the blood vessels, as well as the skin and the skeletal muscles. These receptors feed into the nervous system information about movement, tension and pressure.

The transducer mechanism in the mechanoreceptor was first demonstrated in 1950 by Bernhard Katz of University College London. He discovered that the stretching of a muscle spindle (a mechanoreceptor built into skeletal muscle) generates a local electric current. When the current reaches a certain intensity, he found, it triggers the firing of an impulse in the nerve fiber leading from the muscle spindle to the higher nerve-centers [see "The Nerve Impulse," by Bernhard Katz; SCIENTIFIC AMERICAN, November, 1952].

This result did not come as a complete surprise. Since the time of Luigi Galvani and Alessandro Volta, physiologists have used electric currents to trigger impulses in nerve fibers. But the current that tripped the nerve impulse in Katz's experiment did not come from a battery or any other external power supply; it came from within the muscle spindle itself. Several other workers soon obtained similar results in experiments on mechanoreceptors from organisms as diverse as the crayfish and the cat.

In all these receptors mechanical stimulation produces a weak local current. It is known as the generator current, because it in turn triggers the nerve impulse. The generator current is the earliest detectable step in the transducer sequence. In a typical mammalian mechanoreceptor the current follows the stimulus within a thousandth of a second. Moreover, the generator current increases in direct relation with the increase in the energy of the stimulus. This relation between the input and output of energy resembles that of a good mechanoelectric transducer of the type represented by a carbon microphone. In the microphone mechanical deformation of the disk of carbon by the impinging sound wave reduces its electrical resistance, permitting the electric current to flow through it in strength proportional to the intensity of the sound. The output current from the biological and from the man-made transducer thus conveys a measurement of the strength of the stimulus and of the sound.

With this much known about the mechanoreceptor, the next problem was to discover which of its several structural components is the transducer element. I became interested in the question in 1955, and looked for an appropriate receptor with which to look into it. The Pacinian corpuscle—found in the skin, muscles, tendons and joints of mammals—occurs in an especially accessible



SENSORY NERVES such as olfactory receptors of the nose (*a*) have their cell body at the periphery; pain receptors of the skin (*b*), mechanoreceptors of muscle (*c*) and taste receptors of the tongue (*d*) have their cell bodies buried in the organism. All of them act as biological transducers. The muscle receptors end in leaflike structures; the others are bare.

form in the mesentery of the cat, that is, the fold of tissue that connects the intestine to the rear wall of the abdomen. From the mesentery it can be easily removed and kept alive for hours in a suitable salt solution. Moreover, John Gray and his colleagues at University College London had already shown that the corpuscle can be stimulated mechanically and the resulting current recorded through an electrode attached to its nerve fiber. But the greatest experimental advantage of the Pacinian corpuscle is its large size. It is truly a giant among receptors, measuring almost one millimeter long and .6 millimeter thick. Under the microscope it looks like an onion: it consists of many concentric layers, or lamellae, ultimately enclosing a nerve ending. The nerve fiber leading from it can be kept functioning along with the corpuscle. This easily manageable unit became our experimental subject.

For mechanical stimulation of the corpuscle we used a piezoelectric crystal of the type employed in phonograph pickups. In its familiar applications such a crystal converts mechanical energy into electrical energy. But it can also be used to convert electrical energy into mechanical; it deflects when a voltage is applied across it, the deflection increasing linearly with voltage. In our experiment a glass stylus transmitted the deflection to the corpuscle as a readily measurable stimulus.

To locate the transducer site in the corpuscle, R. Rathkamp and I adopted a direct approach; we removed pieces of its structure in the hope that we might isolate the part essential to the transducer process. We peeled off the outer layers of the corpuscle, stimulating it after each step of dissection. It soon became clear that more than 99.9 per cent of the mass of the corpuscle could be dissected away without impairing the transducer function. A preparation consisting of the nerve ending surrounded only by a thin sheath of "inner core" was as good a transducer as the intact corpuscle. When stimulated mechanically, it produced generator currents which, if the outgoing nerve fiber was left intact, triggered the firing of nerve impulses in the normal manner.

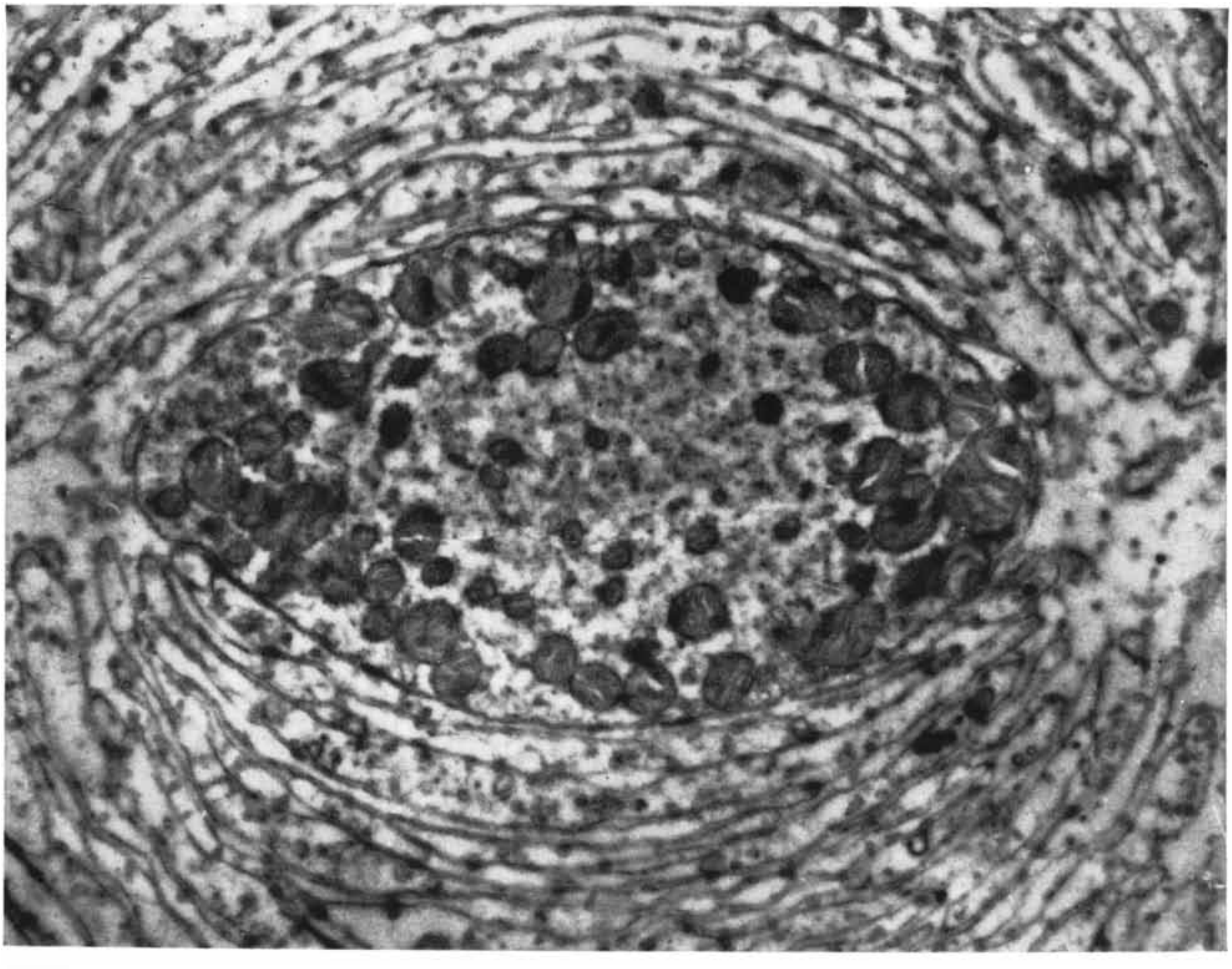
Since the transducer mechanism had to be somewhere within the inner core, the nerve ending appeared to be the most likely site. We tried to strip away the inner core around the nerve ending, but did not succeed because the tissue here is only about .01 millimeter thick and is too intimately attached to the nerve. However, with a pair of micromanipulators we were able to tease off the outer layers, cut out a few pieces of the remaining layers and puncture the rest with a fine glass needle. This preparation, in which the nerve ending was the only intact structure, was still a good transducer, producing currents as in the intact organ.

Thus we could not yet say whether the core tissues or the nerve ending produced the current. Since the technique of microdissection could not completely free the nerve ending from the surrounding core material, we decided to try the opposite tack. We prepared an "endingless" core by severing the nerve fiber of the corpuscle in the living animal and allowing the nerve ending to degenerate. When this preparation was removed two or three days later and stimulated, it failed to produce a generator current, indicating that the nerve ending was indeed the transducer site.

Investigators have now begun to take a closer look at the mechanosensitive nerve-ending with the electron microscope. The two different types, the Pacinian corpuscle and the muscle spindle, that have been examined so far have three characteristics in common: (1) the absence of the insulating sheath of myelin found in nerve-circuit cells; (2) the presence, characteristic of cells that must produce large amounts of energy, of a relatively large number of mitochondria, the small bodies associated with metabolic activity; and (3) the presence of many small, round structures of unknown function that resemble certain structures found in motor-nerve endings.

The generator current produced by the nerve ending in the mechanoreceptor does not itself travel along the nerve fiber. It serves merely to trigger the nerve impulse which does propagate along the nerve circuit, often for considerable distances. Generator current and nerve impulse originate at different places in the corpuscle. Rathkamp and I located the site at which the impulse originates by blocking the activity of selected portions of the nerve fiber. The myelin sheath that covers this fiber extends well into the corpuscle, and is interrupted at intervals of about .25 millimeter by small gaps known as the nodes of Ranvier. In a dissected preparation several nodes and the nerve ending are visible under the microscope; the first node lies within the corpuscle. We applied pressure to the nodes with a wisp of glass about .004 millimeter in diameter, blocking the electric activity of each one in turn. The nerve continued to fire its impulse in response to mechanical stimulation of the nerve ending and to the resulting generator current until we blocked the first node. Plainly the first node is the point at which the nerve impulse starts.

The production of the nerve impulse could now be visualized as a two-step



NERVE ENDING of the Pacinian corpuscle is enlarged some 20,000 diameters in this electron micrograph made by D. C. Pease and T. A. Quilliam of the University of California. The section cuts across the long axis of the ending, which is the oval area in the center. The round, dark bodies within this area are mitochondria. Around the area are the layers, or lamellae, of the corpuscle core.

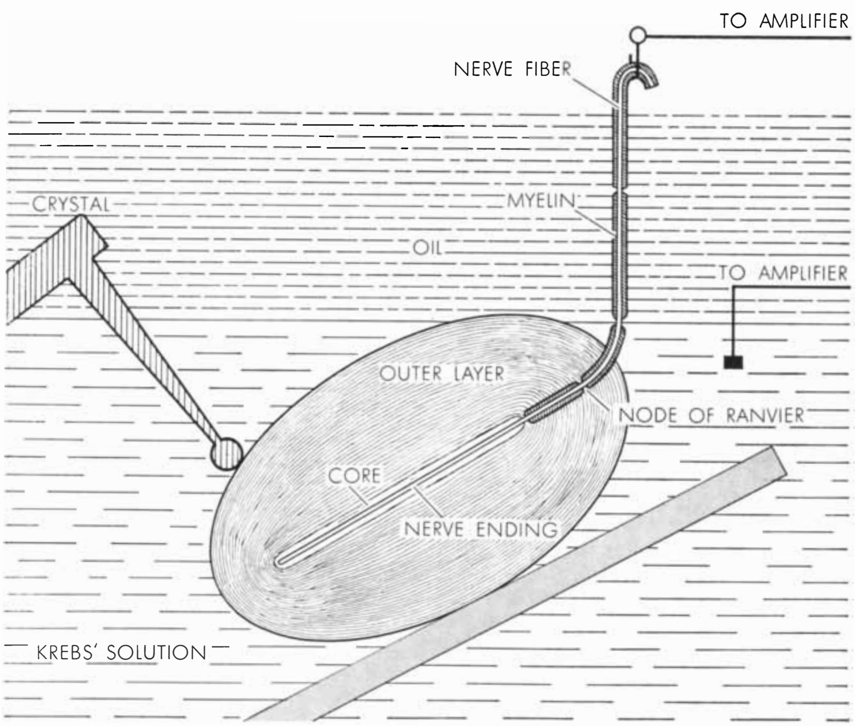
process, each step related to a particular structure. Under resting conditions there is a potential across the "receptor" membrane or the nerve ending in the corpuscle; the inside of the ending is several tenths of a volt negative with respect to the outside. This potential appears to be produced and maintained by unequal concentrations of ions (that is, charged atoms or molecules) on the two sides of the membrane. The ending thus resembles other excitable—nerve and muscle—tissues. It differs markedly from such tissues, however, in its high sensitivity to mechanical stimulation: deformation of the receptor membrane leads to a drop in resting potential. Under resting conditions the membrane resistance is so high that no appreciable net ion current leaks through it. Distortion produces a decrease in resistance which allows ions to move along their concentration gradients across the membrane, causing the resting potential to drop. Mechanical stimulation thus results in a transfer of charges across the receptor membrane; this constitutes the generator current. Part of the generator current flows through the first node, where it triggers the nerve impulse [*see illustration on page 104*]. Apparently the generator current must be of a minimal intensity and must reach this intensity at a minimal rate in order to have this effect.

The nerve impulse has been far more thoroughly studied than has the generator current. It is the signal which in the sensory nerve fibers travels from the periphery to the nerve centers, conveying information about color, shape, texture, temperature, sound and so on; and in the motor and secretory fibers in the opposite direction, conveying orders for contraction of muscles or for secretion of glands. No basic qualitative differences are known to exist among these fibers. The nerve impulse is a pulse of current that under equal conditions and in any given fiber is of the same size and duration [see "The Nerve Impulse," by Bernhard Katz; SCIENTIFIC AMERICAN, November, 1952]. In the case of the fiber that leads out of the Pacinian corpuscle, the generator current excites the membrane of the first node of Ranvier. The node responds with a change in permeability to certain ions, and the result is an abrupt surge of current through the membrane lasting for a thousandth of a second or so. From here on propagation of the nerve impulse follows the pattern of other myelin-insulated nerve fibers. Part of the current set up at the first node flows through the second node, and this current is more than sufficiently strong to trip off a current pulse of the same magnitude in the next node. In this manner the impulse regenerates itself at each node and propagates at full amplitude to the nerve centers. That amplitude bears no relation, however, to the intensity of the generator current that triggered it at the first node.

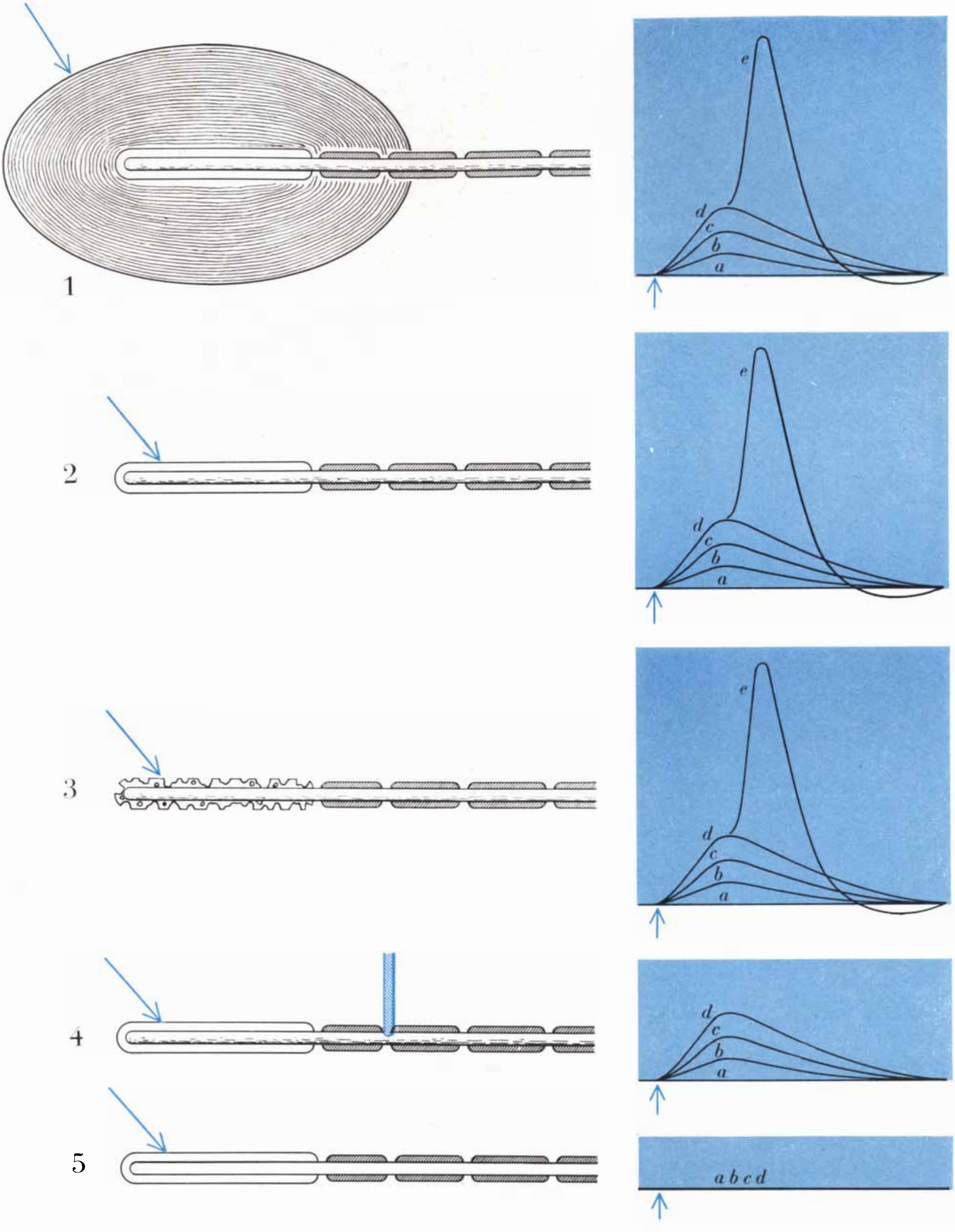
Here one encounters an apparent difficulty. The receptor chain begins with a mechanical stimulus of a given energy content; the stimulus is transformed into a generator current with an energy content proportional to that of the stimulus, and now the chain ends in a signal—the nerve impulse—with an energy content that bears no relationship to either of the preceding events. How can the all-or-none signal of the nerve impulse convey quantitative information about the strength of the stimulus along the nerve fiber?

A clue is furnished by the fact that many man-made information systems operate with all-or-none signals. Digital computers send and store information by all-or-none pulses, and the telegraph transmits messages of the most varied content with dots and dashes, two types of all-or-none pulses. Biological sensory systems operate on the same digital principle and use only dots. As long ago as 1926 E. D. Adrian of the University of Cambridge recorded the signals from skin and muscle receptors and made the far-reaching discovery that the frequency—not the amplitude—of the nerve impulses varies with the strength of the stimulus. Adrian and his colleagues soon broke the code of other sensory systems, and investigators in many parts of the world took up the task of decoding the rest. All turned out to be frequency-modulating systems which translate an increase in the intensity of the stimulus into an increase in the frequency of the nerve impulse. In fibers connected to mechanoreceptors it has been found that the impulse frequency varies with the intensity of the generator current and with the rate at which it increases.

For the student of biological transducers the most interesting and still not completely answered question is how the receptor produces a generator current that varies with the strength of the stimulus and serves to measure it. If the membrane were a carbon microphone, current would flow only in the region distorted by the stimulus, and this would explain the linear relationship between the flow of current and the strength of the stimulus. But physiologists deal with information systems in which signals are carried by ions through conduction lines composed chiefly of water and salts. In a



ISOLATED PACINIAN CORPUSCLE was stimulated by a rod attached to a vibrating phonograph crystal (*left*). The resulting nerve impulse was picked up by a pair of electrodes (*right*). This illustration also schematically depicts the corpuscle and its various parts.



DISSECTION OF CORPUSCLE revealed the site of the transducer mechanism. Stimulation (*arrow*) of the corpuscle when intact (1), with outer layers removed (2) or after partial destruction of the core sheath (3) produced the same responses. A weak stimulus produced a weak generator current (*a*); progressively stronger stimuli produced correspondingly stronger generator current (*b* and *c*); the threshold stimulus (*d*) fired an all-or-none nerve impulse (*e*). When the first node of Ranvier was blocked (4), no all-or-none impulse could be induced. After degeneration of nerve ending (5), receptor did not respond at all to stimuli.

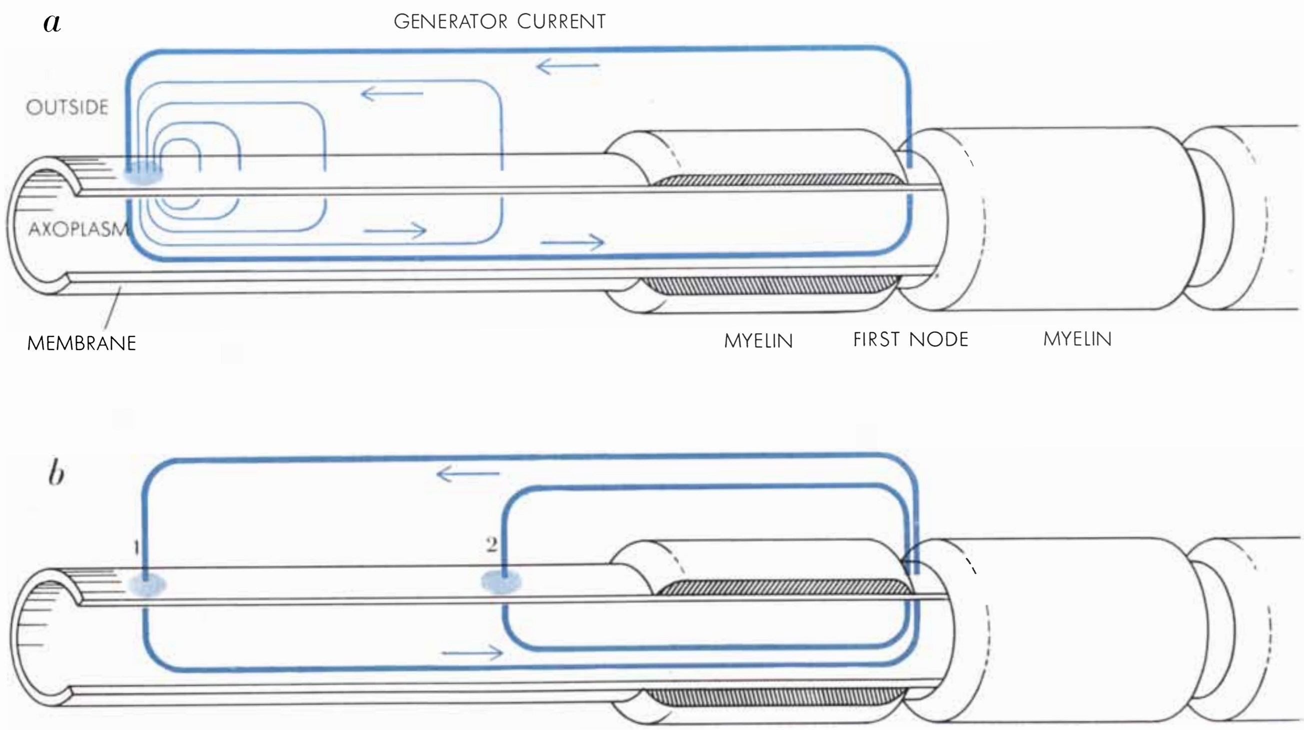
typical conductile nerve-fiber a region of membrane cannot remain unexcited for long next to an excited one. The excited region generates an electric current that is more than sufficient to excite the neighboring region; this region in turn excites the next, and so on. In this manner excitation sweeps in a wave over the entire membrane. Such is the behavior of the nerve fiber. Does the transducer membrane in the corpuscle act like a carbon microphone or like a nerve fiber? Or, to rephrase the question, is current generated throughout the membrane, or generated only in the mechanically distorted region?

A technique worked out in my laboratory at Columbia University provided an approach to this question. We applied a mechanical pulse to a tiny patch of membrane, about .03 millimeter in diameter, and measured the resulting generator currents at varying distances from the stimulated site. We found that the current decreases exponentially with the distance. This is precisely what one would expect if the excitation were restricted to the stimulated region of the membrane. Some of the generator current leaks into the unexcited regions, but the unexcited membrane acts like a passive cable in which signals fade out with distance. The experiment showed clearly that excitation in the receptor membrane is confined to the mechanically distorted region.

I have recently succeeded in exciting two generator currents in the same nerve ending by simultaneously stimulating two spots on the membrane separated by about .5 millimeter. This experiment brought to light a most significant effect: Two such independently generated currents sum to produce a single large generator-current.

The summation of two or more currents, each generated at a separate active site on the membrane, thus promised to explain why the intensity of the generator current is proportional to the strength of the stimulus. To test this hypothesis we applied a series of mechanical stimuli of progressively increasing strength to part of the nerve ending and scanned the membrane with a microelectrode. We found that as the stimulus strength increased, deforming progressively more of the receptor membrane, the excitation spread over a correspondingly greater area.

This opened the rather attractive possibility that the receptor membrane might contain a great number of tiny active sites that show the conventional all-or-none response to mechanical stimulation, and yet give rise to a continuously variable generator current which represents the sum of the currents generated by each of these sites. Theoretically this model can account for the entire input-output response of the mechanoreceptor, and it is alluring because of its simplicity. Unfortunately it must remain rather tentative because there may still be an intensity factor at work. A membrane node that fits the experimental results just as well is one that operates on the basis of spatial summation and in which each active site generates a variable current. We have as yet no way to distinguish between these two possibilities. The only evidence of excitation that can be traced at present is the flow of electric current through the membrane. Current flow is a good index, but a rather blurred one. Even the finest microelectrode is far too large to discrimi-



GENERATOR CURRENT arises in limited region of the receptor membrane of the nerve ending (*at left in top diagram*) in response to mechanical stimulation of that area. This current dies out quickly over the nonstimulated area of the membrane, but if sufficient current reaches the first node of the conducting fiber (*at right*) it triggers a nerve impulse. Two or more generator currents produced by stimulation of separate membrane regions (*bottom diagram*) sum to produce a strong current at the first node.

nate changes in the molecular structure of the membrane which apparently account for the flow of electric charges.

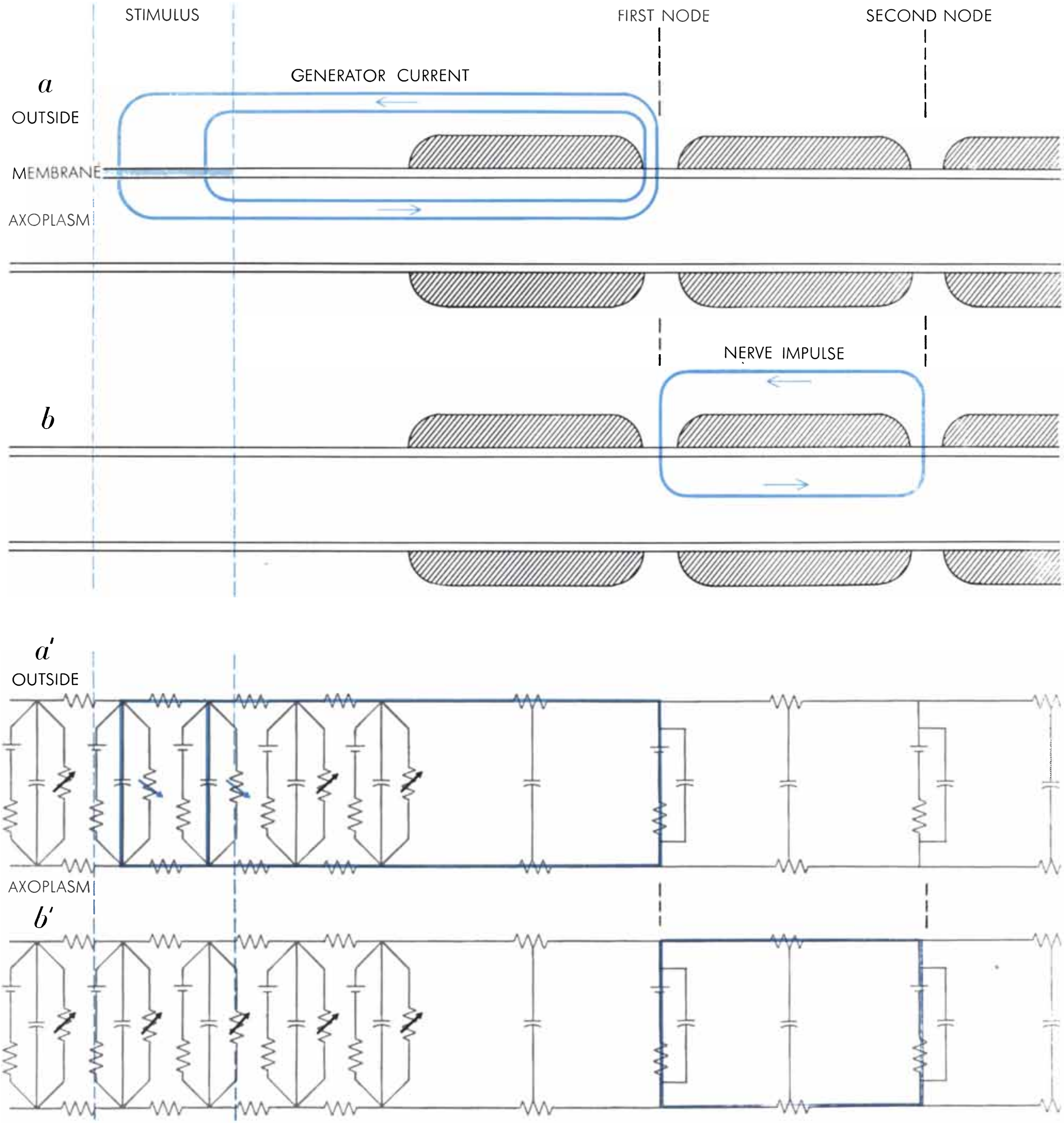
The finding that current flow increases with the area of membrane deformed by the stimulus suggested that the excitation might be a statistical process. In other words, the deformation of a given area of membrane might be expected to excite a statistically fluctuating number of active sites, producing a statistically fluctuating generator current. The fluctuations proved, upon measurement, to be large. My colleague Nobusada Ishiko and I were able to show that a constant mechanical stimulus elicits a generator current that fluctuates at random, and that these fluctuations increase with stimulus strength as predicted by the spatial-summation model.

One may now perhaps picture the receptor as a membrane in which there is a number of tiny holes. In the resting state the holes are too small for certain ions to pass. Mechanical deformation of a given area opens (excites) a statistically determined number of holes, and the ions move through these, setting up the generator current. The opening may occur directly—through stretching, for example—or indirectly, through some biochemical process. As the stimulus strength increases, an increasing number of holes opens up and a correspondingly increasing number of ions passes through the membrane.

A glance at an electron micrograph of the receptor suggests that the number of ions available for transfer must be limited. The lamellae of the receptor core, which are formidable barriers for ion diffusion, are tightly wrapped around the ending, leaving little fluid space between the receptor membrane and the first lamella [*see illustration on page 101*]. This prompted Stanley Cohen and me to see whether the receptor could be "depleted" of ions by repeated stimulation. We found that the reduction of responsiveness is considerable. For example, a stimulus that produces a generator current of 100 units in the fully rested receptor produces a current of barely 10 units after the application of 5,000 stimuli (at the rate of 500 per second) and none at all after 7,000. The effect is now being studied in our laboratory by Sidney J. Socolar and Masayasu Sato. Preliminary results suggest that the transfer of charges across the membrane depends on the interplay of two competing processes: the depletion and the restoration of something, or the inactivation and reactivation of something. But what this something is—whether it is ions or some

chemical precursor—is not yet clear.

The linear relationship between stimulus and response observed in the mechanoreceptor is characteristic of all sensory receptors, and in all sensory circuits the rise in the intensity of the generator current increases the frequency of the nerve impulses dispatched to the higher nerve centers. Another important factor reinforcing the correspondence between input and output in the sensory system is the fact that the receptors occur in groups. Thus a weight pressing on the skin excites many Pacinian corpuscles; light shining into the eye excites a large number of photoreceptors. The greater the strength of the stimulus, the greater the number of excited receptors; if the light is brightened or the pressure on the skin is increased, more receptors are excited, and hence more parallel nerve-fibers fire off impulses to higher centers. Moreover, since several receptor endings are generally the twigs of a single nerve-fiber, there will be considerable convergence of impulses in the common fiber. Thus when a strong stimulus in-



MECHANISM OF TRANSDUCER can be explained by analogy with an electrical circuit. Stimulating a portion of the receptor membrane (*colored area*) causes a drop in the resistance of this membrane region to ion movement. This leads to a transfer of charge, a drop in membrane potential and the generation of current (*colored loops*) in that region. The current flows through the first node of Ranvier and triggers a nerve impulse, the current of which in turn excites the second node (*b*) and so on. In the electrical equivalent (*a′* and *b′*), membrane potential is represented by battery units, and membrane resistance and capacitance is distributed uniformly over a large number of units. (Only five are shown here.) Excitation of a unit causes its resistance to drop (*colored arrows*) and starts events indicated by colored loops. Current discharging into inactive receptor membrane is omitted.

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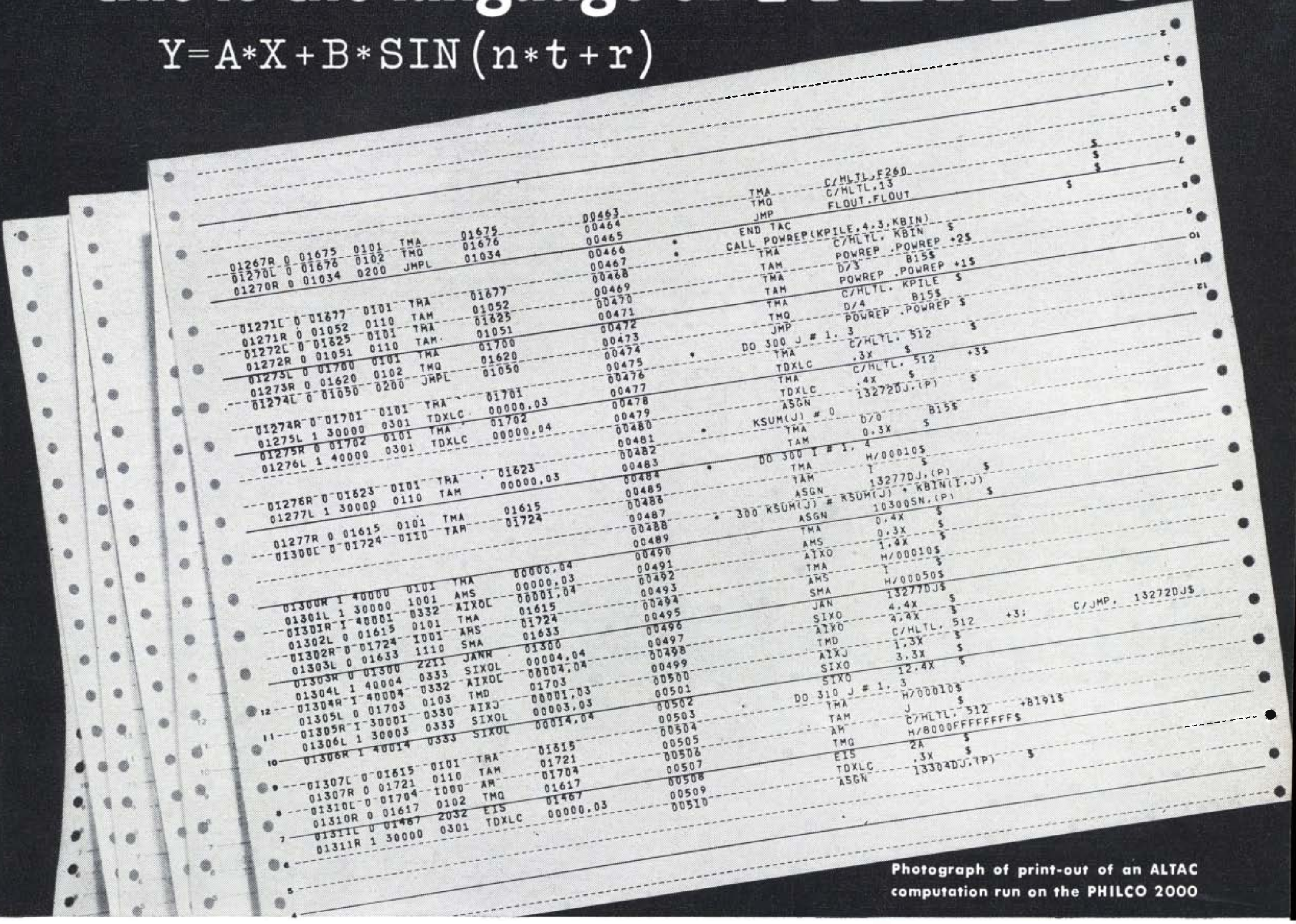
$Y=A*X+B*SIN(n*t+r)$



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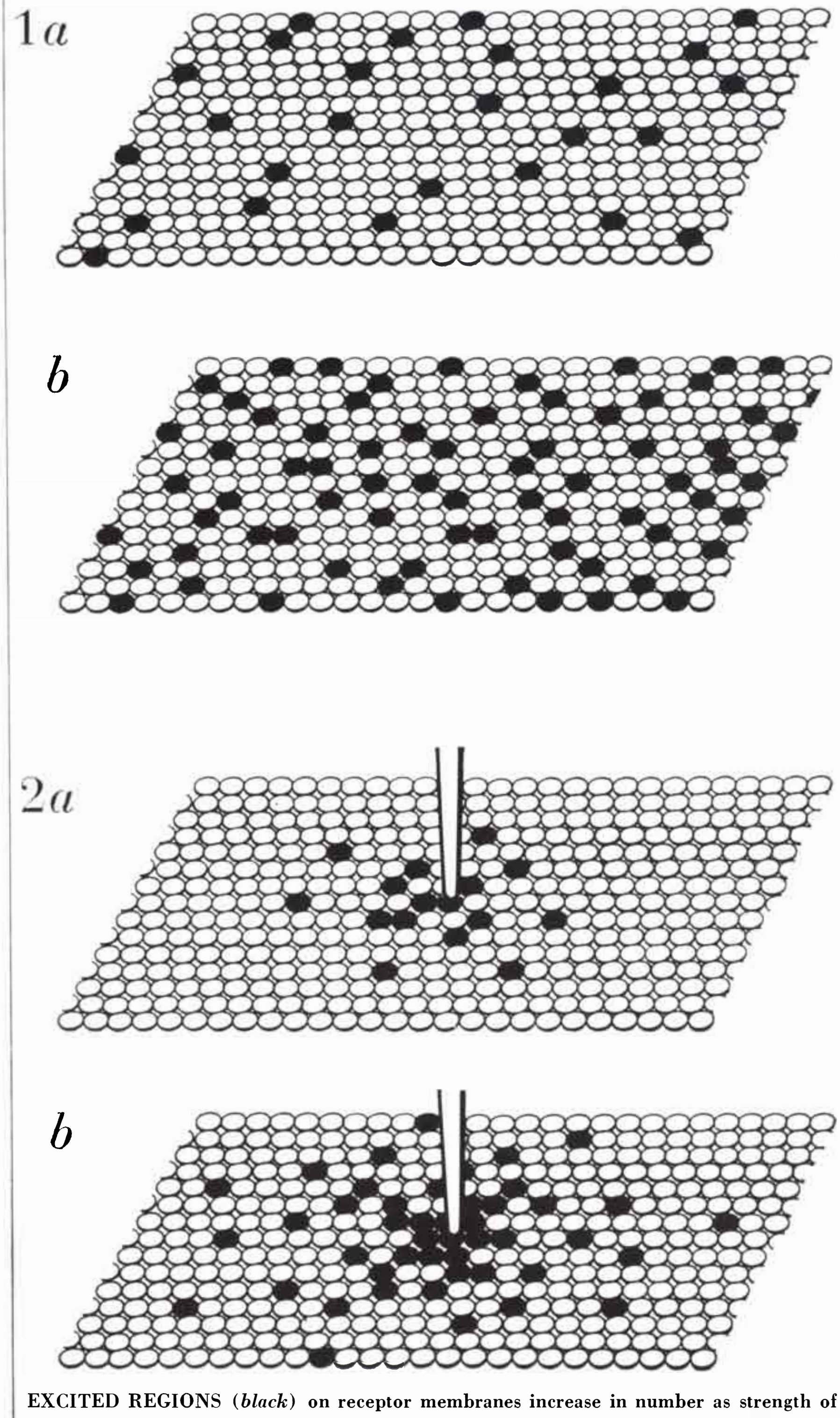
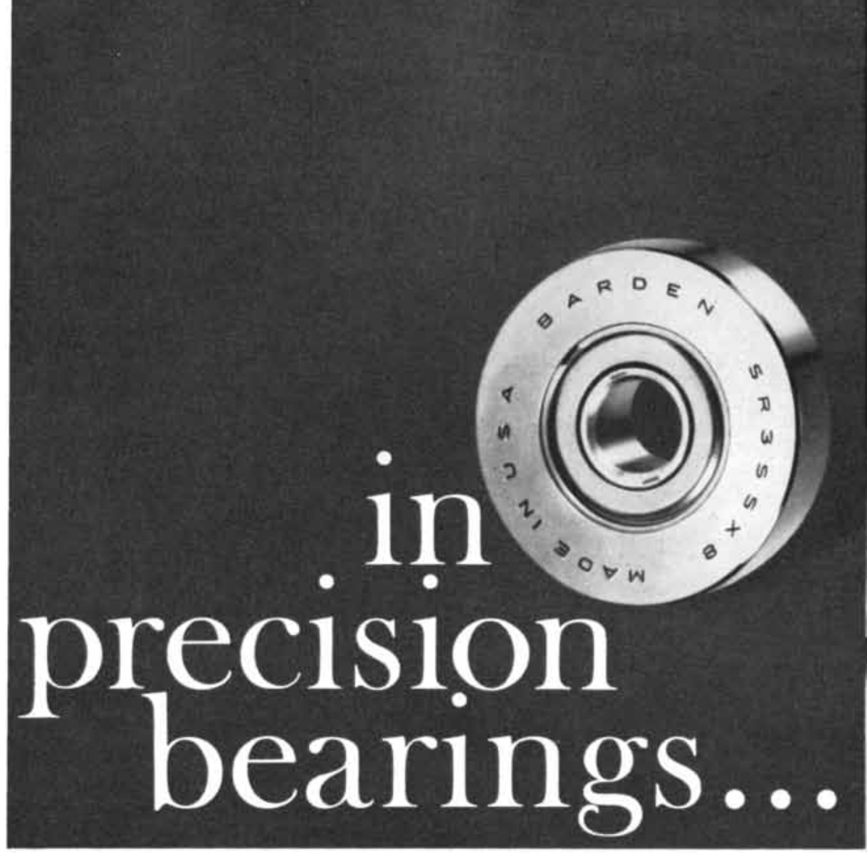
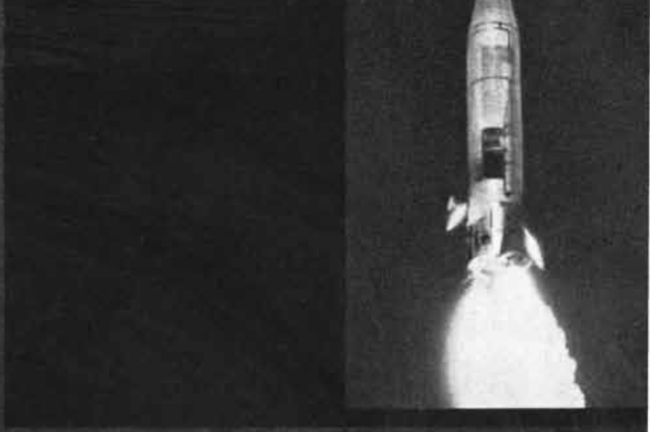
creases the number of activated receptors, this also increases the frequency of impulses traveling along the fiber.

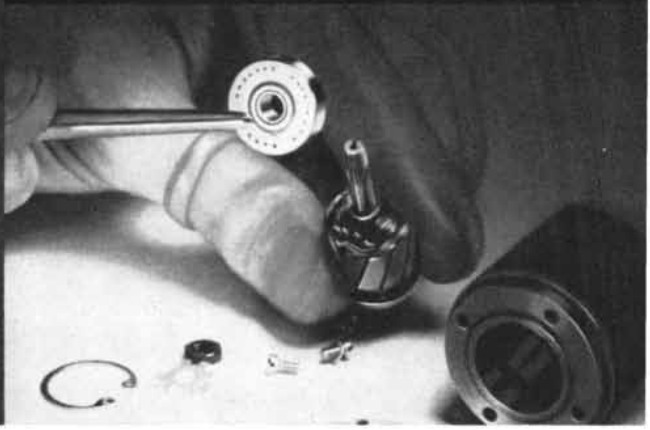
The higher nerve-centers may decipher a receptor message and estimate the strength of the stimulus in at least two ways: by counting the number of parallel information channels engaged in impulse traffic, and by gauging the frequency and sequence patterns of impulses transmitted in each information channel. However, the nature of the mechanisms that decode and store such information is still one of the many open questions on the brain-mind frontier.



EXCITED REGIONS (*black*) on receptor membranes increase in number as strength of stimulus increases. A possible pattern of spread with increase in stimulus strength is shown for the case in which the stimulus is distributed rather uniformly over the entire membrane, as probably occurs in the intact Pacinian corpuscle (*1a* and *b*), and for the case in which a small area of membrane is stimulated by means of a fine stylus (*2a* and *b*).







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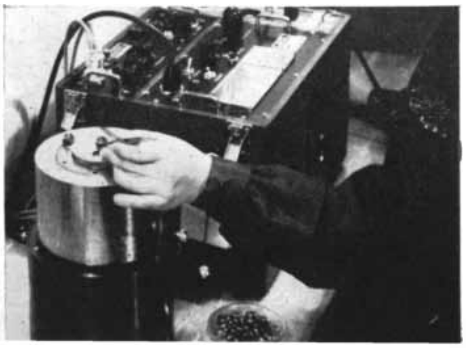

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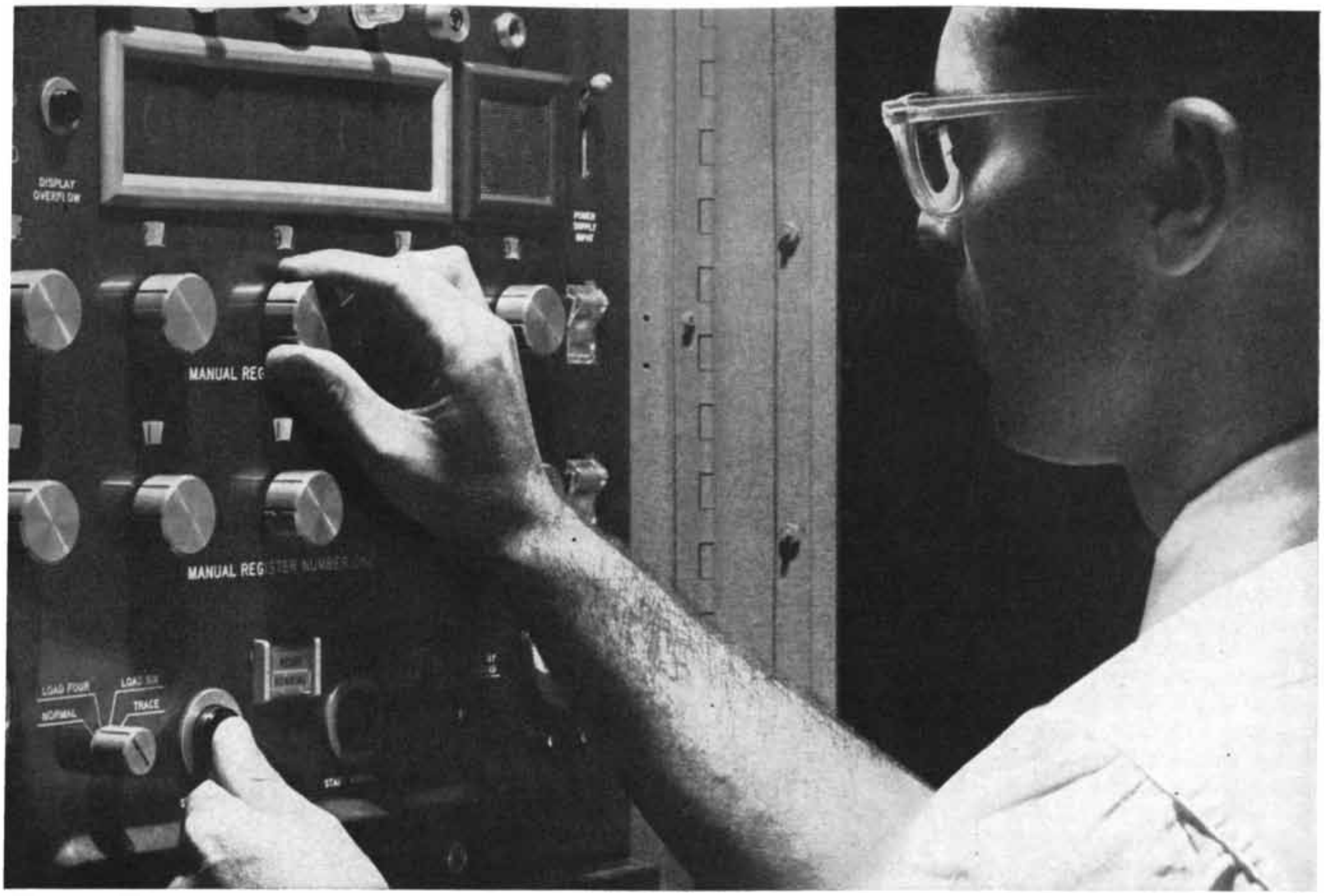

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PEASANT MARKETS

In a primarily agricultural country such as Haiti the market is the central economic institution. Chaotic though they may seem, these gatherings possess an elaborate underlying order

by Sidney W. Mintz

On market days in Haiti the towns and the country market-places gather thousands of peasants for hours of busy and noisy activity. The people come for gossip, courtship and the playing-out of personal rivalries, to visit a clinic or to register a birth; but above all they come for business—to sell the tiny surpluses of their little farms and to buy necessities. They press together in the ragged lanes among the stalls and the heaps of produce spread on the ground, inspecting and handling the displays of textiles, hardware, spices, soap and cooking oils, buying, selling and chaffering. Children push by hawking trays of sweets; farmers pull produce-laden animals through the crowds, calling loudly for the right of way. Trucks back up and turn around, their drivers honking horns, apparently oblivious of the people and the great piles of goods. There are vigorous arguments, sometimes ending in blows and arrests. In the very intensity of color, sound and smell the outsider is overwhelmed with an impression of confusion and disorder.

But for all its apparent anarchy the market place is characterized by an elaborate underlying order. Wherever they exist, peasant markets reveal a great deal about the societies they serve. They are a central economic institution in many countries where large numbers of small-scale farmers work their own land. To follow the movement of marketers and stock through the system is an ideal way to begin to study the economy and to trace the distribution of economic and political power in the society.

In the simpler economies, wherein producers merely exchange local commodities, the market place may do little more than facilitate barter. In societies that use money but have fixed or traditional prices, the market place reflects that isolation from the world market; its transactions neither affect nor respond to economic events in the world at large. Where trade crosses national boundaries, links diverse regions and supports specialist traders, the market place takes on a new significance, joining local activities to the world outside.

As the underdeveloped areas of the world—for example, Jamaica, Haiti, Ghana, Nigeria, India, Burma, Indonesia—move more fully into the orbit of world trade, their market systems have been passing from the earliest of these stages to the next. The transition disrupts traditional relationships and creates new alignments and rivalries in the society, and these are nowhere more dramatically revealed than in the market place. It is here that the peasant trades his surplus for the necessities he cannot produce from his own holding, and it is the market place that determines, directly or indirectly, the prices at which the exporter will purchase the peasant's produce for delivery to the world market. In certain countries the connection that the market establishes between the peasant producer and the world market is the keystone of national development. Those who hold political power may use the peasant market-system to try to educate, persuade, coerce and manipulate the peasantry, particularly with the aim of maintaining or increasing export production. The market places are primarily loci of trade, but they are also the arena where the diverse interests of the peasantry, traders and officials are pitted and exposed.

The study of the tangle of interests that animates the peasant market thus brings into the open numerous connections between regions, classes and interest groups. Traditional anthropological studies, which focus on small, local groups, cannot yield comparable insights into such large, differentiated societies as those of India and Nigeria or even Haiti. Courts and legislatures provide good settings for observation of the competing elements in a society. But the market place reveals far more because it allows these elements so much greater freedom to express themselves.

Though man has probably been a trader since the beginnings of society, his trading activities have not invariably produced market places. When the Spanish conquerors came to the New World, for example, they were stunned by the size and grandeur of such Aztec market places as Tlatelolco, where 50,000 traders assembled on market day. A wealthy merchant group, the *pochteca,* controlled trade and wielded considerable power, and also served as efficient spies for the military. But in the great contemporary Andean empire of the Incas the conquistadors found neither market places nor merchants. Instead of trade they found royal monopolies in gold, silver, coca and fine textiles. Thus while market places are not found everywhere, their very absence tells us something about a society. The presence of markets does not necessarily imply a particular course of social development. Yet there are striking similarities among the peasant markets of the world, especially those of the new nations of Africa, Asia and tropical America.

Haiti is an older nation, with a history of political independence. But at its present stage of economic evolution this Caribbean republic is representative of the new nations that are emerging in the colonial regions of the world. Before the revolution of 1791-1804, Haitian slaves grew their food on plantation wastelands, selling surpluses in supervised

BUSTLING ACTIVITY OF MARKET DAY animates a clearing in rural Haiti. Tradeswomen are grouped by commodity they sell. In this photograph woman in left foreground inspects wares of grain seller. At left in middle distance is lean-to of tuber sellers.

HAITIAN FARMS CLING TO TERRACED HILLSIDES near rural village of Kenskoff. Characteristically cluttered, the Haitian farm grows small but widely diversified crops.

ROAD TO MARKET PLACE is crowded with peasants. Whole families often walk all night, carrying their crop surpluses, in order to arrive at the market in time for early trading.

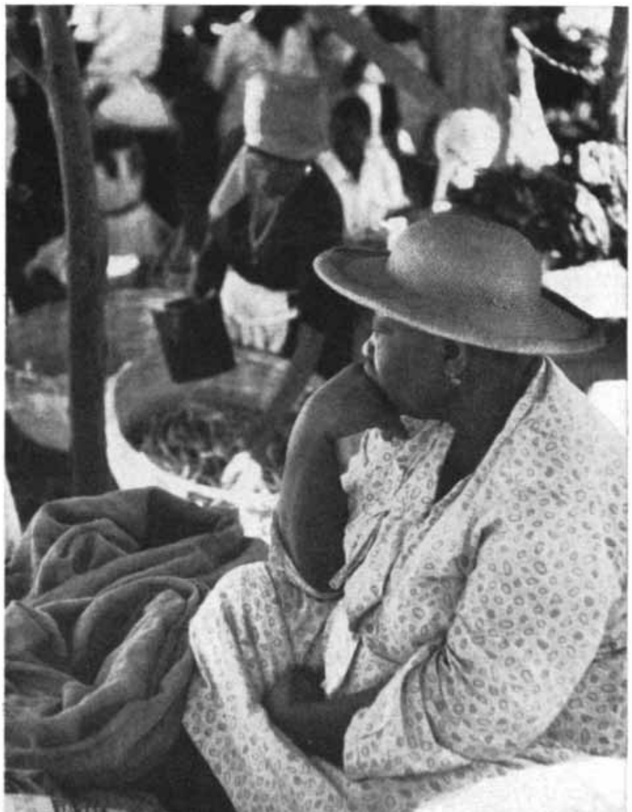
market places. In the 1790's the French observer Moreau de Saint Méry described such a market place, where 15,000 slaves traded on market day. The revolution destroyed the plantations that had made the island of Saint-Domingue one of the richest colonies in history, and substantially eliminated the French planters. Gradually Haiti became a peasant country where small-scale landholders cultivated their subsistence crops for local sale and a few items for export. The cash they received paid for the soap, cloth, oil, metal tools and flour they needed and could not produce. The national government sustained itself almost entirely by taxes on imports and exports; the local government, by levies on dealings in the market place.

Today, 150 years later, nearly 90 per cent of the people live in the countryside, and 80 per cent of them work their own land. Haitian peasants still cultivate much of their own food and produce a small surplus destined for export or for consumption in the domestic economy through sale in the peasant market. By aiming at these three different production goals they try to minimize risk and to secure a reasonably stable subsistence. They further hedge their investment of time and capital by diversifying the cultivation of their land, and this accounts for the curiously cluttered look of their little plots. Like other Caribbean farmers, the Haitian peasant makes thorough use of his land: he grows root crops underground, vines and creepers on the surface, grains above ground and trees and climbing vines in the air. Though technologically backward, the method provides a constant trickle of varied produce for the household where storage is difficult or impractical, a supply of craft and medicinal materials as required and a small quantity of items for sale at various times. It is upon this foundation that the Haitian market-system rests.

The peasant's wife most often handles the market transactions of the family, selling what the land has produced for sale and using the cash received to buy household necessities. Many peasant women become professional traders in this way. This further distributes the family's economic risks, since the men do the farming and the women do the trading partly as separate ventures.

Most of the trade in Haiti goes on in the nearly 300 officially controlled market places. In each region one or more central market-places services other, smaller centers. The larger centers are established in the towns; the satellite country market-places spring up over-

WOMEN DOMINATE TRADE in perishables in Haiti. In photograph at left, purchaser holds a measuring can while bean seller fills it. They may fill and empty the can again before agreeing that it is properly filled. At right is section of the tuber market.



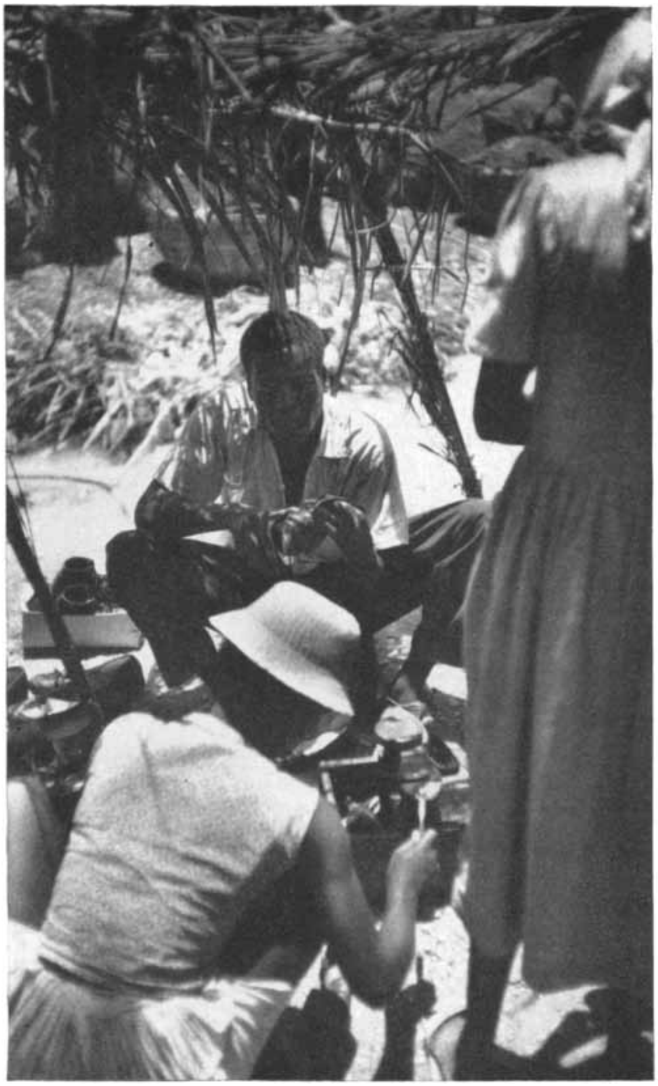
SUCCESSFUL TRADESWOMAN operates between markets. Her annual volume of business may amount to thousands of dollars.

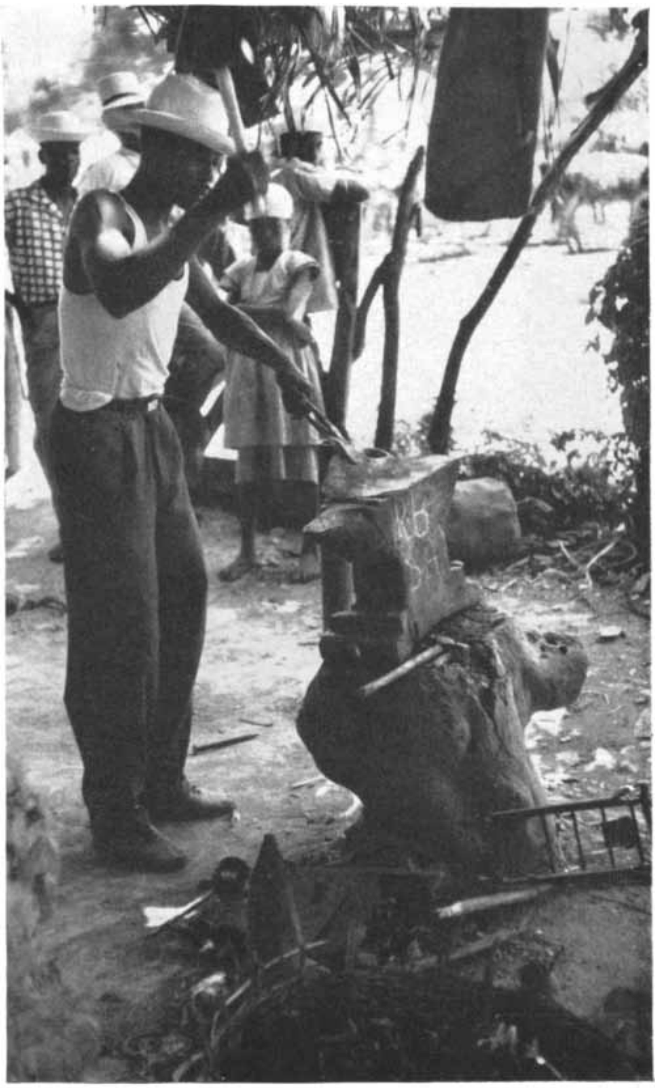
SALT VENDOR'S CHILD arranges stock of coarse, unrefined salt for sale. Salt is among the few commodities shipped in bulk.

night as little towns that last only through the day to gather in and to absorb the peasant buying-power. Market days are staggered, enabling itinerant buyers and sellers to move from one market to another. Most of the important market places are on well-traveled truck routes. Thus the markets form a network, and the produce bought in one is put up for resale—after bulking, processing and transport—in another. For example, pork purchased in one market is cut up, salted and shipped to the next, while rice, millet and maize are husked or ground between purchase and resale to increase their value. The whole system of market places constantly adjusts and readjusts to seasonal changes, to the success or failure of harvests, to the growth and contraction of production areas, to the expansion of roads and trucking.

Trade begins beyond the fringes of the market, where licensed tradesmen from the towns, called *spéculateurs*, maintain outposts at which they buy commodities for export. Peasant women on their way to market stop to sell their coffee, beeswax and sisal to the *spéculateurs*, and then proceed to market with the cash they have received. Because competition is heavy and supplies uncertain, *spéculateurs* do not always wait for the peasants to come to them. They often send illegal buyers called "zombies" or "submarines" to make purchases directly at the farms.

But it is in the tumult of the market place that most trading activity goes on. Only after many days of observing and classifying the actors and their activities does the underlying order become apparent. Sellers of the necessities that peasants come to buy are present each day in a given market place. Perishable foods come and go seasonally, but grains are nearly always available. Prices for different products fluctuate differently, perishables showing the greatest eccentricity, cloth and hardware changing very little from week to week, though perceptibly from season to season. Watching the market place each market day, one sees women dealing in the same goods always clustered together; grain sellers, corn-meal retailers and sellers of spice and sundries arrange themselves in rows. For the seller this permits a quicker check on the day's trade, on one's favored customers, and of course on prices. When sellers of the same stocks are together, the speed with which price is established, and with which it changes during the trading, is increased. Buyers of particular goods come regularly where the sellers are clustered.



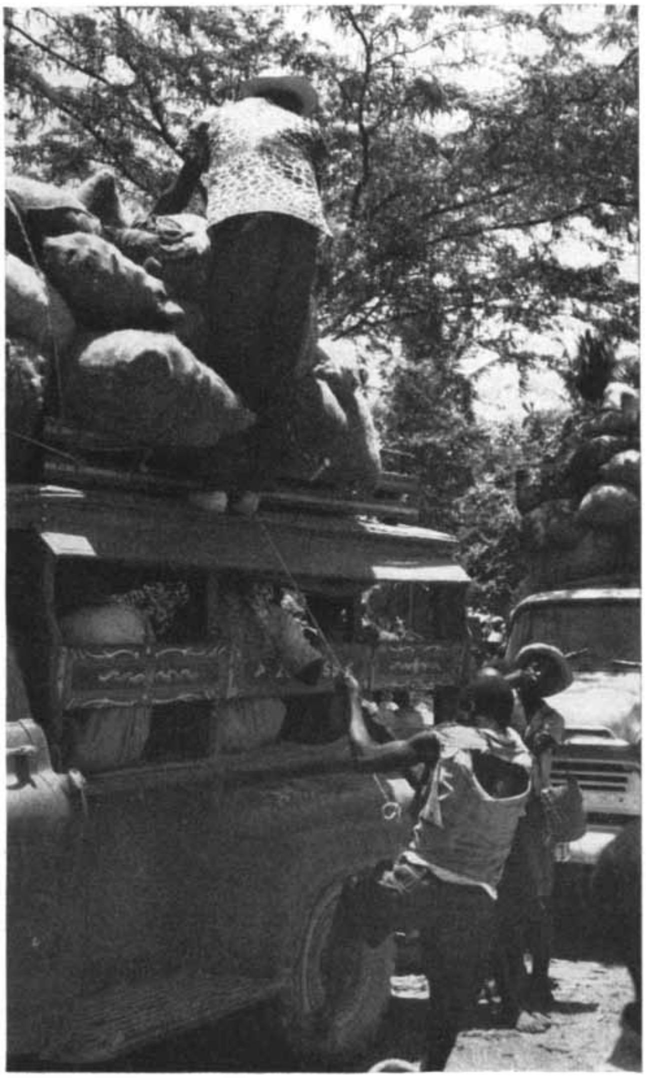


PEASANT MEN WORK AS ARTISANS in the market, rarely as tradesmen. At left is a cobbler who rebuilds discarded shoes and sells them. At right a blacksmith hammers sheet metal into hoes. Artisans usually tend their farms on other than market days.

Behind the facade of apparently uniform and competitive prices, however, there exists a relationship called *pratique*, in which the retailer gives her favored customers certain concessions in price or quantity or in the terms of credit in return for assurances of the customer's patronage when the market is glutted and prices are low. The retailer also makes *pratique* with her suppliers, thus assuring herself of a stock when certain commodities are scarce. Since *pratique* is a clandestine relationship, it can only be understood by carefully noting the details of many transactions.

Even the casual observer soon notices that the important heavy trade in perishables and the small-scale retailing of imports are carried on entirely by women. Men rarely trade; both sexes believe women are commercially shrewder than men. There are, to be sure, male traders, but with the exception of the peasant who has come to market to sell livestock or craft articles they are almost always townsmen. The peasant woman makes her entrance into the market as a trader on the most modest terms, first as her household's representative in the market, then perhaps with a small stake borrowed from relatives or other traders. In a country where a handful of grain makes a meal and a bit of land a farmer, a few pennies constitute operating capital for the middleman, and what one can carry in one's hands is enough stock to begin trading. If the woman is resourceful she may parlay her small stake in a series of small trading transactions to a sum sufficient to secure her status as a *revendeuse* (literally reseller).

Thousands of these women move from market place to market place, each dealing in small amounts, but together buying and selling vast quantities of stock. They live by connecting centers of supply and demand; their potential profit rests in the price differentials between regions and in their ability to contribute to the value of products by carrying, processing, storing, bulking and breaking bulk. They often render services at incredibly low cost. Thus salt retailers in one market place interpose themselves between truckers and consumers, breaking bulk and retailing salt for earnings that sometimes fall below five cents a day. If these services were not provided, consumers would have to buy in uneconomically large quantities, or truckers would have to sell in uneconomically small ones. The fact that consumers buy from them even though they sit only a few feet from the trucks that bring the salt is proof that the service they sell is



TRUCKING AND TINKERING are other male occupations. Trucks carry resellers and their stock between markets. They serve a vital function because regular bulk shipments are unknown. Tinker (*right*) does brisk business because new pots are expensive.

MARKETING OF FISH is characteristic of way trade is conducted in Haiti. Resellers wade out to fishing boats to buy fish (*photograph at top*); return to shore to sell them to waiting consumers (*photograph at bottom*). Fishermen will not deal directly with consumers.

worth buying. In their intermediary activities, the *revendeuses* scour remote countrysides. They buy basic commodities at their sources, where they are cheap, because the economic integration of the back country with the national economy is incomplete. Thus, by servicing buyers and sellers both, they help unite the peasant plot and the local market place with national currents of exchange, stabilizing general price levels and contributing to economic growth. The path to success is uncertain, but some few reach the top. The volume of a *revendeuse's* business may approach that of the famous "market mammies" of Nigeria, whose transactions amount to thousands of dollars a year. Though all apparently aspire to become city retailers, women with rural family-attachments incline to remain in the countryside and usually identify themselves with the peasantry.

For transportation from market place to market place the *revendeuses* depend upon the truckers. Demand is not sufficiently firm and centralized to give the truckers bulk cargoes to haul. It is not surprising, therefore, to discover that they are essentially passenger carriers, whose business it is to transport the *revendeuses* and their modest stocks. Trucking is a risky enterprise in a country where roads are few, maintenance facilities are poor and high taxes are levied against fuel and passengers. The trucker is a relatively new figure in the economy. His economic interests are at present firmly identified with those of the *revendeuses* and opposed to the *rentiers,* merchants and officials of the towns and cities. With the *revendeuses* he is against any forces aimed at the restriction and centralization of trade in Haiti. On the other hand, if the growth and evolution of the economy should make it possible for the trucker to profit by bulk transport, this general accord might well vanish.

In such an eventuality the truckers might find themselves allied with the townsmen. The *spéculateurs,* coffee processors, wholesalers and merchants, separately and in combination, all aim to encompass as much of the peasants' economic activity as possible. For although each peasant may be poor, the wealth that changes hands when thousands of peasants shop in the market place is considerable. Successful market places outside the towns constantly tempt the town merchants, particularly cloth- and shoe-sellers, who carry large stocks from their town shops into the country on market day. The townsmen

would of course prefer that all peasant trading took place in towns, where markets could be centralized, and the small reseller subjected to more control. To that end they have inspired repeated attempts at restrictive legislation. In this they are joined by the *rentiers*, the value of whose property would appreciate with increase in town trade. The importers and exporters among the city merchants would prefer to see export production rise, even at the cost of subsistence crops.

Officials of the national government are often similarly disposed. Unlike the local governments, which are largely supported by taxes on market-place transactions, the national government derives its revenues chiefly from taxes on imports and exports. Hence the state officials want to see peasant agriculture producing more exportable goods. One could say that their aim is to maximize the peasantry's taxable income.

In the market place one sees the whole structure of official power: police, military, judicial, executive. All market places in Haiti are under some supervision by state officials, who carry on two major and familiar functions: maintaining order and collecting taxes and license fees. At the top this structure is tied to the ministries in the capital; at the bottom it embraces notaries, justices of the peace, soldiery and local political leaders. It is within the market place, in the regulation of concrete economic transactions, that the penetration of political control is seen at its most complete as well as its most trivial. State officials supervise the workers who clean and maintain the market place; they catch and imprison thieves; they stop fights. They are supported by the lowest ranks of political officials, the *chefs de section*, who come from the rural areas to the market place to oversee peasants from their neighborhoods. The peasantry's name for any official, no matter how lowly, is always *l'état*.

Traders are taxed or licensed for taking livestock to market, for butchering, for selling animals, for selling meat, for selling foods of any kind, for selling alcoholic beverages and tobacco, for dealing as intermediaries in all other agricultural products, for tethering beasts of burden and for the stands and sheds they use to display meat and other products for sale. This revenue goes largely to governments of the *arrondissements*, though part is drained off by the national government. Tax revenues are used for the operation of local governments, and to pay for tax collectors' sala-

ries and the administration of the tax system.

Just as the political and commercial elements of the towns seek to centralize and control the markets, so the rural tradesmen seek to maintain the status quo. Their interests dictate a diffuse and open market in which ingenuity and intelligence enable them to compensate for lack of capital, and where they may hope to make the transition from perishable-produce dealers to hard-goods wholesalers or credit merchants.

The contention of these various groups, however, is ultimately intelligible only in terms of the behavior and power of the peasant, whose best interests do not lie decisively in either camp. In determining how he may maximize his cash income by transactions in the market place, he weighs the demand and prices of the domestic market against the opportunities offered by the export market. In striking a balance between the two alternatives he may incline toward the production of export goods to supplement his cash, but he is wary of export-market fluctuations which can deeply affect him and which he cannot control. His choices are not entirely free, for the various factions of the nation, especially those that favor increased production for export, exert considerable pressure upon him. As the source of his cash income, the market places are the peasantry's first line of defense against greater dependence upon the world market and a greater involvement with the officialdom of the state.

Apparently the alignments of interest that may be discerned in the peasant markets today have characterized Haitian society for many years. During the 19th century Haiti's seacoast towns sought to maintain economic hegemony over the inland towns. In the struggles of town merchants against the peasantry, and of the seacoast against the interior, climaxed by the capital's economic dominion over the nation, there are startling parallels with conflicts waged during the growth of capitalism in the nations of Western Europe. In both cases groups with vested economic interests sought to restrict the spread of competitive trading activity.

Thus study of an internal market-system may provide a lively vision of relationships among key economic and political groups in a society. Eventually it may be possible to compare internal market-systems in different societies as total systems, thereby revealing similarities and differences among the societies themselves that might otherwise be difficult to discover.

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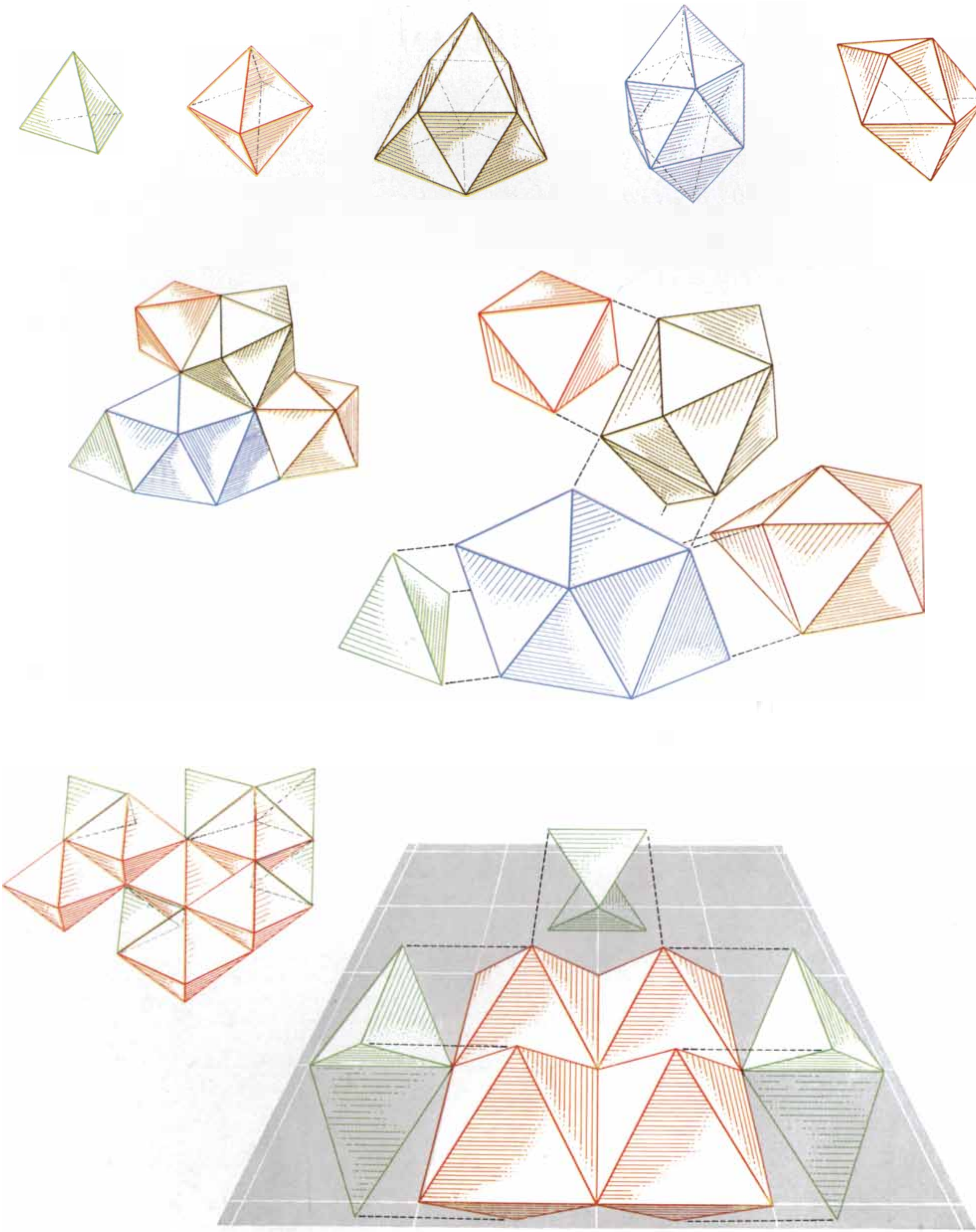


"POLYHEDRAL HOLE" MODEL of liquid structure, discussed in the text, makes possible a simple description of the irregular distributions of molecules in a liquid. In an ideal structure the molecules are all the same distance apart, and the lines between their centers form the edges of five polyhedra (*left to right at top*) : regular tetrahedron, regular octahedron and three semiregular solids with 14, 16 and 12 faces respectively. Possible liquid structures correspond to various ways of fitting polyhedra together. Two arrangements are shown, nested at left and exploded at right. The upper pattern is typically irregular; if extended, it would not give a repeating arrangement. The lower pattern, with only tetrahedra and octahedra, is the only regular one that is possible.

The Structure of Liquids

A new geometrical analysis shows that there is some order in the disorderly arrangements of the molecules of a liquid. The method may lead to a general theory of the liquid state

by J. D. Bernal

"Structure" may seem an odd word to apply to liquids, implying as it does an enduring form. Is not lack of structure—fluidity—the very essence of a liquid? I shall argue here that it is not; that liquids do have, if only instantaneously, an internal molecular architecture in which the key to understanding their properties lies. In trying to get at their nature by way of fluidity it seems to me we are attacking secondary properties before learning to deal with the primary ones.

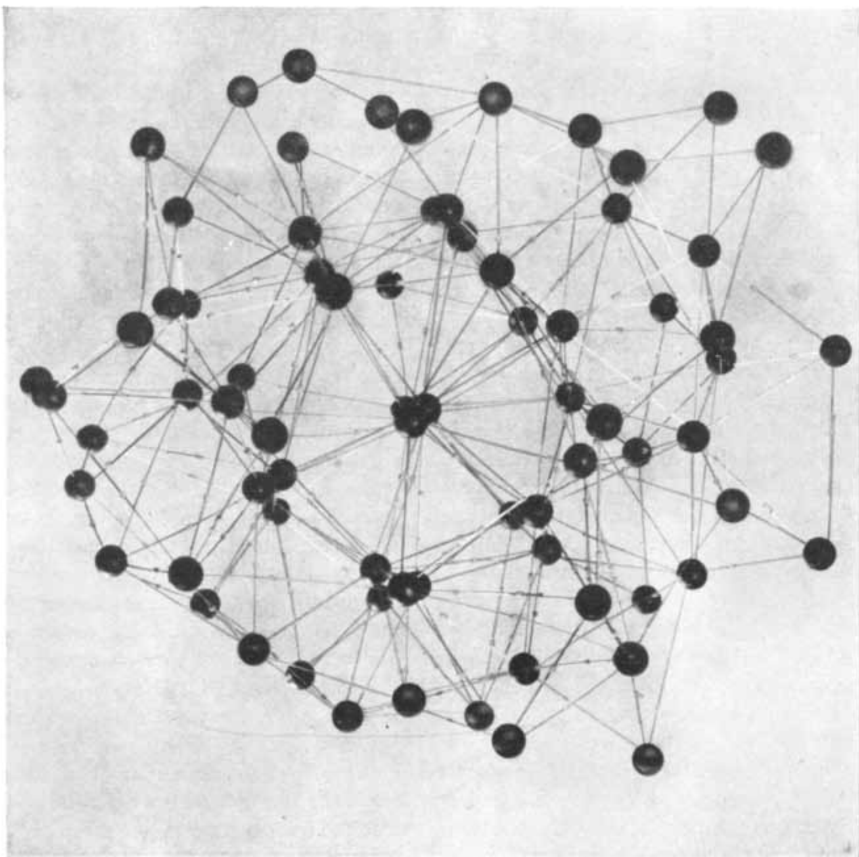
Whether or not I am right, there is no question that we do not yet understand liquids as well as we do solids or gases. The disordered state of the widely separated, darting molecules in a gas has been well known for about a century, since the classic researches of James Clerk Maxwell. The ordered state of molecules condensed in crystalline solids was taken for granted much earlier, and W. L. and W. H. Bragg finally demonstrated it by X-ray analysis in 1912. In both cases there are now theories that derive many of the properties of the materials from the relationships of their molecules.

In contrast our knowledge of liquids is largely empirical. Physicists and physical chemists have learned to predict fairly well the properties of any liquid from those of liquids already known. But the laws do not arise out of any fundamental theory, and they ignore molecular structure.

Attempts at a more fundamental approach have been frustrated by the hybrid nature of liquids. At once highly condensed and completely disordered, they present a very difficult mathematical problem. Simplified models, chosen because they lead to manageable calculations, are so implausible that even their inventors do not pretend that they represent the actual instantaneous structure of a liquid. If many of the calculated values based on them differ quite widely from experimental measurements, this is hardly surprising.

Nonetheless I believe that a molecular model, much closer to the actual arrangements, can be constructed and that, even if it is qualitative at first, it will be more likely to lead to correct quantitative predictions. I have been working on the problem on and off for many years, more intensively in recent months. To put these efforts in proper perspective it will be helpful to consider a little more closely the relationship between liquids and the other two states of matter.

One primary property of a liquid is that it occupies a certain amount of space. At a given temperature or pres-



BALL-AND-WIRE MODEL of liquid structure is one of several built by the author. The position of each ball is limited only by the range of allowed distances to its neighbors. Such models can closely approximate the so-called distribution function of real liquids.

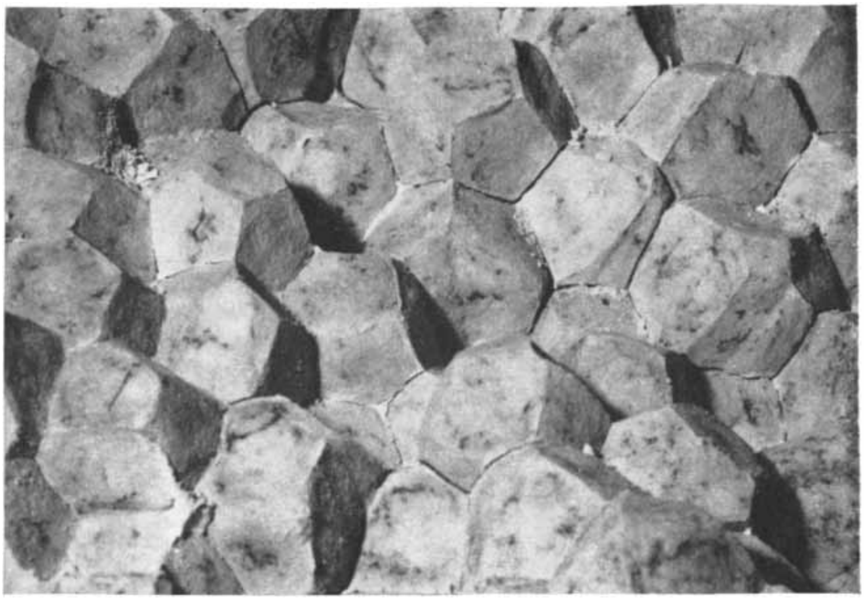
sure it has a quite definite density, one that is affected much less than the density of a gas by a change in the conditions. Its bulk compressibility, as well as its density, is much like that of a solid.

In fact, when a liquid is not far from its freezing point, its structure cannot be very different from that of a solid. It occupies only about 10 per cent (in the case of molten metals 3 per cent) more room. Each molecule therefore must have about the same number of molecules surrounding it at about the same distance that it has when the material is in the solid state.

Not only that, but if the time-scale of observation is made small enough, the material actually exhibits solid properties. Ultrasonic vibrations of sufficiently high frequency set up shear waves in a liquid, as they do in a rigid solid. Experiments on the diffraction of neutron beams by liquids suggest that a molecule in a liquid has time to vibrate from 10 to 100 times before the structure changes. During that time the structure of a liquid is physically, though not geometrically, similar to that of a crystal. However, the irregularity of the liquid structure does allow a greater degree of tolerance. Crystals admit only a very limited degree of variation of composition. The use of crystallization to purify substances is evidence of the exclusiveness of the particular architecture that marks each crystalline phase. On the other hand, liquids mix much more readily, with each other and with both solids and gases. (They do not, to be sure, mix as readily as gases. Any two gases will mix in any proportion. Some liquids, such as the proverbial oil and water, will not.)

Hence it would seem that the atoms in a liquid do not occupy such closely specified positions as they do in solids; they have more elbow room, and they are not so particular about their partners. Indefiniteness or irregularity is an essential feature of the liquid state.

Another manifestation is the clear distinction between liquids—simple liquids, at any rate—and the corresponding crystalline solids. The melting point of a pure crystal is always a sharply defined temperature, but this sharpness of melting point appears only from the solid side. A liquid cooled through the freezing point, with appropriate precautions, does not solidify, nor do its properties change perceptibly when it passes through the temperature of freezing. In other words, the crystalline and the liquid phase are really two alternative ways of arranging molecules. They are at least as different from one another as the arrangements in different crystalline phases of the same substance.



ANOTHER MODEL was made by placing spheres of plasticine in a rubber bladder and exhausting the air so that the balls were pressed together tightly enough to fill all the space.

There is, moreover, one other fundamental distinction between the structure of liquids and crystals. When a crystal is heated, the molecules vibrate and move farther apart, but do not change their neighbors. When a liquid is heated, on the other hand, both the identity and the number of neighbors change. A liquid therefore corresponds not to a single crystal phase but to a continuous series of such phases, each stable only for a single temperature.

When we compare liquids and gases, we find a much less marked distinction. True, at temperatures below the so-called critical temperature (above which a gas supposedly cannot be liquefied) a liquid has a definite boiling point, and a gas has the same condensation point at the same pressure. But the liquid can be markedly overheated and the gas can be undercooled. As the critical point is approached, the difference between liquid and gas fades out; at the critical point it appears to vanish. In my opinon this is only apparent; at temperatures well above the critical point it is still possible to demonstrate a sharp transition from a vapor-like to a gas-like phase, marked by a maximum in the specific heat (the amount of heat necessary to raise the temperature of one gram of the material one degree centigrade). According to my ideas, the essential difference between a liquid and a gas is that in a liquid the molecules are coherent: every molecule is touching at least three others. In a gas the molecules are free or, at high pressures, are associated in small groups.

All this suggests what seems to me the simplest way of characterizing the states of matter in terms of molecular or atomic structure: Crystalline solids (all solids but glasses) have regular and coherent structure; liquids (including supercooled liquids and glasses), irregular and coherent structure; gases, irregular and incoherent structure.

Most theories of liquids have approached the problem from either of two extremes, considering liquids as disordered crystals or as condensed gases. Both viewpoints have led to useful conceptions, and even to calculations of properties, some of which agree reasonably well with experiment. But each is an unbalanced picture of a liquid, which is essentially disordered and essentially coherent. Furthermore, neither gives a detailed description of how the molecules are actually arranged, in short, of the structure.

There was an early attempt to get at liquid structure by means of X-ray diffraction, which had proved so effective in marking out the detailed arrangement of atoms in crystals. The X-ray diffraction pattern of a solid is a series of sharp rings, corresponding to reflections from crystal planes at various well-defined angles. The liquid pattern, however, consists of diffuse halos, usually no more than two or three.

COMPRESSED SPHERES from model at left are polyhedra of various irregular shapes. The most common number of faces is 13 and the most common number of sides to a face is five. In fact, almost every polyhedron has more five-sided faces than any other.

The latter pattern shows that the molecules in a liquid have no long-range order. That is, beyond two or three molecular diameters the arrangement in one place has no effect on that in another. At the same time the existence of the halos shows that there is some short-range order. This order is best described in terms of the so-called radial distribution function, which can be derived from the angular variation of X-ray scattering, and from which, in turn, several properties can be calculated. To understand what the distribution function is, imagine that we have picked a molecule (considered as a point) at random within the liquid and drawn a series of spheres around it with their volumes regularly increasing so that the volume interval between two neighboring spheres is always the same. Then the distribution function is simply the average of the number of other molecules between such neighboring spheres, at each distance from the central molecule. The distribution function is thus a measure of the average density as a function of intermolecular distance.

At very small distances the function is zero; molecules occupy a finite space and cannot be closer together than their diameters. The value jumps to a high maximum at the distance of the nearest neighbors of the molecule. It falls off, then peaks less sharply for the next to nearest neighbors and less sharply still for those at third remove. Very soon, however, it smears out to a uniform value [*see illustration on next page*].

To a first approximation the distribution function of a simple liquid resembles that of a dense but random arrangement of hard spheres such as marbles. Some years ago Joel H. Hildebrand of the University of California demonstrated this experimentally by suspending a number of gelatin balls in a liquid and shaking the container. Later B. J. Alder, also at the University of California, performed a similar experiment numerically, with a computer [see "Molecular Motions," by B. J. Alder and Thomas E. Wainwright; SCIENTIFIC AMERICAN, October, 1959].

What I have tried to do in the first place is to make a model of a liquid structure which will give a better approximation to the distribution function than the hard sphere model. To find it, I have tried to discern some order in disorder, some rules that govern the instantaneous arrangements of the molecules, irregular though the arrangements are. The eventual goal is to count the number of different possible arrangements. As we shall see, this would provide the basis for a general thermodynamic theory of liquids.

When I undertook the task, I began by assuming that a liquid consists essentially of a set of molecules similarly but never identically placed with respect to one another. I have restricted myself to the simplest case of spherical molecules, which corresponds to liquefied metals or to liquefied monatomic gases such as neon and argon. I have also assumed that the liquids are approximately homogeneous. They may vary slightly in density from place to place, but not in general structure; there are no regions where the molecules are regularly arranged.

I spent considerable time trying to imitate this kind of irregularity with physical models, and found it fairly easy to do so. Among the constructions was one in which I built up an array of balls joined by stiff wires of various lengths, doing the job in my office, where I was interrupted every five minutes or so. This enabled me to achieve almost perfect randomness, because by the time I got back to work I had forgotten what I had been doing last.

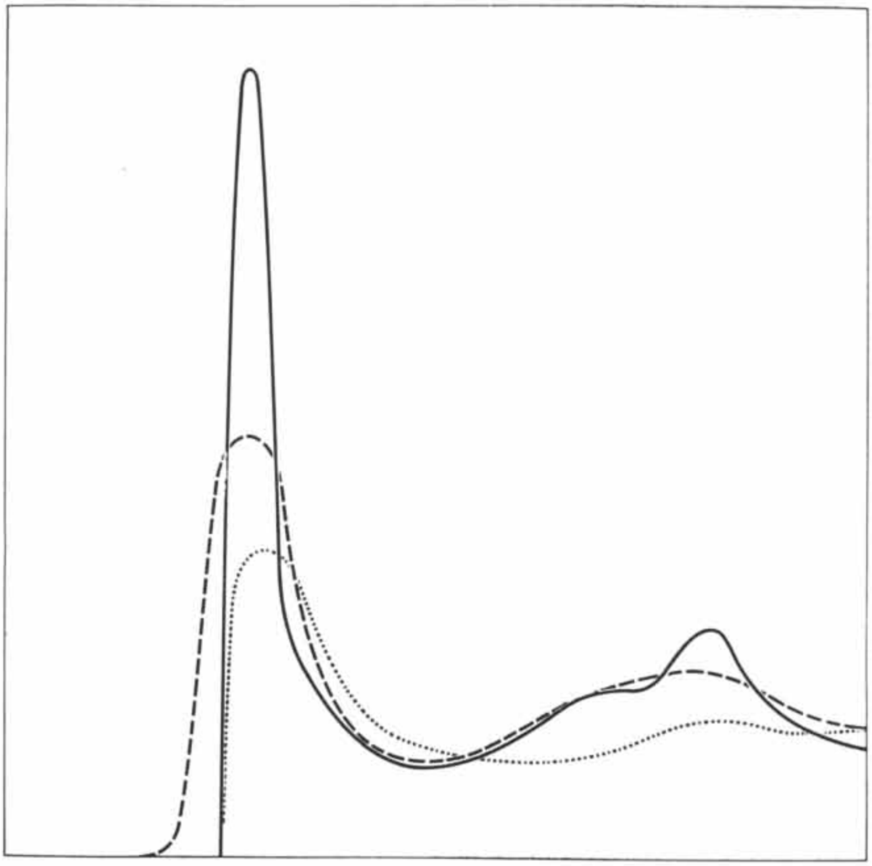
The model turned out to have the right sort of disorder, and also approximately the right density. It occupied about 15 per cent more space than an array of "close-packed" spheres. I wondered, however, whether I might not have introduced some order unconsciously, so I checked the model against randomized arrangements of spheres, some of which are illustrated on these pages. What appeared in all these cases was the prevalence of five-fold arrangements among the balls surrounding any one of them. Now to a crystallographer this was somewhat shocking, for we had got into the habit of considering it as an axiom that molecules can be arranged with two-fold, three-fold, four-fold or six-fold symmetry, but that five-fold symmetry is not allowed. However, the rule actually applies only to crystals. It is true that one cannot form regular patterns with five-fold symmetry that fill space solidly and extend indefinitely in three dimensions. It is like trying to pave a floor with five-sided tiles.

Only in the last few years have we appreciated that this is not a law of nature but a definition of crystals. In a noncrystalline, irregular structure five-fold arrangements are, for purely geometrical reasons, likely to be the rule. The reluctance of crystallographers to contemplate such arrangements accounts, I believe, for the fact that there have been so few attempts to understand the geometry of liquid structure.

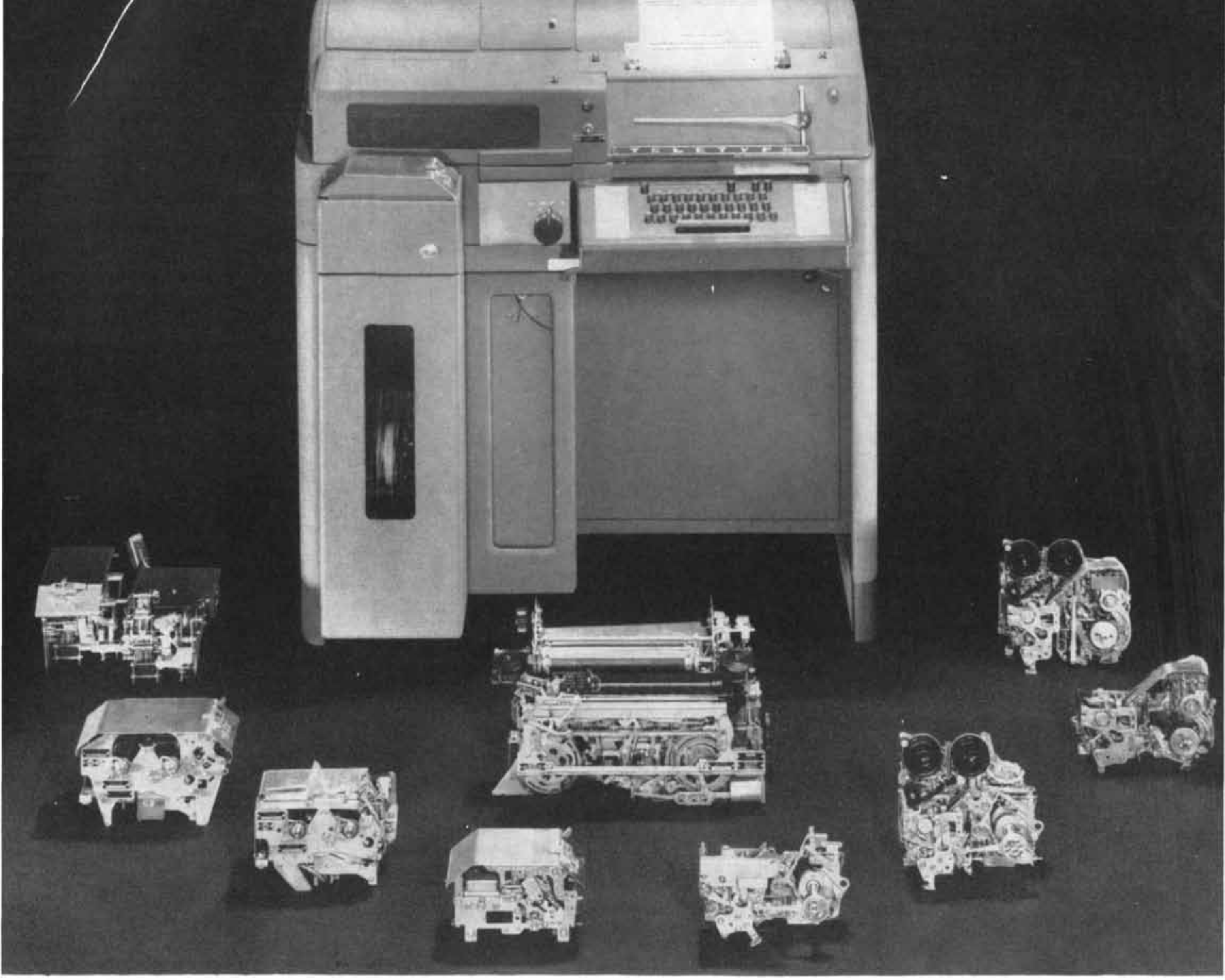
In order finally to eliminate any human or physical elements that might have introduced order into the model, I turned to a purely mathematical method, using a computer at the University of London. My son, M. J. M. Bernal, devised a program for producing a dense but absolutely random distribution of points with the one condition of a minimum distance between them. Starting with a point as a center, the computer picks at random a second point not less than the minimum distance away, then a third not less than the minimum distance from each of the first two and so on until no more will fit in a given volume. It turns out that the space around the center out to about three times the minimum distance can be filled with about 70 or 80 points.

The distances as measured by the computer could be used directly to set up a radial distribution-function. The result turned out to be similar to that of actual monatomic liquids, but not identical. In particular, the first peak was too broad, indicating that the distances between nearest neighbors varied more than in a real liquid.

The difference, it seemed clear, arose from the fact that the simple minimum-distance rule used in constructing the model ignores the attractive part of the force that exists between molecules of a real liquid. At extremely close range there is a strong repulsive force, which falls off very rapidly with distance (it



RADIAL DISTRIBUTION FUNCTION of a liquid measures the probability of finding a molecule at any given distance from any arbitrarily chosen molecule, as explained in the text. Dashed curve represents the actual distribution function for molten lead, as determined by X-ray diffraction. Dotted curve is function derived from ball-and-wire model with balls placed at random but separated by a minimum distance; solid curve, function derived after adjusting model so as nearly to equalize distance between nearest neighbors.



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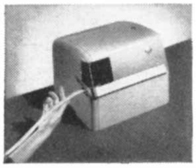

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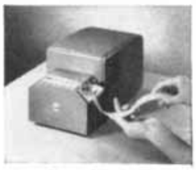

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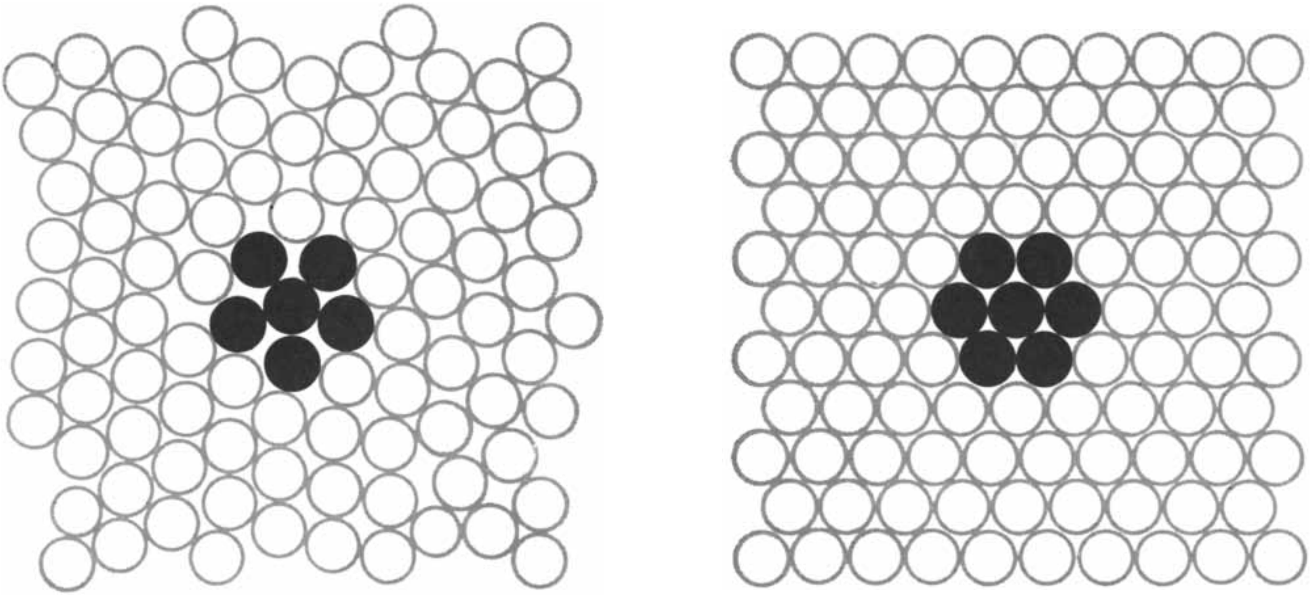


FIVE-FOLD SYMMETRY, which turns up repeatedly in models of liquid structure, makes filling space with a regular array impossible. In two-dimensional representation at left the central circle is surrounded by five others. The remaining circles cannot be made to form an orderly condensed pattern. Six-fold symmetry, as at right, leads to familiar regular hexagonal pattern.

varies inversely as the 13th power). The curve is so steep that the molecules act almost as if they were hard spheres that do not repel until they touch. This part of the force is the one that the condition of minimum distance does represent. However, as the range increases, an attractive force appears. It, too, decreases rapidly (as the seventh power of distance), so that the force between nonneighboring molecules is effectively zero.

Immediate neighbors, on the other hand, are within the range of the intermolecular force. If nothing interfered, each pair would obviously lie at just the distance where the force disappears in changing from repulsion to attraction and where the relative potential energy of the molecules is zero. In an actual liquid the interactions of many neighboring molecules make the situation more complicated. However, there is a distance of separation, corresponding to minimum energy, at which the molecules tend to lie, and it is somewhat greater than the minimum distance of possible approach.

In order to take this factor into account, I built a ball-and-wire assembly corresponding exactly to the machine model, but with wires of adjustable length. Then I proceeded to squeeze the model until most of the distances approached the same value. By doing so I was able to come much closer to the actual distribution function. I was thus encouraged to think that the model, with all the neighboring balls now at approximately the same distance, represented fairly accurately the momentary situation of molecules in a liquid. The actual number of nearest neighbors of each molecule in the model varies from eight to 14, with an average of 11. In a real liquid this average coordination number, as it is called, determines the internal energy. When a liquid expands on heating, the average number of nearest neighbors of course decreases. Near the critical point, where the volume is three times the minimum volume, the number falls to between three and four.

It was only at this point that I saw that the equidistance model contained the key to the problem of finding the order of disorder. The answer was extremely simple, and I might have saved myself a lot of trouble by thinking hard first and computing and measuring afterward.

I conceived of an ideal model of a liquid, with each molecule surrounded by a limited number of others at equal distances. This corresponds to the ideal model of a crystal from which the real crystal differs only in small atomic displacements.

Consider a point that is not at the location of a molecule. The molecules surrounding this point, or rather their centers, can be thought of as defining a hole in the shape of a polyhedron (a solid bounded by plane faces) with centers at the corners. In the ball-and-wire model the wires would represent the edges of these polyhedra.

Now the significant thing about the ideal model is that all the edges of all the polyhedra are almost equal. If we limit ourselves to relatively dense packing, where there are no holes large enough to accommodate an extra ball, we need only consider the five smallest polyhedra with equal edges. These polyhedra, all with triangular faces, are the regular tetrahedron and octahedron, and three semiregular figures [*see illustration on page 124*].

Here is the key to the order we have been seeking. An ideal, dense-packed liquid is allowed only those structures that correspond to the ways in which some or all of the five polyhedra can be nested together to fill space completely. And the ideal model seems to be a reasonable approximation to a real liquid, at least to a liquid not too far from the freezing point.

When we examine how the holes go together, we find that the only combination that really fits is a mixture of tetrahedra and octahedra, in the proportion of two to one. They can be put together to give two or three of the orderly arrays found in crystals. In any other selection the ideal polyhedra must be distorted slightly in order to fit together. A variation of about 10 per cent in the edge length is enough. Properly adjusted, the holes fit together, but rarely in repeating arrangements. Most kinds of packing generate only indefinite irregular arrangements. The basic reason is the

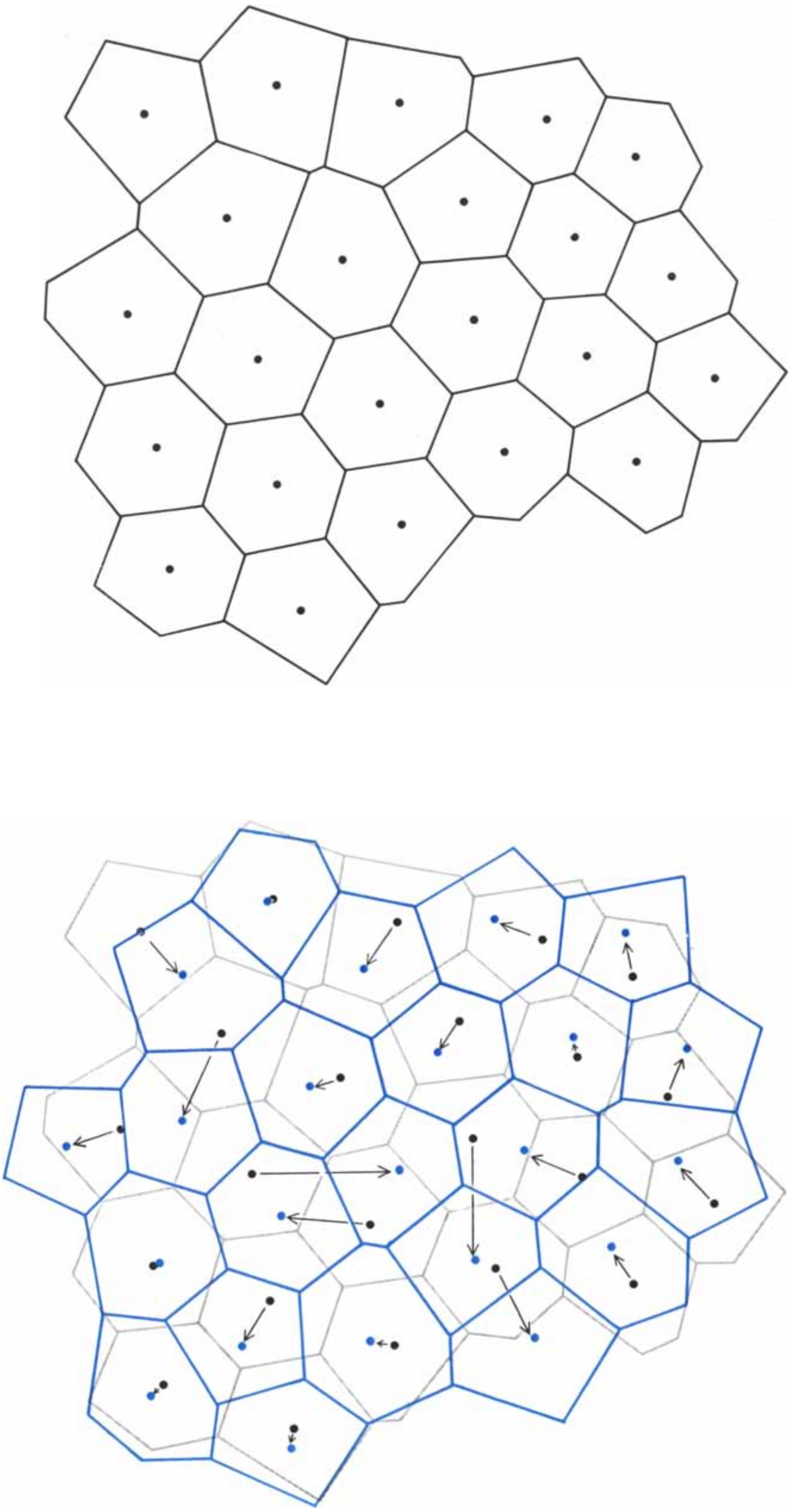
prevalence in the three larger holes of corners where five edges meet. As has been mentioned, five-fold symmetry cannot lead to crystal-like structures.

Thus there is an enormous number of arrangements that correspond to the irregularity of a liquid, and only two or three that correspond to the regularity of a solid. In other words, just putting molecules together is very much more likely to lead to a liquid than to a solid. But the necessity for changing the length of the edges of polyhedral holes means that the molecules are not at their equilibrium distance, and consequently the energy is always high. This explains why every liquid will crystallize if the temperature is low enough. When some nucleation process starts the building of a regular arrangement, the arrangement always grows, because of its lower internal energy.

Closer inspection of the irregular arrangements corresponding to a liquid reveals that they have more tetrahedral holes than other kinds. Furthermore, the tetrahedra are not free and separated from one another by holes of other forms, but are mostly joined together in aggregates. These groups are very dense; even denser than the close-packed crystalline arrangements, since the latter must contain one larger, octahedral hole for every two tetrahedra. The super-dense aggregates cannot grow indefinitely, however. If you put three tetrahedra together and add another in one of the three possible ways, they join in a ring of five slightly distorted tetrahedra with one edge in common. Here again we meet five-fold symmetry—the form that prohibits any large-scale regular extension.

I have called these aggregates, which necessarily form in any dense irregular array, pseudonuclei. They are nuclei in the sense that they are hard and dense, in fact they are denser than true crystalline nuclei. But unlike them they are not viable; they can lead only to a very limited growth. Between the closed systems must be larger holes that can more than compensate for the extra density, and so the liquid arrangement is generally less dense than the solid.

The idea of pseudonuclei helps to explain the phenomena of supercooling and glass formation. As the temperature is lowered and energy is extracted from an irregular array, it may fail to crystallize, because the energy of snugly packed pseudonuclei is less than that of the same molecules in the regular array they adopt in the crystal. The reason why at low temperatures the crystal as a whole has lower energy, is that it does



DIFFUSION IN LIQUIDS takes place as molecules continually change neighbors and shift among equally likely patterns. Structure at one instant (*as at top and in gray at bottom*) is shown as a two-dimensional diagram representing polyhedra around each molecule (not the polyhedral-hole model). Colored pattern shows structure at a later instant, after various pairs of polyhedra have lost or added common sides and after the molecules have moved.

not have the relatively high-energy holes that must necessarily exist between pseudonuclei.

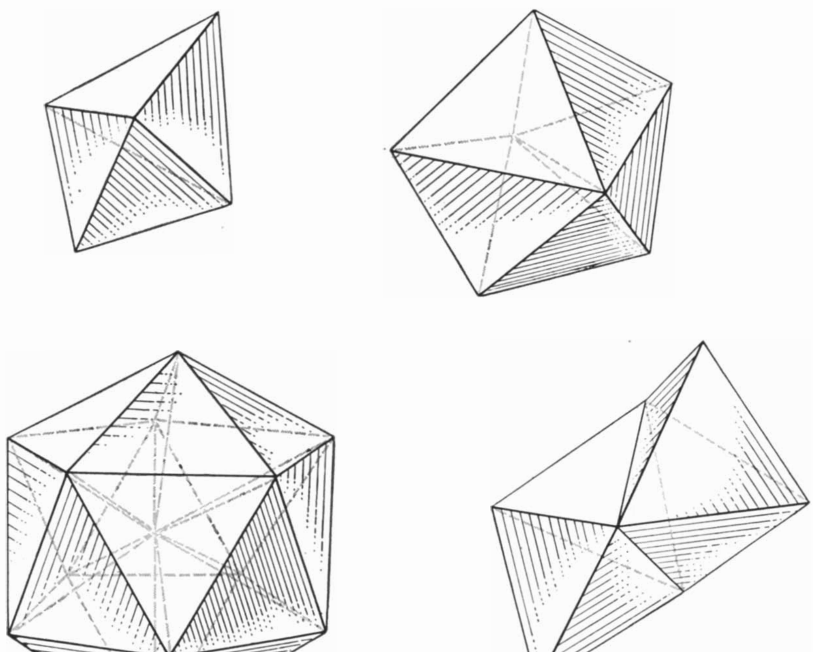
The picture I have sketched so far is essentially static, but it provides a basis for explaining dynamic fluid properties as well. The essential feature of an irregular array is that there is at any temperature a number of arrangements differing by very small quantities of energy. To go from one to another is very easy, and this must occur spontaneously all the time. Thus a liquid has not one structure but a large number of equally likely structures, and is in constant flux between one and another. In each change-over some molecules change neighbors. The molecules move about in a random way; after a series of changes, original neighbors find themselves far apart; in short, the molecules diffuse.

Now if a stress is put on a liquid, those change-overs that tend to relieve the stress are favored, and those change-overs that increase it are disfavored. The motion is no longer completely random, and the liquid as a whole flows. Thus we have at least a semiquantitative picture of diffusion and viscosity.

The only truly quantitative information to emerge from the model so far is the distribution function. My hope, however, is that it will eventually lead to a precise measure of disorder, or, in technical terms, to a calculation of entropy. Here is where existing theories go quite wrong. They fail, often by a factor of five or more, to give the right answer for entropy and for properties such as melting point and critical point that depend on it.

In essence, calculating the entropy involves finding all the different possible arrangements of the molecules and adding their relative probabilities. The lower the energy of an arrangement, the higher its probability. But the characteristic of a liquid is that very few molecules can be in low-energy arrangements, and then they can be in such arrangements only locally. The big difficulty with an irregular system is to recognize different arrangements and to be sure they have all been accounted for. Perhaps I can do it by analyzing the finite number of ways in which the polyhedral holes can be put together with one corner in common. This will give all the possible arrangements of nearest neighbors around any molecule, which may provide the solution.

My approach might be termed statistical solid geometry. It is too early to tell whether it will work out. If it does, it may not only provide a rigorous theory of the liquid state, but may prove helpful in a number of other problems.



PSEUDONUCLEI are extra-dense aggregates of tetrahedra alone that are always found within close-packed arrangements of the five polyhedra of the polyhedral-hole model. The aggregates cannot grow indefinitely, however, because they eventually close on themselves.

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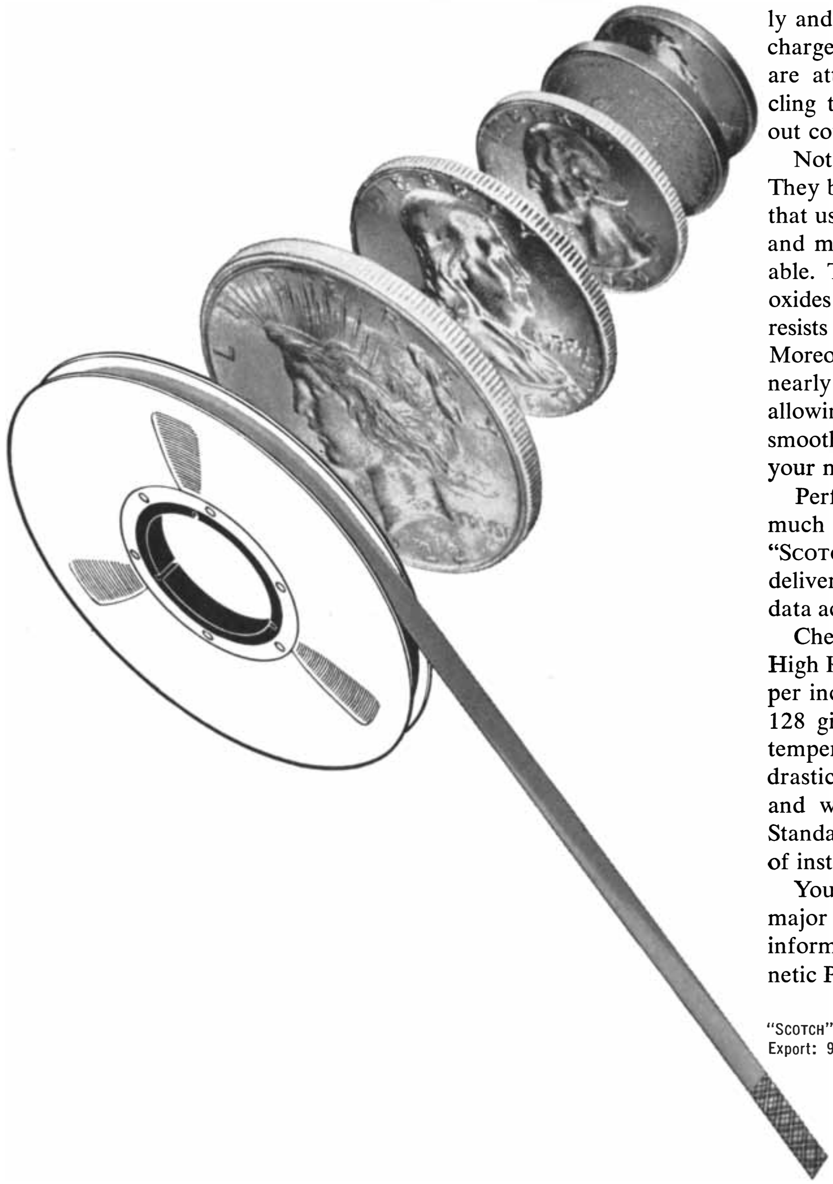

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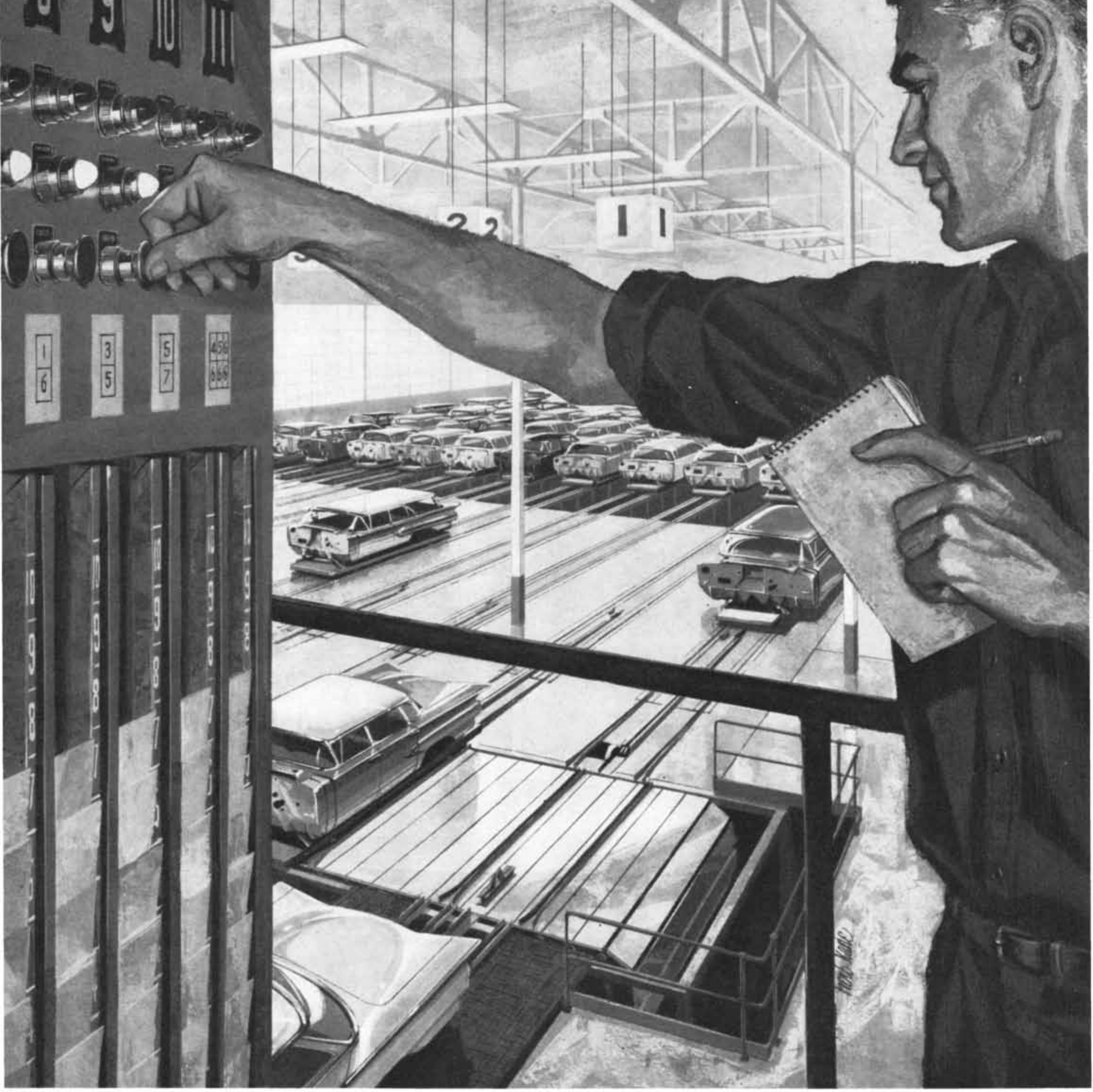

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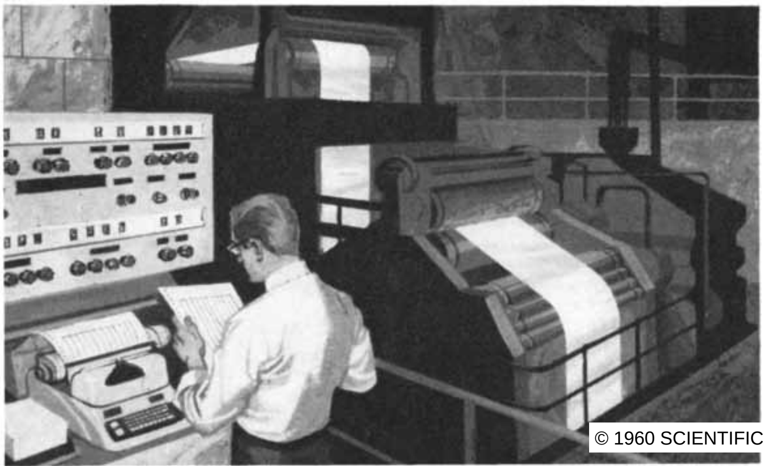

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FRIENDLY VIRUSES

Not every virus is harmful to its host. Among the beneficent viruses is one that causes a desirable streaking of tulips and another that enables an insect to feed on plants on which it would normally starve

by Karl Maramorosch

Though the word "bacteria" suggests disease, it takes no more than a second thought to realize that bacteria play a vital role in sustaining the economy of life. Bacteria in the soil fix atmospheric nitrogen and process inorganic and organic matter into soluble food material for plants; in the human intestine they synthesize essential vitamins. When it comes to viruses, on the other hand, there is apparently no reason to qualify the first bad impression. These minute particles of protein and nucleic acid can reproduce themselves only at the expense of the living cell; they "live" by infecting higher organisms. From time to time, virus diseases have decimated the population of the world; the medieval smallpox plagues, the yellow fever epidemics of early American history and the influenza pandemic of 1918 come at once to mind.

I must admit that for a long time I shared the common opinion that all viruses are disease agents. Then one day two years ago I heard René Dubos, my distinguished colleague at the Rockefeller Institute, declare that virus infections do not necessarily cause disease. By way of example he cited the virus that causes "breaking" in tulip blossoms, that is, the streaking and variegation of color so admired by tulip-fanciers. Dubos's original perception has since suggested a great many other instances of benign and even helpful virus infection. To the lengthening list of friendly viruses (not always friendly, however, to man) I have had the pleasure of adding one that turned up recently in my own research. It may be that viruses serve constructive functions in nature as varied and universal as those played by bacteria, but as difficult to see as the viruses themselves.

The virus infection of tulips beset the people of the 16th- and 17th-century Netherlands with a real craze that is recorded in history as the "tulipomania." Wealthy Dutchmen paid fortunes for infected plants; a single bulb that gave a flower of rare beauty is said to have furnished the entire dowry of the daughter of one of the country's richest merchants. Only a few families knew the secret of producing the streaked flowers. It was not, however, a very complicated process; the bulb-grower simply rubbed the juice of a streaked plant onto a solid-color one. Such a secret could not be kept forever. Soon every bulb-grower around Haarlem and Lisse knew how to induce breaking in the tulip, and speculators lost fortunes in the collapse of the market.

In textbooks today paintings by old Dutch masters that show the streaked blossoms are used to illustrate "one of the earliest known plant virus diseases." No one at the time, however, thought of breaking as a disease. Not until many years later was it discovered that the effect was caused by a virus, which in nature is transmitted from plant to plant by a plant louse. But, as Dubos pointed out, there is hardly any justification for calling this virus infection a disease. It breaks up the normally single-hue coloring of the flower into streaked patterns. Far from harming the species, the virus gave the tulip a greater popularity and

STREAKED TULIPS result when a solid-colored tulip becomes infected with a virus. At left is a pink tulip from a newly infected plant. A year after infection, the tulip "breaks" and produces red-and-white streaked flowers (*second*). In successive seasons the white area tends to increase (*third and fourth*). This photograph was provided by Frank P. McWhorter of Oregon State College.

so, indirectly through man's cultural response, caused the plant to be more widely propagated and spread.

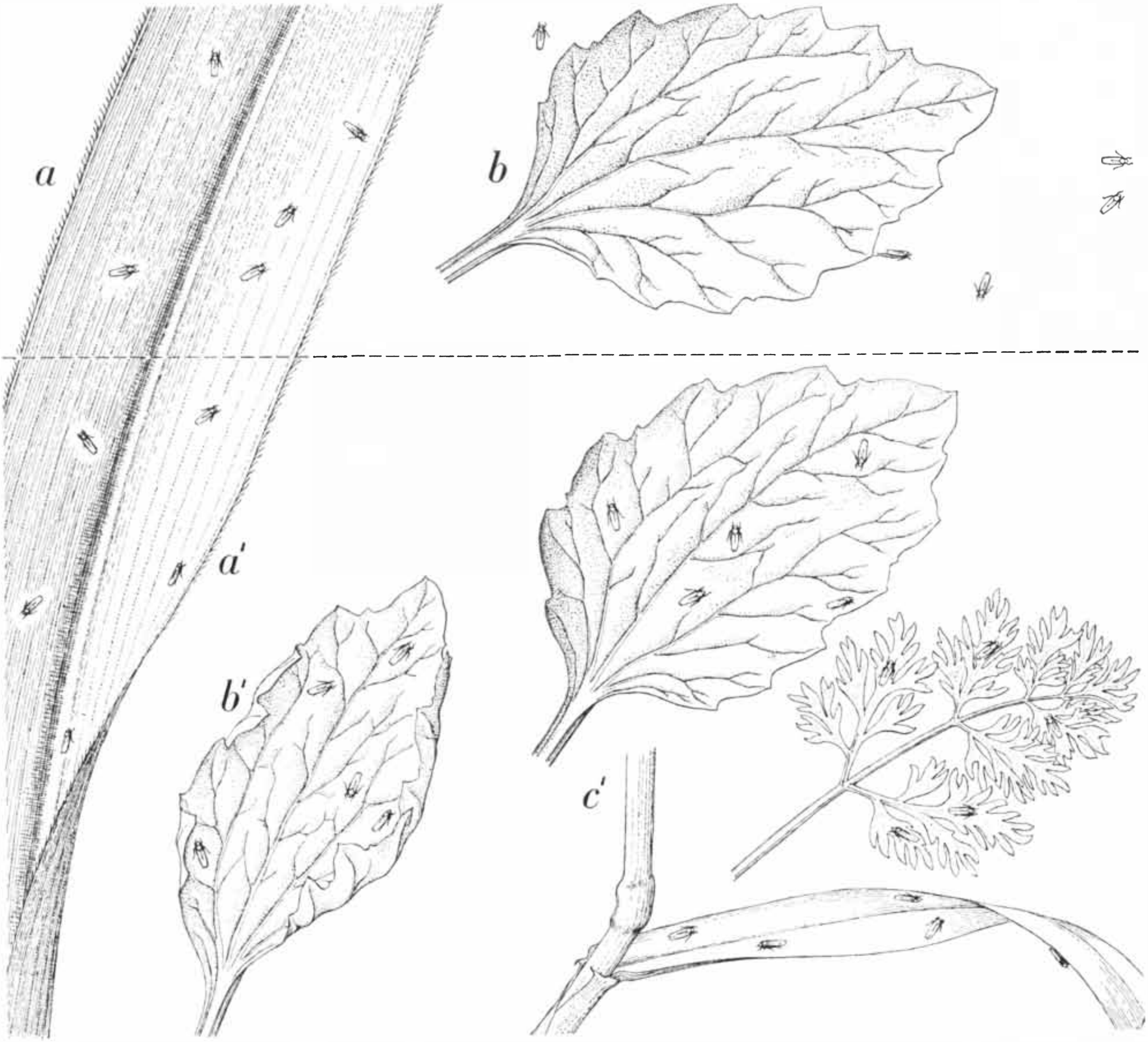
It is true that the infection is not always completely harmless to the individual plant. Over the years most of the infected varieties become weaker and smaller. Few, if any, of the most famous tulips of the 17th century exist today. After decades of cultivation, the flowers lost progressively more of their color, until all their pigment was gone, and they lost their attractiveness [*see illustration on opposite page*].

The flowering maple—a white-blossomed plant of the genus *Abutilon* that bears no relation to the maple tree—owes a similar reputation and wide propagation to another virus. Plants distinguished by showy spotted leaves were introduced to Europe from the West Indies in the middle of the 19th century. Since the variegated trait was never transmitted naturally from one plant to another in either Europe or the U. S., the spotted type was classified as a horticultural variety. Then in 1904 Erwin Baur, the founder and first director of the Institute for Researches into Heredity in Berlin, reported that he could transfer the variegation to normal plants by grafting. He thus concluded that spotting was not a genetic trait but the result of infection. A man of strong personality and confidence in his own judgments, Baur carried his interpretation one unfortunate step further. Since the only known method of transmission was grafting, he declared that the infection could not be caused by a living organism "since no organism could exist that would be dependent upon occasional grafting carried out by gardeners." Baur's students never dared question his logical conclusions, and so the infectious chlorosis of the flowering maple remained a mystery for half a century. Effort to discover the cause was marked, in fact, by still another misstep by another distinguished worker. In 1944 the English geneticist C. D. Darlington postulated that the virus originated *de novo* when grafting brought together the proteins of two related plant species. The idea that viruses might be synthesized by such a procedure was soon dissipated by the discovery of the natural vector of infectious chlorosis.

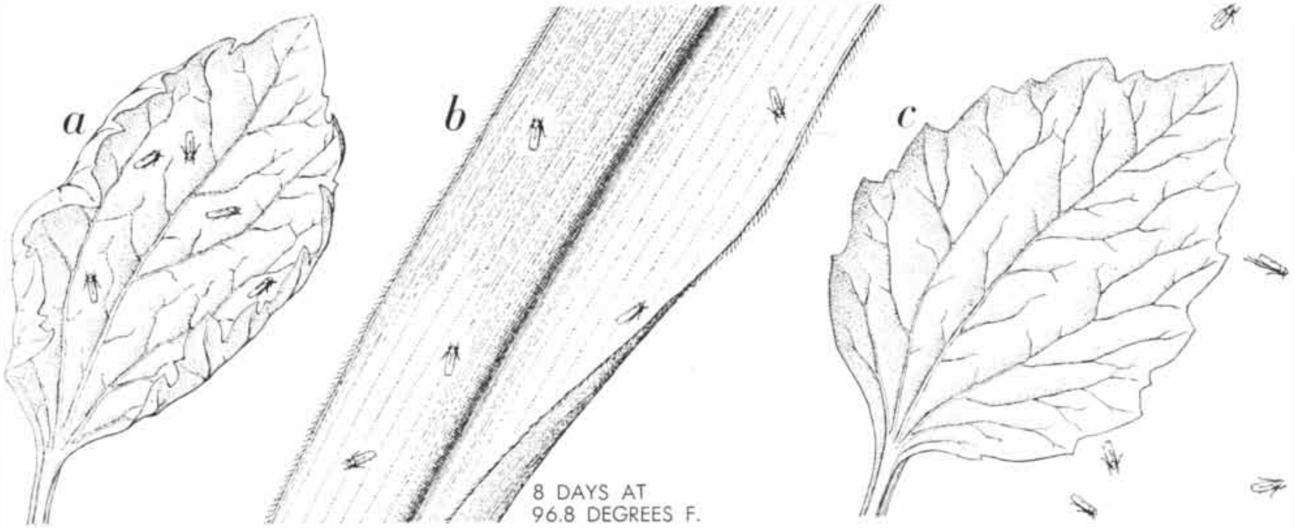
Karl M. Silberschmidt, a Brazilian plant pathologist, noticed that every summer new plants along the streets of São Paulo developed spotting without artificial aid. This meant that in Brazil, at least, the virus did not depend upon

FLOWERING MAPLE, a white-blossomed bush of the genus ***Abutilon***, is no relation to the ordinary maple. It is subject to infection by a virus that gives rise to spotted leaves.

SPOTTED MAPLE is the result of a virus infection transmitted by grafting the branch of an infected bush to a normal one. In Brazil the infection is also transmitted by white flies.



HOST OF CORN LEAF-HOPPERS ordinarily is the leaf of the corn plant (*a* and *a′*). The insects will not feed on the leaf of a healthy aster (*b*), but they will feed on an aster infected with the aster-yellows virus (*b′*). Afterward the insects that have acquired the virus from the diseased plant will feed on various hosts such as a healthy aster or even carrot and rye plants (*c′*).



INFECTED CORN LEAF-HOPPERS (*a*) that are transferred back to corn and kept warm for eight days (*b*) lose the ability to feed on diverse hosts such as the healthy aster (*c*). The heat does not harm the insects but does destroy the virus in their bodies.

grafting for its spread. With the help of the entomologist A. Orlando, Silberschmidt tried various ways of infecting healthy plants isolated under glass globes. One day they found one of the globes cracked and the plant under it infected with white flies. They removed the insects and placed the plant under an intact globe. Afterward, among all the plants in the experiment, this one alone manifested the sought-for spots. The riddle was solved: White flies of the species *Bemisia tabaci* spread the virus in nature. Because these insects thrive only in tropical and subtropical regions, the virus does not spread by natural means when the plant is transported to Europe and the cooler regions of North America.

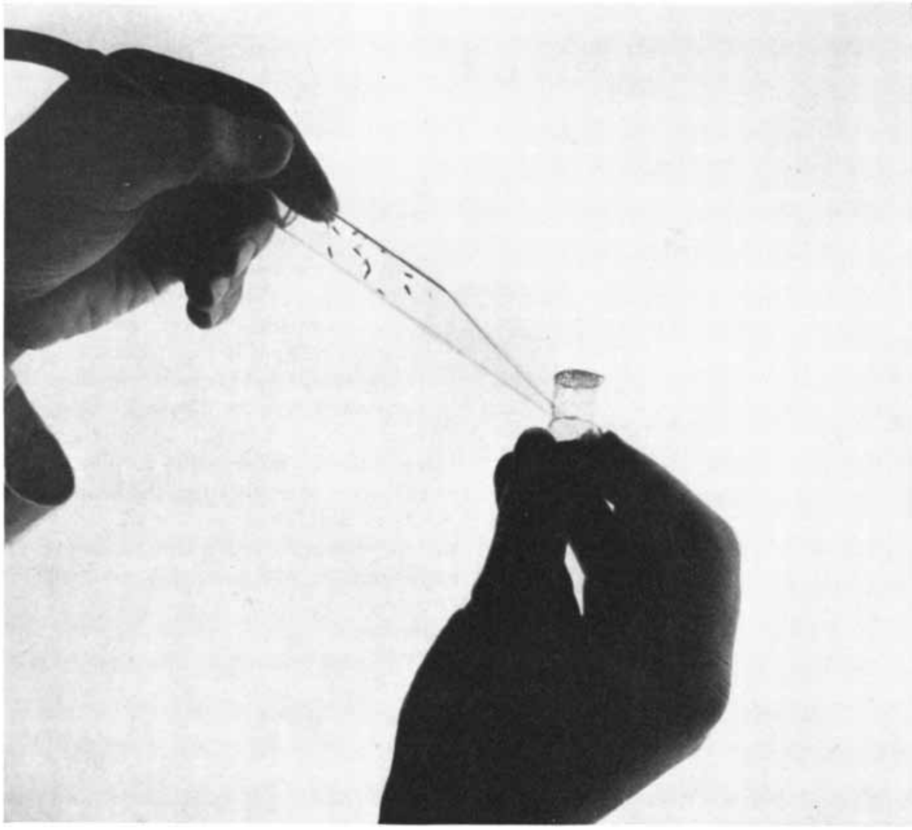
Perhaps the most beneficent viruses are those of live-virus vaccines which are used to confer immunity against such diseases as yellow fever, smallpox and poliomyelitis in man, and rinderpest and distemper in animals. Plants too can be immunized against certain diseases by means of harmless virus infections. Several years ago Louis O. Kunkel of the Rockefeller Institute found that a virulent strain of tobacco-mosaic virus, which invariably killed infected tobacco plants, can be blocked by inoculating the plants first with a very mild strain of the same virus. Infection by the mild strain produces only slight, almost imperceptible, mottling of the leaves. Once the mild infection has spread throughout the plant, the virulent strain is unable to multiply in the tissues of the plant and cannot kill or injure it. The main difference between the immunization of plants and of animals by mild virus infections is that in plants the infection persists, and the virus can be recovered throughout the life of the plant, whereas in most vaccine infections in man and other animals the virus seems to disappear after a short time. The lasting immunity established by live-virus vaccination apparently depends upon the persistence of high levels of antibodies against the virus; in plants the existence of antibodies is still in controversy and the mechanism of immunization is not well understood.

Viruses confer benefits upon lower as well as higher forms of life. As is well known, the bacterial virus, or bacteriophage, may subject bacteria to fatal infection. But viruses can also greatly benefit bacteria by serving as the agent for the important genetic process known as transduction [see "'Transduction' in Bacteria," by Norton D. Zinder; Scientific American, November, 1958]. In

POTTED CORN PLANTS, grown in a glass enclosure, are hosts to corn leaf-hoppers used in the author's experiments. Two of the tiny insects are visible on the bottom of the leaf at left center. The insects are removed from the corn leaves by sucking them into a

this case the virus infects the bacterium without causing discernible harm and is reproduced in successive divisions of the cell as though it were a unit of the cell's own genetic apparatus. Occasionally such a virus will become active; it takes over the cell's metabolic machinery and reproduces itself in large numbers from the substance of its host. The escaping daughter viruses often carry with them some genetic material from the host cell. When one of these viruses infects another bacterium, the bacterial genes it carries may change the hereditary characteristics of the new host. The new genes may, for instance, permit the cell and its offspring to manufacture an essential nutriment or to become resistant to an antibiotic. If the bacteria involved are disease germs, such a change may not seem at all beneficent to man.

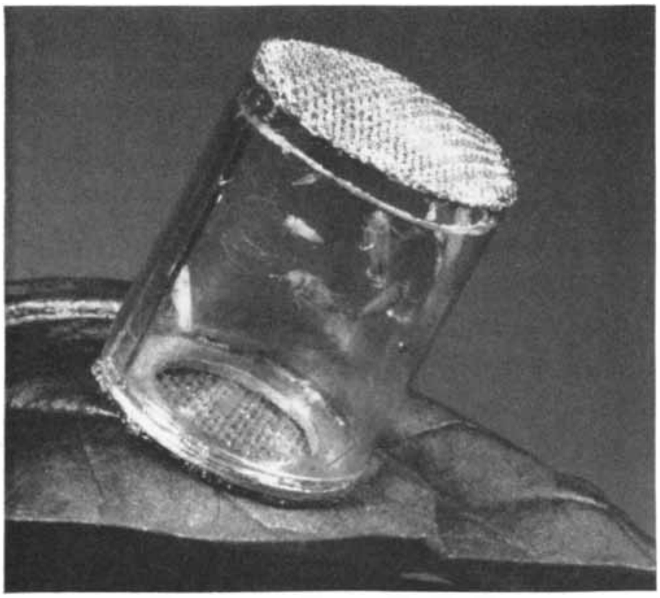
CAGED INSECTS are confined to a normal aster plant (*first picture*) and to a diseased aster (*second picture*). A small magnet placed beneath the leaf holds each cage in position. The insects will not feed on the healthy plant, and tend to remain on the sides of



glass pipette (*middle*). A gauze pad inside the pipette prevents the insects from being sucked up too far. When enough insects have been collected, they are blown into small mesh-covered plastic cages (*right*). Such a cage can then be fastened to the leaf of a plant.

Whether a virus is to be classified as friendly or not depends upon the point of view.

The friendly virus that turned up in my research exhibits this kind of ambiguity. It sickens a plant but helps an animal. I had been studying the virus that causes the withering disease of asters known as aster yellows [see "A Versatile Virus," by Karl Maramorosch; SCIENTIFIC AMERICAN, June, 1953]. Although the disease is spread only by aster leaf-hoppers (insects in which the virus can multiply), other insects also may acquire the virus while feeding on diseased asters. Certain species actually retain aster-yellows virus in their bodies for a considerable time, yet they fail to transmit the virus to plants. In trying to determine what happens to the virus acquired by such non-transmitters I tested,



the cage (*third picture*). These leaf hoppers will die in three days unless they are returned to corn plants. Those on the plant infected with aster-yellows virus do feed on the leaf; several can be seen on the mesh at the bottom of the cage in fourth picture.

among other insects, the corn leaf-hopper, a native of the southernmost part of the U. S. and of Central and South America. Corn leaf-hoppers have stringent dietary requirements and die within a short time when deprived of their proper diet. Only two plants are known to be suitable for their survival: corn (maize) and teosinte, a wild ancestor of maize. When confined to aster plants, corn leaf-hoppers die within three days. Thus in exposing corn leaf-hoppers to aster-yellows virus, the insects were placed in cages on diseased aster plants for only a few hours. The leaf hoppers were then returned to corn plants to assure their survival.

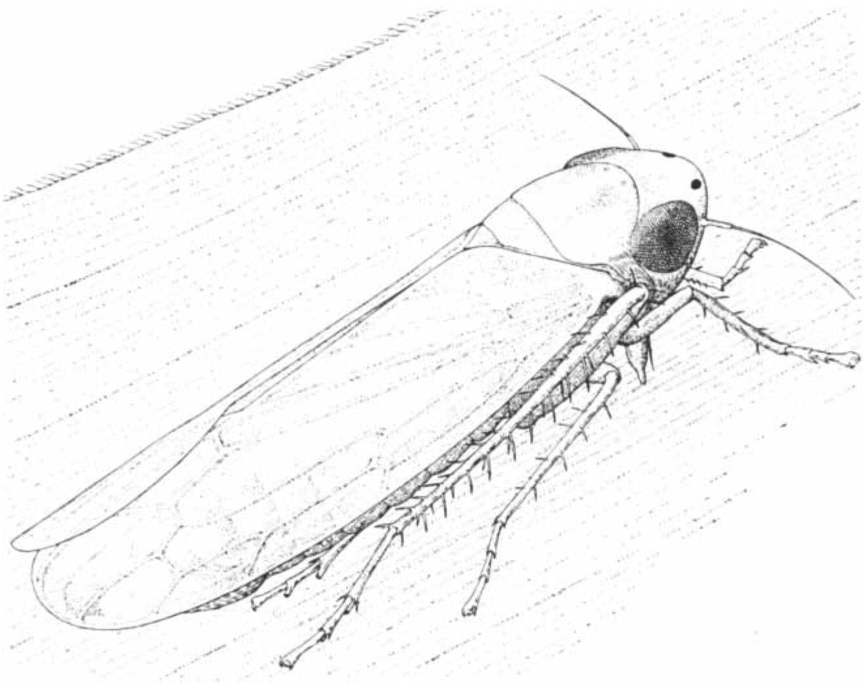
One afternoon a cage fastened on a diseased aster plant in a corner of the greenhouse was overlooked when the insects were transferred to corn plants. Upon discovery of this cage several days later, I was surprised to find all the corn leaf-hoppers still alive. This unexpected finding led to a whole series of tests which showed that corn leaf-hoppers can indeed survive on asters infected with aster yellows, although they perish on healthy plants. They not only survive in the imago, or "adult," form, but even proceed through the more tender phases of their metamorphoses on the aster plants. Even more unexpectedly, we found that insects that have been fed on diseased asters acquire the capacity to feed equally well on healthy aster plants. Furthermore, infected corn leaf-hoppers will feed on healthy carrot plants, which are susceptible to the aster-yellows disease, and even on rye plants, which are immune to the disease. Infected females do not, however, deposit their eggs on the strange host plants nor do the offspring of infected insects inherit the acquired dietary habits.

How do corn leaf-hoppers "learn" to survive on new, strange plants? Our first thought was that the insects perhaps became attracted to diseased asters, learned to accept them as food, and then, like an animal conditioned in the classical Pavlovian style, accepted the healthy plants as well. However, the discovery that the insects will also feed on carrot and rye plants, which are quite different from asters, ruled out conditioning as an explanation.

Since corn leaf-hoppers acquire the aster-yellows virus while feeding on diseased plants, it seemed reasonable to test the hypothesis that the virus is somehow responsible for the change in feeding habits. Kunkel had found earlier that the virus may be inactivated in the body of its insect vectors if the insects are kept at a constant temperature of 87 degrees Fahrenheit for eight days. This treatment destroys the virus without harming the insects in the least. With the virus thus inactivated in their bodies, all corn leaf-hoppers that had previously been able to survive on strange hosts starved to death when confined on healthy asters! That the virus (and not some other heat-sensitive factor) is the culprit was further indicated by experiments involving other strains of aster-yellows virus. When we infected asters with a California virus-strain that typically infects celery plants, the corn leaf-hoppers could not adapt to feeding on the plants. Only the typical Eastern strain of virus would change the insect's dietary habits.

How the virus strain exerts this effect on the insect is still unknown. It is conceivable that the virus induces production of an enzyme that helps the insect to digest the strange new food. But improved digestion does not necessarily mean improved acceptance; that is rather a question of palatability. On this score it may be that the virus changes the sensory reactions of the insect by affecting either the peripheral nervous system or the brain. John S. Kennedy of the Entomological Field Station in Cambridge, England, has speculated that the virus might act by strengthening the stimulus to eat—which is presumably supplied by some factor common to all plants—or, alternatively, by weakening the inhibitory effects associated with strange plants. Almost nothing is known about these sensory mechanisms in insects. Perhaps the first step would be to determine what parts of the plant stimulate or inhibit feeding. Leaf hoppers feed on the sap that flows in the phloem tissues of the plant, and these may furnish the stimuli. On the other hand, it may be the external tissues of the plant that attract the insect.

The accidental discovery that the aster-yellows virus confers a significant advantage upon the corn leaf-hopper suggests that numerous similar relationships may exist in nature. Viruses that alter the diet of insects can mean the difference between survival and extinction for an insect species during periods when its normal plant hosts become unavailable. The discovery and the possibilities it raises have practical significance as well. Such virus infections could lead to invasion of new host plants, possibly of important crops, by species of insects not previously known to feed on them. Should the virus find conditions suitable for its multiplication both in the insects and in the new plant hosts, the relationship could generate and propagate new plant diseases. Unfortunately, friendly viruses of this kind are no boon to man.



CORN LEAF-HOPPER is a tiny insect, about an eighth of an inch long, found in Central and South America and in the southern part of the U. S. It sucks juices from corn by means of a long proboscis, part of which is visible just in front of the insect's right middle leg.

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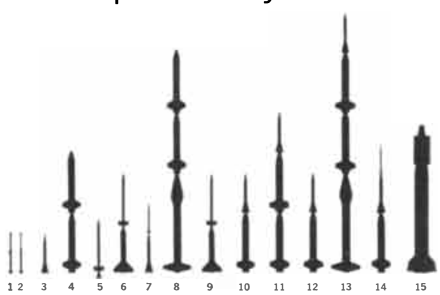

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MATHEMATICAL GAMES

An imaginary dialogue on "mathemagic": tricks based on mathematical principles

by Martin Gardner

An increasing number of mathematically inclined amateur conjurers have lately been turning their attention toward "mathemagic": tricks that rely heavily on mathematical principles. Professional magicians shy away from such tricks because they are too cerebral and boring for most audiences, but as parlor stunts presented more in the spirit of puzzles than of feats of magic, they can be interesting and entertaining. My friend Victor Eigen, an electronics engineer and past president of the Brotherhood of American Wand Wielders, manages to keep posted on the latest developments in this curious field, and it was in the hope of finding some off-beat material for this department that I recently paid him a visit.

The front door was opened by Victor—a plump, gray-haired man in his mid-fifties with humorous creases around his eyes. "Do you mind sitting in the kitchen?," he asked as he led me toward the back of his apartment. "My wife's absorbed in a television program and I think we'd best not disturb her until it's over. How do you want your bourbon?"

We sat on opposite sides of the kitchen table and clinked glasses. "To mathemagic," I said. "What's new?"

Victor lost no time in taking a deck of cards from his shirt pocket. "The latest thing out in cards is the Gilbreath principle. It's a whimsical theorem discovered by Norman Gilbreath, a young California magician." As he talked, his short fingers skillfully arranged the deck so that red and black cards alternated throughout. "You know, I'm sure, that riffle shuffling is notoriously inefficient as a method of randomizing."

"No, I didn't realize that."

Victor's eyebrows went up. "Well, this ought to convince you. Please give the deck one thorough riffle shuffle."

I cut the deck into two parts and shuffled them together.

"Take a look at the faces," he said. "You'll see that the alternating color arrangement has been pretty well destroyed."

"Of course."

"Now give the deck a cut," he went on, "but cut between two cards of the same color. Square up the pack and hand it to me face down."

I did as he suggested. He held the deck under the table where it was out of sight for both of us. "I'm going to try to distinguish the colors by sense of touch," he said, "and bring out the cards in red-black pairs." Sure enough, the first pair he tossed on the table consisted of one red and one black card. The second pair likewise. He produced a dozen such pairs.

"But how . . . ?"

Victor interrupted with a laugh. He slapped the rest of the deck on the table and started taking cards from the top, two at a time, tossing them face up. Each pair contained a red and a black card. "Couldn't be simpler," he explained. "The shuffle and cut—remember, the cut must be between two cards of the same color—destroys the alternation of red and black all right, but it leaves the cards strongly ordered. Each pair still contains both colors."

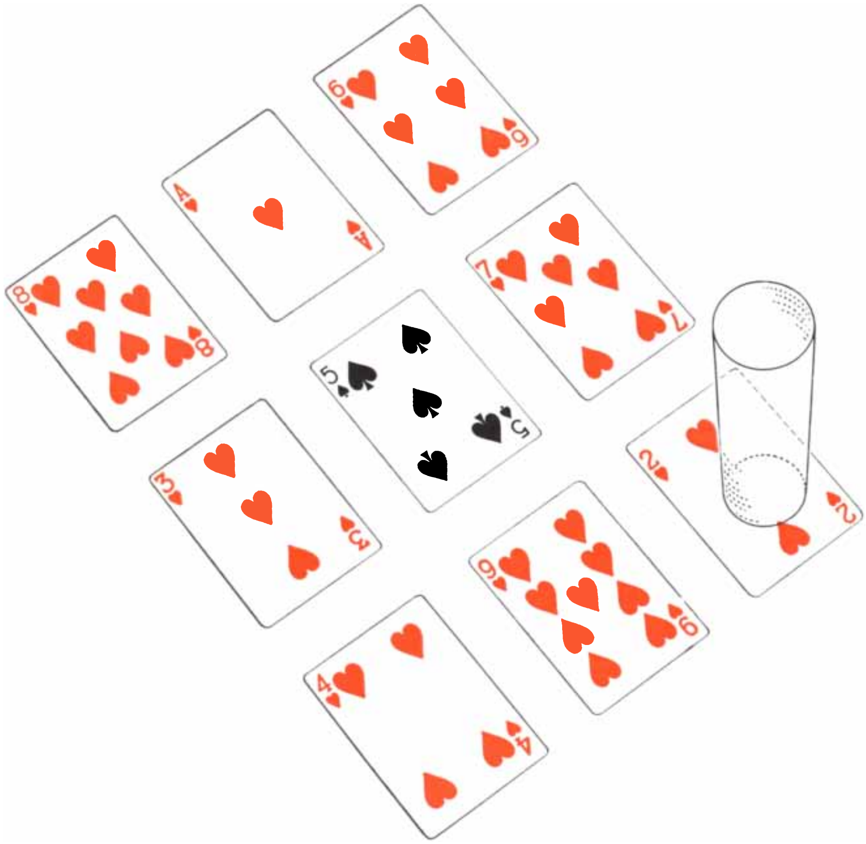
"I can't believe it!"

"Well, think about it a bit and you'll see why it works, but it's not so easy to state a proof in a few words. By the way, my friend Edgar N. Gilbert, of Bell Telephone Laboratories, included an interesting puzzle along similar lines in a recent unpublished paper of his on card shuffling and information theory. Here, I've jotted it down for you."

He handed me a sheet on which was printed:

T L V E H E D I N S A G M E L R L I
E N A T G O V R A R G I A N E S T Y
O F O F I F F O S H H R A V E M E V S O

"That's a garbled sentence," he said, "from a *Scientific American* article of five years ago. Gilbert wrote each letter on a card, then arranged the deck so it spelled the sentence from top down. He cut the cards into two piles, riffled them together, then copied down the new sequence of letters. It takes, he tells me,



Cards and a glass arranged for a demonstration of precognition the average person about half an hour to unscramble them. The point is that one riffle shuffle is such a poor destroyer of information conveyed by the original sequence of cards, and the redundancy of various letter combinations in English is so high, that it's extremely unlikely—in fact, Gilbert computes the exact probability in his paper—that the message one finds is different from the correct one."

I rattled the ice cubes in my glass.

"Before we refill," Victor said, "let me show you an ingenious experiment in precognition. We'll need your glass and nine playing cards." He arranged nine cards, with values from one to nine, on the table in the form of the familiar three-by-three magic square [*see illustration on preceding page*]. The cards were all hearts, except for the five of spades in the center. He took an envelope from his pocket and placed it beside the square.

"I want you to put your glass on any one of the nine cards," he said, "but first let me explain that in this envelope is a file card on which I have jotted down some instructions. The instructions are based on my guesses as to the card you're going to choose, and how you are going to move the glass at random from card to card. If my guesses are correct, your glass will end on the card in the center." He tapped his finger on the five of spades. "Now put your glass on any card, including the center one if you wish."

I placed my glass on the two of hearts.

"Just as I expected," he chuckled. He took the file card from the envelope and held it so I could read the following instructions:

1. Take away the seven.
2. Move seven times and take away the eight.
3. Move four times, take away the two.
4. Move six times, take away the four.
5. Move five times, take the nine.
6. Move twice, take the three.
7. Move once, take the six.
8. Move seven times, take the ace.

A "move," he explained, consists of transferring the glass to an adjacent card above, below or on either side, but not diagonally. I followed the instructions carefully, making all moves as random as I could. To my vast surprise the glass never rested on a card that I was asked to remove, and after eight cards had been taken away, there was my glass, resting on the five of spades just as Victor had predicted!

"You've befuddled me completely," I admitted. "Suppose I had originally placed my glass on the seven of hearts, the first card removed?"

"I must confess," he said, "that a bit of nonmathematical chicanery is involved. The magic-square arrangement has nothing to do with the trick. Only the positions of the cards matter. Those in the odd positions—the four corners and the center—form one set; those in the even positions form a set of opposite parity. When I saw that you first placed your glass on a card in the even set, I showed you the instructions you see here. If you had placed your glass on a card in the odd set, I would have turned over the envelope before I took out the file card."

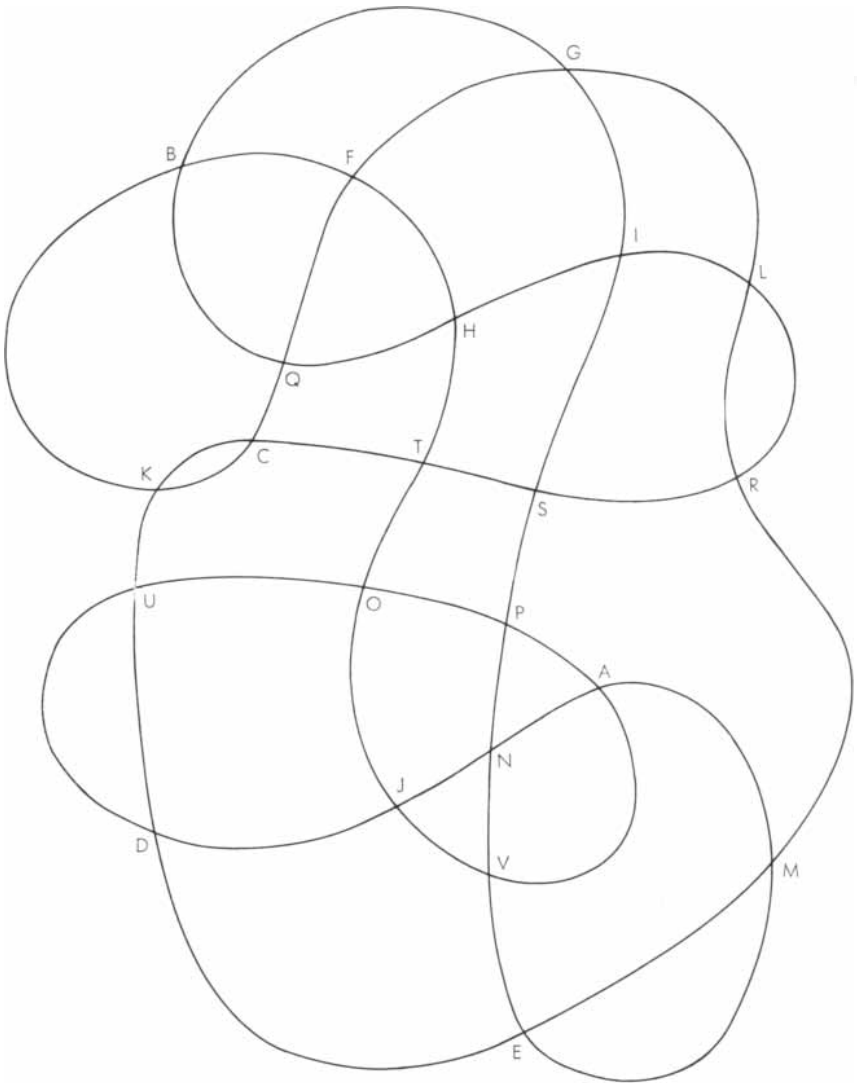
He flipped over the card. On its back was a second set of instructions. They read:

1. Take away the six.
2. Move four times and take away the two.
3. Move seven times, take away the ace.
4. Move three times, take away the four.
5. Move once, take the seven.
6. Move twice, take the nine.
7. Move five times, take the eight.
8. Move three times, take the three.

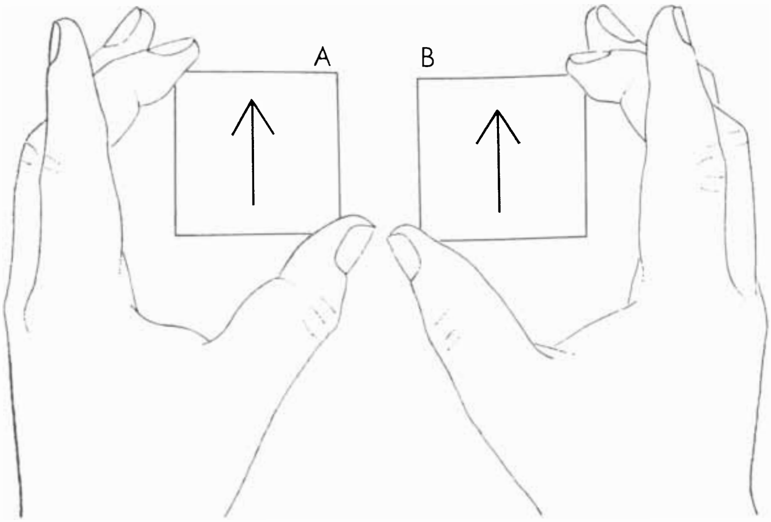
"You mean that these two sets of instructions—one to use if I start on an even-positioned card, and the other if I start on an odd—will always guide the glass to the center?"

Victor nodded. "Why don't you print both sides of the card in your department and let your readers figure out why the trick has to work?"

After refilling our glasses, Victor said: "Quite a number of ESP-type tricks exploit a parity principle. Here's one that seems to require clairvoyance." He handed me a blank sheet of paper and a pencil. "While my back is turned I want you to draw a complicated closed curve that crosses itself at least a dozen times, but never more than once at any one point." He turned his chair so that



Randomly drawn and labeled closed curve for an experiment in clairvoyance



How soda crackers are held for the trick of the transposed arrows

he faced the wall while I drew the curve [*see illustration on page 150*].

"Label each intersection with a different letter," he said over his shoulder.

I did as I was told.

"Now put your pencil on any spot along the curve and start tracing it. Each time you come to a crossing, call out the letter. Keep this up until you've traced the entire curve, but at some point along the way—it doesn't matter where—switch two letters as you call them. The two letters must be adjacent along the path. Don't tell me when you switch them."

I started at point N, moved up to P and continued along the curve, calling out the letters as I came to them. I could see that Victor was jotting them down on a pad. When I approached B for the second time, I saw that the letter after it was F, so I called out F and then B. I made the switch without a break in the timing of my calls, so that Victor would have no clue as to which pair had been switched.

As soon as I finished he said: "You switched B and F."

"Amazing!" I said. "How did you know?"

Victor chuckled and turned back to face me. "The trick's based on a topological theorem that's important in knot theory," he said. "You'll find it neatly proved in Hans Rademacher and Otto Toeplitz's book *The Enjoyment of Mathematics*." He tossed over the pad on which he had jotted down the letters. They were printed alternately above and below a horizontal line like this:

NSGQIRTKDMLFCFHOVPUJAE
PIBHLSCUERGQKBTJAODNMV

"If no switch is made," he explained, "then every letter must appear once above and once below the line. All I have to do is look for a letter that appears twice above, and a letter that appears twice below. Those will be the two letters that are exchanged."

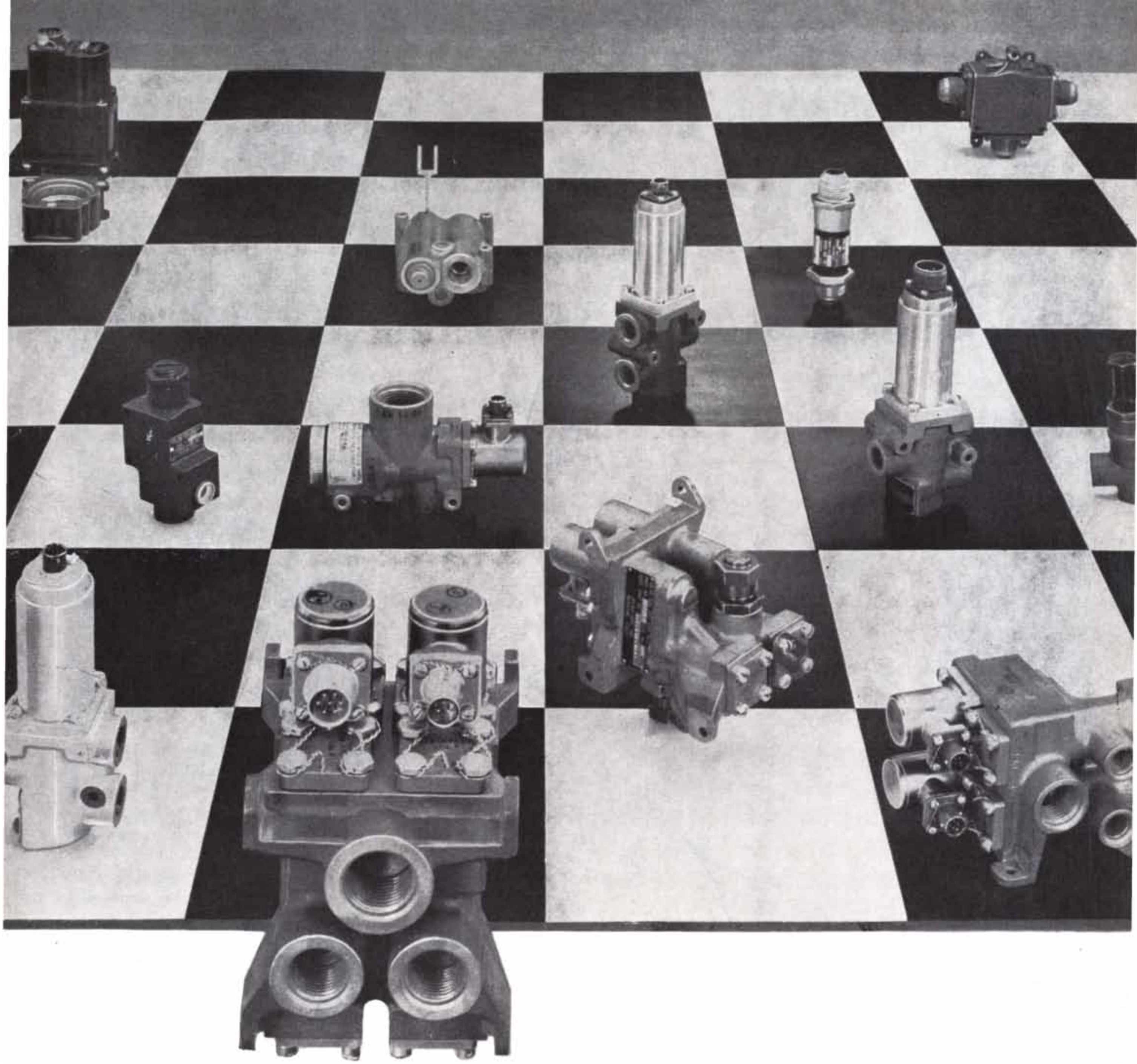
"Beautiful!" I said.

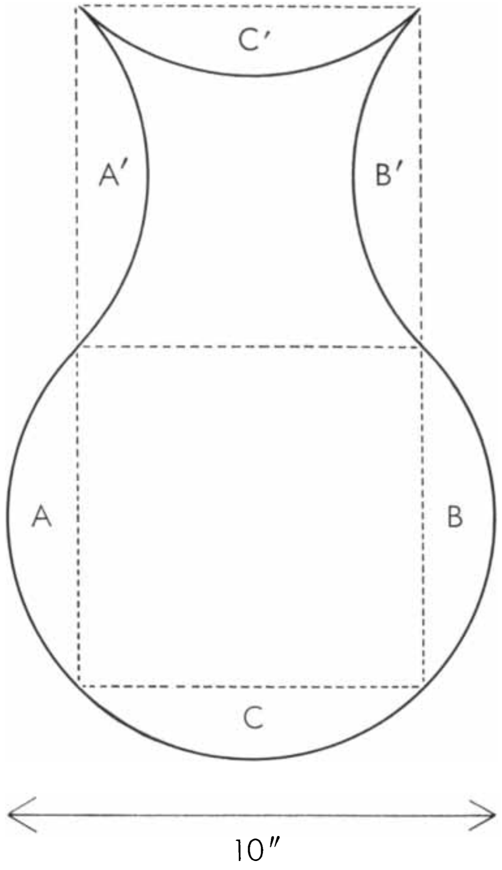
Victor opened a box of soda crackers, took out two and placed them on the table, one to his right and one to his left. On both crackers he drew an arrow pointing north [*see illustration above*]. He held the cracker on the left between his thumb and middle finger as shown, then with the tip of his right forefinger he pressed down on corner A to turn the cracker over. It rotated on the diagonal axis between the two corners that were held. He drew on the cracker another arrow that also pointed north.

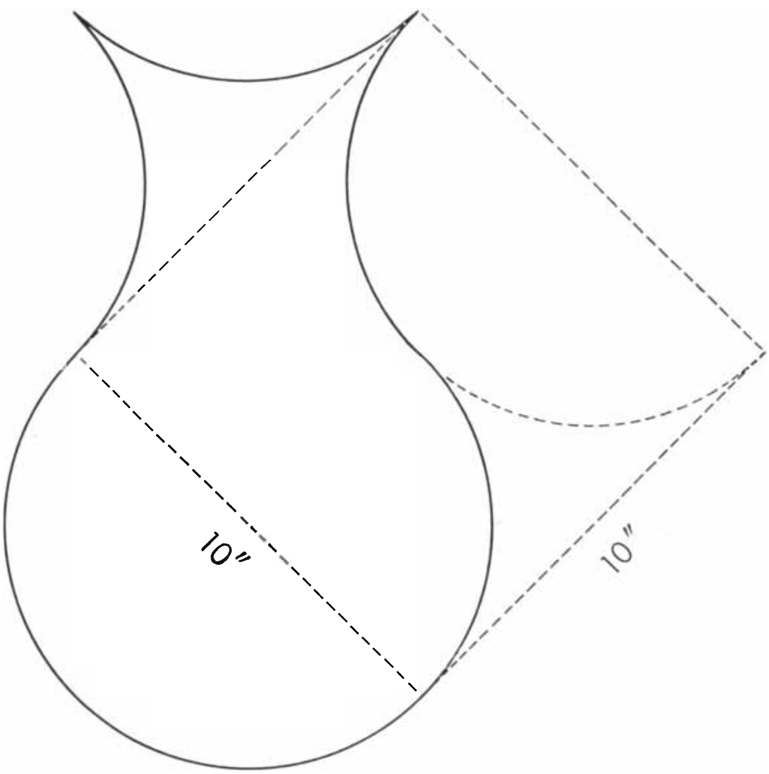
Next, he held the cracker on his right in similar fashion, with his right hand, and rotated it by pushing with his left forefinger on corner B. This time, however, instead of drawing an arrow that pointed north, he drew one that pointed south.

"Now we're all set," he said smiling, "for an amusing stunt involving the symmetry rotations of a square. You'll note that on the left I have a cracker with a north arrow on both sides." He picked up the cracker with his left hand and rotated it several times to show that on both sides the arrow pointed north. "And on my right we have north and south arrows." He picked up the cracker with his right hand and rotated it rapidly several times to show that the two arrows pointed in opposite directions.

Victor returned the cracker to the table. Then, slowly and without altering their orientation, he switched the positions of the two crackers. "Please rotate them yourself," he requested. "I want you to verify the fact that the cracker







Solution to last month's problem of squaring the vase

with the two north arrows is now on my right, and the other cracker on my left."

He handed me each cracker and I rotated it in exactly the same way he had done, one in my right hand and one in my left. Yes, the crackers had been exchanged.

Victor placed the crackers in front of him, then snapped his fingers and commanded the crackers to return invisibly to their former positions. He rotated the cracker on his left. I was startled to see that the arrows now pointed north on both sides! And when he rotated the other cracker, its arrows jumped back and forth from north to south!

"Try it," Victor said. "You'll find that it works automatically. Actually, both crackers are exactly alike. The difference in appearance depends entirely on which hand is holding them. When you ask your spectator to check on the crackers, be sure he takes the cracker on your right in his left hand, and the cracker on your left in his right hand. And see that he puts down the north-south cracker so the arrow on the top side points north."

I drained my glass. There was just enough left in the bottle for one more highball. The kitchen wobbled slightly.

"Now let *me* show *you* one," I said, taking another cracker from the box. "It's a test of probability. I'll toss this cracker into the air. If it falls rough side up, you get the rest of the bourbon. If it falls smooth side up, you get the rest of the bourbon. If it falls with neither side up" (I held the cracker perpendicular to the table but made no comment about it), "then *I* get the last drink."

Victor looked wary. "Okay," he said.

I squeezed the cracker in my fist and tossed the crumbs into the air.

Dead silence. Even the refrigerator stopped humming. "I observe that most of both sides came down on your head," Victor said at last, unsmiling. "And I must say it's a pretty crumby trick to play on an old friend."

In this department last month it was suggested that the reader give the side of a square equal in area to the vase-shaped figure at the top of this page, bounded by arcs of a circle with a diameter of 10 inches. The answer is also 10 inches. If we draw the broken squares shown in the illustration, it is obvious that segments A, B, C will fit into spaces A′, B′, C′ to form two squares with a combined area of 100 square inches. The illustration at the bottom shows how the vase can be "squared" by cutting it into as few as three parts that will form a 10-inch square.

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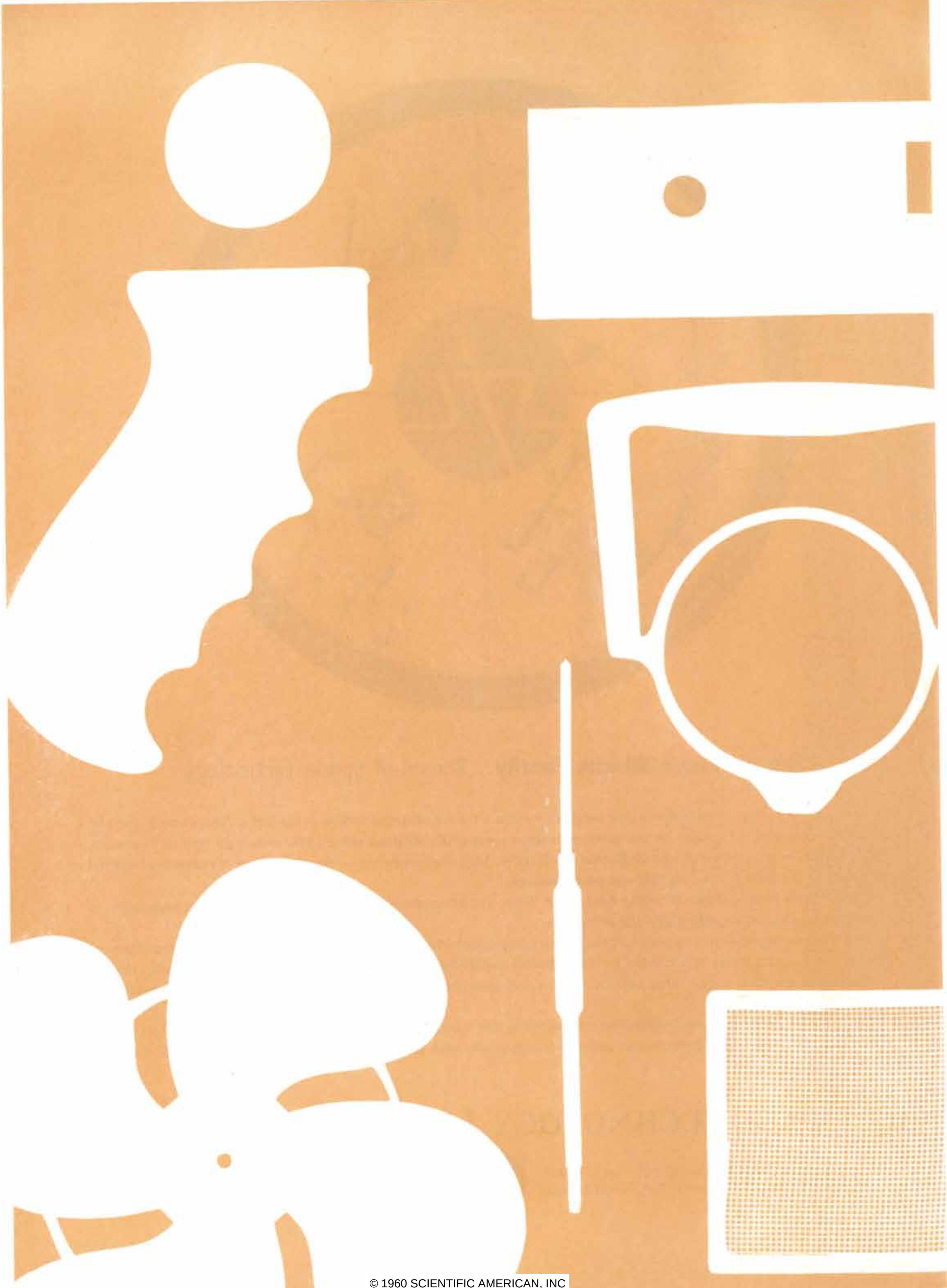
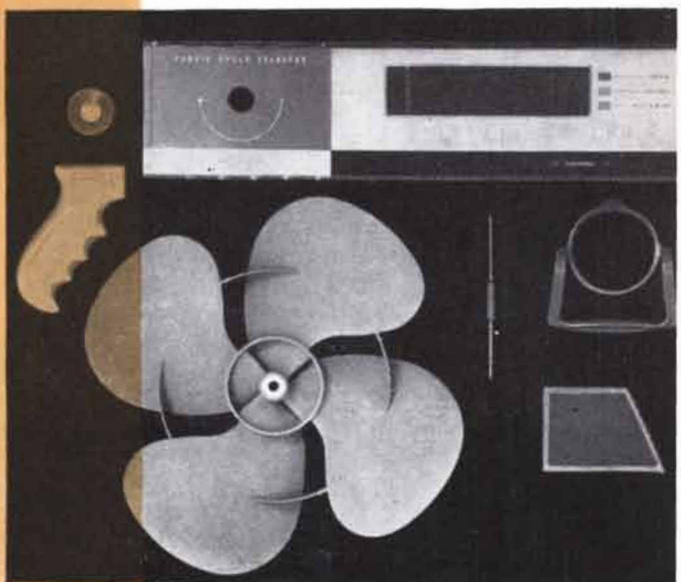




THE AMATEUR SCIENTIST

A second article about how two amateurs refined the accuracy of a pendulum clock

Conducted by C. L. Stong

Although electronic oscillators have largely replaced pendulum clocks for the most accurate timekeeping, the mysteries of the pendulum continue to intrigue experimenters. Errors from at least a dozen sources prevent a pendulum from swinging at a constant rate. The sources include changes in temperature and in barometric pressure, mechanical irregularities in the suspension and in the system of drive, electrostatic forces, seismic motion and variations in gravity of a tidal nature. Ten years ago Vannevar Bush, formerly president of the Carnegie Institution of Washington, and John Early Jackson, director of the Office of Atomic, Biological and Chemical Warfare in the Department of Defense, undertook a collaboration as amateur horologists to determine just how accurately a pendulum clock could be made to keep time. In the course of their experiments they worked out a number of improvements in the mechanism for driving a pendulum and in conventional methods of compensating for changes in temperature and barometric pressure. They also solved the 300-year-old problem of "circular error": the change in rate that accompanies variations in the length of the pendulum's swing [see "The Amateur Scientist," July]. Still another kind of error, long known but largely neglected by clockmakers, arises from the motion communicated by the clock to the wall or to any other support on which it is mounted.

"There is no such thing as an immovable support," writes Jackson. "A pendulum with a 14-pound weight, or bob, swinging through an arc of 1.5 degrees at the rate of one beat per second produces a horizontal force on its support that varies from zero in the center of the swing to nearly a fifth of a pound at each end of the swing. If the circular error has been corrected, or if the pendulum swings through a very small arc, the force varies sinusoidally. There is a similar sinusoidal force in the vertical direction which varies with twice the pendulum frequency, but which is very much smaller in magnitude (about a hundredth as large). Vannevar Bush and I have devoted much effort over a period of several years to gaining a detailed understanding of the effects of such small forces on the rate of a pendulum and devising means of overcoming them. We call the effect 'support reaction.'

"Support reaction does not seem to have received much recognition in the past, other than the realization that a solid and massive support is desirable. We have found that the reaction is subject to experimental, quantitative investigation, and we have devised means for overcoming the effects, which turn out to be unexpectedly large.

"The experiments were made on a Shortt clock borrowed from the National Bureau of Standards. (The clock had been superseded by quartz-crystal oscillators.) The instrument was mounted on a cinder-block wall in the basement of my home, where it was fitted with an attachment that corrects circular error, and its original gravity-electric drive was replaced with a new kind of air drive. At that time it was felt that escapement errors were the chief cause of irregular behavior. Actually the air drive turned out to be difficult to adjust and generally not worth the trouble, but after modification the pendulum held to the time signals on the Bureau of Standards Station WWV within one millisecond for one period of 36 hours. Then, during the next eight-hour period, we observed a departure of several hundredths of a second from the signals of Station WWV.

"Everything about the clock seemed to be functioning perfectly during these last eight hours. We noted, however, that it had rained during the night. Subsequent observations showed that changes in humidity affected the rate of the clock, in spite of the fact that it was sealed in an airtight case! It became obvious that the mechanical properties of the cinder-block wall and/or the house foundation must be changing enough to influence the rate by several hundredths of a second a day.

"It can be shown mathematically that the horizontal force on the support of a theoretical pendulum swinging through a small angle (or, if the pendulum is corrected for circular error, through a large angle) varies sinusoidally. The force has a maximum value equal to the centrifugal force that would be produced if the mass of the pendulum were rotated uniformly about a vertical axis on a radius equal to half the amplitude of swing, at a rate of one revolution for each complete swing of the pendulum, that is, one revolution in two seconds for a 'seconds' pendulum. It can also be shown that the sinusoidally varying vertical force has a maximum value equal to the centrifugal force that would be produced by rotating the mass of the pendulum about a horizontal axis on a radius equal to half its vertical rise during each half swing, at a rate of one revolution per half swing, that is, one revolution per second for a seconds pendulum.

"This information enables us to construct a system of revolving weights that at every instant precisely balances and counteracts the dynamic forces exerted by a swinging pendulum on its support. The centrifugal force produced by a given mass revolving at a given radius is proportional to the product of the mass times the radius. So instead of using a rotating weight with a mass equal to that of the pendulum, we can use a weight with a 10th or 100th of this mass, mounted on a lever arm 10 or 100 times longer. The vertical motion of the bob of a seconds pendulum swinging through a total arc of 1.5 degrees is less than .004 inch, but if the bob weighs 10 pounds, we can use a weight of .01 pound rotating on a radius of slightly less than two inches to counteract the vertical force. This is obviously more convenient than trying to rotate a weight of 10 pounds on a radius of .002 inch.

"To prevent motion in a plane at right angles to the plane of swing of the pendulum, two half-size weights on parallel shafts can be rotated in opposite directions to give a sinusoidal thrust in only one plane at right angles to the plane of the two shafts [*see illustration on next page*]. The weights compensating for vertical motion can be conveniently mounted directly above or below the point of suspension of the pendulum so as to produce their thrust through this point, but the weights that generate horizontal thrust must be mounted so their centers of gravity are at the same level as that of the bob. As they move from side to side they will then not only cancel the horizontal forces but also obviate the torques exerted on the clock support by gravity.

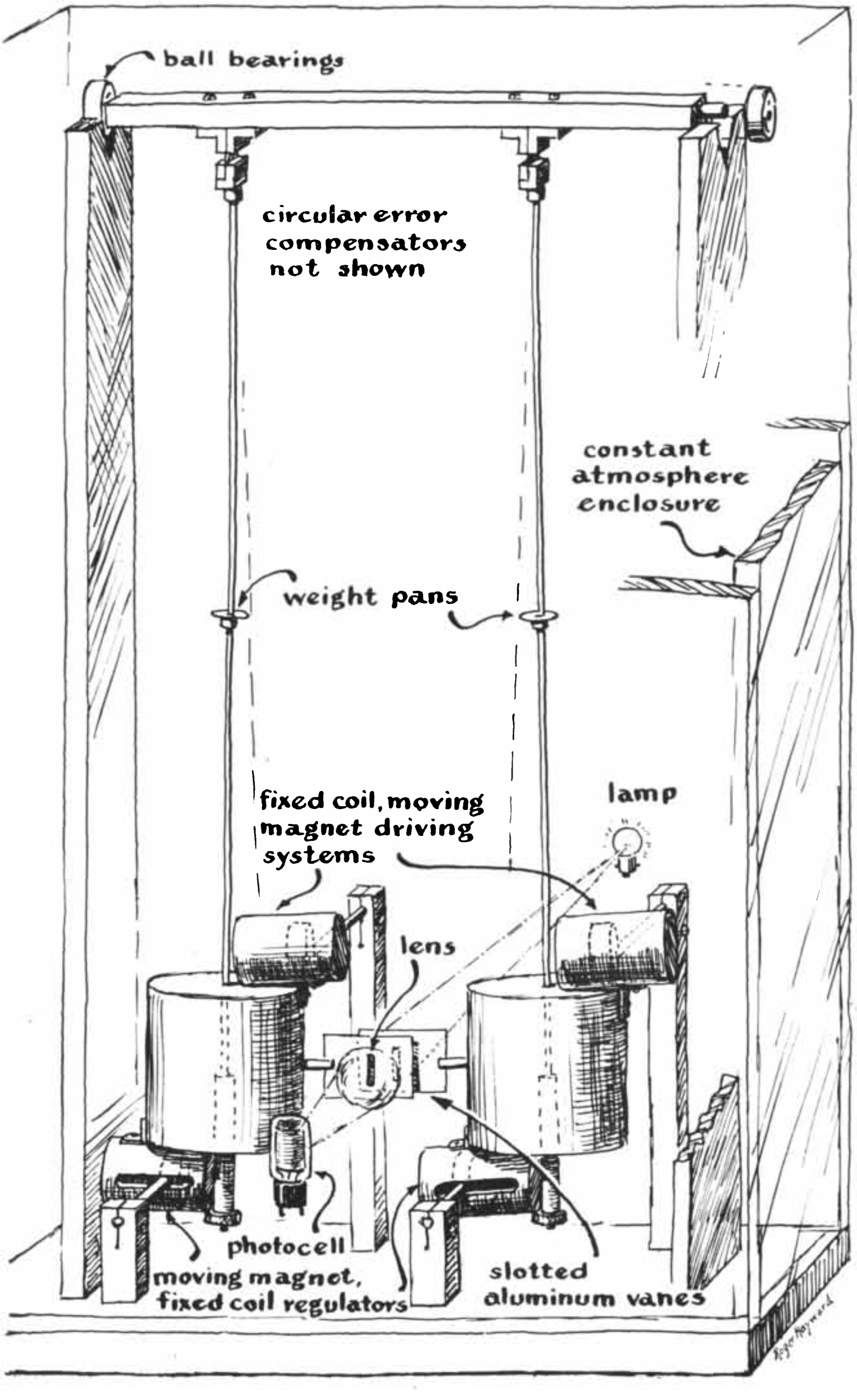
"The problem of synchronizing these revolving weights so that they always rotate at exactly the right rate, and exactly 180 degrees out of phase with the pendulum, was a formidable one. It was finally solved with fair accuracy by driving the weights with a synchronous motor operating on ordinary 60-cycle alternating current, the frequency of which seldom varies more than five seconds from the correct time. The motor was coupled with the weight system through a differential gear. The 'cage' of the differential, in turn, was connected to a reversible direct-current motor that received impulses each second from a photoelectric-cell pickup on the pendulum. This signal was fed through a series of relays and cam-operated switches on the revolving shafts, arranged so that the direct-current motor added or subtracted a fraction of a revolution as needed to keep the weights 180 degrees out of phase with the pendulum.

"A stroboscopic-flash unit actuated by the weights as they passed their dead-center position illuminated a beat plate on the pendulum for initial adjustment of phase angle. Observation showed that this system remained synchronized and maintained phase angle to within less than a degree. The system is still not quite good enough, however, for a truly accurate clock.

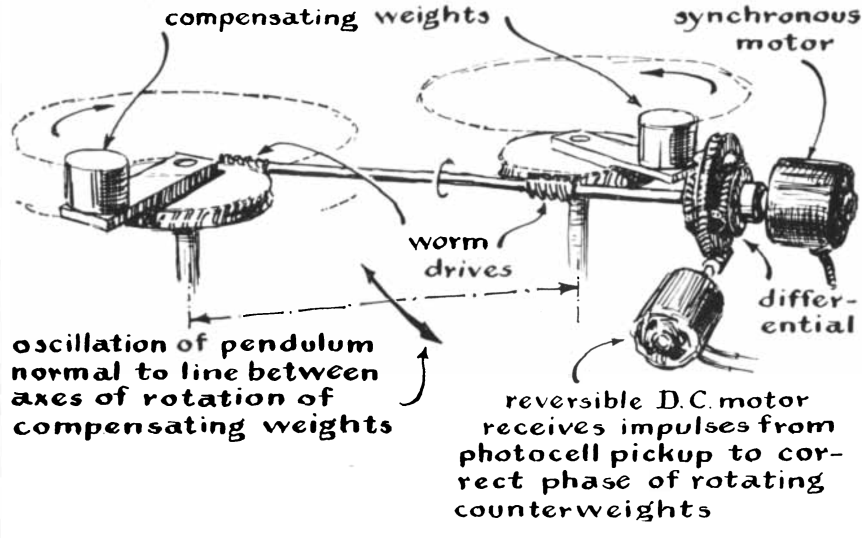
"Such a system is capable of canceling all support reaction and movement only when the arc of the pendulum can be held to the value for which the mass of the weights and their lever arm was designed. Considerable difficulty has been experienced in maintaining the arc at constant amplitude. Added to this effect is the error caused by the slight variation in phase angle between the weights and the pendulum. With this arrangement, however, our clock has held the same rate as Station WWV to within a few milliseconds per day, with an accumulated error at the end of a week of only about three milliseconds.

"In order to exaggerate the effect of support reaction, the whole clock case, together with its rigidly attached system of revolving weights, was mounted about seven inches out from the wall on four half-inch steel bolts. This provided a cantilever mounting that is sufficiently stiff to support the 100-pound clock, but is more resilient than the usual mounting, in which the clock is bolted directly to the wall.

"The horizontal resilience of this mounting, measured by the movement of the pendulum support when a known horizontal force was applied, was about 285 millionths of an inch per pound. The



A twin-pendulum system for a precision clock



Motor-driven weights for compensating support reaction in a single-pendulum clock

force of the swinging pendulum, weighing .118 pound, thus deflected it less than 60 millionths of an inch.

"Three stiff metal struts—two horizontal and one vertical—were also provided to reduce the resilience at will. (They could be anchored to the wall at their outer ends with lag screws.) The rate was adjusted with the struts removed and the compensating weights running. When the weights were stopped, the rate of the pendulum was 6.42 seconds per day slower. With the struts bolted to the wall (which made the mounting almost as stiff as a case mounted rigidly on the wall), there was still a loss of two seconds per day when the weights were not running, caused by movement of the wall and doubtless of the whole house. But with the weights operating, no difference could be detected when the struts were removed, showing that the weights were completely canceling the support movement.

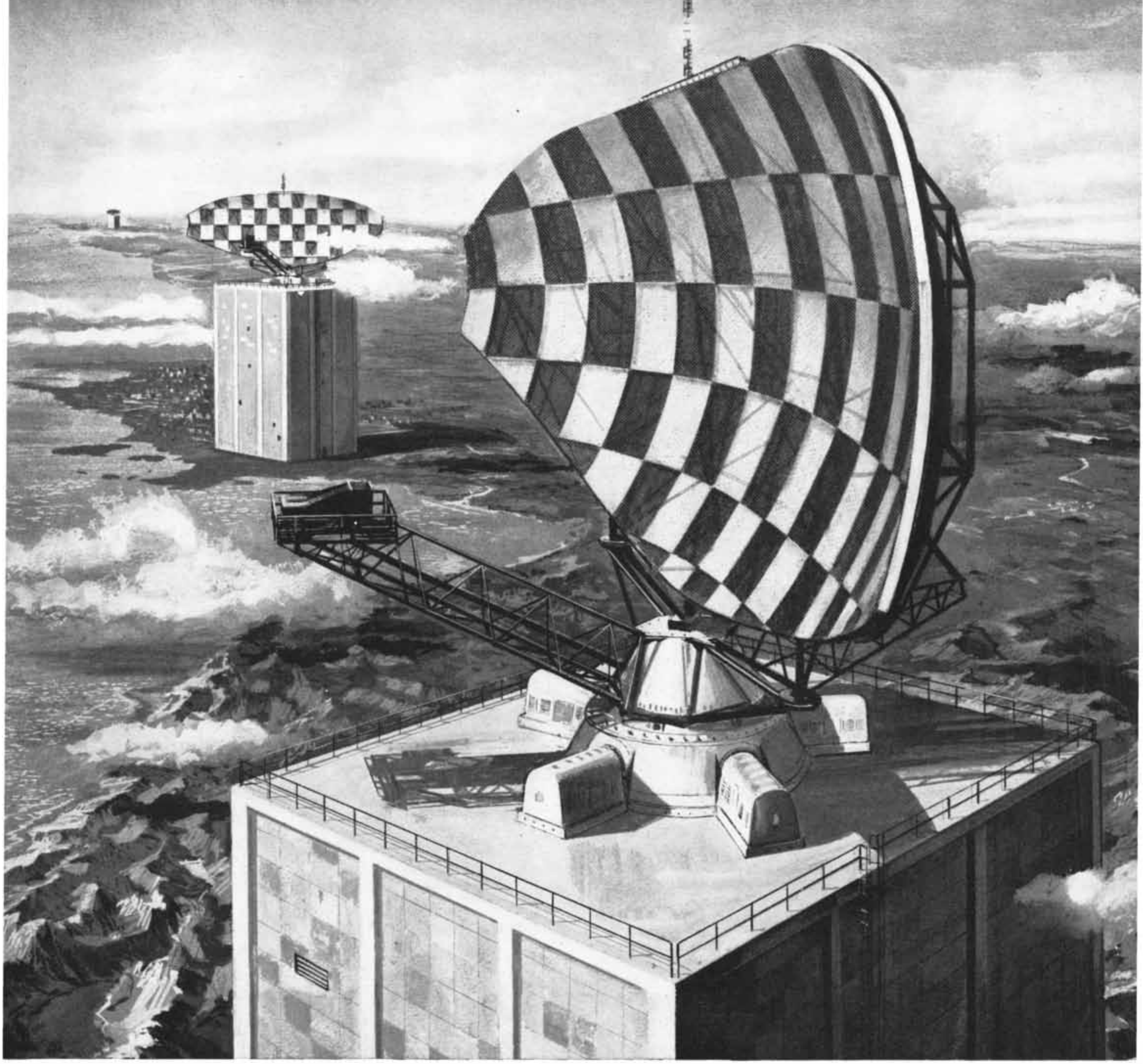
"A most astonishing result emerged from these tests. No effect on the pendulum's rate could be traced to vertical support reaction! It makes no difference whether the vertical compensator is operated or not, or even if it is run in phase, instead of 180 degrees out of phase, so as to add its effect to that of the pendulum rather than providing a cancellation. This is true whether the struts are bolted to the wall or not.

"It now becomes evident that the simplest way to remove the effect of support reaction on rate is to use a double pendulum with two identical bobs swinging in opposite directions 180 degrees out of phase. The vertical forces developed by the pair on the support add up, but cause no change in rate; the horizontal forces cancel precisely at every instant. Hence, although it is not possible to find a perfectly rigid support for a pendulum, it is possible to reduce the harmful forces of support reaction to zero and thus to remove this source of error."

(In the case of a perfectly springy support Jackson has demonstrated by a simple algebraic analysis that the frequency of a pendulum is decreased by half the ratio of the horizontal movement of the bob. In the case of a nonresilient support with the same motion the demonstration shows that the loss is doubled. He has similarly shown that vertical-support reaction has no effect on rate, as shown in the illustration on page 162. The reader can obtain a copy of Jackson's algebraic analysis by forwarding a stamped, self-addressed envelope to this department.)

"Bush has shown mathematically by an electrical analogy that increasing the mass of the clock case and its attachments tends to increase the loss in rate produced by support resilience, but that this effect is relatively small and can be neglected for all practical purposes.

"Most, if not all, actual clock supports introduce losses. Even if a perfectly elastic metal beam were used for the mounting, its support would ultimately be stone or earth, which would introduce some losses. In general, therefore, the loss in rate caused by support motion cannot be calculated by any formula, even if the resilience of the support is determined by deflecting it with a known force and measuring the deflection with a strain gauge. Furthermore, the losses and probably the resilience of the ultimate support are subject to unpredictable change with time and will



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cause the rate of the pendulum to vary accordingly.

"Admittedly a cinder-block basement wall is not an ideal clock-mounting. The clock vault of the U. S. Naval Observatory in Washington has three specially constructed masonry piers, each carried down to a separate foundation and mechanically insulated from the rest of the building. Yet it has been found that if Shortt clocks are mounted on the two piers on opposite sides of the vault, they interfere so seriously that it is impossible to use them for precise timekeeping. If the clocks are on piers at right angles to each other, there is essentially no interference. Each pier still moves, however, and the clocks run slower than if they were mounted on an 'immovable' support. It seems reasonable to assume that hitherto unexplained changes in the rates of observatory clocks are, at least in part, caused by changes in the resilience or other physical characteristics of their mountings.

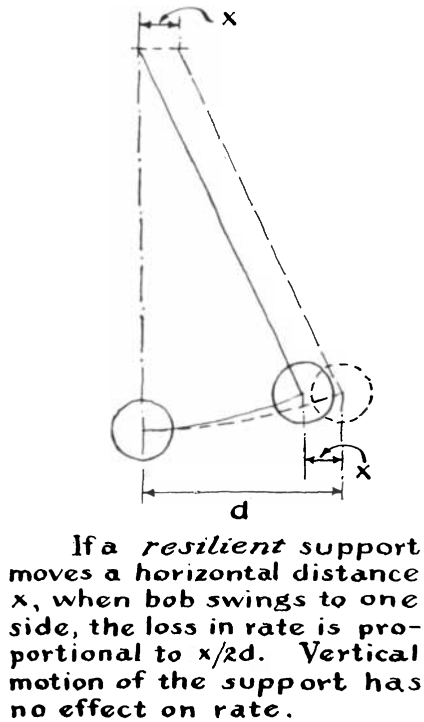
"The following rough design for a clock is submitted to the readers of *Scientific American*, without having been tested, in the hope that it may stimulate interest in amateur horology. A clock based on the design is now being built. The design includes the features and principles that have been studied over a period of several years, and that are believed essential to a really precise pendulum clock. We recognize that other designs may be even better.

"As has been indicated, a double pendulum will remove all support-reaction errors if the two pendulums are identical, and if they can be made to swing 180 degrees out of phase. The mechanical arrangement is important, because the horizontal forces must cancel without introducing twisting or other spurious forces that might move the support in any direction. However, a distinction can be made between that part of the support inside the clock enclosure, which is held at constant temperature, and the external support such as a wall or floor that is subject to nonuniform conditions. A constant loss in rate caused by movement of the internal frame can be corrected by shortening the pendulum, but variable effects cannot be corrected.

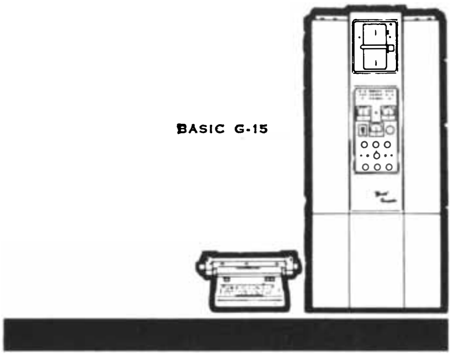
"The following design involves mounting at each end of a horizontal support-bar two pendulums that swing in the plane of the bar, as shown in the accompanying illustration [*page 164*]. This requires two circular-error correctors, constructed as described in 'The Amateur Scientist' last month, with their springs mounted on temperature-compensated members carried by the same bar. The bar can be supported at the center, where there is no motion. The bar will be bent and alternately stretched and compressed slightly, of course, but even if it is supported at its ends, there will be no net motion of the base on which the clock rests; there will be only a slight bending of the metal inside the clock case. This will be uniform if temperature and other environmental conditions are held constant.

"An airtight clock case 45 or 50 inches tall is not convenient, and since beats of one-second duration are not necessary if the beats coincide with seconds at reasonably short intervals, a 2/3-second period was chosen. This frequency requires a pendulum only about 17.5 inches long and provides coincidence on every other second with radio time-signals. A half-second pendulum would coincide every second, but only when it was swinging in the same direction, making it difficult to tell when the clock was 'out of beat,' or 'ticking' evenly, as it would do if it was not perfectly level.

"The metal frame of the proposed arrangement can be made of aluminum alloy. It is proposed that the case be made of clear plastic about half an inch thick. All edges of the case would be cemented except for the bottom, which would be grooved to hold a ring-shaped rubber



Geometry of the support reaction



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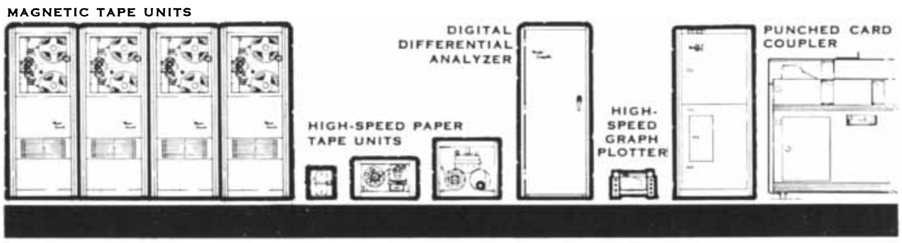

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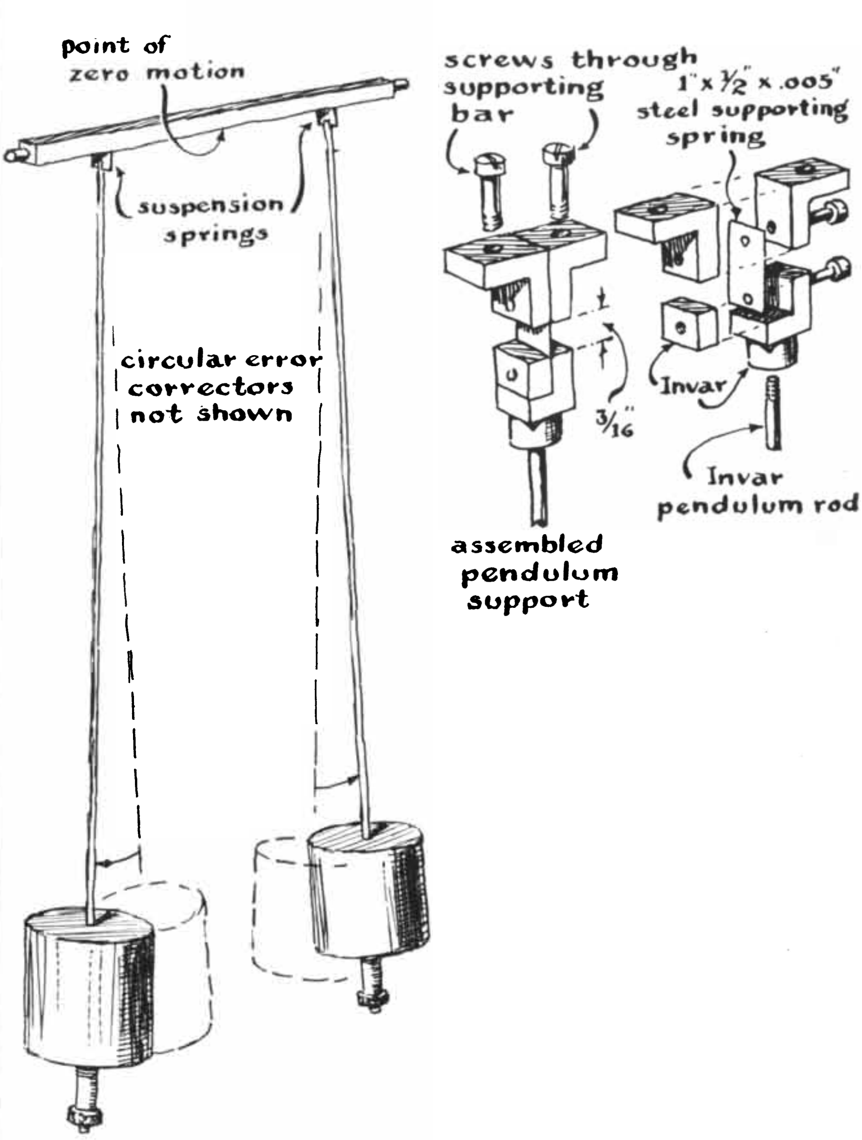


Details of the twin-pendulum suspension

vacuum-seal. The case could be lifted from the bottom plate like a large bell jar, exposing the entire clock and frame for easy access. The metal frame would simply rest on the bottom plate, also made of clear plastic. The bottom plate would rest on a flat and reasonably firm bench or table that can be carefully leveled. The proposed design is depicted in the accompanying drawing [*page 159*].

"Because the coils of the electronic-drive mechanism deliver less than a microwatt of energy to each pendulum, and because the thrust acts through the entire swing in each direction, there is no need to mount the pendulums so that their thrust is exactly at the center of percussion, and no need for a stiff pendulum rod. One-eighth-inch Invar rods, or even thin wires, are ample for bobs in the form of right cylinders three inches in diameter by three inches long, each weighing about 7½ pounds.

"A light, polished aluminum vane with a vertical slit at its center is fastened opposite the center of each bob so that the vanes overlap and the two slits coincide when the pendulums are at rest. Being nonmagnetic, the vanes are not attracted to each other by magnetism induced by the earth's field, or by leakage from the magnet systems on the bobs, even though they swing very close together. Good metallic bonding to the pendulums prevents any electrostatic attraction between the vanes.

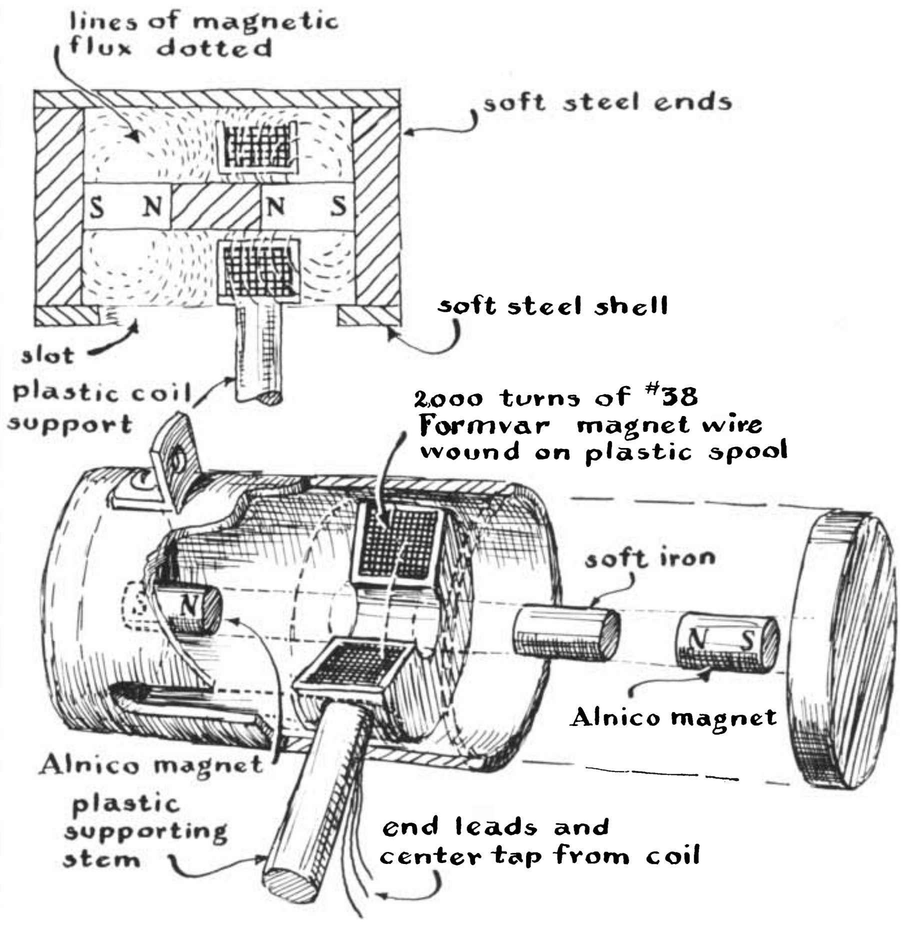
"The narrow vertical slits in the vanes allow a pulse of light to reach a photocell when the slits coincide near the center of each swing. A collimated beam of light somewhat larger in diameter than the length of the slits is directed on the

vanes from front to back. An oversize beam eliminates the need for fussy adjustments and allows the same amount of light to reach the photocell even if slit coincidence does not occur exactly at dead center. A lens beyond the slits focuses the light on the photocell. The electrical impulse from the cell is displayed on an oscilloscope, along with radio time-signals, for accurate comparison. If the slits are quite narrow, a photomultiplier tube may be required. The pulse may be made as sharp as desired to give extremely accurate time comparison, and can, of course, operate a chronograph if sufficiently amplified.

"The advantage of this arrangement lies in the fact that the slits coincide with each swing at the instant representing the mean time of the two pendulums. If for any reason the phase of one pendulum is slightly more than 180 degrees ahead of the other, it will pass dead center a bit too soon; however, the other pendulum, approaching from the opposite direction, will be a bit late. The slits will pass at the same instant that coincidence would have occurred if the phase displacement had remained exactly 180 degrees and they had passed dead center at the same instant.

"Since the two pendulums are normally swinging in opposite directions at any given time, any small seismic or other disturbance that speeds one up is apt to slow the other down by the same amount, but the mean time of the two remains the same. Moreover, if such a disturbance occurs, the system is corrected automatically. The two voltage-pickup coils are connected in series, so that the net voltage fed to the amplifier, and the resulting current in both drive coils, are in phase with the correct mean time of the two pendulums. This makes the driving force lead the slow pendulum and lag the fast one, causing them to pull back into synchronization.

"Furthermore, if the phase angle is not exactly 180 degrees, a slight horizontal movement of the support occurs, which also produces a synchronizing force. Two pendulums hanging from a half-inch steel bolt in a stone wall were found to lock into step in opposite phase and to swing at their average rate, even if their individual periods differed as much as five or six seconds per day. The



Details of electrical driving-mechanism for the twin pendulums

HOW HEAT-RESISTANT VITON® HELPED STRETCH A SMOKESTACK

Nozzle with seal of VITON synthetic rubber adds 100 feet to chimney's effective height

Pennsylvania Electric Co. decided that operations at its Seward Generating Station would be improved if its 214-foot smokestack were extended another 100 feet. But, normal shutdown time was not sufficient for construction, and the extension, if built, would be extremely vulnerable to high winds.

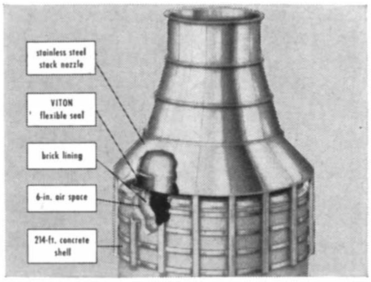
The alternative was to choke the stack's diameter with a nozzle. This would add to the stack's effective height by increasing the velocity of the exhaust gases (much as a restrictive choke on a shotgun increases shot velocity).

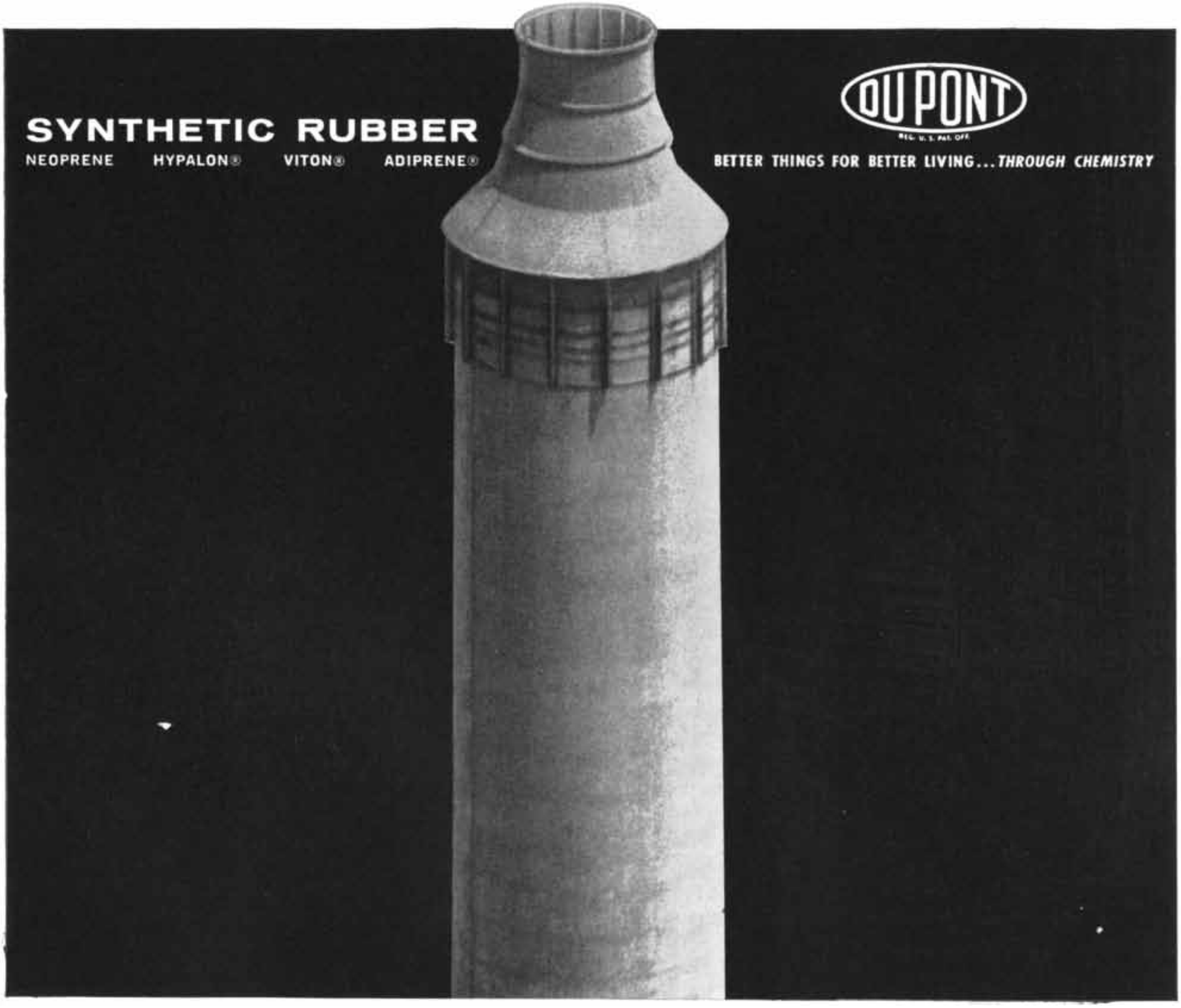
The problem was: how to seal a nozzle to the stack's brick lining while supporting its weight on the stack's outer shell . . . without obstructing the 6-inch sway-clearance space in between the two. The answer was a flexible diaphragm made with Du Pont VITON synthetic rubber. As shown in the sketch, the VITON seal connects the nozzle's inner skirt with the brick liner. The outer skirt of the nozzle is fastened to external supports on the concrete stack. The result: effective sealing without interfering with the chimney's sway clearance space.

VITON'S unique properties—including resistance to temperatures of 400° F. and above, and to fuels, oils and chemicals—helped this unusual nozzle "stretch" the stack the required 100 feet.

To learn how parts made from this new Du Pont synthetic rubber are solving engineering problems throughout industry, contact your rubber goods supplier or write for a copy of INDUSTRIAL REPORT ON VITON. E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Department SA-8, Wilmington 98, Delaware.

Stainless steel nozzle with double shell skirt was designed, prefabricated and installed by Aerotec Industries, Inc., of Greenwich, Conn. The outer skirt is fastened to the concrete stack, which bears the entire 10-ton weight. The inner skirt is sealed to the brick lining by the VITON synthetic rubber diaphragm.





proposed mounting has considerably higher resilience than such a bolt, making the synchronizing force even greater. During experiments with the single Shortt pendulum (using synchronized revolving weights as described above) it was found that the pendulum could be driven by the motion produced by the weights alone. The necessary lead angle of the weights was only about five degrees greater than 180 degrees when the air in the clock case was at a pressure of a few centimeters of mercury.

"Bush has made a complete mathematical analysis of the synchronizing force produced by slight support movement and has applied this same principle to the synchronization of the two opposed pistons of a free-piston engine. There energy is transferred primarily by means of gas bled through small pipes from one end of the cylinder to the other, but the basic principle is the same. This makes it possible to keep the two pistons in opposite phase without mechanical linkages.

"A. L. Rawlings, the noted horologist, suggested that instead of using moving coils, with connections made through fine springs near the point of support of the pendulum (as was done with the electromagnetic drive described last month), the arrangement be reversed: fixed coils react with magnets that move with the pendulum. He cited the advantage that such a magnet system would maintain constant weight and dimensions over long periods of time, whereas coils of insulated wire may gain or lose weight and thus change the rate.

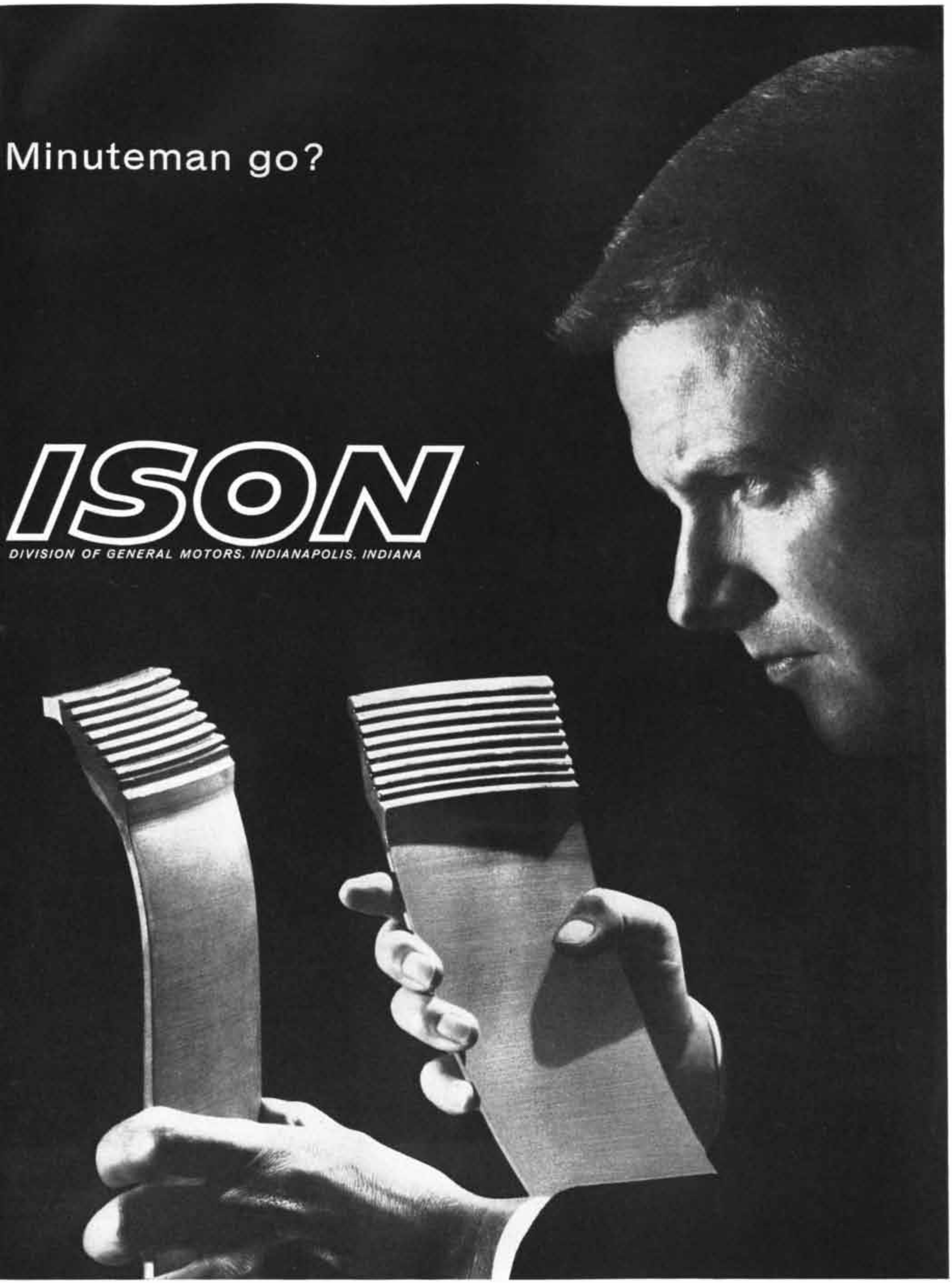
"Recently it has been possible to work out a practical adaptation of this suggestion. The great difficulty is that any magnetic system with an appreciable external field would not only attract the magnets on the second pendulum but also would induce eddy currents in it and in any nearby stationary metal, thus absorbing energy from the pendulums and influencing their rates.

"The proposed design, however, provides a magnet system so completely self-shielded that essentially no lines of magnetic force escape to interact with nearby metal. These structures can therefore be mounted directly on pendulums. Of course strong nearby magnetic fields will cause trouble, but they should be avoided anyway if accurate time is expected from any clock or watch.

"The steel shell of the self-shielded magnet system is made from a piece of one-inch electrical conduit about two inches long. The ends are plugged with steel disks a quarter of an inch thick. This unit houses a center rod made of two Alnico magnets a quarter of an inch in diameter and a half inch long, with a matching steel rod between them. The magnets butt against the outer plugs, with like poles in contact with the plugs, as shown in the accompanying drawing [*page 166*]. The magnet assembly is supported by and moves with the pendulum. Its Alnico magnets and steel rod oscillate through the air core of a fixed coil. The coil is supported by a nonmetallic rod that passes through a longitudinal slot in the side of the pipe. The leads to the coil also enter the shielded enclosure through this slot. The entire coil structure and its supporting rod should be coated with conducting paint to eliminate electrostatic forces.

"The lines of magnetic force extend radially from the center rod to the outer shell, as indicated, but the entire outer surface has the same magnetic polarity. Any substantial flux leakage is therefore inward, even near the slit where the coil support enters. The electrical drive is similar to the one described last month. If a 12AT7 tube, or its commercial version, is used, each voltage and drive coil should be wound on a plastic spool with about 2,000 turns of No. 38 magnet wire to produce between eight and 10 volts of amplified peak output for application to the clipper circuit. This will give good arc regulation and provide a few hundred microamperes for relay operation. A winding space of 1/8 inch by 3/8 inch is needed, which allows the coils to fit nicely in the magnet system. Heavy Formvar insulation should be used.

"Instead of employing grid resistors in the amplifier circuit, the midpoint of the two voltage coils should be connected directly to the end of the bias resistor as shown in the circuit diagram accompanying last month's article. The drive coils, one for each pendulum, are connected to the amplifier output in series. The shape and mass of the two pendulums should be the same, but to equalize the arcs (in case of a slight difference, particularly in the strength of the magnets) a high resistance may be shunted across one drive coil. The energy represented by the loss in this resistor is supplied from the amplifier, which produces a voltage across the coil and resistor at all times sufficiently greater than the back electromotive force generated in the drive coil to produce a positive driving force on the pendulum. There is never any absorption of energy from the pendulum itself, beyond that necessary to charge the grids of the amplifier."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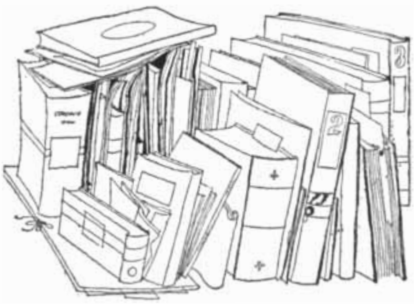


BOOKS

About Johannes Kepler and his role as a progenitor of modern science

by Gerald Holton

KEPLER, by Max Caspar. Translated and edited by C. Doris Hellman. Abelard-Schuman ($7.50).

The early part of the 17th century was the hinge on which the world view of the West, which had been dominated by scholasticism, turned toward science. In this period of transition the center of gravity of intellectual life shifted from the Scriptures to the Book of Nature. The stage for the later triumph of Newtonianism was being prepared by men working on problems that sprawled across the then indistinctly separated disciplines of mathematics, physics, astronomy, cosmology, philosophy and theology. It was, in short, the time of Kepler, Galileo and Descartes.

Of the three Johannes Kepler is perhaps the most interesting, both as a scientist and as a personality. He is also the least known. Until now there has been no serious biography of him in English. This neglect has at last been remedied: The definitive biography by Max Caspar has been translated from the German by C. Doris Hellman of the Pratt Institute in New York.

As Caspar warns the reader, "No one who has once entered the magic sphere that surrounds [Kepler] can ever escape from it." Caspar devoted his whole life to Kepler; at the time of Caspar's recent death his monumental 13-volume edition of Kepler's collected works, his translation of Kepler's letters and his biography had already become a gold mine for scholars—and for popular writers. The more meritorious passages of Arthur Koestler's *The Sleepwalkers*, for example, are little more than a paraphrase of Caspar.

Albert Einstein, who felt a deep kinship with Kepler (and who, like Kepler, was born in Swabia), said of him: "He belonged to those few who cannot do otherwise than openly acknowledge their convictions on every subject." Caspar's dedication and erudition consequently found an enormous amount of material on which to feed. This book is not merely a detailed portrait of Kepler. It is also an account of the intellectual ferment from which modern science arose, and of the historical context: the tragic and turbulent age of the Counter Reformation and the Thirty Years' War.

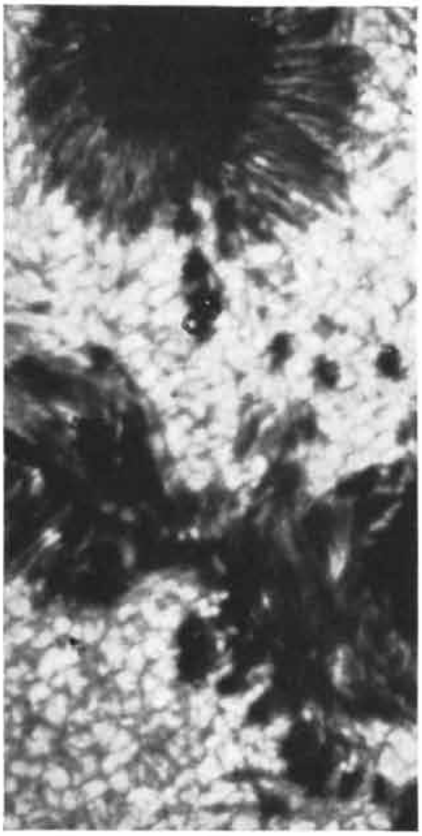
From the beginning Kepler's personal life was unfortunate. His father Heinrich, as characterized by Kepler himself, was an immoral, rough and quarrelsome soldier; his mother Katharina, a querulous and unpleasant woman, did not waste much love on her son. Too weak and sickly for agricultural labor, the boy was sent through a school system leading to theological studies at the Protestant seminary in Tübingen. One of his teachers, Michael Maestlin, introduced him privately to the Copernican system, which Maestlin was prohibited from teaching in his public lectures. This was the spark that set the youthful mind afire.

At the age of 23, a few months before attaining the goal of his studies (the pulpit), Kepler was directed by his seminary to leave in order to serve as teacher of mathematics and astronomy at the seminary in Graz. He was a wretched teacher, and he had few students. This enabled him, however, to devote that much more time to other work. Although he spurned astrology as it was then practiced, he began to write horoscopes and prognostications. He had good reasons to do so: It was part of his official duties as district mathematician and calendar-maker; he believed that he could "separate some precious stones from the dung"; he was convinced that the harmonious arrangement of planets and stars could impart special qualities to the soul; he loved to spread his opinions among the noblemen and prelates who read these writings; he needed the money; and, last but not least, he found that his predictions were often accurate.

At this time he also began a work that combined a little of each of his previous studies: of Plato, Aristotle, Euclid, Augustine, Copernicus, Nicholas of Cusa and Luther. This was not merely astronomy; his aim was nothing less than to discover the plan of the Creator, "to think the thoughts of God over again," and to show that His plan was Copernican. In 1597 Kepler published the *Mysterium Cosmographicum,* in which he hoped to show the reasons for the number of planets, the size of their orbits and their specific motions. His method was to search for geometrical regularities with which to "explain" physical observation. His immense ingenuity, coupled with his unparalleled persistence, enabled him to uncover geometrical coincidences which satisfied him that his prejudices were correct. The key was his famous discovery that the relative radii of the planetary orbits in the heliocentric system correspond fairly well to the relative radii of thin spherical shells that may be thought to separate a nested arrangement of the five Platonic solids. (The agreement is surprisingly good; the discrepancy between the radii of the shells and those of the orbits according to Copernicus was within about 5 per cent, except for the single case of Jupiter—"at which," Kepler said, "nobody will wonder, considering the great distance.")

Kepler soon saw that this was an incomplete effort at best, and changed his method of work. Still, the fundamental motivation behind the *Mysterium Cosmographicum,* namely the search for harmonies, remained strong throughout the remaining 33 years of his life. In 1597 he could feel the elation of the young man who, in Max Weber's phrase, "finds and obeys the demon who holds the fibers of his very life."

But in that same year the dark clouds that seemed always to hover over him sent down some lightning bolts. He married a young widow whom he described later as "simple-minded and fat, confused and perplexed." In 1600, the Counter Reformation having begun in earnest, all Protestants who did not choose to abandon their faith were banished from Graz. Kepler found an uncertain refuge in Prague with the aging and difficult Tycho Brahe, the foremost



astronomer of his time, himself in exile from Denmark at the court of Emperor Rudolph.

Brahe lived for only one more year. When he died, however, he left Kepler two great treasures: a healthy respect for accurate measurement, and a set of the best observations of planetary positions that had ever been made. Out of this raw material came Kepler's second great work, the *Astronomia Nova,* famous because it contained his first two laws of planetary motion. During this period Kepler also did fundamental work in optics.

In 1612 he was obliged to leave Prague. His protector, the Emperor, had been forced to abdicate; Bohemia had been devastated by warfare among the contenders for the throne; his wife had died of a disease sweeping the capital. Kepler fled to Linz, where for 14 years he worked as a schoolteacher and district mathematician. At first this was the most tranquil time of his life. He brought out his *Epitome,* an account of the Copernican system which was more persuasive than Galileo's, but which was neglected by contemporary scholars, including Galileo. He chose a new wife in a comically careful way from 11 candidates (the choice turned out rather well), and fought in his Lutheran congregation for the right to interpret the concept of transubstantiation as he saw fit (he was deeply hurt when, as a result, his pastor excluded him from communion).

This was also the time when Kepler's aged and feeble-minded mother was tried as a witch. It was a miserable affair, involving the full spectrum of human fears and stupidities. Kepler devoted a full year to her defense. He did not claim that witches did not exist, but only that his mother was not one. He barely managed to keep her from the rack and gallows. When one of his children died, he turned for solace to his work on the *Harmonice Mundi,* which contained his third law of planetary motion and was his last major book. He wrote: "I set the *Tables* [the Rudolphine tables] aside, since they require peace, and turned my mind to the contemplation of the *Harmony.*"

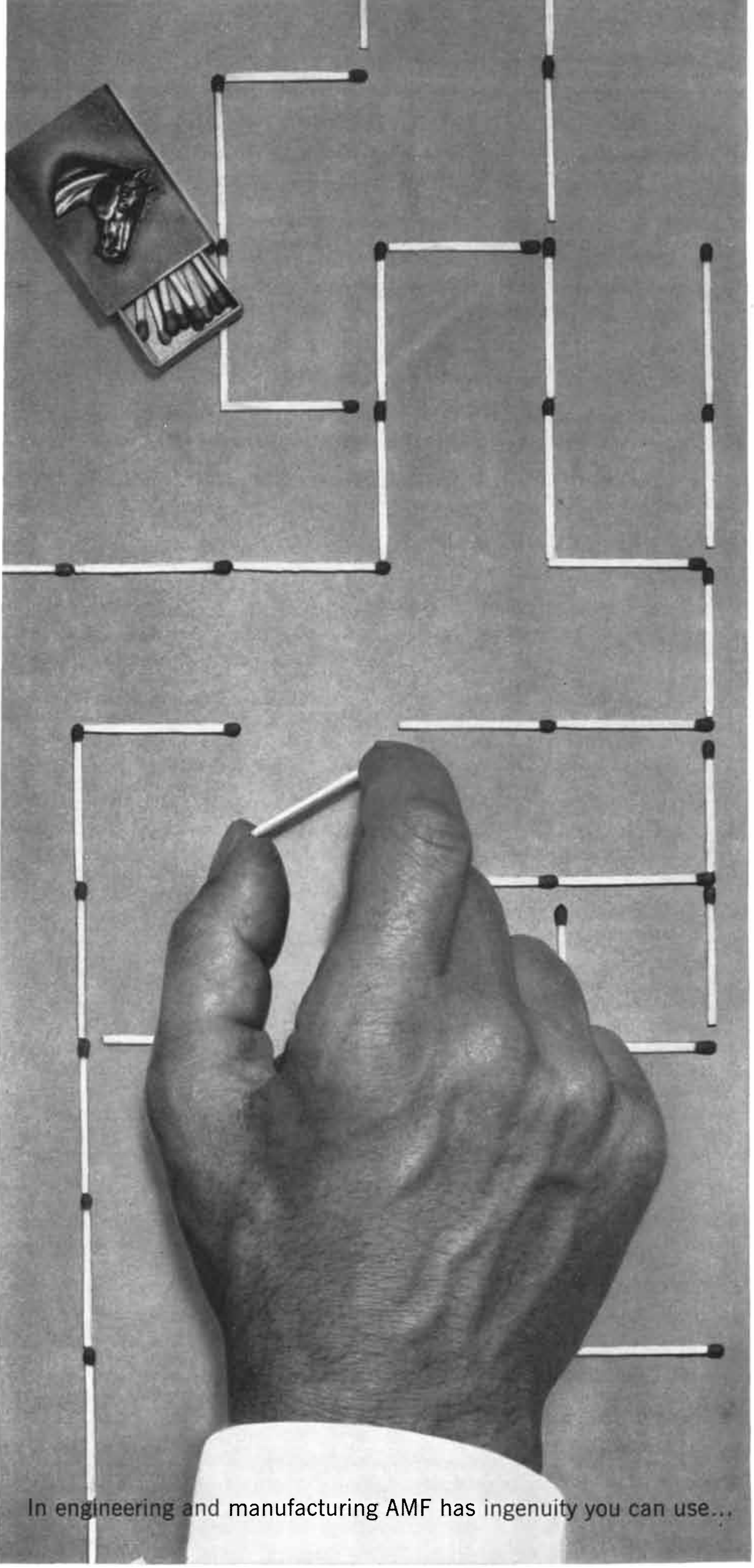
Kepler discovered the third law in May, 1618; the month also marked the beginning of the Thirty Years' War, which devastated Germany. Within a year the published part of his *Epitome* was placed on the Index of forbidden books. By 1626 his stay in Linz had become intolerable; his library had been sealed up by the Counter Reformation Commission; the countryside was swept by bloody peasant uprisings; the city of Linz was besieged; the press that had been printing the Rudolphine tables had gone up in flames. It seemed that he had no place to go. He was received splendidly in Prague by Emperor Ferdinand II, but he refused employment at the court because he would have had to embrace Catholicism. For a time he found refuge in the retinue of the Austrian duke Wallenstein, partly because of Wallenstein's interest in astrology. Then in 1630, as he was passing through Regensburg on a fruitless journey to collect some money that was owed him, he was seized by a fever and died. Soon afterward the churchyard in which he was buried was destroyed by one of the battles of the time. Caspar writes: "It is as though the fate which in life gave him no peace continued to pursue him even after death."

But Kepler had left something more durable than a headstone: the three laws of planetary motion. During his lifetime they attracted little attention. For a generation they slept quietly; then they awoke as the key inspiration for Newton's theory of universal gravitation.

These three empirical rules for which Kepler is remembered are scattered through his voluminous work. They are almost submerged in a flood of other ideas: from a means of calculating the optimum size for wine casks to an attempt to fix the year of Christ's birth, from an excellent discussion of lens optics to an attempt to connect the position of planets with the local weather. (For 20 years Kepler faithfully made weather observations for this purpose; and at the end he bravely confessed that no connection was provable.)

His whole work is characterized by this search for an arena of fruitful study in disciplines that, from our point of view, are incongruously mixed: physics and metaphysics, astronomy and astrology, geometry and theology, mathematics and music. But this was the time when the sciences were emerging from the matrix of general intellectual activity and assuming more specific forms. It fell to Kepler to show, through his successes and through his failures, where the fruitful ground for science lay. It was ground that he himself could not reach.

If we look into Kepler's turbulent life and work for those brief moments that best illuminate the man and the time, I would select passages from two letters. One, written to Guldin in 1626, described Kepler's life during the long siege of Linz. His house was situated at the city wall around which the fighting was raging, and a whole company of sol-



He designed a new interchange for radio traffic

This AMF engineer, part of an AMF-U.S. Army team, solved the problem of traffic delays and personal danger in manual re-connection of jumpers when interchanging R.F. transmitters and antennas.

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diers was stationed in it. "One had to keep all doors open for the soldiers, who through their continual coming day and night kept us from sleep and study." Here we find Kepler deep at work in technical chronology: "I set to work against Joseph Scaliger—one thought followed the next, and I did not even notice how time was passing."

The other revealing view of Kepler is provided by a letter to Herwart von Hohenburg in 1605. Here we come as close as we can to putting our finger on the moment when the modern mechanical-mathematical conception of science breaks out of its earlier mold. Kepler wrote: "I am much occupied with the investigation of the physical causes. My aim in this is to show that the celestial machine is to be likened not to a divine organism but rather to a clockwork . . . , insofar as nearly all the manifold movements are carried out by means of a single, quite simple magnetic force; as in the case of a clockwork all motions [are caused] by a simple weight. Moreover, I show how this physical conception is to be presented through calculation and geometry."

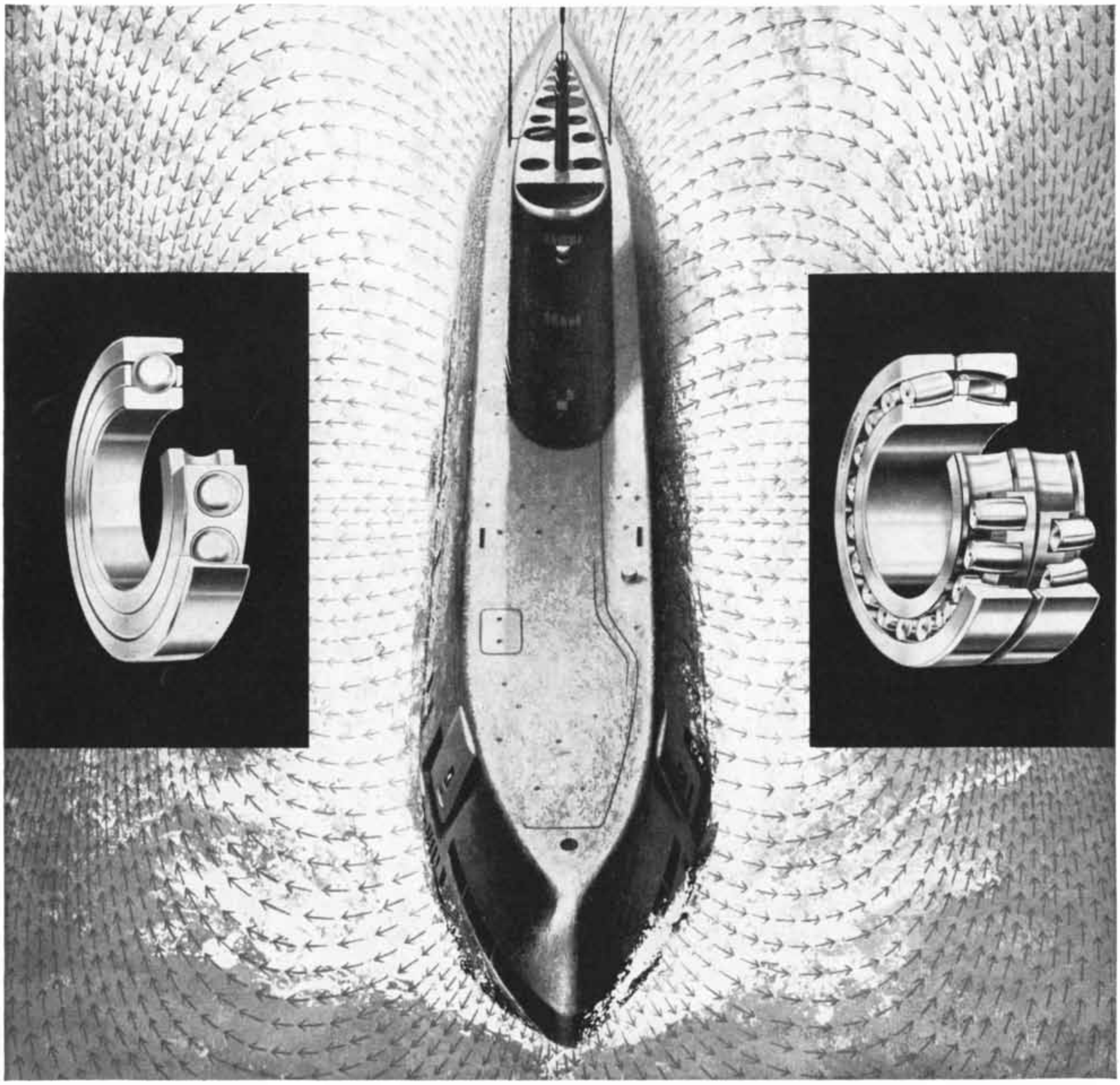
The celestial machine, driven by a single *terrestrial* force, in the image of a clockwork! This was indeed a prophetic goal. When the *Astronomia Nova* (on which Kepler was working at the time) was published four years later, it significantly bore the subtitle *Physica Coelestis.* Here we find the search for one universal force-law to explain terrestrial gravity and the oceanic tides as well as the motion of the planets. It is a conception of unity that is perhaps even more striking than Newton's, for the simple reason that Kepler did not have a predecessor.

Kepler did not, of course, succeed in his aim to find the physics that explains astronomical observations in terms of mechanics. The Achilles heel of his celestial physics was his Aristotelian conception of the law of inertia, which identified inertia with a tendency to come to rest: "Outside the field of force of another related body, every bodily substance, insofar as it is corporeal, by nature tends to remain at the same place at which it finds itself." (The quotation is from the *Astronomia Nova.*) This axiom deprived him of the concepts of mass and force in useful form, and without them his world machine was doomed.

And yet, perhaps precisely because of the failure of his physics, he still had to see the world in one piece, holding before him an image in which there were three components: the universe as a physical machine, the universe as mathematical harmony and the universe as a central theological order. Taken by itself, any one of the three was incomplete and insufficient. It was Kepler's vision of all three together that makes him so interesting to us when we compare his view of the world to ours, so much more successful in each detail but—perhaps necessarily and irretrievably—so much more fragmented.

Short Reviews

ALAN M. TURING, by Sara Turing. W. Heffer & Sons, Ltd. (21 shillings). A memoir by his mother of the life and work of a most creative and original British mathematician who died tragically in 1954 at the age of 42. Turing is well remembered for his contributions to the foundations of mathematics, which, while not numerous, broke fresh ground and were the basis of further advances. In particular, his noted paper "On Computable Numbers, with an Application to the Entscheidungsproblem," written when he was 25, and which contained ideas said to be essential to the development of all general computers, earned him a permanent place in the history of logic. Turing's practical interest in computers, which bore fruit in the engines he designed and worked on at the National Physical Laboratory and at the University of Manchester, was an outgrowth of the famous question that was much to the fore in the 1930's of determining whether all mathematical problems are theoretically solvable, or whether there are classes of problems that cannot be solved by "any fixed and definite process." The paper referred to clarified the concept of such processes and described a "universal" machine which, "when supplied with suitable instructions, would imitate the behavior of any other." Thus the notion of "computable" was sharpened, and Turing was able to show that the machine had limitations; in other words, that there are classes of problems whose solutions are not computable in the sense defined. One of Turing's most interesting philosophical papers, "Computing Machinery and Intelligence," which is accessible to the nonspecialist, examines picturesquely and with great skill the general question of the limits of machines, and whether it can be truly said that they possess "intelligence." (His answer, in effect, is yes; that is, however intelligence is defined, machines can be conceived that have the attribute and thus are indistinguishable from such living organisms as may be thought to have it.) As those who knew him seem to agree, Turing was, even for



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For example, in submarine rudder posts and instruments, good bearing performance often depends as much on corrosion and magnetic resistance as on the load-carrying capacity. In sensitive electronic equipment, valves and other mechanical applications, special metals may be necessary to eliminate undesirable magnetic effects.

Designing and manufacturing bearings to meet unusual requirements is a Torrington specialty. Developments in non-magnetic and corrosion-resistant bearings are a part of Torrington's continuing effort to improve bearings in design, metallurgy and performance.

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PROGRESS THROUGH PRECISION—IN BEARING DESIGN AND PERFORMANCE

a logician and mathematician of genius, a very strange man. He was inward, remote, given to long silences, brusque and offhand in manner. He was more or less indifferent to creature comforts, careless in his dress, sudden and unpredictable in arrivals and departures. He had a "shrill stammer and crowing laugh which told upon the nerves even of his friends." He never "fitted in anywhere quite successfully." But he was what he was without a shred of pretense, and he was capable, by his very loneliness and inscrutability as much as by his great gifts, of gaining human affection. His mother's memoir, which is especially revealing in its glimpses of his childhood and schooling, is admirable both in its restraint and in its candor. It is a poignant story, short as the life it portrays, yet rewarding. Turing remains a mystery, but perhaps he will always remain so even if a fuller biography should be written.

PSYCHOLOGY: A STUDY OF A SCIENCE; STUDY I, CONCEPTUAL AND SYSTEMATIC, edited by Sigmund Koch. McGraw-Hill Book Company, Inc. ($32.25). In 1952 the American Psychological Association, which represents nearly all the professional psychologists in the U. S., called for an analysis of the "methodological, theoretical, and empirical status of psychological science." Shortly thereafter, armed with a grant from the National Science Foundation, they appointed Sigmund Koch director of a project designed to generate the desired analysis. Koch, with the help of a panel of experts, laid out an ambitious and imaginative three-part plan; this three-volume work represents only the first part. The remaining two parts, comprising four more volumes, are still in preparation. When complete, the report will run to something over two million words. In order to carry out the plan Koch enlisted more than 80 authors representing all the major schools of thought—the list of contributors is a veritable *Who's Who* of academic psychology in the U. S. Although critics are likely to see the project as too academic and too American, future historians of science should be delighted to find a science so neatly summarized and analyzed by the men who were creating it. Psychological theory in the U. S. in the middle of the 20th century has now been codified and filed away in a time capsule awaiting the time when it will have become history. Contemporary readers, however, will find these three volumes heavy going unless they are themselves engaged in the business of creating or destroying psychological theories. Although the contributors were not all persuaded that science progresses by intense, self-conscious analysis of where one has got and where one is going, they all took their assignments seriously. The collected and edited result is both an encyclopedia of metapsychology for all future graduate students and a bold attempt to make psychologists reflect on what they are trying to do. Its effects on the future development of psychological science will be interesting to watch.

THE NEW WORLD OF MATH, by George A. W. Boehm and the Editors of *Fortune*. The Dial Press ($2.50). THE MODERN ASPECT OF MATHEMATICS, by Lucienne Félix. Basic Books, Inc. ($5). The common aim of these two books, though they speak to different audiences, is to show that mathematics, like the old gray mare, is not what she used to be. Boehm's little volume, which consists essentially of three articles published in 1958-1959 in *Fortune*, splashes around a bit in various mathematical pools: group theory, topology, number theory, set theory, modern algebra, decision theory, statistics, game theory, nonparametric inference, analysis, logic, computers, Monte Carlo method; the book also contains nine brief appendices that touch on sundry oddments and paradoxes. There is nothing here to make one's head ache from stern concentration, but this is nevertheless a respectable piece of journalism that may give the reader the pleasantly reassuring feeling that he now understands the sort of thing bright young Ph.D.'s worry about and get paid for. Much more ambitious is Mlle. Félix's effort. The flyleaf identifies her as a "close associate" of the so-called Bourbaki group and promises a "semi-popular account" of the Bourbakiste revolution which has allegedly toppled the classical edifices of mathematical theory and pedagogy and replaced them with bright, sound, functional structures in whose sunlit chambers our children and those of us not too atrophied to reform can gain a new and deepened understanding of mathematics through symbolic logic, topology, set theory, general algebra and so on. Mlle. Félix is unfortunately quite unable to fulfill this promise. She writes in a rapturous style, so reverently adorned with quotations not worth quoting and so flushed with Bourbakiste fervor and love of France that it is often hard to know what she is talking about; she assumes a background of mathematical knowledge that the average reader doesn't possess, while the reader who does, doesn't need the book; she is singularly incapable of making

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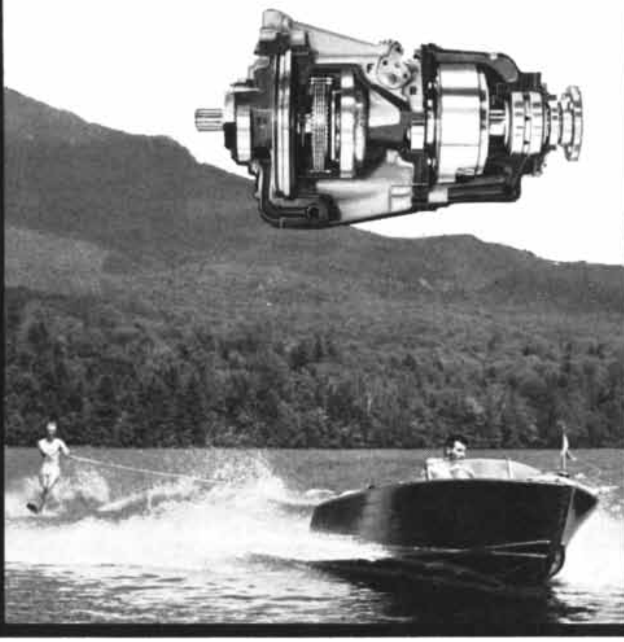

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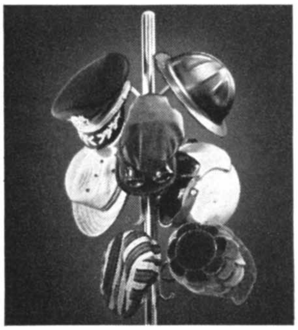

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Borg-Warner Corporation • 200 South Michigan Avenue • Chicago 4, Illinois difficult ideas plain. As a final feature, the translation from the French is as limpid as an industrial creek. The Bourbakistes may have a point, but it is not well served by this tract.

Lewis Henry Morgan: The Indian Journals, 1859-1862, edited and with an introduction by Leslie A. White. University of Michigan Press ($17.50). This book, skillfully edited by Leslie White and richly illustrated with many fine black-and-white pictures and 16 color plates, presents a classic of the Western literature of travel and exploration—the journals of a Rochester corporation lawyer who between 1859 and 1862 made a series of trips to the Far West to study the culture, social organization and living habits of the Indians of the Great Lakes, the Plains and the Southwest. Morgan, called the first American ethnologist and the founder of social anthropology, was of course self-trained, since there was no formal anthropological discipline in existence at the time. But with a group of other young men (including Henry Rowe Schoolcraft) he formed in Aurora, N. Y., a literary and social club called The Gordian Knot, which was soon transformed into the Grand Order of the Iroquois. As announced in its constitution, its purpose was "to encourage a kinder feeling toward the Indian, founded upon a truer knowledge of his civic and domestic institutions and of his capabilities of future elevation." Morgan never lost this interest and never wavered in his determination to understand the Indian and to help him. Despite his busy law practice, he found time to study widely and to reflect deeply upon Indian culture, to evolve an elaborate theory about their system of kinship nomenclature, to visit many reservations, to observe games and ceremonies and to record legends and myths, to defend the Senecas against the rapacities of the Ogden Land Company (for which service he was subsequently adopted into the Seneca tribe), to publish learned papers on Indian intertribal organization and finally, entirely at his own expense, to make the long, hazardous and immensely profitable journey so simply and unaffectedly described in these admirable journals. White's annotations and introductory chapters are excellent, and the entire book, apart from its readability, will do much to introduce this pioneer of social anthropology to the wide audience he deserves.

Heraclitus, by Philip Wheelwright. Princeton University Press ($4.50). The oracular sayings of the sixth century B.C. Ionian philosopher, Heraclitus of Ephesus, called the Dark One, which have survived only as quoted fragments, were first compiled in the early 19th century by the renowned classicist Friedrich E. Schleiermacher and have since then attracted the labors and taxed the ingenuity of many scholars. Obscure and riddling though they are, these aphorisms about life and the cosmos have lost none of their piercing, haunting quality, their uncanny appeal to the imagination. Exactly what Heraclitus meant is often unclear because of semantic, grammatical and philosophical ambiguities; moreover, the ancient writers who quoted him and who are the sources of the fragments had their own difficulties of interpretation and their own bias, so that their comment may be misleading as frequently as it is helpful. What is meant, for example, by the following sayings? "Whatever we see when awake is death; when asleep, dreams." "The name of the bow is life, but its work is death." "The fairest universe is but a heap of rubbish piled up at random." "Unless you expect the unexpected you will never find [truth], for it is hard to discover and hard to attain." This book presents the fragments in a fresh translation, examines the various aspects of Heraclitus's thought and makes them accessible to a wider audience than is reached by more specialized works. There is nothing outmoded about the thoughts of this ancient philosopher; indeed his paradoxes and metaphors and his apocalyptic tone are peculiarly in key with the desperate uncertainties of our own age.

Thomas Geminus: Compendiosa Totius Anatomie Delineatio. A Facsimile of the First English Edition of 1553 in the Version of Nicholas Udall, with an introduction by C. D. O'Malley. Dawson's of Pall Mall (12 pounds, 10 shillings). Andreas Vesalius's *De Humani Corporis Fabrica,* published in Basel in 1543, which "ushered in modern anatomy and laid the groundwork for much of later physiology and medicine," was a work often plagiarized, both surreptitiously and openly. In an age in which copyright was at best weakly protected, Vesalius could do little to thwart "borrowers" of his work, and the most he could do was to offer to send his plates "to any conscientious printer" in the hope that he might thereby encourage skilled plagiarists and discourage the bunglers whose crudities would cast discredit upon the *Fabrica* and upon himself. One of the ablest plagiarists was Thomas Geminus, born near Liége, who migrated to England around 1540, was

RESEARCH AT COLLINS

$$p(\lambda)d\lambda = \frac{C_1}{\lambda^5} \frac{d\lambda}{\exp(C_2/\lambda T)-1}$$

$$C_1 = 8\pi h c$$

$$C_2 = \frac{hc}{k}$$

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The principles of spectral energy distribution of the radiation from a black body, announced by Max Planck in 1900, were of intense interest to the theoretical physicists of the day. Since then, these principles have paved the way for major advances in marine navigation and radio astronomy. For example, Collins new Radio Sextant pictured here is capable of continuously tracking the sun or the moon under any weather conditions, furnishing both the ship's location and heading with high precision.

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COLLINS RADIO COMPANY • CEDAR RAPIDS, IOWA • DALLAS, TEXAS • BURBANK, CALIFORNIA naturalized and set himself up as an engraver. This handsome book is a facsimile of the second edition of Geminus's *Compendious Anatomy,* published in London in 1553, which faithfully copies the Vesalian illustrations and supports them with an English anatomical text prepared—very likely with the help of "other learned men"—by Nicholas Udall, who is known as "the father of English comedy," the author of *Ralph Roister Doister* and also as a classicist of considerable ability. The plates, and the "treatyse" especially, were intended as a guide for dissection to be used by barber surgeons "in conjunction with the dissection of the four cadavers annually allotted to them or such few other cadavers as they might obtain." Apart from its influence on the development of anatomical and surgical knowledge in England, Geminus's book suffered the same treatment as he practiced on the *Fabrica,* being widely copied for at least a century after its publication in many different forms on the Continent. "Few plagiarisms," says O'Malley in his scholarly introduction, "have been flattered by so much imitation."

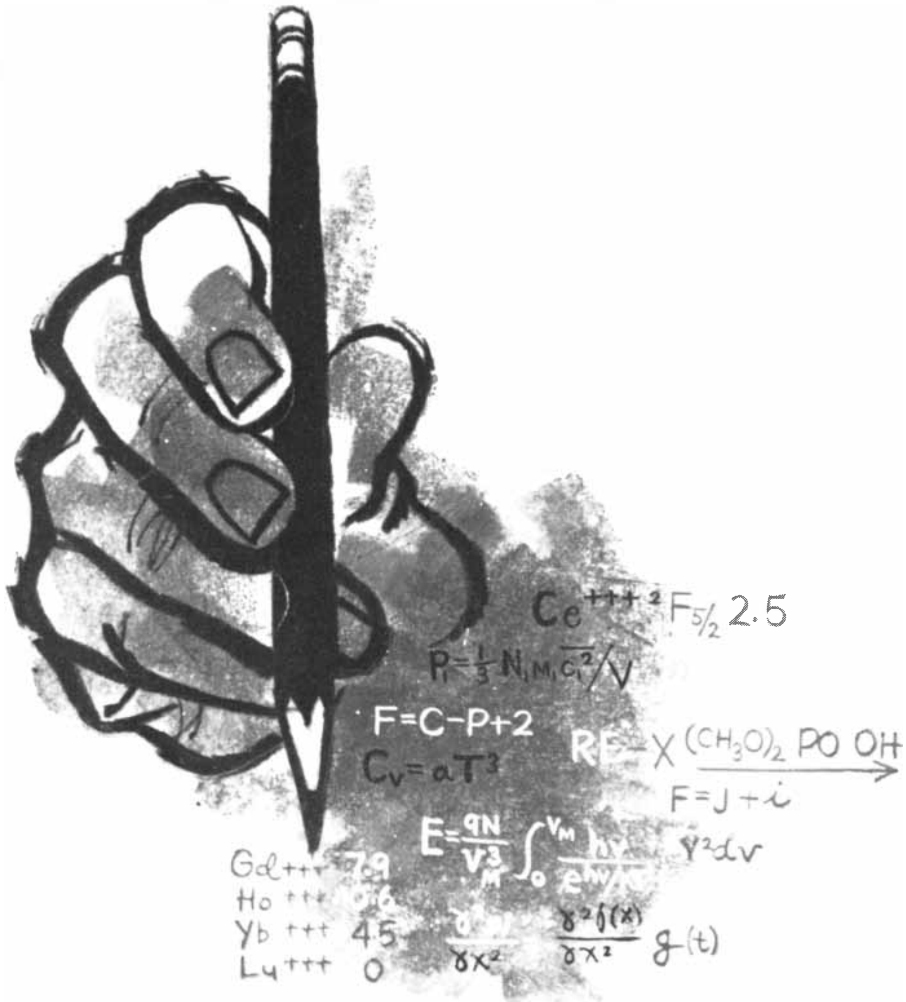
Roman Construction in Italy from Tiberius through the Flavians, by Marion Elizabeth Blake. Carnegie Institution of Washington ($9). This scholarly, illustrated work, a continuation of Dr. Blake's *Ancient Roman Constructions in Italy from the Prehistoric Period to Augustus* (1947), describes in considerable detail the materials, methods and designs of ancient structures in Rome and its immediate vicinity: public and private buildings, monuments and arches, amphitheatres and theatres, baths, roads, aqueducts, harbors, and allied waterworks, emissaria, dams, bridges. Although this is primarily a study of architecture, it touches upon a number of related fields and contains a good deal of material of general historical interest.

The World's Lighthouses before 1820, by D. Alan Stevenson. Oxford University Press ($10.10). Beginning with an account of the Pharos of Alexandria, the first seamark, which the Egyptians completed about 280 B.C. (modern archaeologists believe that it rose about 450 feet from a base 100 feet square), this handsomely illustrated book, replete with diverting antiquarian matter, engineering and nautical details, covers the development of lighthouses from the wood fires of antiquity through the introduction of candles and oil lamps, parabolic reflectors and revolving lights to the great silver-plated lights of the early 19th century. A second volume is promised on modern lighthouses.

A Short History of Scientific Ideas to 1900, by Charles Singer. Oxford University Press ($8). Though based on the author's *A Short History of Science,* this book is a quarter longer than its predecessor, more fully illustrated, stresses ideas and their philosophical implications, and refers, according to the preface, more frequently to the historical and economic setting of science. The plain reader who wants to cross the bridge to explore the other of the two cultures, and the scientist who is curious about the history of his own and other specialties, are fortunate to have this simple, clear, well-written and authoritative guide.

Greek Horoscopes, by O. Neugebauer and H. B. Van Hoesen. American Philosophical Society ($6). Other than the information to be found in Ptolemy's *Almagest* and closely related works, little is known about the techniques of computing the positions of sun, moon and planets during any period of antiquity. This scholarly book examines the extant Greek horoscopes from the first century B.C. to the beginning of Islam, drawing on all available sources—monuments, papyri, ostraca and astrological treatises—to determine what they reflect of the contemporary methods of Greek astronomy. The horoscopes are translated, a commentary is given on each and the authors evaluate the astronomical and historical implications of the whole material. Glossaries, bibliography, illustrations.

Atlas of the Classical World, edited by A. A. M. van der Heyden and H. H. Scullard. Thomas Nelson & Sons. ($15). This colorful and instructive book is both more and less than its title indicates. It contains 73 maps dealing with religious, economic, military, literary, philosophical, scientific and artistic matters, as well as political history; 475 illustrations, many of which are air photographs, of ancient sites, monuments, architecture, sculpture, topography and so on; and a text that sketches the development of the world of Greece and Rome. The maps are little more than conventional outlines to provide a geographical setting for historical events and other information, and represent no high achievement of the cartographer's art; many of the illustrations are of modest merit. Nevertheless this is a handy compendium for the average reader who



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wants a general view of pagan antiquity, or for the student hunting an elusive fact as to a philosopher's birthplace, a battlefield, a trade route, an ancient deity.

The Corrosion and Oxidation of Metals, by Ulick R. Evans. St. Martin's Press, Inc. ($25). An encyclopedic treatise that presents the results of the author's lifelong experimental researches on corrosion, and of the work carried on by others outside the University of Cambridge. The book covers the scientific theory of oxidation and corrosion and also deals with practical matters such as the protection of steel structures, corrosion inhibitors, boiler protection, laboratory techniques and measurements. There are extensive references to the literature and hundreds of illustrations.

Glossary of Meteorology, edited by Ralph E. Huschke. American Meteorological Society ($12). This compact but comprehensive and authoritative glossary "purports to define every important meteorological term likely to be found in the literature today." There are more than 7,000 entries, the majority of which deal directly with synoptic, dynamic and physical meteorology, theoretical and applied, and also climatology and meteorological instrumentation. Most of the remainder are drawn from sister disciplines such as hydrology, oceanography, geomagnetism and astrophysics; some come from physics, chemistry, mathematics and statistics, and even from the "folk language of weather lore." An excellent, up-to-date job that no meteorologist will want to do without, and which will also admirably serve the nonspecialist with questions about weather words.

The Triumph of Surgery, by Jürgen Thorwald. Pantheon Books ($6.50). A fictionalized history of modern surgery, in which the narrator is a physician who acts as an eyewitness to famous operations and is on friendly terms with the principal actors who remove gall bladders, tumors, thyroid glands and make repairs of miscellaneous physical defects. This is a rather heavy-breathing German narrative which in translation comes out as a heavy-breathing English narrative, but perhaps the stertorousness will not bother readers who are engrossed by what is after all a pretty close-to-home and morbidly fascinating subject.

The Vikings, by Johannes Brøndsted. A Pelican Book ($1.25). This attractive paper-back original is an illustrated history of the Nordic Vikings: their voyages, battles, customs and decorative arts. The author, a leading Danish archaeologist, known for his work in the prehistory of his own country, considers such matters as the origins of the Vikings, their industries and equipment, ships and armies, social life and beliefs; why the Vikings made their raids and voyages, why they were unable to secure their settlements in North America, why they were able to reach the coast of Western Europe and to penetrate to Istanbul and Baghdad but not to Central Europe, why they embraced Christianity, a religion "quite alien to their own philosophy." A rich study.

Collected Papers of Charles Sanders Peirce, edited by Charles Hartshorne and Paul Weiss. Belknap Press of Harvard University Press ($45). A most welcome reprint of the writings of (in John Dewey's words) "the most original philosophical mind this country has produced." The fine Hartshorne-Weiss edition was originally published in six separate volumes between 1931 and 1935. (Two further volumes edited by Arthur Burks appeared in 1958 and were reviewed on these pages.) They are now reissued in three volumes, each incorporating two volumes of the original edition: Vol. I, Principles of Philosophy, Elements of Logic; Vol. II, Exact Logic, The Simplest Mathematics; Vol. III, Pragmatism and Pragmaticism, Scientific Metaphysics. Good bookmaking and a service to students of philosophy.

Maya Hieroglyphic Writing, by J. Eric S. Thompson. University of Oklahoma Press ($10). A reprint of a masterly account of Maya hieroglyphic writing, first issued in a small edition by the Carnegie Institution of Washington in 1950. Scholars have not yet discerned a consistent pattern or alphabet in Mayan writing, so that until another Michael Ventris appears or an equivalent of the Rosetta stone is found, past solutions will not appreciably facilitate future labors, and the decipherment of new glyphs will continue to be an immensely complex and arduous task. To this edition Thompson has added a brief preface which surveys advances in the field since 1950. The book is fully illustrated with drawings and plates and is very reasonably priced considering its size and excellent dress.

John Jay Chapman—An American Mind, by Richard B. Hovey. Columbia University Press ($6.50). A study of the life and ideas of an extraordinary American: aristocrat, social and cultural

critic, rationalist, mystic, crusader, rebel, humanitarian, reactionary, bigot, paranoid, obsessive, crackpot, hysteric. As one critic has observed, Chapman was "only an extreme case of the prophetic temperament in American life, an example of the mystic who lives on the razor's edge of sanity." An engrossing, though essentially bewildering, portrait.

THE STUDY OF ELEMENTARY PARTICLES BY THE PHOTOGRAPHIC METHOD, by C. F. Powell, P. H. Fowler and D. H. Perkins. Pergamon Press, Inc. ($40). An account of the methods used in studying elementary particles and their properties by measurements of the tracks they make in photographic emulsions. This review of the principal techniques and discoveries, a 10-year project, includes a wealth of photographs of historical interest, supported by a full explanatory text; properties of mesons and hyperons are also described. A valuable atlas.

A HISTORY OF MODERN ARCHITECTURE, by Jürgen Joedicke. Frederick A. Praeger ($10). From Sir Joseph Paxton's Crystal Palace to Pier L. Nervi's hanging roofs, Miës van der Rohe's Seagram building and Buckminster Fuller's geodesic dome, a history of the evolution of the style, construction methods and new materials of modern architecture, with the main emphasis on the creative efforts of the last 50 years. Clearly written, balanced, intelligent, with an abundance of excellent illustrations, this is a very satisfactory guide.

LOUIS SULLIVAN AS HE LIVED, by Willard Connely. Horizon Press, Inc. ($6.50). A biography of one of the great shapers of American architecture, Louis Sullivan, which draws upon certain hitherto unpublished materials. Sullivan, the creator of the modern skyscraper, was immensely productive for a brief period, then lived recklessly, ruined his business and his marriage, squandered his genius and spent the last years of his life in loneliness and poverty. Illustrations.

Notes

NAIVE SET THEORY, by Paul R. Halmos. D. Van Nostrand Company, Inc. ($3.50). A brief, lucid and readable exposition of mathematical set-theory that will be very welcome to students just setting out in this fascinating and important domain.

THE UNIVERSE OF LIGHT, by Sir William Bragg. Dover Publications, Inc.

($1.85). Bragg's Royal Institution Christmas Lectures on light are the best popular introduction to the subject you can find. This is an excellent paper-back reissue of the original book, with two full-page color plates and approximately 200 other illustrations.

ADVENTURING WITH BEEBE, by William Beebe. The Viking Press ($1.25). A paperback consisting of selections from the writings of an eminent naturalist who is an engaging raconteur and whose adventures cover more than 40 years of time, and range from the jungles to the submarine world.

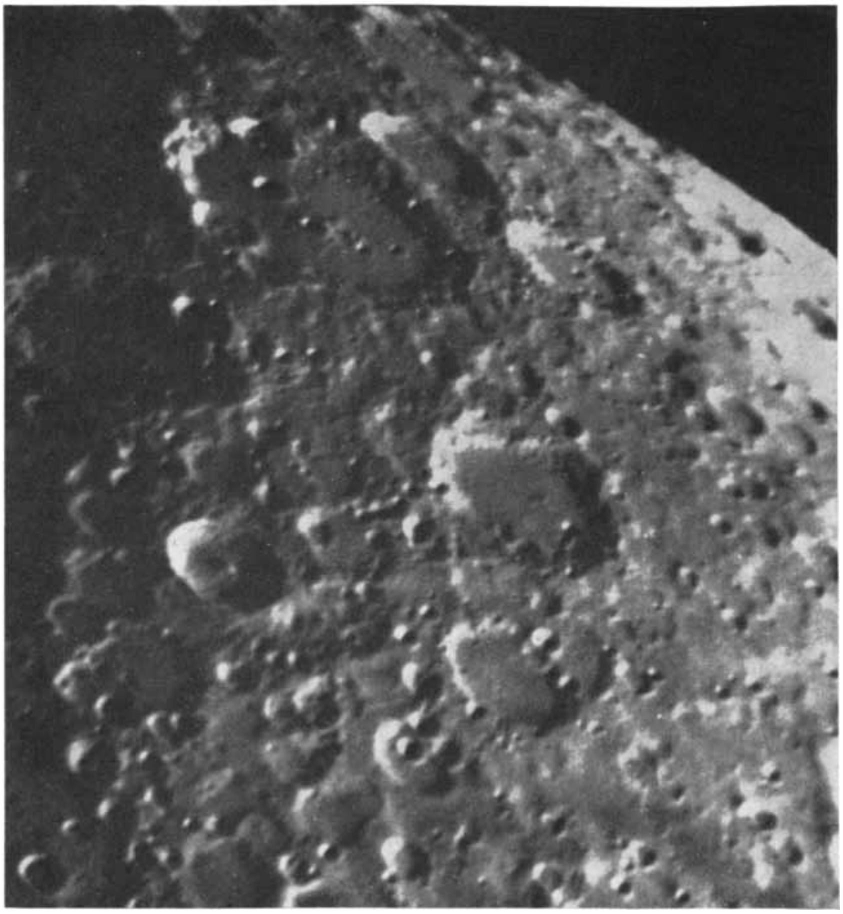
A HISTORY OF SPAIN AND PORTUGAL, by William C. Atkinson. Pelican Books ($1.45). This original paperback in the Pelican History of the World series covers the history of the Iberian Peninsula as a whole from Roman times to the present, treating wars, conquests, political events, the unfolding of the pattern of Spanish and Portuguese society, the growth of their civilizations, including literature and the arts.

INCOMPRESSIBLE AERODYNAMICS, edited by Bryan Thwaites. Oxford University Press ($12). This memoir, a synthesis of original contributions by some 16 specialists, is concerned mainly with the uniform flow of fluid past certain kinds of bodies (*e.g.*, airfoils) and with the methods by which we may predict the physical characteristics of such flow.

THE ART OF SCIENTIFIC INVESTIGATION, by W. I. B. Beveridge. Random House (95 cents). A Modern Library paperback of a relaxed and thoughtful essay on how scientific investigators go about their jobs, the questions and obstacles they encounter, the methods and stratagems they use and so on.

MACROMOLECULES IN CELL STRUCTURE, by A. Frey-Wyssling. Harvard University Press ($5). Based on the author's Prather Lectures at Harvard, this volume, with its fascinating illustrations, presents a few highlights of the submicroscopic structure of protoplasm, with the aid of the electron microscope and of such methods as polarizing microscopy and X-ray diffraction analysis.

DIRECT CONVERSION OF HEAT TO ELECTRICITY, edited by Joseph Kaye and John A. Welsh. John Wiley & Sons, Inc. ($8.75). The age-old dream having become a practical reality, this collection of papers discusses the new technology of direct conversion, dealing with high-



vacuum and low-pressure thermionic engines, magnetohydrodynamic converters, semiconductor devices and fuel cells.

ANCIENT SEMITIC CIVILIZATIONS, by Sabatino Moscati. Capricorn Books, G. P. Putnam's Sons ($1.65). This highly regarded brief synopsis, which sketches the salient features of the ancient Semitic civilizations, now appears as an attractive, illustrated paperback.

AERONAUTICAL DICTIONARY, by Frank Davis Adams. U. S. Government Printing Office ($1.75). A sound and useful 199-page dictionary which lists and defines about 4,000 aeronautical terms, and fundamental terms important to aeronautics in related fields such as physics, meteorology, navigation and space technology.

PHOTOCONDUCTIVITY OF SOLIDS, by Richard H. Bube. John Wiley & Sons, Inc. ($14.75). A unified physical description and interpretation of photoconductivity phenomena, drawing examples from many different kinds of materials.

THE LICHEN FLORA OF THE UNITED STATES, by Bruce Fink. University of Michigan Press ($12.50). Reissue of a manual published in 1935, which is admittedly out of date in many respects, but which is still a foundation for the study of lichens in this country.

THE PHYSIOLOGY OF CRUSTACEA, edited by Talbot H. Waterman. Academic Press Inc. ($22). A co-operative treatise, the first volume of which deals with metabolism and growth of this class of arthropods.

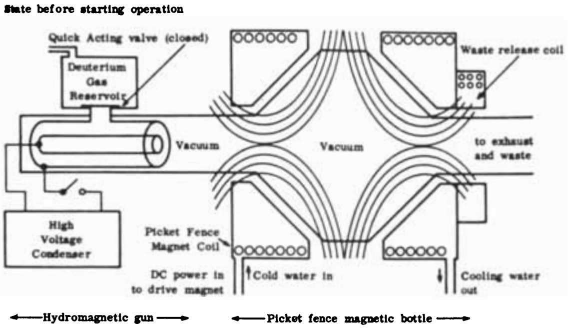
LE VOLCANISME LUNAIRE ET TERRESTRE, by Alexandre Dauvillier. Editions Albin Michel (1,200 francs). The earth was born in fire and, as the author of this book sets out to show, volcanic forces played a major part not only in shaping our planet, its ocean basin, oceans and atmosphere, but also in the evolution of the moon.

PROPULSION SYSTEMS FOR SPACE FLIGHT, by William R. Corliss. McGraw-Hill Book Company, Inc. ($10). A survey of the important propulsion concepts for flight beyond the atmosphere: chemical rockets, nuclear rockets, thermonuclear engines, plasma jets, ion drives, plasma accelerators, photon drives and solar sails.

PYTHON: A STUDY OF DELPHIC MYTH AND ITS ORIGINS, by Joseph Fontenrose.

Science non fiction at Los Alamos

Is this the shape of things to come in Sherwood?



The cusped geometry or picket fence was proposed back in 1954 independently by Grad at N.Y.U. and Tuck at Los Alamos, to get around hydromagnetic instability of plasma-magnetic field interfaces. Nobody did much about it at the time. The pinch effect seemed to hold more promise, so why bother about a leaky picket fence? A large magnet to produce a DC picket fence geometry was built but laid aside. For several years the stabilized toroidal pinch (called Perhapsatron at Los Alamos) held the stage. But as our measuring techniques got better, the pinches began to show a most sinister behavior. An apparently stabilized pinch which should have been radiating energy at the rate of several kilowatts, turned out to be losing it at a rate of hundreds of megawatts. As we got the impurities out of the system, the losses seemed to go down. One pinch (Perhapsatron S-5) has seemed so clean we are trying to raise its temperature to thermonuclear levels by pouring in more power.

Then there appeared the spectre of plasma oscillations and their evil effects on magnetic confinement. In principle, plasma oscillations can thrive on the interaction of a fast wind of plasma electrons moving through a slower cloud of plasma ions. This makes things look bad for the pinch effect, because the plasma has to have a large electric current in it, and therefore an electron wind.

The Russians delivered the next blow. Trubnikov and Kondryatsev predicted an enormous cyclotron radiation flux from a plasma containing a magnetic field. This would ruin the chances for DD reactors, and make things tough even for DT reactors. Among other complications, a nearly perfect mirror would have to be placed around the inner wall of the plasma container to reflect the radiation back.

Then Rosenbluth and Drummond argued that when the angular distribution is considered, the radiation isn't really so bad—say 1/50th of what T and K say. Now Trubnikov has come right back with another paper that says it is five times worse than R and D said it was. The above theories are pretty simple—the real problem is exceedingly difficult theoretically. It may be quite a while before there is anything new in this direction.

Anyhow, the point is that DD reactors with magnetized plasmas now seem to be out. But some people, like Tuck, claim that DD reactors are the only ones that make sense, since a DT reactor which must carry on its back a monstrosity of a tritium recovery plant could never compete with fission power anyhow.

This brings us to the point that if we want to have a DD reactor, it has to have no magnetic field in its plasma. So all right, don't put a magnetic field in the plasma. Unfortunately, there aren't any magnetic confinement systems stable enough to hold a pure plasma, except one. You've guessed it—it's the picket fence.

So we went back to the warehouse and dusted off the magnet we built long ago. Already it is going full blast, a second one has been built and a third one is on its way. Of course, we aren't alone any more in this field. Small cusped geometries are being studied at General Atomic, Livermore, Stevens, Harwell, Utrecht and Kharkov. Pretty soon we will have only picket fences and plasma guns at Los Alamos, aside from a few Scyllas to study plasma at thermonuclear temperatures, unless old Perhapsatron S-5 does something pretty spectacular.

The diagram of Picket Fence I (above), run by D. Hagerman and J. Osher, shows how plasma is injected as a slug, strong enough to push through the magnetic field and spread out inside. (This is called entropy trapping, but that's another story). Does it work? Well, that depends. It's a lot more complicated than we thought. At first, we nearly died of joy when the plasma was shot in and seemed to stay around for ages in our time scale (1000 microseconds), emitting light in the process. But when a magnetic probe was inserted, the harsh truth was revealed—the containment lasted only a few microseconds. In other words, the long time period we thought we had observed was merely cold plasma emitting light by recombination.

Just lately, however, Messrs. Hagerman and Osher have cleaned things up to the point that hot plasmas are pushing the field aside strongly and are keeping the inside field pushed aside for very satisfying periods, like 50 microseconds. Also, if we keep the magnetic probe out of the way of the plasma, it stays around longer, which is what it should do. This particular picket fence is a horror to keep a vacuum in, as it is completely overrun with O rings. The next one will be baked. Fun, eh?

What about the leaks in the fence? It is pretty leaky, but we think we have an answer to that too, so watch for the story on the TLC picket fence one of these days.

University of California Press ($10). A comparative study of combat myths and hero legends in diverse cultures, among them those of Greece, Anatolia, Canaan, Mesopotamia, Egypt, India, China, Japan, Germanic Europe, medieval Christendom, Central America and the Pacific Coast of the U. S.

Physique et Physiciens, by R. Massain. Editions Magnard (800 francs). Fourth edition of a popular, illustrated survey of physics and physicists from ancient times through the present. The material consists of selections from the classical writings, with commentaries by the editor.

Confluent Hypergeometric Functions, by L. J. Slater. Cambridge University Press ($12.50). A discussion for the mathematical physicist of all the main properties of the confluent hypergeometric functions and the Whittaker functions.

The Nature of Physical Reality, by Henry Margenau. McGraw-Hill Book Company, Inc. ($2.95). A paper-back reprint of Margenau's essay on the philosophy of modern physics, first published in 1950.

Readings in the Literature of Science, edited by William C. Dampier and Margaret Dampier. Harper & Brothers ($1.50). A paper-back reprint of the best compact sourcebook of cosmogony, atomic theory and evolution.

The Structure of Scientific Thought, edited by Edward H. Madden. Houghton Mifflin Company ($5). A collection of excerpts and articles on the philosophy of science, containing a better-than-average assortment pertaining to crucial experiments, measurement, philosophy of physics, biology and social science, the meaning of "cause" and of "law," notions of probability, induction, science and values.

Stratigraphic Principles and Practice, by J. Marvin Weller. Harper & Brothers ($10). A comprehensive account of those features of sedimentology, paleontology, tectonics and their problems that particularly apply to stratigraphy. Illustrations and extended bibliographies.

The Analysis of Variance, by Henry Scheffé. John Wiley & Sons, Inc. ($14). A unified presentation of the basic theory of the analysis of variance, the most widely used technique in statistics.

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AUGUST, 1960

Electronics: key to the

secret sea

Hughes engineers and scientists are developing entirely new concepts in electronics to produce effective Underseas Warfare Systems.

Applying their skills to each of the many elements of the problem is but part of the job. The real key is integration of these elements into effective systems.

Working with the Navy, Hughes engineers have instituted a complete systems analysis, or "information environment" approach.

This Hughes "systems orientation" has the unique advantage of drawing on the multifaceted abilities of thousands of engineers with experience acquired in developing scores of successful Hughes systems. These include: airborne electronic armament systems, which can control an entire mission; 3-dimensional radar systems, which constitute the most important advance in the state of the art since radar itself was invented; Falcon guided missiles, which are the most advanced weapons of their type—just to name a few.

Rather than taking standard approaches to the USW problem, Hughes engineers are using a wide variety of electronic disciplines. Studies presently underway include: research in acoustic array systems (both fixed and mobile); radar and IR detection systems; magnetic anomaly detection systems; information, command and controls systems for strategic decision-making and for tactical operations; communications systems; signal recovery techniques; human factors studies.

Hughes advanced projects in Underseas Warfare development are just part of a great number of activities which offer creative engineers a number of opportunities. Some of these are: miniaturized communications systems, new solid state electronics devices, nuclear electronics systems, and others.

The commercial activities of Hughes have many interesting projects for engineers in the research, development and manufacture of semiconductors, microwave components, storage tubes, radiation detectors, radiation handling equipment and microwave tubes.

Whatever your field of interest, you'll find Hughes' diversity of advanced projects gives you widest possible latitude for professional and personal growth.

Newly instituted programs at Hughes have created immediate openings for engineers experienced in the following areas:

Computer Components	Semiconductors
Infrared	Microwave & Storage Tubes
Crystal Filters	Communications Systems
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Write in confidence to Mr. M. W. Welds
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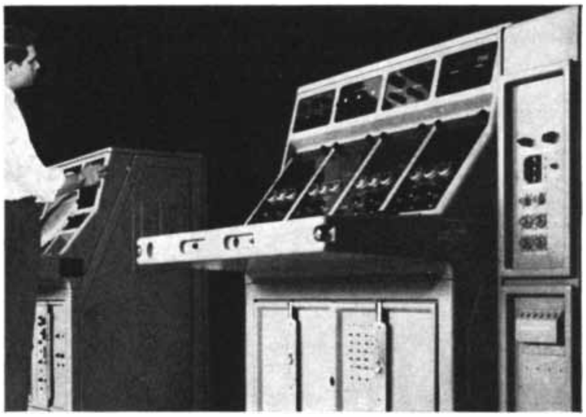
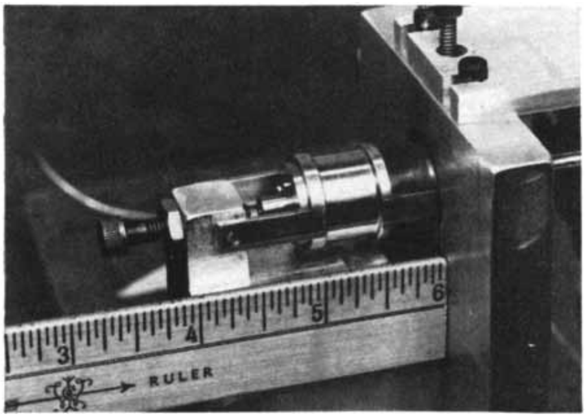
This simulated Navy Combat Information Center uses Hughes advanced information and display systems to unite hundreds of pieces of surveillance data into a meaningful total.



To study ultrasensitive infrared systems for USW, Hughes engineers have developed this prototype miniature super refrigerator which cools sensitive elements to temperatures as low as —260°C.



Creating a new world with ELECTRONICS

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BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

VERTICAL-TAKEOFF AIRCRAFT

AN ASSESSMENT OF INFORMATION ON VTOL/STOL AIRCRAFT AS APPLIED TO COMMERCIAL TRANSPORTS. Philip Donely and Marion O. McKinney, Jr. Paper No. 60-AV-30. American Society of Mechanical Engineers, 1960.

PROBLEMS IN THE DESIGN OF PROPELLER-DRIVEN VERTICAL TAKE-OFF TRANSPORT AIRPLANES. M. O. McKinney, R. E. Kuhn and J. B. Hammack in *Aeronautical Engineering Review*, Vol. 15, No. 4, pages 68-75; April, 1956.

RESEARCH ON VTOL AND STOL AIRCRAFT IN THE UNITED STATES. John P. Campbell in *Advances in Aeronautical Sciences*, Vol. II, pages 845-892. Pergamon Press, Inc., 1960.

VTOL ISSUE. *Journal of the American Helicopter Society*, Vol. 4, No. 1; January, 1959.

RADAR ASTRONOMY

EXTRATERRESTRIAL RADIO ECHOES. J. L. Pawsey and R. N. Bracewell in *Radio Astronomy*, pages 293-305. Oxford University Press, 1955.

METEORS. J. L. Pawsey and R. N. Bracewell in *Radio Astronomy*, pages 306-338. Oxford University Press, 1955.

RADAR ECHOES FROM THE SUN. V. R. Eshleman, R. C. Barthle and P. B. Gallagher in *Science*, Vol. 131, No. 3,397, pages 329-332; February 5, 1960.

RADIO ASTRONOMY. John Pfeiffer in *The Changing Universe*, pages 198-214. Random House, 1956.

RADIO ASTRONOMY SYMPOSIUM REPORT. Ray L. Leadabrand in *Journal of Geophysical Research*, Vol. 65, No. 4, pages 1,103-1,118; April, 1960.

RADIO AND THE AURORA BOREALIS. R. Hanbury Brown and A. C. B. Lovell in *The Exploration of Space by Radio*, pages 171-177. Chapman and Hall Ltd., 1957.

RADIO ECHO OBSERVATIONS OF VENUS. J. V. Evans and G. N. Taylor in *Nature*, Vol. 184, pages 1,358-1,359; October 31, 1959.

RADIO INVESTIGATIONS OF THE MOON, PLANETS AND THE EARTH SATELLITE. R. Hanbury Brown and A. C. B. Lovell in *The Exploration of Space by Radio*, pages 178-191. Chapman and Hall Ltd., 1957.

PATTERN RECOGNITION BY MACHINE

DISCUSSION OF PROBLEMS IN PATTERN RECOGNITION. W. W. Bledsoe, J. S. Bomba, I. Browning, R. J. Evey, R. A. Kirsch, R. L. Mattson, M. Minsky, U. Neisser, O. G. Selfridge in *Proceedings of the Eastern Joint Computer Conference*, pages 233-237; 1959.

HOW WE KNOW UNIVERSALS: THE PERCEPTION OF AUDITORY AND VISUAL FORMS. Walter Pitts and Warren S. McCulloch in *The Bulletin of Mathematical Biophysics*, Vol. 9, No. 3, pages 127-147; 1947.

MACHINE RECOGNITION OF HAND-SENT MORSE CODE. Bernard Gold in *IRE Transactions of the Professional Group on Information Theory*, Vol. IT-5, No. 1, pages 17-24; March, 1959.

THE ORGANIZATION OF BEHAVIOR. D. O. Hebb. John Wiley & Sons, Inc., 1949.

BEACHES

MARINE GEOLOGY. Ph. H. Kuenen. John Wiley & Sons, Inc., 1950.

PROCEEDINGS OF THE SIXTH CONFERENCE ON COASTAL ENGINEERING. Edited by J. W. Johnson. Council on Wave Research—The Engineering Foundation, 1958.

SHORE PROCESSES AND SHORELINE DEVELOPMENT. Douglas Wilson Johnson. John Wiley & Sons, Inc., 1919.

WAVES, TIDES, CURRENTS AND BEACHES: GLOSSARY OF TERMS AND LIST OF STANDARD SYMBOLS. Robert L. Wiegel. Council of Wave Research—The Engineering Foundation, 1953.

BIOLOGICAL TRANSDUCERS

THE GENERATION OF ELECTRIC ACTIVITY IN A NERVE ENDING. Werner R. Loewenstein in *Annals of the New York Academy of Sciences*, Vol. 81, Article 2, pages 367-387; August 28, 1959.

THE PHYSICAL BACKGROUND OF PERCEPTION. E. D. Adrian. Oxford University Press, 1947.

RECEPTORS AND SENSORY PERCEPTION. Ragnar Granit. Yale University Press, 1955.

PEASANT MARKETS

THE ECONOMICS OF MARKETING REFORM. P. T. Bauer and B. S. Yamey in *The Journal of Political Economy*, Vol. LXII, No. 3, pages 210-235; June, 1954.

INTERNAL MARKET SYSTEMS AS MECHANISMS OF SOCIAL ARTICULATION. Sidney W. Mintz in *The Proceedings of the 1959 Annual Spring Meeting of the American Ethnological Society*, pages 20-30; 1959.

THE JAMAICAN INTERNAL MARKETING PATTERN: SOME NOTES AND HYPOTHESES. Sidney W. Mintz in *Social and Economic Studies*, Vol. 4, No. 1, pages 95-103; March, 1955.

TRADE AND MARKET IN THE EARLY EMPIRES. Edited by Karl Polanyi, Conrad M. Arensberg and Harry W. Pearson. The Free Press, 1957.

WEST AFRICAN TRADE. Pèter Tamàs Bauer. Cambridge University Press, 1954.

THE STRUCTURE OF LIQUIDS

KINETIC THEORY OF LIQUIDS. J. Frenkel. Dover Publications, Inc., 1955.

THE KINETIC THEORY OF MONATOMIC LIQUIDS. G. H. A. Cole in *Reports on Progress in Physics*, Vol. XIX, pages 2-36; 1956.

LIQUIDS AND LIQUID MIXTURES. J. S. Rowlinson. Butterworths Scientific Publications, 1959.

MOLECULAR THEORY OF GASES AND LIQUIDS. Joseph O. Hirschfelder, Charles F. Curtiss and R. Byron Bird. John Wiley & Sons, Inc., 1954.

THE STRUCTURE OF LIQUIDS. J. D. Bernal in *Proceedings of The Royal Institution*, Vol. 37, No. 168, pages 355-393; 1959.

FRIENDLY VIRUSES

BENEFICIAL EFFECT OF VIRUS-DISEASED PLANTS ON NON-VECTOR INSECTS. Karl Maramorosch in *Tijdschrift over Plantenziekten*, Vol. 64, No. 5-6, pages 383-391; 1958.

MATHEMATICAL GAMES

ON CLOSED SELF-INTERSECTING CURVES. Hans Rademacher and Otto Toeplitz in *The Enjoyment of Mathematics*, pages 61-65. Princeton University Press, 1957.

THE AMATEUR SCIENTIST

CLOCK REPAIRING AND MAKING. F. J. Garrard. C. Lockwood and Son, 1920.

ELECTRICAL TIMEKEEPING. F. Hope-Jones. N. A. G. Press Ltd., 1940.

THE SCIENCE OF CLOCKS AND WATCHES. A. L. Rawlings. Pitman Publishing Corporation, 1944.

Basic Research at Honeywell
Dr. Finn Larsen
Vice President for Research

Thermal Radiation: Studies In Emittance And Reflectance Properties of Materials

Because of possible high temperatures and the absence of an atmosphere, radiation becomes the primary method of heat transfer in space. Current interest in space exploration makes it mandatory to accurately determine the reflectance and emittance of various materials. Honeywell scientists have developed new techniques that promise useful new data on this method of heat transfer.

Heat transfer can take place in only three ways: convection currents, conduction, and radiation. Radiation becomes increasingly important to scientists because, at high temperatures or in a vacuum, it is the predominant or possibly the sole form of heat transfer. An understanding of radiation is particularly important today as man looks ahead to space travel. In space the vacuum exists, and high intensity heat radiation will be encountered.

In discussing heat transfer by radiation, clear terminology is important. Reflectance refers to that fraction of incident radiation that is reflected. The remaining fraction not reflected is absorbed when it strikes an opaque body. When given a numerical value it is called absorptance, and if the surface is at the same temperature as the radiator, absorptance is exactly equal to emittance. Emittance is the amount of energy emitted by a body related to the energy emitted by a perfect emitter given a value of unity. Thus, if reflectance (ρ) equals x, then absorptance (α) equals 1—x. And under conditions of temperature equilibrium, emittance (ϵ) also equals 1—x.

In transferring heat through radiation, the reflectance and emittance of surfaces determine the amount of heat transferred, and the understanding of emittance becomes the key to the heat transfer problems occurring in space.

Complicating our understanding of emittance is the fact that emittance is a function of the temperature of the surface under consideration. Also, emittance varies with the wave length of radiation.

The problem in the study of emittance over the years has been the inability to obtain consistent data. Various authorities have reported widely differing results. Contributing to these differing results is the inability to specifically describe identical surfaces and to repeat identical experimental conditions.

Additional problems complicating the ability to make comparable quantitative measurements are:

1) Energy from surrounding extraneous bodies is often reflected.
2) The measuring instrument cannot differentiate between reflected and emitted energy from the test specimen.
3) The amount of energy emitted varies with the angle of incidence with respect to the surface of the specimen.
4) Slight impurities can change the emittance characteristics of the specimen.
5) The atmosphere absorbs energy, thus the atmospheric pressure under which the observations are made is significant.

Honeywell scientists, however, have developed a new technique that avoids most of these problems. Their approach is to measure the spectral reflectance from which they can calculate spectral emittance. Total emittance and, therefore, total absorptance can be calculated by integrating spectral emittance.

Prior to the development of this technique, only a limited range of the spectrum could be measured by a single procedure. Different techniques and equipment were necessary to measure the remainder of the spectrum. The resulting multiplicity of procedures and equipment frequently introduced discrepancies.

With the Honeywell technique, monochromatic energy from an infra-red spectrometer is beamed on a diffuse reflector surface. The diffuse reflector is located at one of two conjugate foci of a highly reflecting integrating hemisphere. The energy is reflected by the diffuse reflector to the hemisphere. The hemisphere collects the energy and focuses it on the specimen located at the adjacent focus. Some of this energy is reflected out through a small port in the hemisphere to a sensor.

A complex equation involving the unknown reflectance and the known reflectance of a previously determined reference makes possible the calculation of the reflectance of the specimen.

It is possible to measure reflected energy in the presence of emitted energy, since all energy entering the system from the monochrometer is "chopped" at 13 cycles per second. Thus, energy reflected will also be at 13 cycles per second while inherently emitted energy will be continuous radiation.

Honeywell's apparatus and technique represents extensions of earlier work in the field. They are unique, however, in combining a monochromatic beam, an outside sensor, and a hemispheric reflector.

An important immediate result of the work done by Honeywell scientists is the ability to determine the specific emittance characteristics of different anodizing techniques for several different metals. Thus, accurate specification of an anodizing technique will predetermine the desired emittance. Ultimately it will permit specification of the entire surface of a space vehicle, allowing it to operate at predetermined temperature ranges in space. There are also several important industrial processes to which such knowledge would bring substantial improvement. Honeywell has as an eventual goal the control and adjustment of emittance in flight.

If you are engaged in scientific work relating to emittance and reflectance, and would like to know more about Honeywell's research, you are invited to correspond with Mr. J. E. Janssen, Honeywell Research Center, Hopkins, Minnesota. If you wish a recent paper by Mr. Janssen, write to Honeywell Research, Minneapolis 8, Minnesota.

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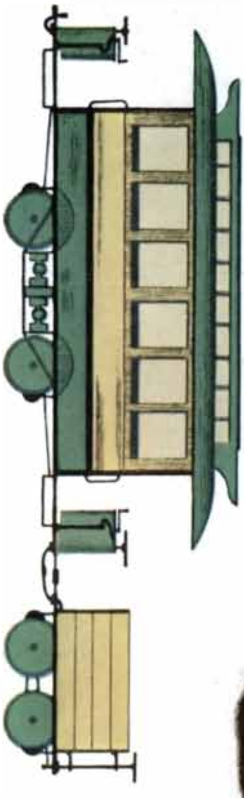

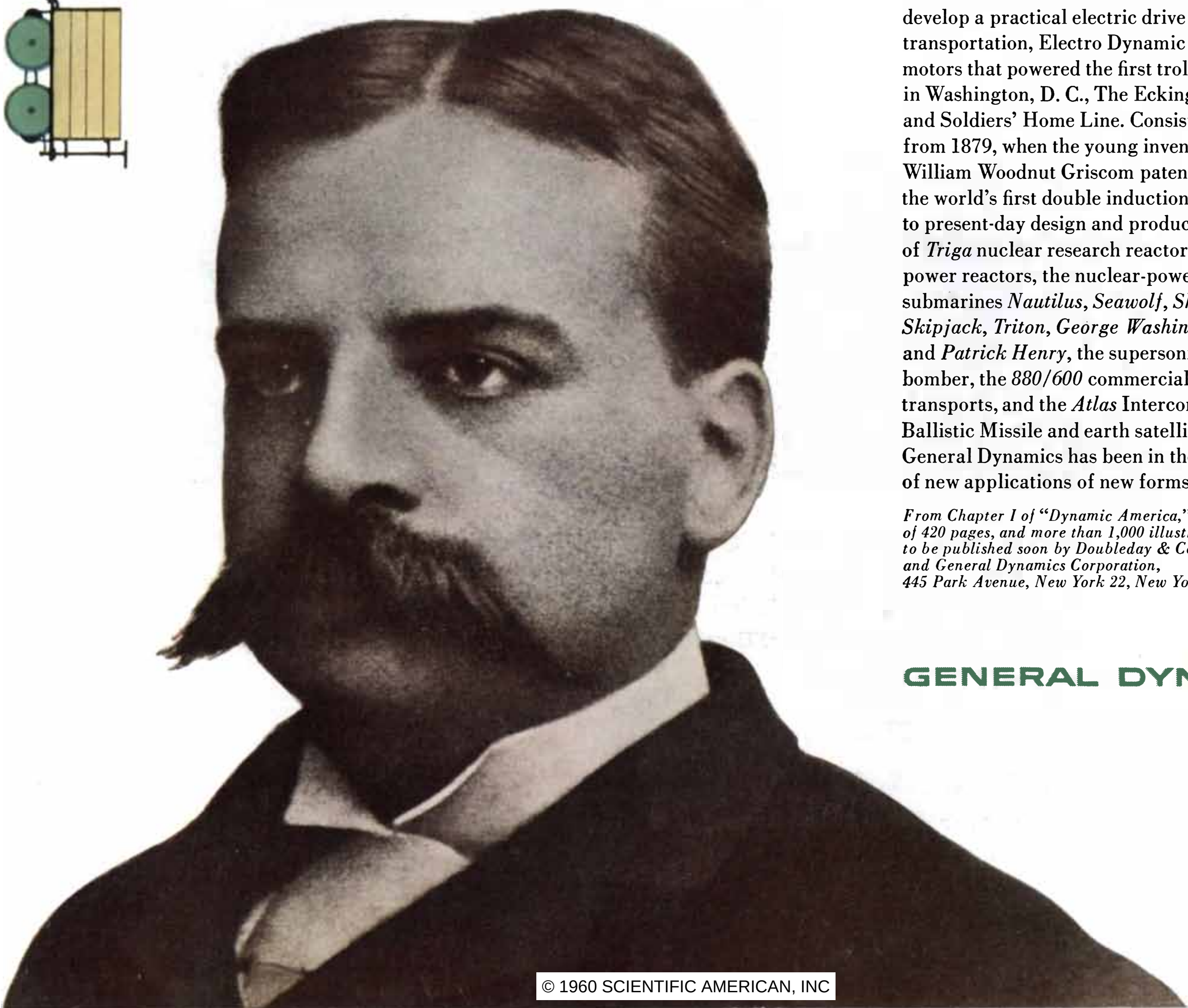

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