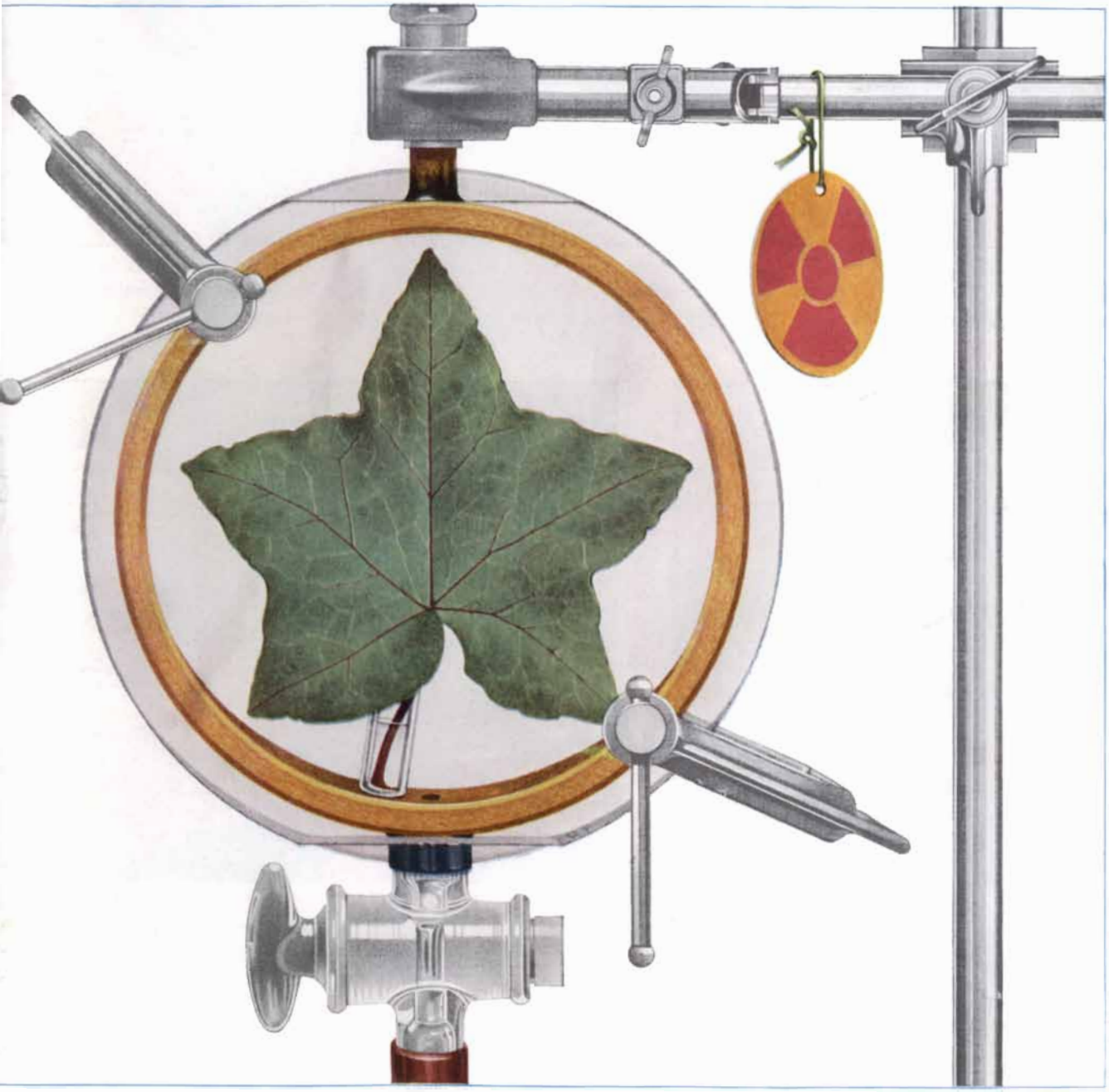
SCIENTIFIC AMERICAN



PHOTOSYNTHESIS EXPERIMENT

FIFTY CENTS

June 1962

"ZIPPER"-STOPPER KEEPS VINYL CRYSTAL CLEAR: Heat or sun exposure on many plastics triggers a "zipper" reaction which quickly travels down the polymer molecule chain causing discoloration and degradation of the material. But M&T's THERMOLITE® organotin stabilizers block this molecular weakening. Very small amounts keep vinyl plastics such as convertible back windows crystal clear through high temperature processing and long outdoor service.

CHEMICAL COATINGS SHIELD MOLTEN METALS: Metals being welded should not suffer chemical change. Coatings on "MUREX" electrodes shield the molten metal, inhibit reaction. An iron powder coating does still more. It increases amount of metal deposit, improves arc characteristics. Iron Powder Electrodes are among M&T's electrodes for metals of almost every analysis.

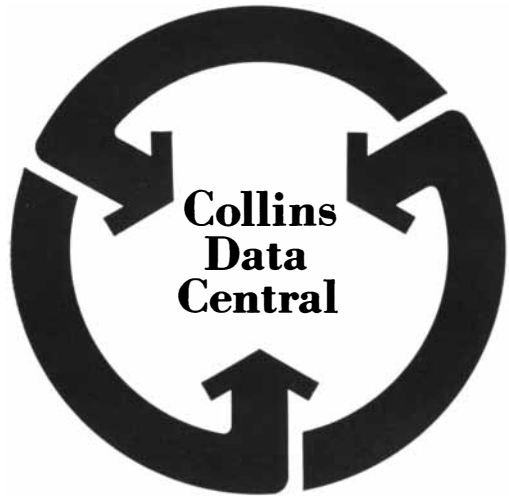
MICRON PARTICLES WEIGH HEAVILY IN COLOR BALANCE: In high temperature chemistry of ceramic glaze opacification, particle size is critical. Carefully controlled sub-micron particles of M&T ULTROX® zirconium silicate make white glazes brighter, but particles of another ULTROX grade just a micron or two larger opacify without "killing" expensive stains in color glazes.

M&T's chemistry...the magic ingredient. Solving problems for diverse industries, it enables vinyl plastics to defy aging, ceramic tiles to reflect complete uniformity, metals to be joined for good. In all of M&T's divisions, chemistry and metals meet in one way or another. Our customers benefit from this union.

METAL & THERMIT CORPORATION

General Offices: Rahway, N. J. • CHEMICALS • COATINGS • CERAMICS • MINERALS • WELDING PRODUCTS • PLATING PRODUCTS • DETINNING

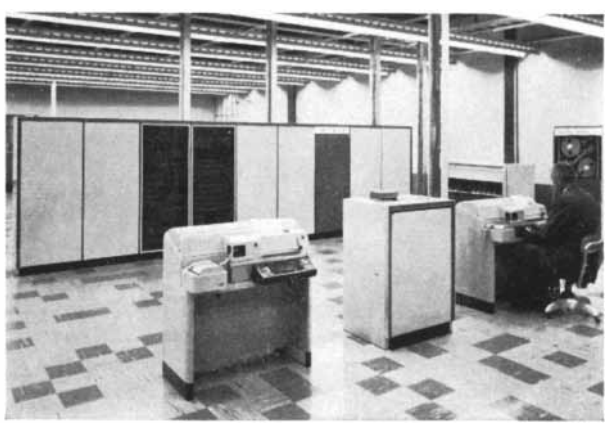
Announcing:



A fast, flexible electronic switching center for your company's communication network

Data Central offers you new advantages and economies because it is designed specifically as a communication processing system. Its direct TTY connections save you the cost of line conversion equipment. It gives you micro-second speed in switching messages from incoming to outgoing lines. It can be organized, as no other system can, to meet your own *specific* TTY requirements, and it accommodates any change in your requirements.

A unique, solid-state processor gives Data Central its flexibility. This processor has two memories — a conventional computer memory, and a *Programmed Logic Unit.* This unit performs functions handled by fixed wiring in other processors. By removing fixed wire restrictions, Data Central gives you the freedom you need to organize an automatic switching center to meet your specific communication needs . . . and to change the operation of your center as your requirements vary. All that's required are simple changes in the Programmed Logic.



Here are other features of this versatile switching system:

Conventional TTY operation — Serial, mixed speed on full or half duplex lines.

Store and forward — Messages awaiting free circuits are held in temporary storage.

Multiple priority — Immediate interrupt for no-delay priority messages.

Multiple address — From a two-station to all-station broadcast as each circuit becomes available.

Automatic conversion — Code, speed and format, concurrent with switching.

No lost messages — Automatic message accounting, queuing and check-off.

Accuracy — Internal parity check. System check optional.

Traffic analysis — Historical files permit message retrieval for analysis, logging and retransmission.

High-speed trunking — Collins Kineplex® high-speed data transmission systems operate under stored program control of the Data Central processor.

System balance — Handles peak loads efficiently.

Expandability — Processor memories, storage and input-output devices, and TTY circuits are expandable to meet changes.

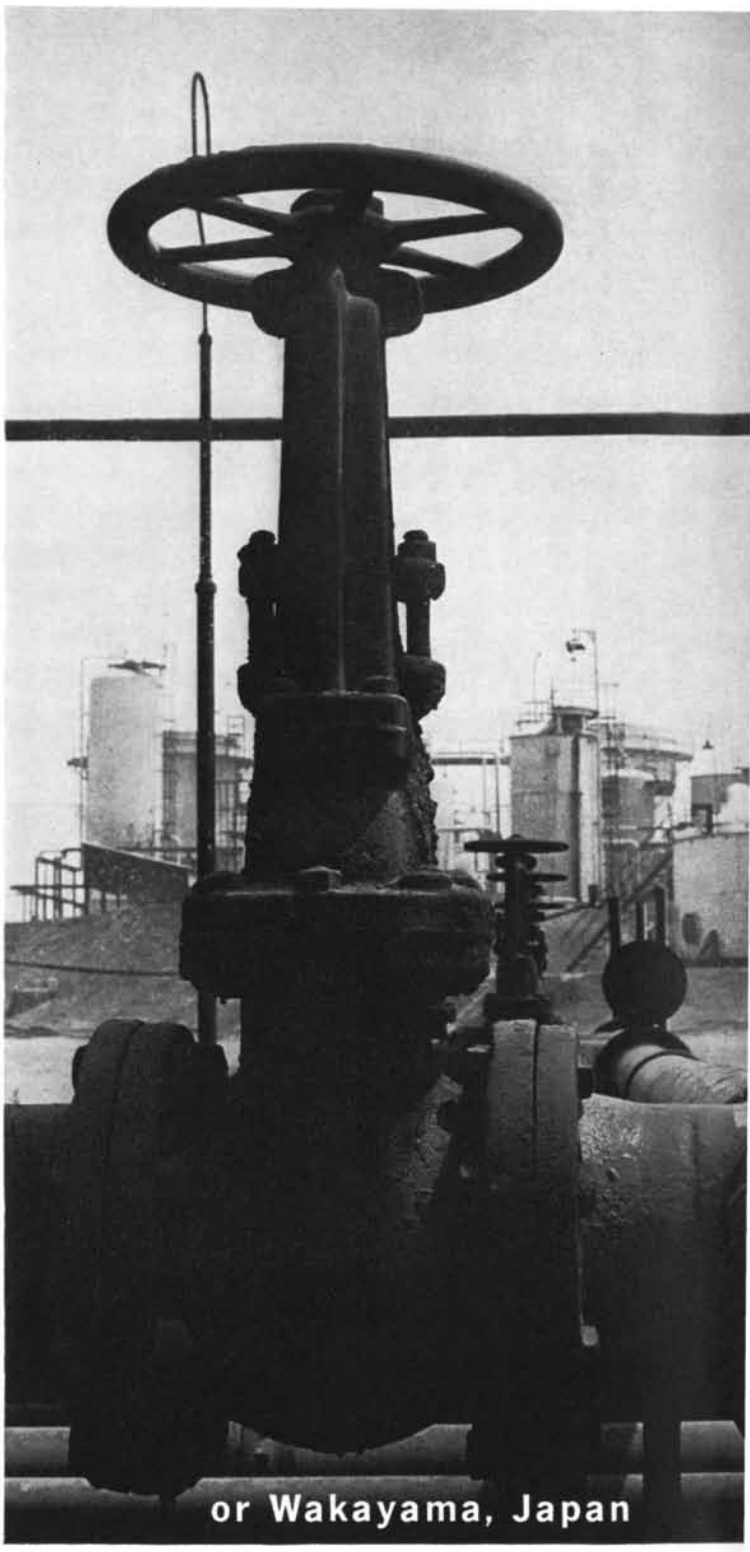
Complete customer service — Includes installation, maintenance, programming and training.

Data processing, too. The Data Central processor is also capable of handling both scientific and business data processing assignments. This system is the first to be made commercially available from Collins' new C-8000 Series of communication and data systems. Find out why leading companies are turning to Data Central . . . how it can advance your own communication capabilities. Write:

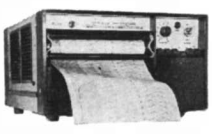
COMMUNICATION AND DATA SYSTEMS DIVISION, COLLINS RADIO COMPANY, DALLAS, TEXAS.

FOR THE BEST COMMUNICATION OF BUSINESS INFORMATION . . . CALL COLLINS

COLLINS



CEC instruments deliver the facts



A multi-channel oscillograph makes a continuous record of acceleration, pressures, and strain in parachute capsule ejection tests made at supersonic speeds.

An analytical mass spectrometer makes qualitative and quantitative analyses of gases and liquids from various parts of a refinery to give better process control data.

And they're both from CEC – instruments that deliver CEC's important end product: FACT... mathematical fact... vast amounts of vital information obtained quickly, accurately and reliably. CEC's field is broad – instruments for measuring and recording of physical phenomenon, analytical instruments, process control instrumentation, high vacuum technology. If information is a key element in your operations... whether in research and development or in production... CEC instrumentation may be of service to you. Why not see? Your request will bring our new 28-page brochure describing CEC's capabilities. Ask for Bulletin CEC 101.

CONSOLIDATED ELECTRODYNAMICS

Analytical & Control Division, Transducer Division,
Data Recorders Division, DeVar-Kinetics Division,
Consolidated Vacuum Corporation

a subsidiary of Bell & Howell

Pasadena, Calif.

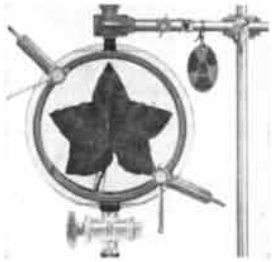
CEC

Established 1845 **SCIENTIFIC AMERICAN** June 1962 Volume 206 Number 6

ARTICLES

DEPARTMENTS

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



THE COVER

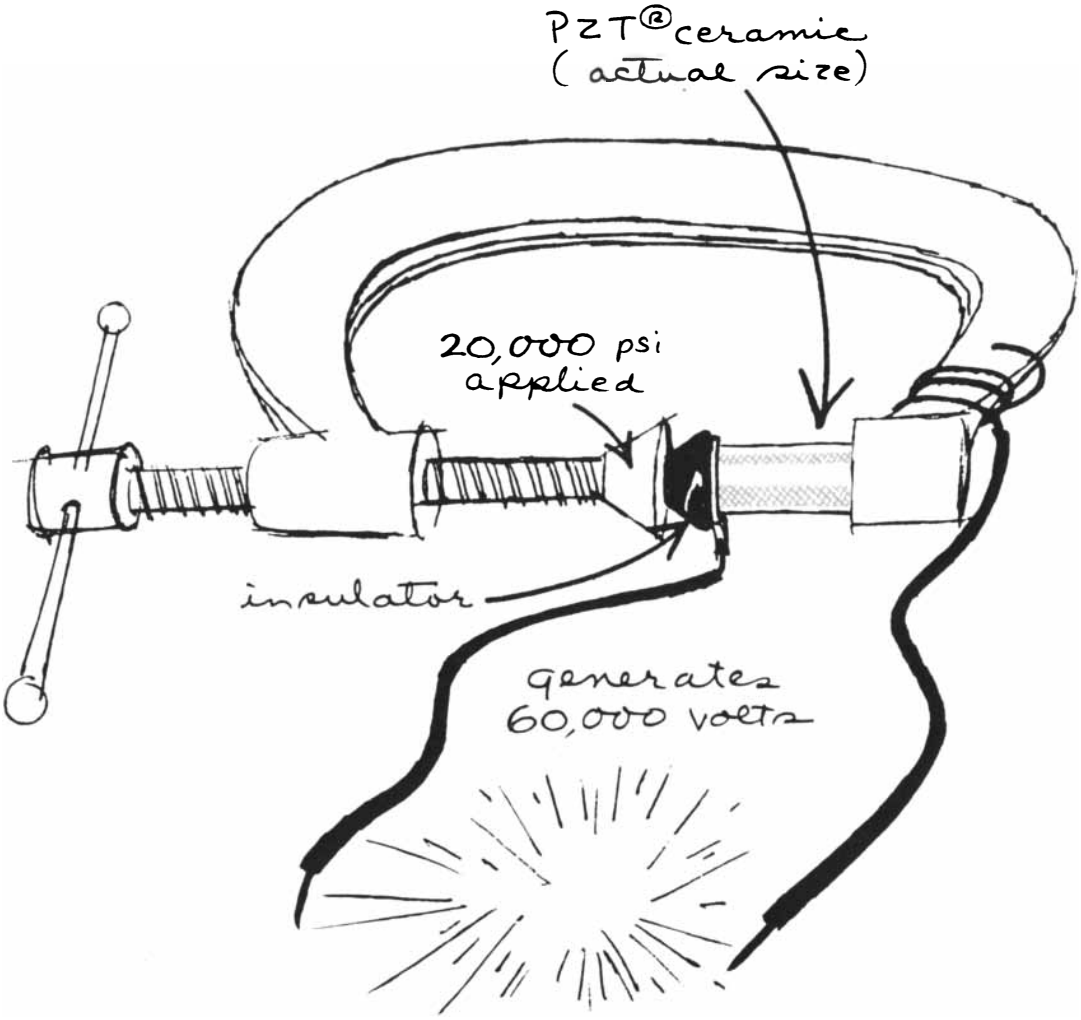
The painting on the cover shows part of the apparatus used in early experiments on the path of the element carbon in the process of photosynthesis (see "The Path of Carbon in Photosynthesis," page 88). The large circular object at the left side of the painting is a chamber consisting of two glass plates and a brass ring. One plate is cemented to the ring; the other is held in place by the clamps at upper left and lower right. Within the chamber is an ivy leaf with its stem in a small vial of water. At the beginning of the experiment ordinary air is introduced into the chamber. Illuminated through the walls of the chamber, the leaf takes up the carbon dioxide in the air in the course of photosynthesis. After a few minutes the air is flushed from the chamber and air containing carbon dioxide labeled with the radioactive isotope carbon 14 is introduced. The leaf then takes up the radioactive carbon dioxide. Soon thereafter the leaf is removed from the chamber and immersed in alcohol, which denatures the enzymes in the leaf and stops its biochemical activity. In this way the pattern of reactions in the leaf that involve the atoms of radioactive carbon is "frozen" and the path of carbon in the reactions can be traced. In later experiments green algae suspended in water were found preferable to leaves. The round tag at upper right is a warning that radioactive material is being used in the experiment. The horizontal shaft at top and the vertical shaft at right are part of the stand supporting the apparatus. The experiment was performed in the Lawrence Radiation Laboratory of the University of California.

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

Page	Source
55–59	Joan Starwood and Mary Russel
61	William Vandivert
62–67	James Egleson
69–70	Alex Semenoick
72	Victor H. Yngve, Massachusetts Institute of Technology
73–76	Alex Semenoick
88	Jon Brenneis
89–93	Dan Todd
94–95	J. A. Bassham, University of California
96	Alex Semenoick
97	Dan Todd
98–99	Jon Brenneis
100	Alex Semenoick
105	Jean de Heinzelin, Geological Institute, University of Ghent
106–113	Irving Geis
114	Jean de Heinzelin, Geological Institute, University of Ghent (*left*); Irving Geis (*right*)
116	Jean de Heinzelin, Geological Institute, University of Ghent
119–125	Thomas Prentiss
129	Ron Church (*top*), Jerry Greenberg (*bottom*)
130–134	Bunji Tagawa
137	Jan Hahn, Woods Hole Oceanographic Institution
142–143	David Linton
144–145	Hans Berger (*left*), Hatti Sauer (*right*)
146	David Linton
148–152	Hatti Sauer
158–162	Patra McElwee
172–178	Roger Hayward

NEW PARAMETERS IN PIEZOELECTRICITY



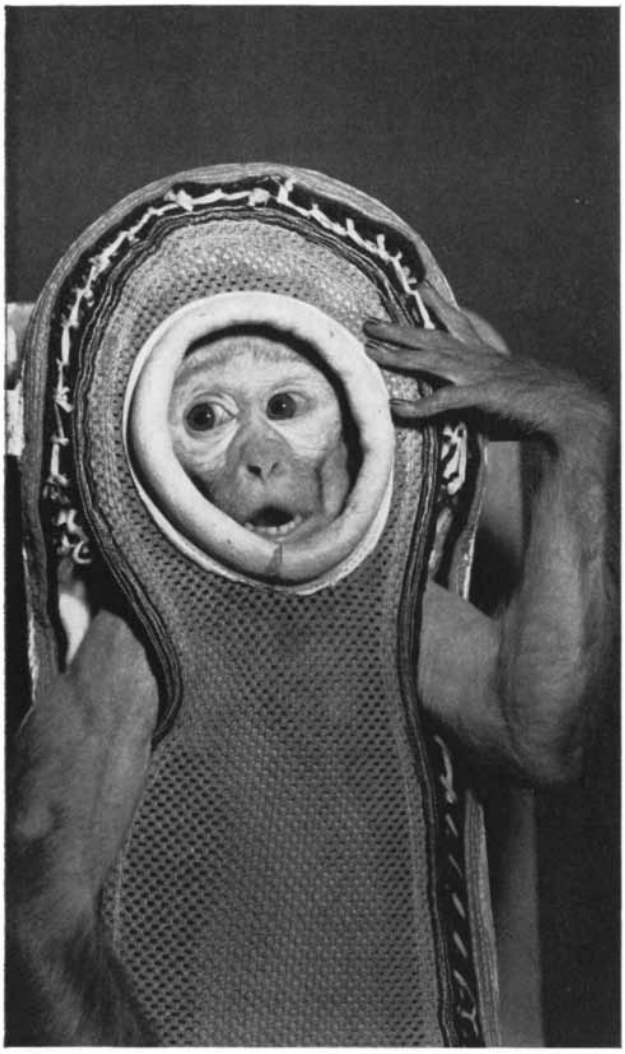
. . . 10 times more power conversion than any other solid state material

One pound of PZT piezoelectric ceramic is capable of converting 11 hp. dynamic stress directly to 7,500 watts. The reverse phenomenon—converting electrical charge to mechanical force—is equally important and challenging for many new design applications. This unique conversion factor illustrates the new power handling ability of Clevite's piezoelectric materials. Other properties include stability at temperatures ranging from the freezing point of liquid hydrogen to +500°F, and dependable performance after millions of cycles—they virtually never wear out when properly applied. In addition, they cannot be matched in power delivered per dollar invested.

Economical PZT materials, uniformly produced in many shapes and sizes by Clevite Electronic Components, are at work now in applications ranging from precision laboratory instruments to mass-produced ignition systems. Whatever your field of interest—astronautics or automation, communications or ultrasonics, or the many new areas of engineering—here are design materials well worth your evaluation. ■ Useful data on piezoelectric design is available. We'll appreciate your request on company letterhead.

CLEVITE
ELECTRONIC
COMPONENTS
DIVISION OF CLEVITE CORPORATION
232 FORBES ROAD, BEDFORD, OHIO

Vitro serves the space effort with imagination . . .



The Eglin Gulf Test Range, site of important missile tests, space probes and experimental weapons development, is a prime Mercury tracking station as well. The 1000 Vitro engineers and technicians here, collect critical take-off and re-entry data of orbital and other flights. These services can be applied to other military and commercial electronics needs.

from Little Joe to Col. John . . .

Vitro scientists working on Navy ASW and other classified programs, have developed radical, new concepts of underwater communications . . . one result, free-payout wire coils up to 20 miles long. Exploring outer space, Vitro is project manager for Princeton's Stratoscope II, instrument-laden balloon that will send back telescopic data from the edge of space.

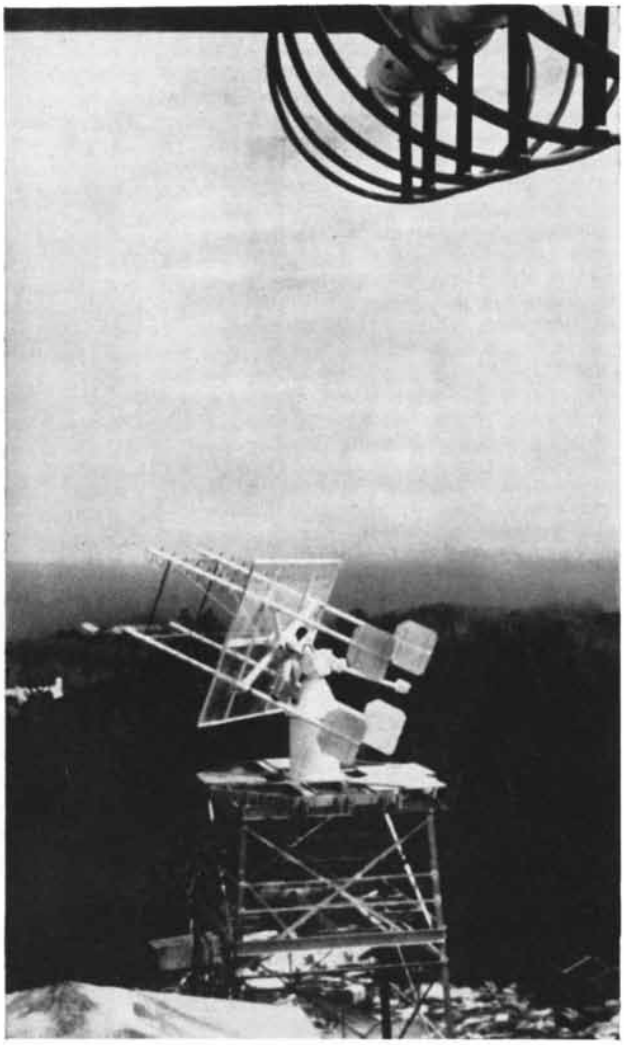
from inner space to outer space . . .

Vitro CORPORATION OF AMERICA

261 MADISON AVENUE • NEW YORK 16, NEW YORK

DIVISIONS: Vitro Chemical Company • Vitro Electronics • Vitro Engineering Company • Vitro Laboratories • Vitro International

experience . . . organization . . .



In preparation for the Apollo and Gemini test shots, as well as for Projects Mercury and Centaur, NASA is now installing the newest Vitro telemetry equipment in its world-wide tracking complex. The receivers being supplemented are also by Vitro Electronics. We believe this is the most advanced production-line telemetry equipment ever designed.

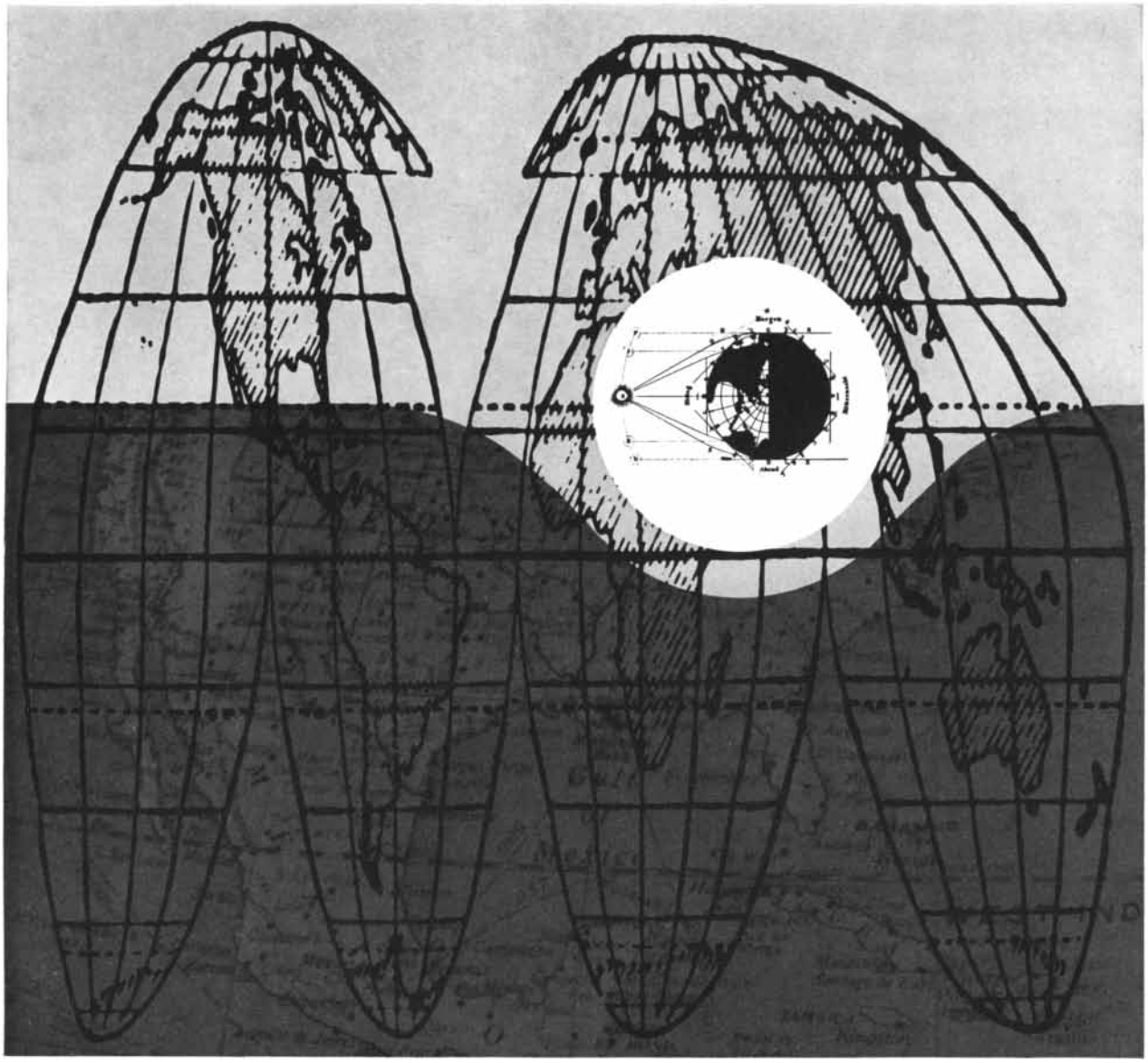
from Kano to Kauai . . .

Italy's Air Force has asked Vitroselenia to design, build and instrument a missile range on Sardinia to serve NATO's needs. Around the world at Jackass Flats, Nevada, Vitro is designing and engineering major test facilities for nuclear-powered space vehicles. These Vitro engineering skills are available for space, military and commercial installations.

from Mediterraneo to moon . . .

These varied abilities are interlinked within the Vitro organization to provide full technical competence from initial R&D through project management. Vitro ingenuity, keyed to United States space efforts, serves industry as well as government—in electronics, in chemistry, in metallurgy, in nucleonics. It will pay you to talk to Vitro at the planning stage. We'd like to send you a 1962 Vitro capabilities brochure. Write today to Department 27C.

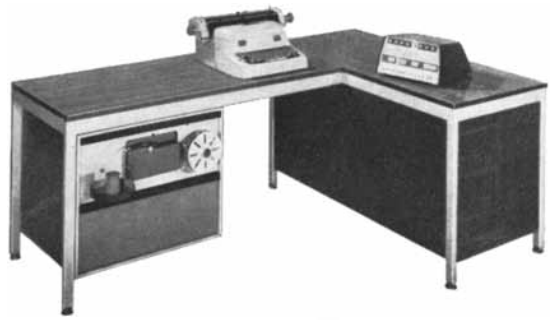
SUBSIDIARIES: Vitro-Smith Corporation • Vitroselenia, S.p.A. • Vitro Minerals Corporation • REGIONAL OFFICES: Washington • Houston • Los Angeles



purposeful imagination....in form

The men of Aerospace exercise high technical competence and constructive imagination in the creation and assessment of form and configuration for advanced ballistic missile and space systems. □ As a partner of the Air Force-science-industry team, Aerospace Corporation is chartered exclusively to serve the United States Government in this mission. The men of Aerospace provide advanced systems analysis and planning; theoretical and experimental research; general systems engineering and corresponding technical direction of programs. □ Through concept, research, development and completed mission the men of Aerospace improve the form of components, equipments, and systems. Trade-offs and interface considerations are objectively appraised on the basis of performance, reliability, and cost. □ Men with the depth and breadth of experience required to solve these interdisciplinary problems are needed by Aerospace Corporation, an equal opportunity employer. Highly skilled engineers and scientists with advanced degrees are invited to contact Mr. Charles Lodwick, Room 120, Aerospace Corporation, P. O. Box 95081, Los Angeles 45, California. □ Organized in the public interest and dedicated to providing objective leadership in the advancement and application of science and technology for the United States Government.

AEROSPACE CORPORATION



Impostor!

Masquerading as a desk, this solid-state computer, designed for rugged industrial service, is infiltrating instrumentation, process control, and industrial systems throughout the country as successfully as it is revolutionizing general business functions. Under stored program control this computer demands and accepts digital data, processes it (logically and arithmetically), and delivers command and control data to your system. It can store 9,000 digits, 2,000 instructions. Yet it costs only $24,500 to buy, $700 a month to rent. Its input and output devices can process any language...binary, decimal, and alphabetic...and it can be fed directly from your system, serially by character, in any coded form. It speeds at 160 arithmetic operations per second and is compatible with real time instrumentation systems. Most important, it is backed by Monroe's practical program of service. It begins with consultations between our engineers and yours and lasts throughout the life of the machine with continuing service by Monroe's own electronic service engineers. Don't you think your engineers ought to discuss this with our engineers? For detailed information, contact: Electronic Components Division, Monroe Calculating Machine Company, 60 Main Street, San Francisco, California.

MONROE

*For less complex operations, inquire about the Monrobot IX. Price: $9,650.

A DIVISION OF LITTON INDUSTRIES

Wunder-kälte

No. 4 in a series of science-fiction originals created expressly for Hoffman Electronics Corporation

By FRANK RILEY

Now they could see through the cold glow. Against the far wall of the cubicle was a transparent case the size and shape of a coffin. Within it was a man of about sixty, frozen so suddenly there was still a half-questioning twist to his lips.

Freda's fingers tightened on her husband's hand, clinging to these final moments of warmth.

The Director explained quietly:

"This man's been at the Institute nearly thirty years . . . He was brought here in '75 with one of the few forms of cancer that couldn't be treated then . . . rather than let him die, we simply froze his body, malignant cells as well as healthy . . ."

Freda stared at the twist of the man's lips, and whispered to Jonathan:

"He was a little frightened – too!"

Moving down the corridor again, toward their own "Project X," Jonathan Kemper asked the Director:

"How long will this man be – be kept frozen?"

A smile warmed the ice-sculpture of the Director's face.

"We've discovered how to treat him – and he's in transition from the storage vaults to internal therapy . . . In a few days, he'll be released to live out the rest of his years . . .

Freda paused by the tall window, holding back her husband, letting the bright sun of morning touch her body through the thin robe. The sun made her shiver, and the Director said gently:

"Don't be nervous. Cold used to be the seal of death . . . Now it is a portal to life . . ."

Outside the window, reaching across the valley, the vast complex of the Ettinghausen Institute shimmered in the clear sunlight of the high desert.

Row on row, vaulting a hundred stories into the sky, burrowing as many more underground, the bright towers of glass and steel looked more like surrealist sky-

scrapers than repositories for the coffins of the living.

Jonathan Kemper drew thoughtfully on the last embers in the bowl of his pipe, knowing there was not time to refill it, wanting to savor it all. He asked:

"How many – uh – people do you have here now?"

The Director picked up his hesitation with another brief smile.

"They're still *people,* Dr. Kemper . . . You and your wife will be, too! . . . We have about 30,000 at the present time – in all the programs . . ."

Jonathan put his arm around his wife's strong body. To break the tension in their silence, the Director pointed to an old oil painting a few feet down the corridor:

"That's Albert von Ettinghausen – the 19th century German physicist who started all this . . ."

Jonathan understood his kindness and tried to show interest.

"We didn't know that . . . In psychical research, there's not much chance to study physics . . ."

The Director chuckled as they continued down the long, music-scented corridor.

"To be frank, I don't think Herr von Ettinghausen himself knew all he would be given credit for! . . . He called it Wunderkälte – wonder cold – but nobody saw anything very wonderful in the Ettinghausen Effect . . . not even after the first semiconductor scientists caught up with it . . ."

To hold their attention, the Director went on quickly:

"Some pioneer once called the semiconductor a Genie – awaiting masters to find uses for his talents . . . But of all the uses they found, no greater wonder has come to man than the absolute control of cold . . ."

Freda shivered again, involuntarily. Jonathan caressed the small of her back with his thumb, and prompted:

"Then this Ettinghausen thing didn't really have too much to do with – what you're going to do to us?"

The Director pursed his chiseled lips in negation.

"Quite to the contrary, Dr. Kemper! . . . The Ettinghausen Effect is the galvanomagnetic . . . Well, put it this way: Herr von Ettinghausen found that when you place a conductor perpendicular to the plane of a magnetic field – and send a current through it – you create a temperature difference at right angles to both . . ."

"Which means you've just lost two parapsychologists!" Jonathan grinned.

"Everybody else was lost, too – until someone finally learned that the Ettinghausen Effect could be about a million times greater with a semiconductor than with a piece of copper!

"This still didn't mean much – except better and cheaper refrigerators – until the potential of the effect was again tremendously magnified – this time by organic semiconductors, inside as well as outside the body . . ."

Not at all certain he was continuing to distract them, the Director concluded quickly:

"Today, with energy from the blue spectrum of the sun, we have completed the conquest of cold . . . We can instantly create any fractional degree of temperature – down to below what was once considered absolute zero . . ."

"Is that what they're doing at the North and South Poles?"

"Not exactly – but they have stabilized the ice packs, and very likely prevented a fifth ice age."

Without warning, the Director stopped abruptly before a door they had been about to pass. He held it open for them.

"I want to show you something else – just to prove there's no need to be nervous . . ."

Inside was a smaller coffin-like case, containing the body of a baby.

"This child was born with a defective heart . . . The heart was removed and the body frozen instantly to prevent death . . . That was ten days ago . . . Now the heart has been repaired, and we'll put it back in this afternoon . . ."

Tears came to Freda's eyes.

"I wonder," she said softly, "if the baby can dream – without its heart . . ."

In spite of all his years here, the Director was touched, too.

"I wish," he said earnestly, "there were time to show you more of the miracles being developed here today . . . the new surgeon's scalpel with a blade of cold that simultaneously seals the flow of blood, sterilizes and anesthetizes while cutting through the flesh . . . The dental drills that work with compressed cold instead of air – and desensitize the tooth in picoseconds while cleaning the cavity . . ."

The Director's voice had a ring to it now, but he kept his eyes on the baby's still form.

"That man you saw a few moments ago – he won't even need a scalpel! . . . we'll simply keep his healthy cells frozen until the malignancy starves itself!"

He looked up and smiled apologetically.

"Sorry! . . . We're not really a hospital, you know . . . You might be more interested in the Space Chamber where whole colonies are being prepared for the planets of Sirius . . . or the Sleep Center – where we're proving that one hour of so-called frozen sleep a night is all the body needs!"

Jonathan Kemper smiled at his wife.

"We'll have to sleep a little longer than that – to prove that life is dreaming . . . and that reality begins when the dream is over . . ."

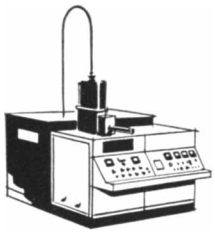
Inside the vault marked "Project X," the technicians helped Freda into the plastic crypt. Then Jonathan got in beside her. The Director's knowing eyes were shadowed with the wonder of it all, and he told them:

"I hope you find what you are looking for."

In the moment before the swirling oblivion of cold, Freda remembered the man with the twisted lips. She brought Jonathan's hand to her cheek, and whispered:

"Please help me be smiling."

The tiny ties that bind

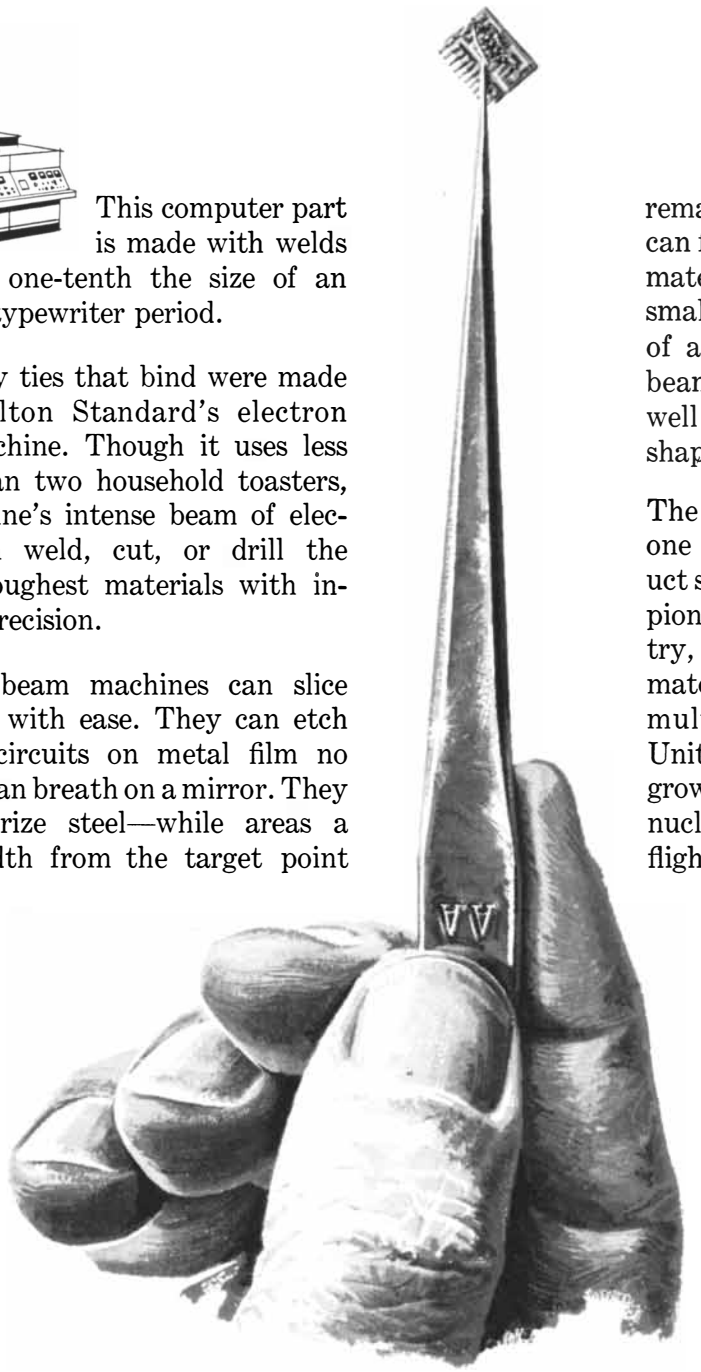


This computer part is made with welds less than one-tenth the size of an ordinary typewriter period.

These tiny ties that bind were made by Hamilton Standard's electron beam machine. Though it uses less power than two household toasters, the machine's intense beam of electrons can weld, cut, or drill the world's toughest materials with incredible precision.

Electron beam machines can slice diamonds with ease. They can etch complex circuits on metal film no thicker than breath on a mirror. They can vaporize steel—while areas a hair's width from the target point remain cool and undistorted. They can fuse large pieces of "unweldable" materials or build durable devices small enough to pass through the eye of a needle. The versatile electron beam machine does so many tasks so well that it will certainly change the shape of myriad things to come.

The electron beam machine is only one example of the expanding product spectrum at United Aircraft. This pioneering corporation serves industry, commerce, and defense with unmatched research capability and the multiple skills of 60,000 people. United Aircraft is a significant and growing force in power, propulsion, nuclear energy, electronics, vertical flight, navigation, and controls.



United Aircraft

PRATT & WHITNEY AIRCRAFT • HAMILTON STANDARD • SIKORSKY AIRCRAFT • NORDEN • RESEARCH LABORATORIES • UNITED AIRCRAFT CORPORATE SYSTEMS CENTER • CANADIAN PRATT & WHITNEY AIRCRAFT CO., LTD. • UNITED AIRCRAFT INTERNATIONAL • UNITED TECHNOLOGY CORPORATION

Another vital application of Ohio Semiconductors' Hall Effect Current Transducers

A Hall effect current transducer, using Ohio Semiconductors' "Halltron" device, now performs an important function on United States' atomic submarines.

This newly developed transducer measures DC current without physical attachment to the DC line. It has a high degree of reliability, even when subjected to extraordinary overloads.

No longer a laboratory phenomenon, the Hall effect is now employed by Ohio Semiconductors in this and other practical current transducers where currents from a few amperes to 300,000 amperes are measured without using shunts or current transformers.

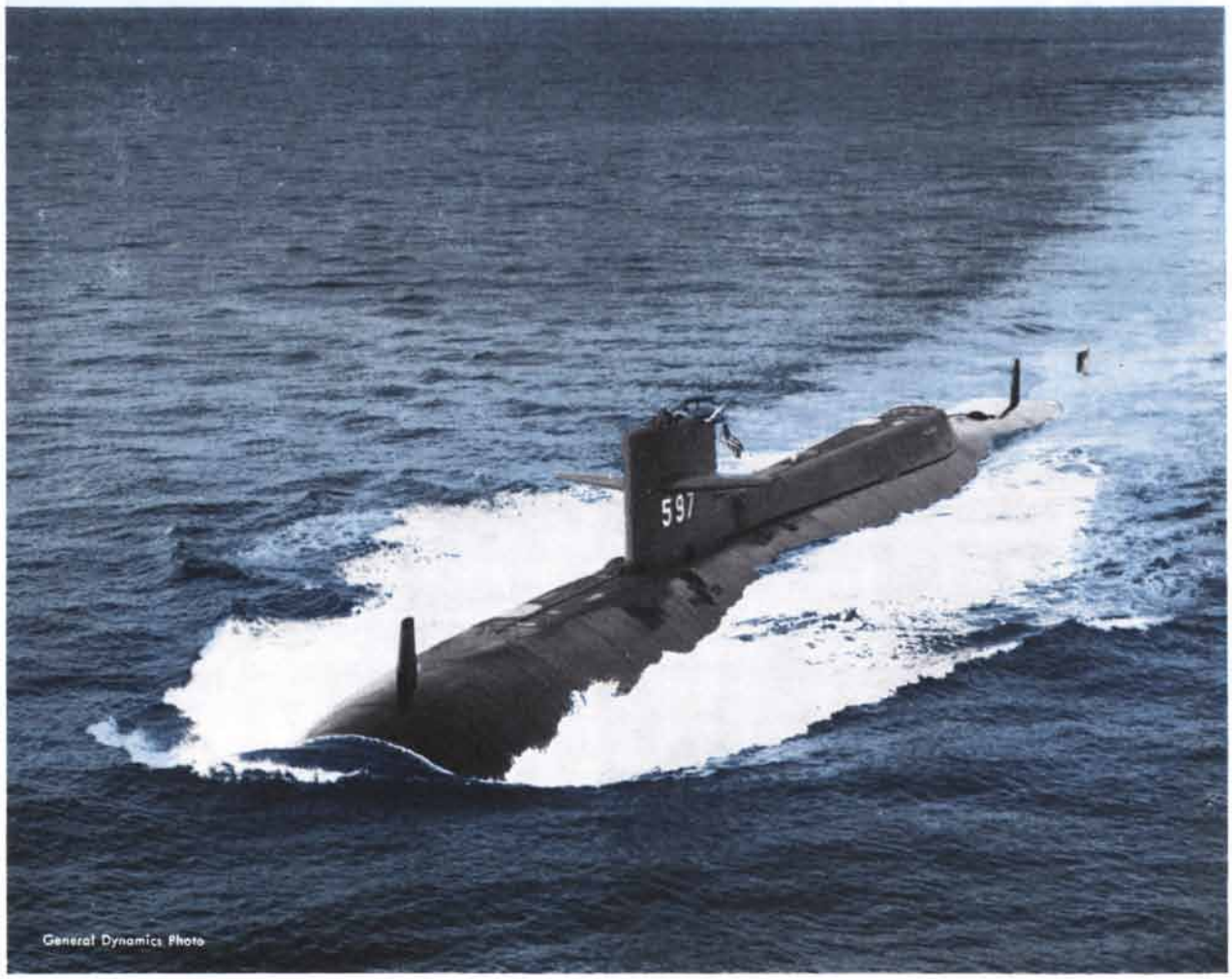
This is only one of the many practical applications of the Hall effect developed by Ohio Semiconductors. Write or call for specific information on our Hall effect product line.

OHIO SEMICONDUCTORS

1205 Chesapeake Avenue • HU 6-9561 • Columbus 12, Ohio

A DIVISION OF TECUMSEH PRODUCTS COMPANY

Pioneer in the design, development and production of compound semiconductors, and components and sub-systems, for electronic, thermo-electric and infrared applications.



LETTERS

Sirs:

The excellent article on ultrahigh vacuum by H. A. Steinherz and P. A. Redhead [SCIENTIFIC AMERICAN, March] covered virtually every recent development in the technology and physics of the measurement of ultrahigh vacuums. The authors failed to mention, however, the best technique known, that of adiabatic demagnetization of paramagnetic salts.

For many years now cryogenists have been achieving temperatures in the neighborhood of a few millidegrees Kelvin (10^{-3} degrees K.) by demagnetization techniques. The vacuums that result from this as a by-product are far and away the best in the entire universe. Admittedly these vacuums cannot be measured, but the computations that I shall use in estimating them stand on excellent footing.

At low temperatures the only vapor pressure we need consider is that of helium. All other materials have vapor pressure far below this. For simplicity I will refer only to the most abundant isotope of helium: helium 4. The less abundant helium 3 has a slightly higher vapor pressure, but not enough to make much difference in the millidegree temperature range. The vapor pressure above liquid helium 4 is given rather accurately below one degree K. by

$$P\ (\text{torr}) = 1.6 \times 10^{2} T^{2.5} 10^{(-3.12/T)}$$

where T is the temperature in degrees K. and P is the pressure in millimeters of mercury (torr). The equation is based on thermodynamic considerations. The experimental quantities used to obtain numerical coefficients have been accurately determined in the accessible temperature region above one degree K.

Using this equation, we can readily calculate that at .1 degree K. the helium vapor pressure is about 3.2×10^{-31} torr, at .01 of a degree it is about 10^{-315} torr, and at the lowest temperatures ever attained, near 10 microdegrees above absolute zero, the vapor pressure is about $10^{-300,000}$ torr. In terms of the number of atoms of gas per unit volume, at .1 degree Kelvin there are about 3×10^{-11} atoms per cubic centimeter. At .01 degree the density has fallen so low that there is substantially less than one atom of helium vapor in a volume equivalent to that of our entire galaxy.

Thus inside the experimental chamber of a demagnetization cryostat, if the system is in equilibrium, there is a negligible probability that even one atom is contaminating the vacuum. Clearly such a vacuum is vastly superior to that in outer space, or anywhere else. In practice, of course, there are contaminants on the relatively hot (usually about one degree K.) chamber walls that may desorb into the vacuum. However, as soon as a desorbed atom strikes the cooling salt it is immediately frozen out. The cooling salt therefore acts as an infinitely efficient pump.

As far as I know no one has ever made any practical use of these ultimate vacuums. The only experiment I have ever heard proposed (I do not know who suggested it first) that might take advantage of them is an experiment to test the hypothesis of spontaneous creation of matter in the universe. In this experiment one would simply prepare a vacuum and then wait patiently for a particle to be created. Perhaps one would wait for an antiparticle, as this would be easy to distinguish from wall contaminants. Of course, these cryostats remain cold for only a few hours, and in this experiment, with available volumes, one would expect to have to wait for years. Furthermore, when the conclusive particle did appear, you might not be at all sure that it was not a cosmic ray or that your detector did not have a little instrumental noise.

PAUL P. CRAIG

Los Alamos, N.M.

Scientific American, June, 1962; Vol. 206, No. 6. Published monthly by Scientific American, Inc., 415 Madison Avenue, New York 17, N.Y.; Gerard Piel, president; Dennis Flanagan, vice-president; Donald H. Miller, Jr., vice-president and treasurer.

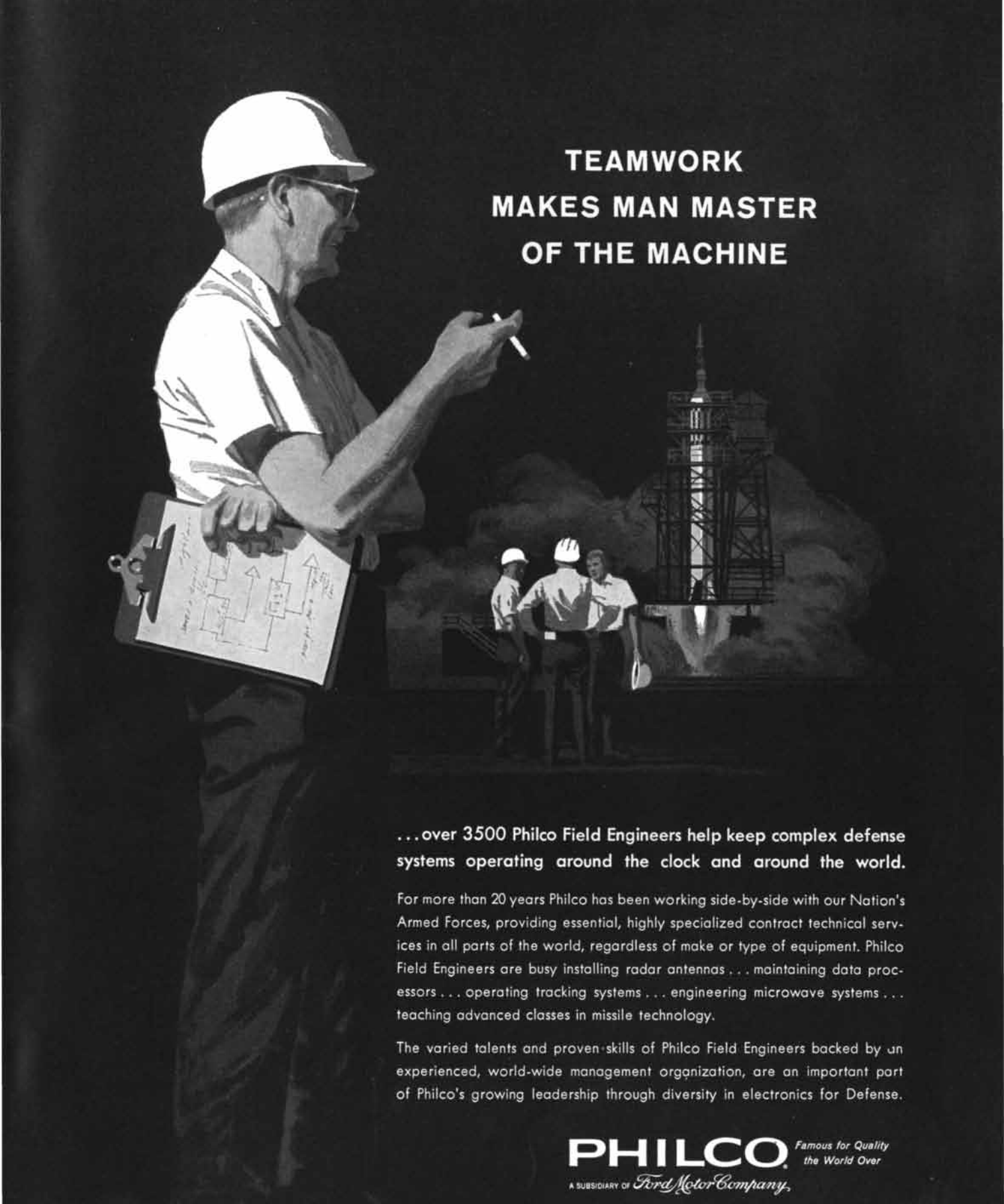
Editorial correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York 17, N.Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Martin M. Davidson, Advertising Manager, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York 17, N.Y.

Subscription correspondence should be addressed to Jerome L. Feldman, Circulation Manager, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York 17, N.Y.

Subscription rates: one year, $6; two years, $11; three years, $15. These rates apply throughout the world. Subscribers in the United Kingdom may remit to Midland Bank Limited, 69 Pall Mall, London SW 1, England, for the account of Scientific American, Inc.: one year, two pounds four shillings; two years, three pounds 19 shillings; three years, five pounds eight shillings.

Change of address: please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.



TEAMWORK MAKES MAN MASTER OF THE MACHINE

...over 3500 Philco Field Engineers help keep complex defense systems operating around the clock and around the world.

For more than 20 years Philco has been working side-by-side with our Nation's Armed Forces, providing essential, highly specialized contract technical services in all parts of the world, regardless of make or type of equipment. Philco Field Engineers are busy installing radar antennas . . . maintaining data processors . . . operating tracking systems . . . engineering microwave systems . . . teaching advanced classes in missile technology.

The varied talents and proven skills of Philco Field Engineers backed by an experienced, world-wide management organization, are an important part of Philco's growing leadership through diversity in electronics for Defense.

PHILCO *Famous for Quality the World Over*

A SUBSIDIARY OF Ford Motor Company

Communications and Weapons Division • Communications Systems Division • Computer Division • Lansdale Division • Scientific Laboratory • Sierra Electronic Division • TechRep Division • Western Development Laboratories

Wouldn't it be wonderful if someone invented... sun glasses that grow darker as the sun gets brighter?

As a matter of fact, the chemists, physicists and engineers who work at research for NCR have come up with a development that makes just such glasses possible.

But you won't be able to buy sun glasses labeled NCR for some time . . . if ever.

For, you see, the glass that changes with the light was developed for quite another use. It is among the many new and important projects currently in process by NCR's two thousand research and development workers. And, like all the others, it has as its central focus the objective of improving the capacity and efficiency of computers, calculators and other machines in modern business systems.

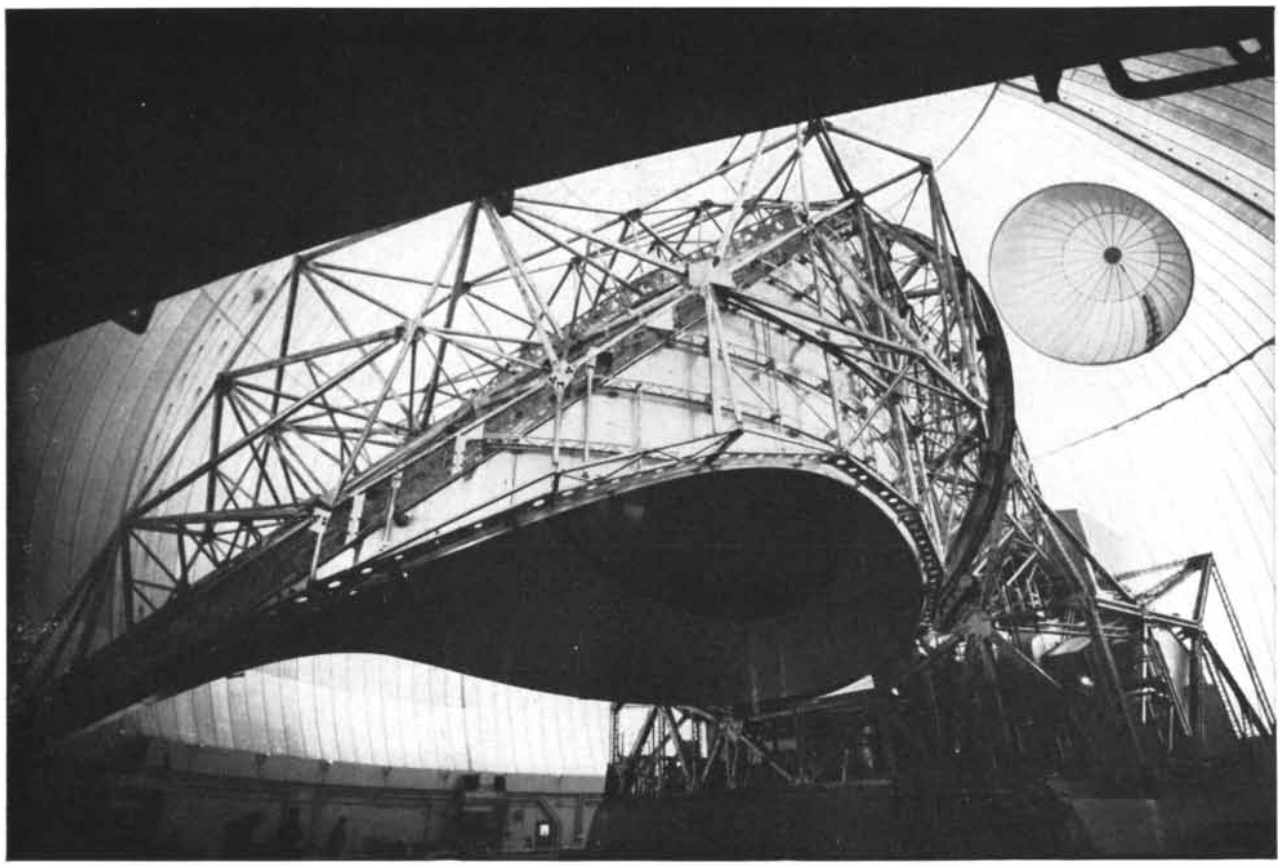
The secret of the glass that changes color is being explored to enhance the speed and flexibility of data processing systems. The use of photochromism is an extremely advanced method of increasing the utility of electronic computers. The operating principle is based on color changes which occur under varying wave lengths of light.

Obviously, this principle has application to other complex commercial and military devices which we can't discuss here.

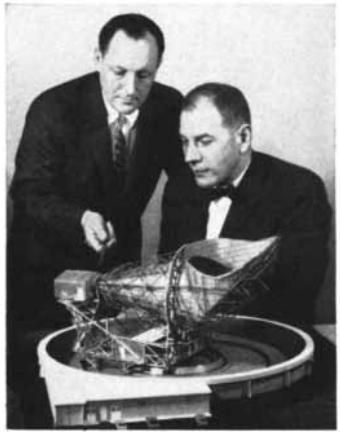
It's another reason why we say. Look to NCR for the forward developments dedicated to providing the finest in total systems . . . from original entry to final report — through NCR accounting machines, cash registers, adding machines and electronic data processing.

NCR

New sign of The National Cash Register Company, Dayton 9, Ohio—1,133 offices in 120 countries—78 years of helping business save money



World's largest horn antenna shown under construction at Andover, Maine. The McKiernan-Terry Corporation, under prime contract to Bell Telephone Laboratories of AT&T, is installing the "horn" as part of a new experimental space communications ground station. The horn was designed and developed by McKiernan-Terry and Bell Telephone Laboratories to beam signals to the Telstar satellite for overseas relay. It also serves as a giant ear trumpet to scoop up faint signals that are relayed back by Telstar. The $10,000,000 station, when completed, is expected to be a major step in linking countries of the world by telephone, data and TV via satellites.

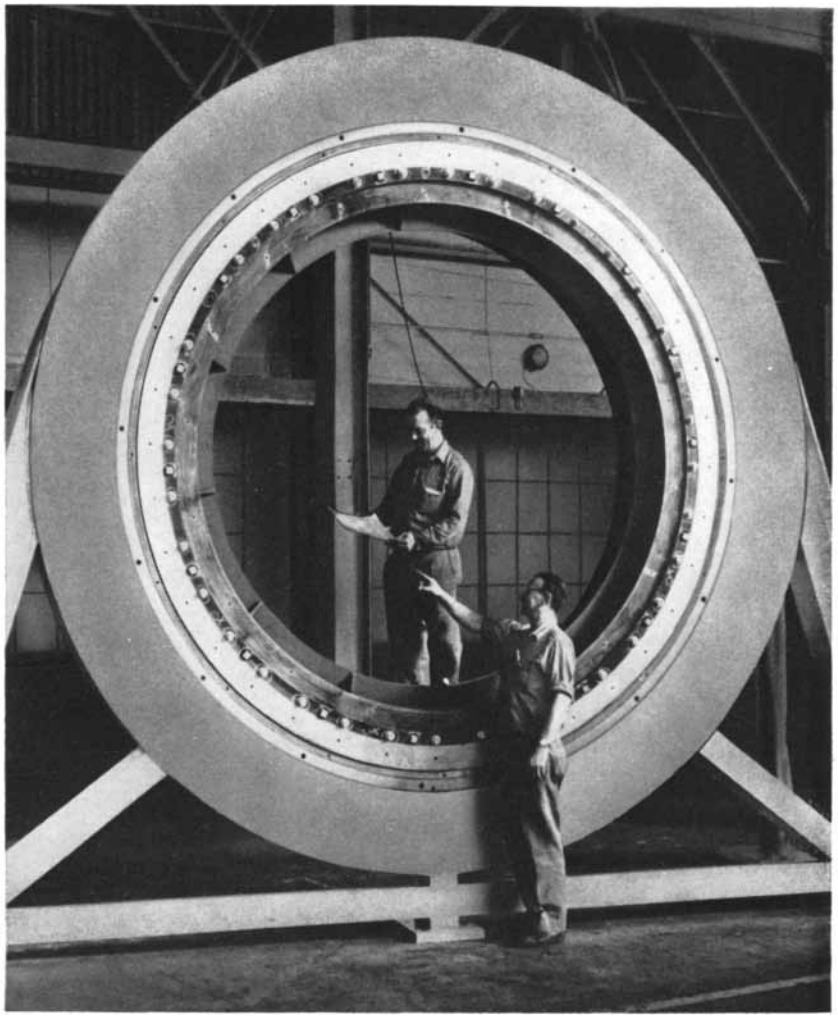


THE STORY: The design of a rotating antenna as part of Bell Telephone Laboratories' new experimental space communication ground station involved several problems related to the selection of bearings. The huge 380-ton steel and aluminum structure rotates on a vertical axis on two concentric circular tracks. It also turns on a horizontal axis in order to track a satellite from low to high angles of elevation.

Of special consideration was the bearing needed to maintain the position of the structure's vertical axis. This position must withstand 300,000 lbs. radial load under survival wind conditions (100 m.p.h.). Torrington engineers designed a self-aligning precision bearing that compensates for antenna tilt caused by differential deflection of track under rolling loads.

A second problem had to do with the bearing used for rotating the antenna on the horizontal axis. This position is subject to maximum thrust loads of 185,000 pounds and a radial load of 3000 pounds. The bearing had to accommodate these load factors, compensate for misalignment (any kind) and be extremely accurate. Maximum allowable axial play: .010". Maximum allowable radial play: .002". McKiernan-Terry, engineers and manufacturers for the job, also required that the maximum breakaway torque be no greater than 1000 foot-pounds. And they wanted both bearings in a hurry.

Telstar satellite—34″ sphere has 72 gem-like facets, is intended for experiments in relaying telephone calls and other communications overseas. Solar cells convert sunlight into electricity. Launching is scheduled for this spring.



4-point contact ball radial bearing used in Telstar ground antenna in the McKiernan-Terry plant prior to shipment. Bearing has raceways with contours approaching gothic arch design. So, balls contact raceway surfaces at only four points. Design has these advantages over conventional ball bearing designs: (1) superior rigidity, (2) lower end play for a given diametral clearance and lower rate of axial deflection because of high initial contact angle, and (3) more compact and economical.

Torrington Engineers come up with design solution... Torrington engineers worked closely with McKiernan-Terry and Bell Telephone Laboratories' engineers. During the course of construction they were able to anticipate and plan changes in bearing design to meet modifications made in the design of the antenna. As a result, Torrington came up with the right bearing on schedule.

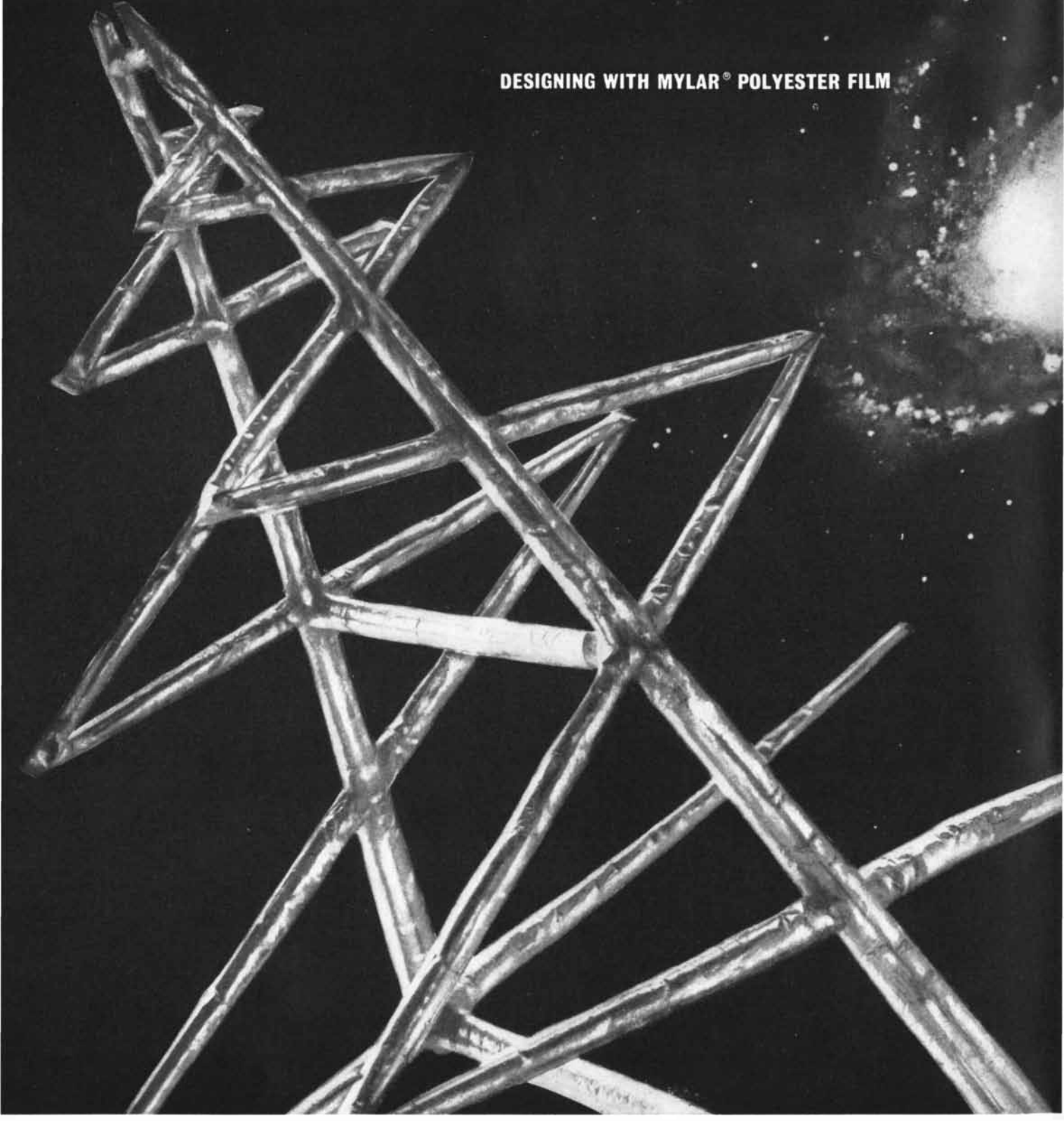
On the vertical axis of the antenna, a special 1500-pound spherical roller bearing (710 mm x 1030 mm x 236 mm) handled the misalignment problem. The bearing was manufactured to special precision tolerances: radial runout of both inner and outer rings was held to .0005″. Face runout of both inner and outer rings was .001″.

On the horizontal axis of the antenna, Torrington used a four-point angular contact ball bearing. Measurements: 112″ bore, 128½″ O.D., 4½″ inner ring width, 6½″ outer ring width. To eliminate play in the bearing, it was preloaded. An aligning seat fitted to the outer ring compensates for misalignment and deflection. Actual breakaway torque measured only 500 foot-pounds.

This, then, is Torrington at work on Project Telstar: experienced, versatile, accurate—and fast! Are you currently working on a precision project that requires precision bearings? Why not call Torrington? We make every basic type of antifriction bearing. And there's no obligation when you call Torrington. At Torrington, service is part of the product.

PROGRESS THROUGH PRECISION **THE TORRINGTON COMPANY** SOUTH BEND 21, INDIANA TORRINGTON, CONNECTICUT

Serving industry throughout the world with all basic types of antifriction bearings, metal specialties and rotary swaging machines.



MYLAR . . . in the inflatable sentry in space

On earth, it weighs 12 ounces and fits in a six-inch cube. In space, it stretches to eight feet and weighs nothing. An inflatable antenna of tough "Mylar" polyester film. For twelve months it will maintain communications with NASA . . . a sentinel above the earth.

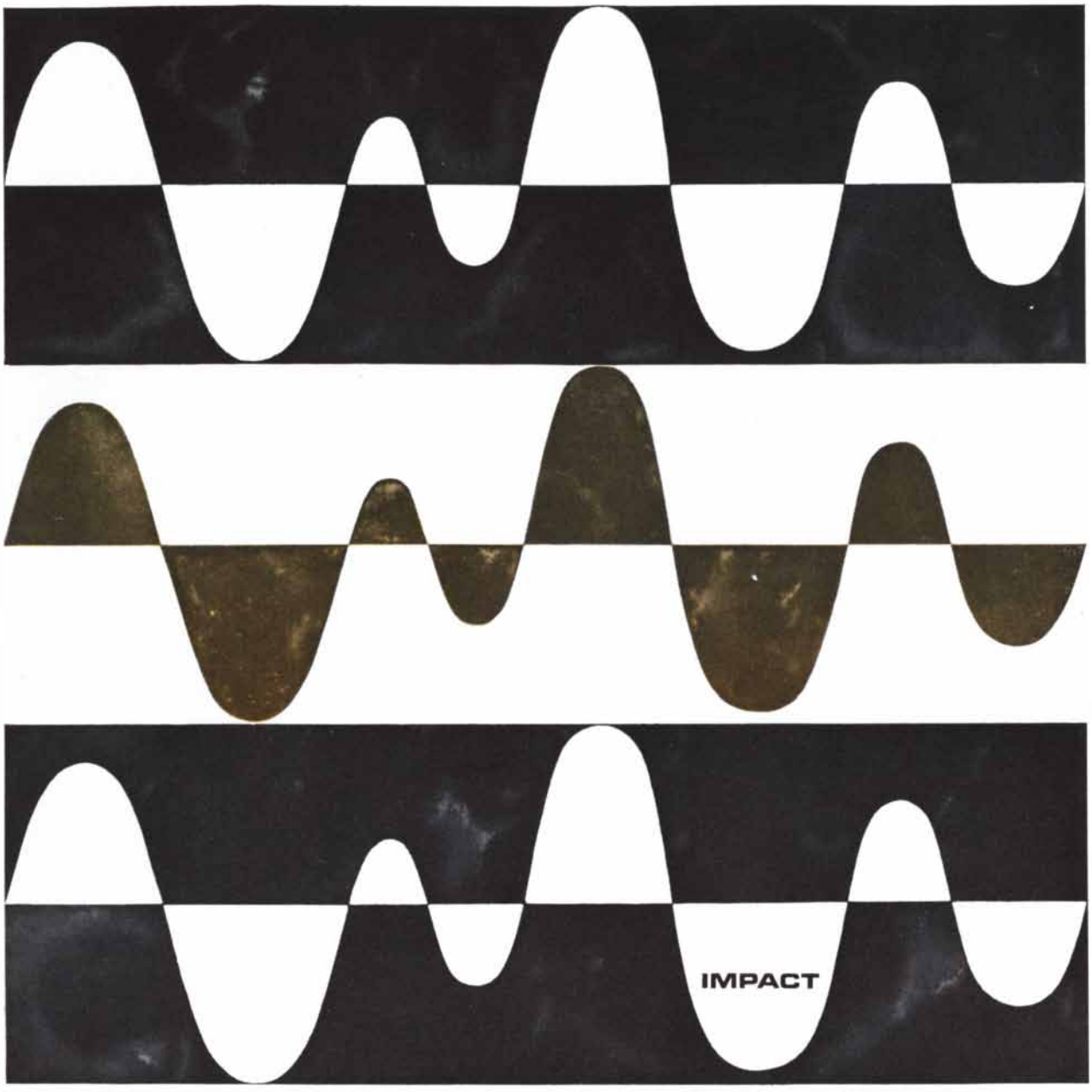
The Lockheed Missile and Space Company wanted a versatile material for the antenna. Thin, but immensely strong. Capable of being crushed in a ball, then pumped with pressure in 90 seconds. Able to endure the incredible temperatures of space without drying or cracking. Able to resist the impact of micrometeorite bombardment. They found the qualities in "Mylar".

Today, "Mylar" is a basic material for design. Flexible, but strong. Thin, but durable. Doing new things that couldn't be done before. Doing old things – better.

Try "Mylar". Investigate its amazing properties as a key to solving your design problem. Write or call Du Pont, Film Department, N-10452 SC, Wilmington 98, Delaware.

DU PONT
REG. U. S. PAT. OFF.
Better Things for Better Living . . . *through Chemistry*

only DU PONT makes
MYLAR®
POLYESTER FILM

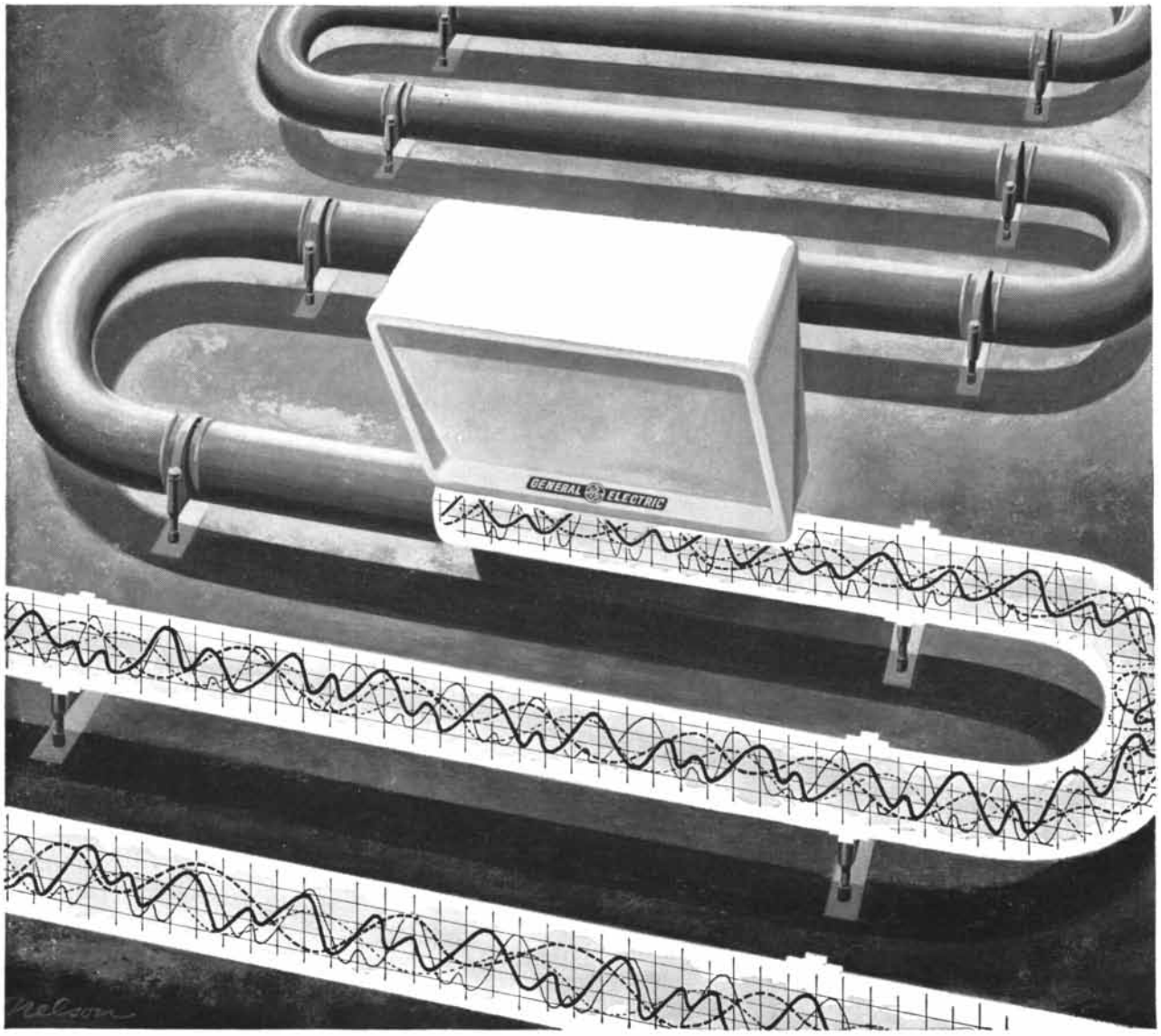


One of the more pleasurable impacts of electronics on man has been aural—first, monaural and, more recently, binaural. But the recording arts have done more than entertain. Recording technology has contributed to more precise scientific and medical analyses—to widespread use of computers and business data processing—and to a host of applications which require the preservation and rapid retrieval of data. Because it is vital, greater fidelity in recording and reproduction is continually sought by equipment manufacturers.

Critical evaluation of manufacturing processes, as well as rigorous life tests, have enabled Tung-Sol to achieve exceptional stability in the operating characteristics of electron tubes, transistors and diodes. Much of the finer recording equipment is built with Tung-Sol components. With impartial experience in the application of both vacuum and solid state electronic components, Tung-Sol is competent to advise on circuitry best suited to achieve a desired end. Consult Tung-Sol while your equipment is in the design stage. Tung-Sol Electric Inc., Newark 4, N. J.

TUNG-SOL®

ELECTRON TUBES AND SEMICONDUCTORS — LAMPS FOR INSTRUMENTATION



XEG: Your sixth sense on any continuous process line

As an on-line sensor, the General Electric X-Ray Emission Gage is a dependable, accurate source of facts about your process flow. With XEG you run a continuous check on the qualitative and quantitative composition of material in production for as many as five elements — or *six* where practical to operate without a reference.

Liquids, solids, slurries, dry or moist powders, sheets, wires, rods, even gases . . . you keep them all under full-time surveillance with trend analysis so accurate, so fast that adjustments can be made before serious, costly spoilage.

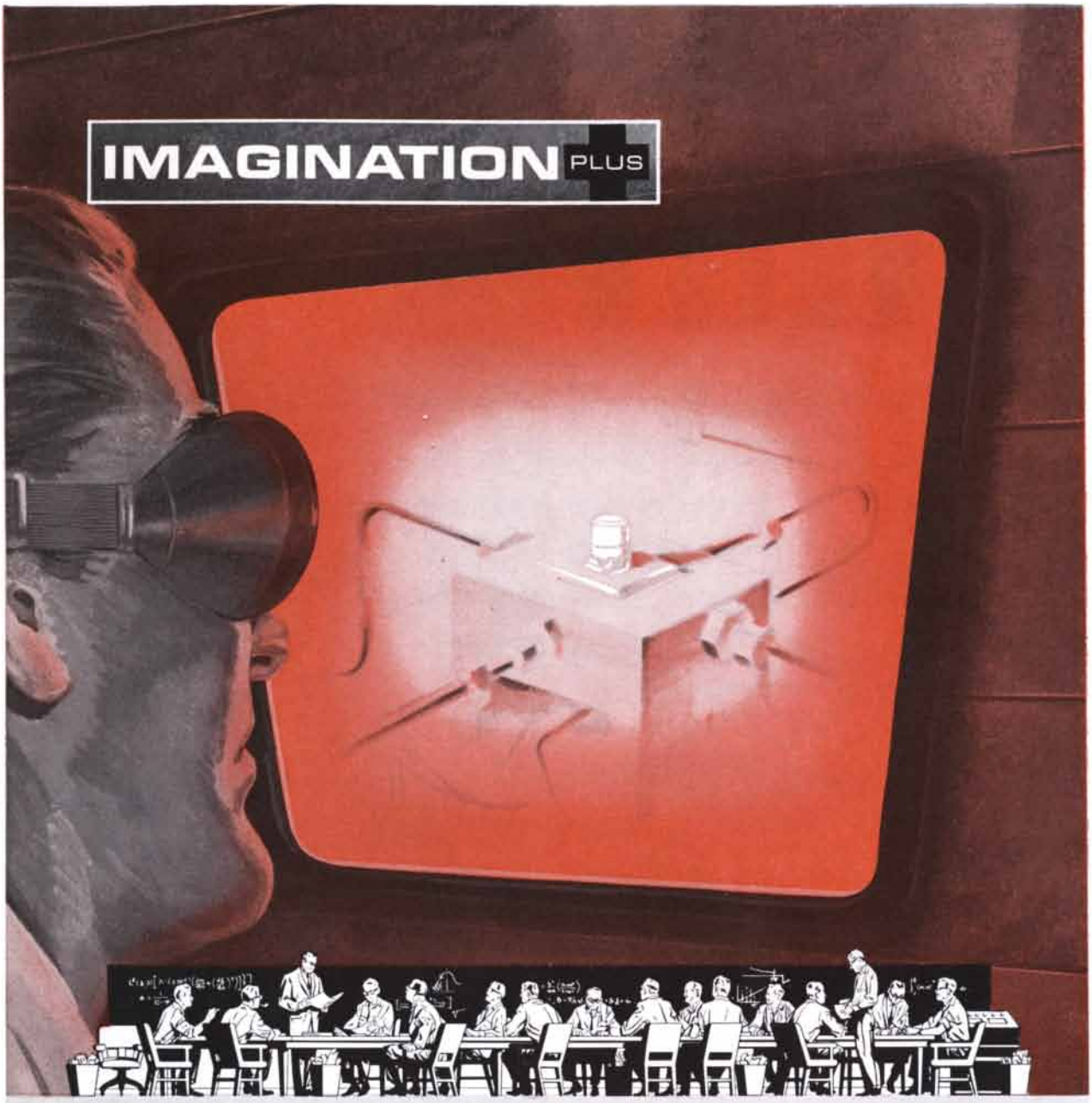
XEG is rugged as well as accurate. With no moving parts, it is durably built to withstand the vibration and shock normally encountered in industrial operations. Information from the XEG can be fed into recorders, indicators, process computers or directly into process control devices.

Contact your G-E representative for details on XEG. Ask him how MAXISERVICE® Rental Plan can provide you with x-ray equipment, service and parts at no capital investment. Or write to X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Room TT64.

GENERAL ELECTRIC MAKES X-RAY "PLANT-PRACTICAL" FOR

Progress Is Our Most Important Product

GENERAL ELECTRIC



BENDIX-PACIFIC

actuation and controls at work in aerospace

25th ANNIVERSARY

Designed to meet the severe environments of advanced aircraft and space vehicles, Bendix-Pacific actuation and control components and systems are working at temperatures of minus 250°F to plus 2000°F. As typified by sub-miniature servo valves, maximum performance of Bendix-Pacific equipment is assured through thorough testing in the Division's own high temperature facility. The development of Bendix-Pacific hydraulic and pneumatic servos, and electromechanical actuation for thrust vectoring and surface control applications, illustrates the depth of experience and "imagination plus" of Bendix-Pacific...where creative engineering teams have more than 20 years experience in hydraulics/pneumatics/electromechanics. This is another example of the broad capabilities which have made Bendix-Pacific a recognized leader in the fields of Airborne Radar, Data Handling, Guidance, Hydraulics/Pneumatics/Electromechanics, Military Navigation, Oceanics and Telemetry.

Discover for yourself how Bendix-Pacific "imagination plus" in any of these fields can go to work for you. Write or call Bendix-Pacific Division, North Hollywood, California.

Bendix-Pacific Division

THE Bendix CORPORATION

WHY

■ *does one computer system take maximum advantage of its computing speed, peripheral equipment and storage capacity at all times and under all conditions—whereas others do not (and cannot)?*

■ *do three jobs that each take an hour to do on other systems take only 1¼ hours all told on this system?*

■ *do interrupt conditions that make other systems bog down have no effect on this system?*

■ *do you get more throughput per dollar with this system than with any other?*

■ *can this equipment lay claim to a totally new concept in computer system operation?*

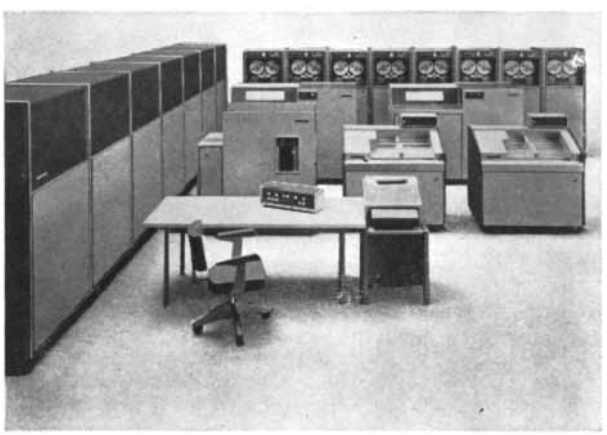
The Master Control Program (MCP) of a Burroughs B 5000 Information Processing System is the answer. It's one of the primary answers to all the questions above, and it's also the solution to just about every operational drawback that's ever drained away a computer user's time, money and patience.

Take the question of interrupts, for example. Conventional systems employ programed interrupt detection. In the B 5000, interrupt detection is built right into the hardware. The hardware then switches electronically to the appropriate portion of the MCP for automatic handling of that specific interrupt condition. Meanwhile, the current program is processed further or another program is run instead, if preferred. In either event, the B 5000's MCP assures that an interrupt *condition* does not mean an interruption of the system itself or the work in progress.

Or consider the paradox of how three jobs that each take one hour to do on other systems can be completed in less than half that time by the B 5000. It's easy—the way the MCP does it. Since some jobs need a lot of processor time but little input-output time, whereas some jobs need just the opposite, the MCP cuts the total processing time of each by running them *concurrently*. The programer needs to write only the basic program and the MCP takes over from there, scheduling and assigning different components when free. This ability to time-share unused processor and input-output capacities is one of the main reasons the B 5000 can give you more throughput per dollar.

Versatile as it is, however, the MCP doesn't fully account for the fact that the B 5000 is a totally new concept in system operation. There's the B 5000's ability to incorporate a second central processor, for instance—without reprograming. And there's the fact that the B 5000's basic design concept provides effective and productive use of the higher level languages of ALGOL and COBOL. Plus enough other reasons to fill a whole booklet—which we'll be glad to send to you. It's called *The B 5000 Concept* and is available from our main office at Detroit 32, Michigan.

Burroughs—TM



Burroughs Corporation

ANACONDA COMMENTS...

new facts about copper—man's oldest metal

NUMBER 6 OF A SERIES

INSULATED HOLLOW CONDUCTORS CAN ADVANCE CURRENT-CARRYING CAPABILITY

Hollow copper conductors, used in heavy-current-density electrical equipment, are now provided in new insulated forms by Anaconda American Brass. This product is an extension of Anaconda's line of fluid-cooled hollow conductors which can carry heavier electrical loads at elevated temperatures.

These new hollow conductors are ready for use in magnet coils, rotor and stator windings, induction coils, and similar heavy load applications; no further insulation processing is needed. Because requirements for insulated hollow conductors are generally highly specialized and widely varied, Anaconda will engineer each order individually—to meet specific needs.

Estimated outside diameters of film-coated hollow conductors will range from .125″ to .350″ square. Hollow conductors covered with glass fiber, paper, or cotton, will be available in sizes to .450″ O.D. In all cases, a heavy epoxy coating is the insulating material.

For complete information about available types, sizes, forms, and tempers, write: Anaconda American Brass Company, Waterbury 20, Connecticut.

NEW RESEARCH CENTER TO EXTEND RANGE OF SEMICONTINUOUS CASTING

Nearly 200 copper alloys may soon be produced from bigger and better castings. The basis: studies to extend the useful range of semicontinuous casting, at Anaconda's Research and Technical Center.

Current tests are expected to yield castings which deliver highest attainable quality levels . . . plus lower production costs, through minimized milling and scalping operations.

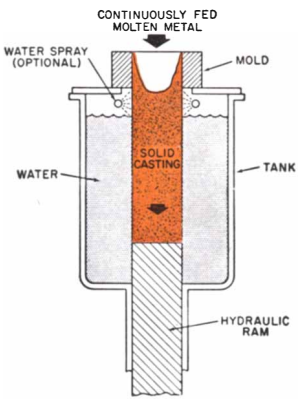
Semicontinuous casting of copper metals is not a new technique. But it is relatively underdeveloped. Until now, it was limited to a few specific alloys—and quality levels tended to be inconsistent.

Conversely, semicontinuous casting could be a valuable production technique with numerous advantages. Bigger castings provide high quality, uniformity, and longer continuous mill forms such as sheet, strip, or tube—without welds or other discontinuities. Compared to conventional static casting, semicontinuous casting also offers: minimized gas and shrinkage porosity, thus cleaner and higher-density castings; superior cast surfaces from a continuous relative motion between mold and solidifying casting; adjustable cooling rates for crack-sensitive alloys.

The Project and The Proof

Anaconda's Research and Technical Center is using a production-scale machine, instrumented for pilot plant studies, to prove the potential of semicontinuous casting. Present and projected tests involve: (1) heat extraction rates and barriers, (2) surface phenomena such as segregation, (3) shape factors, (4) freezing behavior, (5) internal structure—grain size and configuration, nature of constituents.

Even in these early investigation stages, results show great promise for the semicontinuous process. For example, Anaconda can substantially exceed the 3:1 length-to-cross-section ratio inherent in static casting, and produce virtually flawless castings up to 12 feet long.



The Anaconda semicontinuous casting process uses short (1 ft. approx.) water-cooled molds, open top and bottom, mounted above a tank of water and centered over a hydraulic ram. Casting begins with the ram up in the mold. As the ram is steadily withdrawn, molten metal is continuously introduced at the mold top. Ram stroke determines maximum casting length. If required, direct submold water-spray cooling can be employed.

Moreover, semicontinuous casting has already been extended to a wide range of copper-zinc alloys. And near-success is reported with some of the most difficult of all alloys to cast: chromium copper and silicon bronzes (such as Everdur® alloys).

Exploring ways to produce higher-quality alloys at lower costs is another example of how Anaconda contributes to progress in copper metals.

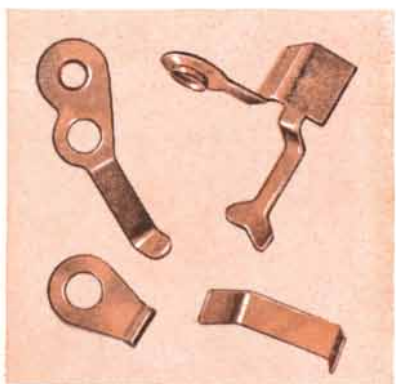
Can this experience be of any help to you? Write Anaconda American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 61-1966

AMBRONZE BRINGS ECONOMY TO SPRING-CONDUCTIVE COPPERS

Specify economy, along with spring and conductivity for fuze or meter clips and similar electrical applications. Ambronze thin sheet and strip is available from Anaconda at a cost just slightly above that of brass—and way below that of phosphor bronze. In fact, Ambronze has become a value-analyzed replacement for the phosphor bronze alloys in numerous light spring applications.

Ambronze is supplied in several alloys suitable for spring-electrical service. *Zinc content* ranges from 4.0 to 11.0%; *tin*, from 0.5 to 2.0%; *electrical conductivity*, from approximately 23.0 to 38.0% depending on composition. Each alloy is supplied in fine-grain material to assure superior fatigue properties.

For value analysis suggestions, technical assistance, or complete information about Ambronze electrical copper alloys, write: Anaconda American Brass Company, Waterbury 20, Connecticut.



Typical array of commercial switch components fabricated from Ambronze.

ANACONDA®
AMERICAN BRASS COMPANY

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JUNE, 1912: "During the long days of suspense before the full details of the *Titanic* disaster were brought in, there were many mutterings against the slow pace of the rescuing vessel and the inadequate wireless equipment, which could carry but 85 nautical miles. Many realized then for the first time how completely isolated a passenger vessel might be upon the high seas. But the full measure of the failure of wireless telegraphy to meet the crisis came out when it was shown that the steamship *Californian* was actually within sight of the wreck, and yet heeded not its wireless signals because its wireless operator was asleep. Had it not been for the amazing indifference or stupidity of the captain of the *Californian*, who failed to rouse his operator when he saw the rockets fired by the *Titanic*, no doubt all on board might have been saved, or at least a far larger number than was saved by the *Carpathia*, and the public would have overlooked the weak feature of the system that prevails on the smaller passenger vessels of providing only one wireless telegraph operator."

"Misunderstood though he was in the early stages of his experimental work, carried out in collaboration with his brother; unappreciated at first even by his own countrymen, Wilbur Wright, who died of typhoid fever on May 30, in the brief space of nine years saw the flying machine develop under his hands and those of his brother from a crude gliding mechanism into a great, motor-driven artificial bird; lived to see the realization of a dream that has haunted inventors ever since the world began; lived to see himself honored by kings and potentates, legislators and scientists, statesmen and artists the world over. A hundred years hence, it may be, the conquest of the air, attended as it has been by the disheartening defeat of hundreds of misguided men and the sacrifice of many lives, will be deemed of less material importance than the invention of the telegraph or the introduction of Bessemer steel. Yet if we measure the significance of navigating the air in an aeroplane by the difficulties that have accompanied the building of the really first practical heavier-than-air machine, who will deny that Wilbur Wright must be accorded the honor of standing beside Morse, Bell, Fulton, Bessemer, Watt, Arkwright—in a word, beside the men who have given us the machinery of modern civilization?"

"The action of a majority in the House of Representatives in opposing the appropriation requested for the annual increase of the United States Navy by two battleships a year is perilous to the interests of the navy and therefore endangers the security of the United States. A few years ago the United States stood second in naval rank, a rating that is demanded by our wealth and population and by the great value and far-removed location of our foreign possessions. Today we are in the third position, with Germany holding a strong position as second naval power and steadily gaining upon the United States in the numbers and power of its modern fleet. Now if the fatuous policy of obstruction followed by the majority of the House of Representatives is successful, and if it be persisted in for but a few years, the United States will inevitably drop to the fourth, if not to the fifth, position."

JUNE, 1862: "Gen. McClellan's valuable adjunct to his corps d'armée—the Lowe reconnoitering balloon—is getting to be quite an institution. During a fight lately between the rebels and a force of Union troops, in which the latter were engaged in dislodging some batteries that had been erected, the balloon did effective service in directing the movements of our artillery. A telegraph wire, attached to an instrument on board, conveyed intelligence to our men what to do and what not to do, and corrected any mistakes made by the transmission of such messages, as 'too short,' 'just a little over,' 'fire lower,' &c. The enemy could not be seen by the men at the batteries, and our batteries in turn were hidden from the view of the enemy, the majority of whose shots fell wide of the mark."

"Thurlow Weed says in a late letter from Europe: 'There is beginning to be much anxiety in France about cotton. Their diminished supply will be ex-

BELL LABORATORIES' NEW CONNECTOR STREAMLINES CABLE SPLICING

Telephone craftsman uses special pneumatic tool to flatten connector onto insulated wires. Metal tangs pierce insulation and produce a splice that is equivalent to a soldered joint.

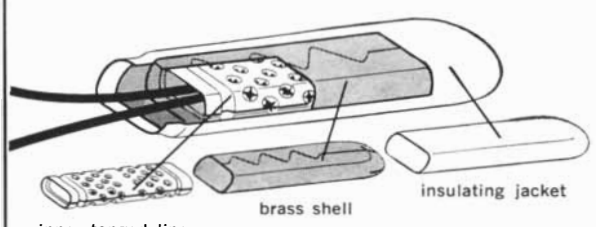
Along the cable routes of the Bell System, wires are spliced at a rate of 250,000,000 a year. Conventionally, connections are made by "skinning" the insulation, twisting the bare wires together, and slipping on an insulating sleeve. Now, with a new connector initiated at Bell Telephone Laboratories, (diagram at lower right) splices can be made faster, yet are even more reliable.

The craftsman slips the two wire ends—with insulation intact—into the connector, then flattens the connector with a pneumatic tool. Springy phosphor bronze tangs inside the connector bite through the insulation to contact the copper wire. The stable, low-resistance splice established is maintained for many years, even under conditions of high humidity, corrosive atmospheres and vibration.

Ultrasensitive measuring techniques devised by our engineers demonstrate that the new connector provides the equivalent of a soldered connection, even with voltages as low as 25 millionths of a volt.

Working with our manufacturing partners at Western Electric, our engineers developed this connector into a design capable of being mass-produced at low cost. It is being introduced in the Bell System.

NEW WIRE CONNECTOR HAS THREE PARTS:



BELL TELEPHONE LABORATORIES

World center of communications research and development

hausted in six or eight weeks. This will deprive several hundred thousand people of employment, for whom, in such an emergency, the government must furnish bread. Hence the government appeals to us for cotton. Other governments are not unlikely to unite with France in an earnest appeal on this subject."

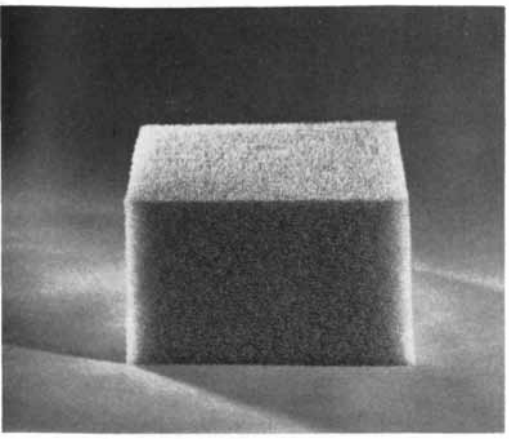
"The people of Sweden—his native country—have voted Ericsson a medal for services in connection with the *Monitor*."

"The appraisers of Col. Colt's estate reckon his property at over $3,000,000, exclusive of his Western and Texan lands, his gold and lead mines in South America and his property in England—all of which are probably worth another million."

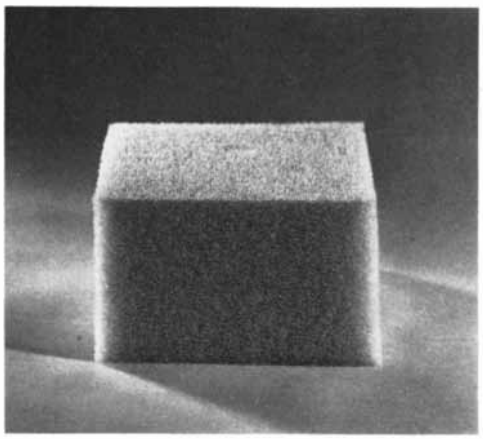
"Where are the rebels against the government to make their last and final stand is now a question of intense interest. Columbus, Ky., was at one time proclaimed the Gibraltar of the Confederates, the key to the vast Mississippi Valley—the stronghold for the defense of Memphis and even New Orleans. Bowling Green was a point of great strategic importance, the key to the capital of Tennessee as well as a base for operating against the independence of Kentucky in her proud place as a State of the Union. But by the superior strategy of the Federal generals and the indomitable bravery of the Union troops, these confessedly strong positions were all turned and evacuated of their rebellious contents, and the victorious legions have pressed forward to the very central spot where treason was incubated and hatched into life."

"The British Admiralty has granted to the Atlantic Telegraph Company the services of the ships and crews necessary for revising and extending the former surveys of the route along which the Atlantic cable is intended to be submerged. The route westward from the Irish coast, for a distance of some 500 miles, will be sounded at distances of about a mile apart, the previous soundings having been some 30 miles asunder. Careful examination will also be made of the Newfoundland coast. Further negotiations are in progress, the result of which will undoubtedly lead to facilities for raising the additional capital necessary to complete this enterprise, the want of which has of late been so seriously experienced by both England and America."

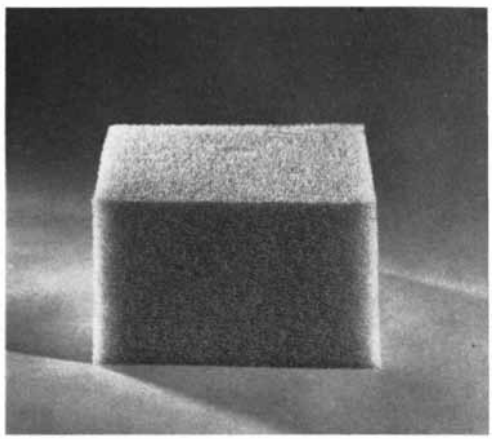
unique foam looking for new uses



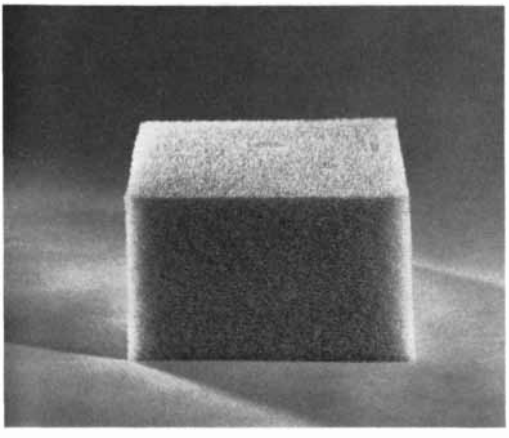
IT'S A STRUCTURE. Not bubbles, but little strands of polyurethane joined in a three-dimensional web.



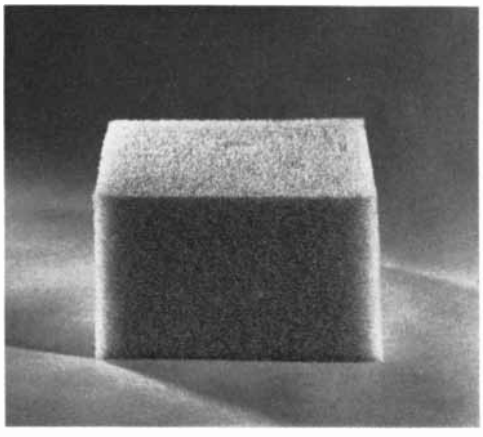
IT'S A CONTAINER. Has 97% void volume. Provides tremendous holding capacity.



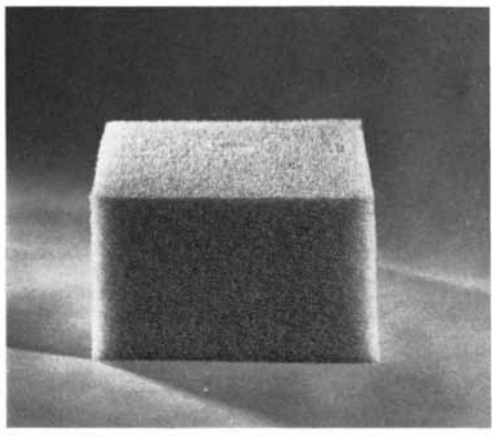
IT'S AN AIR FILTER. The first, dry, permanent, efficient medium on the market. 10 to 80 pores per lineal inch.



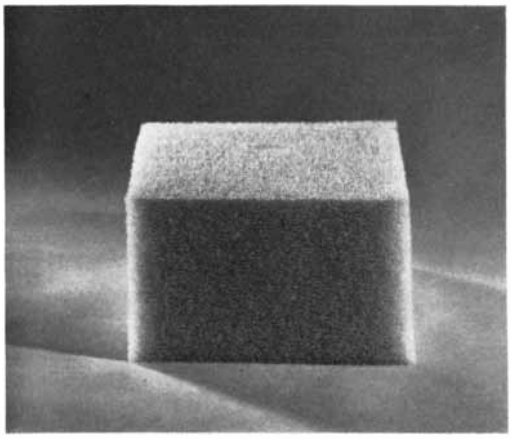
IT'S A VAPOR TRAP. Blow mist through Scott Industrial Foam. Air gets through, droplets don't.



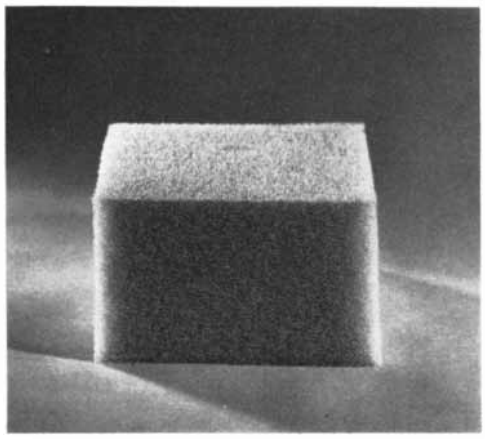
IT'S A SOUND DAMPENER. It screens sound waves, keeps out undesirable noises.



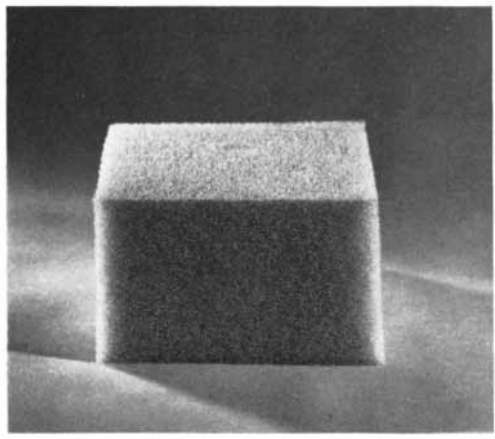
IT'S CLEANABLE. Wash in soap and water or solvents. Can be vacuumed. Can even be reverse flushed with water.



IT'S A LIQUID SEPARATOR. Jet fuel is strained through Scott Industrial Foam during refueling. Fuel goes with plane, water stays behind.



IT'S AN AIR CLEANER. Own a '60 or '61 GM automobile? There is probably a permanent air cleaner in your car made with Scott Industrial Foam.



WHAT'S YOUR IDEA for using Scott Industrial Foam? Write and we'll send facts and a sample: Edgar Mack, Manager Industrial Sales, Foam Division, Department A, Scott Paper Company, Chester, Pennsylvania.

At home and work too

SCOTT

makes it better for you

MEASURE. RECORD. ANALYZE.

(It sounds easy when you say it fast.)

It used to be that data acquisition was as simple as looking at a dial or a glass thermometer. No more. The entire data handling process itself has become more and more complicated and demanding. Because of this, it has become increasingly prudent to call for expert advice when you have a challenging problem—or even a routine one, for that matter—in the field of data handling. We believe the examples cited below bear out this practical wisdom.

"LONG DISTANCE" DIAGNOSIS. In experimental tests in Birmingham, Alabama, electrocardiograms are being "dialed" by special telephone hook-up directly from patients in one hospital and automatically charted on a Honeywell Visicorder direct-writing oscillograph at another hospital across town for immediate interpretation and diagnosis. The success of these experiments, conducted by the Memorial Institute of Pathology, with the Birmingham Baptist Hospitals and engineers of Honeywell collaborating, demonstrate the feasibility of transmitting and recording, even thousands of miles distant, practically any type of physiological data which can be sensed electronically. Thus the knowledge and ability of medical specialists can be made available to physicians and their patients in any part of the country.

GET DOWN TO THE ELEMENTS. This was the assignment recently handed to Honeywell engineers by a midwestern manufacturer of scientific instruments. That is: determine the various elements in a hydrocarbon mixture: carbon, hydrogen, oxygen, nitrogen, sulfur, and so on. For some time, gas chromatographs have been used to determine the percentage of components of a gaseous mixture—methane, butane, ethane, hexane, propane, and other hydrocarbon compounds. Starting with this instrument and its Honeywell strip chart recorder, adding a mass spectrometer, and feeding the signals into a multichannel Visicorder oscillograph, a time-correlated record of the various component elements of a gaseous mixture was readily obtained. Since few recorders can keep up with the speed of a mass spectrometer, an extremely wide range of galvanometric sensitivities had to be provided to measure the wave lengths of the various elements. In practice, the assembly works with speed and precision, doing instantaneously analytical work that previously took hours of laborious laboratory time.

ELECTRONIC "SLIDE RULE" FOR STEEL MILLS. In the basic oxygen steelmaking process, a heat of steel is produced very quickly, and the charge for the next batch must be calculated as the current one is being poured. If the mix is off, the steel may not reach the proper temperature by the time the furnace is tapped, and the whole batch has to be reblown. If the narrowly limited tapping temperature range is exceeded, the steel has to be cooled down. In either case, it's costly, and seriously interferes with production schedules. The proper proportion of charge ingredients—raw steel, scrap, scavengers, etc.—can be figured out empirically on a slide rule, but even the best human calculations are too slow to keep up with the furnaces. Honeywell engineers designed for Jones & Laughlin Steel Corp. a special analog computer that determines instantly the proper charge formula for a specified end temperature.

CLINICIAN TURNS REPORTER. In the treatment of Parkinson's disease and other musculomotor disorders, it would be most helpful if the therapist could accurately measure cogwheel rigidity (muscular resistance) before and after treatment. Working with Duke University Medical Center, Honeywell field engineers and university physicians devised a two-channel amplifier that measures the angle of the patient's arm and reports muscular resistances while the arm is being rotated through an arc. A two-pen Honeywell recorder forms an integral part of this system, and furnishes the hospital a permanent strip chart record for further study and evaluation.

You will find that a combination of experience, equipment, and engineering competence offers a unique capacity for coping with the complete range of data handling problems—acquisition, reduction, computation and analysis, and presentation. If you would like to enlist Honeywell's cooperation in solving yours, call your nearby Honeywell field engineer or write Industrial Products Group, Minneapolis-Honeywell, 4412 Wayne Avenue, Philadelphia 44, Pa.

Honeywell

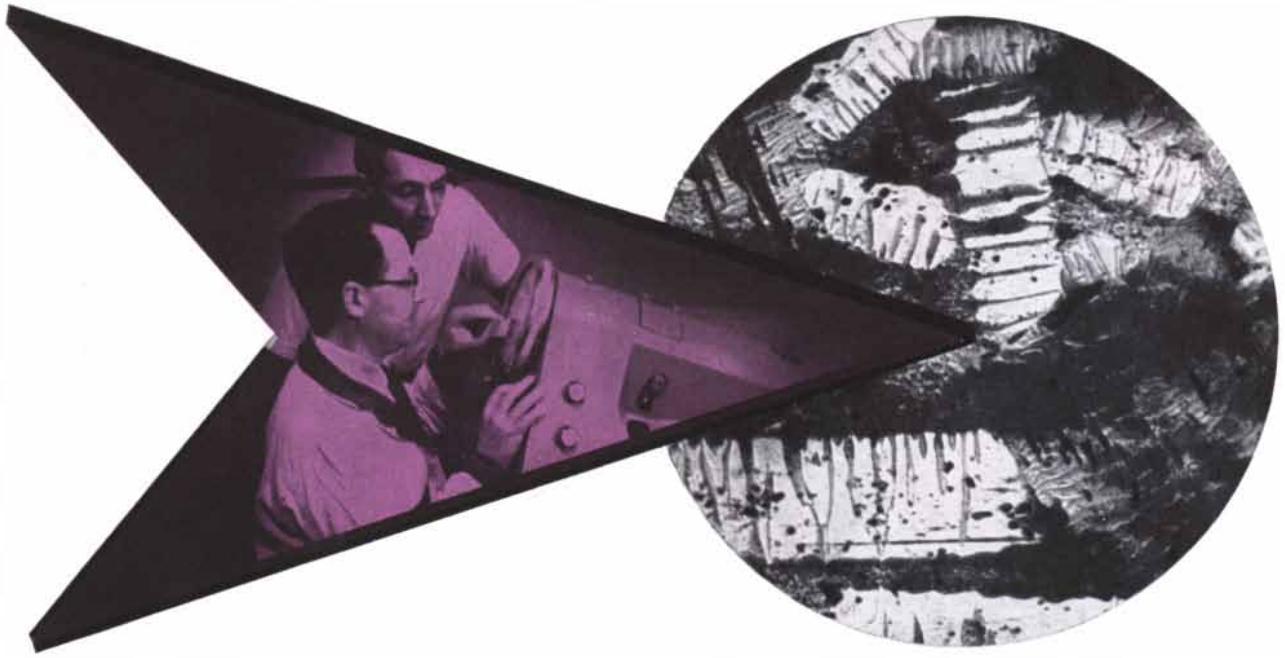
Data Handling Systems

HONEYWELL INTERNATIONAL Sales and service offices in principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

we probe magnetic domains . . .

because magnetism is our business

Analyzing magnetic materials is an essential facet of our continuing research in the broad field of applied magnetics. Take the microscopic magnetic domains, for example, created when magnetic moments of electrons are oriented in the same direction. They vary with different materials and with the magnetic force applied. By applying a suspension of iron oxide to a sample, and observing through the microscope how the particles line up in domain patterns (as illustrated here), we can draw definite conclusions about the material's magnetic characteristics. ■ Micro-motion pictures of these "powder patterns," taken as the magnetic field is varied, show us how a material goes through a complete hysteresis loop traverse. In modern, high-quality permanent magnet materials, the structures are of such an extremely fine dispersion, we often apply an electron microscope to reveal the details. ■ In practical application, such materials research was extremely valuable in developing our INDOX® ceramic magnets. If you would like to read more about this subject, **write today for "Magnetic Domains,"** to Indiana General Corporation, Valparaiso, Indiana.



INDIANA GENERAL

When the Egyptians referred to royalty in hieroglyphs, they surrounded the characters for these superior names with an oval frame called a cartouche. The hieroglyphs in this cartouche refer to Cleopatra.

In microwave technology, there are also superior names. Example: Varian Associates, who provide the highest power and efficiency available today in traveling wave tubes.

Varian Wave Tubes represent the maximum extension of the art in several areas, namely:

MULTI-MEGAWATT, high efficiency, pulsed TWT's in S and C-bands.

MULTI-KILOWATT, high duty cycle, pulsed TWT's with PPM focusing.

HIGHEST FREQUENCY BWO's available with permanent magnet focusing.

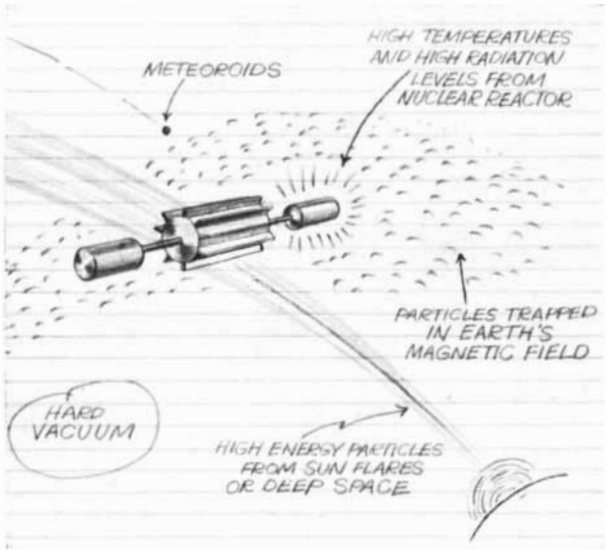
CW TWT's for AIRBORNE ECM, lighter and more compact than previously available tubes.

Current programs, including 5 KW L-band TWT's for high performance phased array radars, and one watt BWO's to 75 gc, will maintain Varian's leadership in TWT technology.

Varian is a superior name in TWT's, with an extensive line of available tube types. If you need superior TWT's, Varian has (or can design) the ideal tube for you. Contact Tube Division.

VARIAN associates
PALO ALTO 7, CALIFORNIA

Varian Subsidiaries: BOMAC LABORATORIES, INC. • S-F-D LABORATORIES, INC. • SEMICON ASSOCIATES, INC.
VARIAN ASSOCIATES OF CANADA, LTD. • SEMICON OF CALIFORNIA, INC. • VARIAN A. G. (SWITZERLAND)



Hypothetical research satellite, showing typical space environment hazards encountered.

Extreme Environments Technology, Vital Step in Space Progress

A few of the basic environmental problems in space are sketched above. For example, the nuclear reactor power source at one end of the vehicle generates not only relatively large quantities of heat, but neutron and gamma radiation as well. If cryogenic propellants are present, the designer must cope with an extremely *wide range* of temperatures.

Externally, the vehicle will be exposed to high energy radiation from nuclear particles trapped in the earth's geomagnetic field. Though the regions of particles have not yet been completely mapped, their boundaries appear to be not only variable but overlapping. And since the total dosage of radiation to be encountered by a satellite in any given orbit is unknown, the designer's first order of business is to "harden" the vehicle's systems and components against heat and radiation to the maximum practical degree. Weight limitations on payload rule out all but minimum shielding.

The first step in the Bendix Extreme Environments Program was to study sensitivity of state-of-the-art components. To date, we've made considerable progress in determining component and systems reliability under known heat and radiation levels. For example, recently we've produced successful reliability correlations for several types of transistors, expressing failure rates as a function of total fast neutron dose. We've concentrated on solid state devices mainly because of their weight and power advantages.

Many non-electronic components will also require hardening.

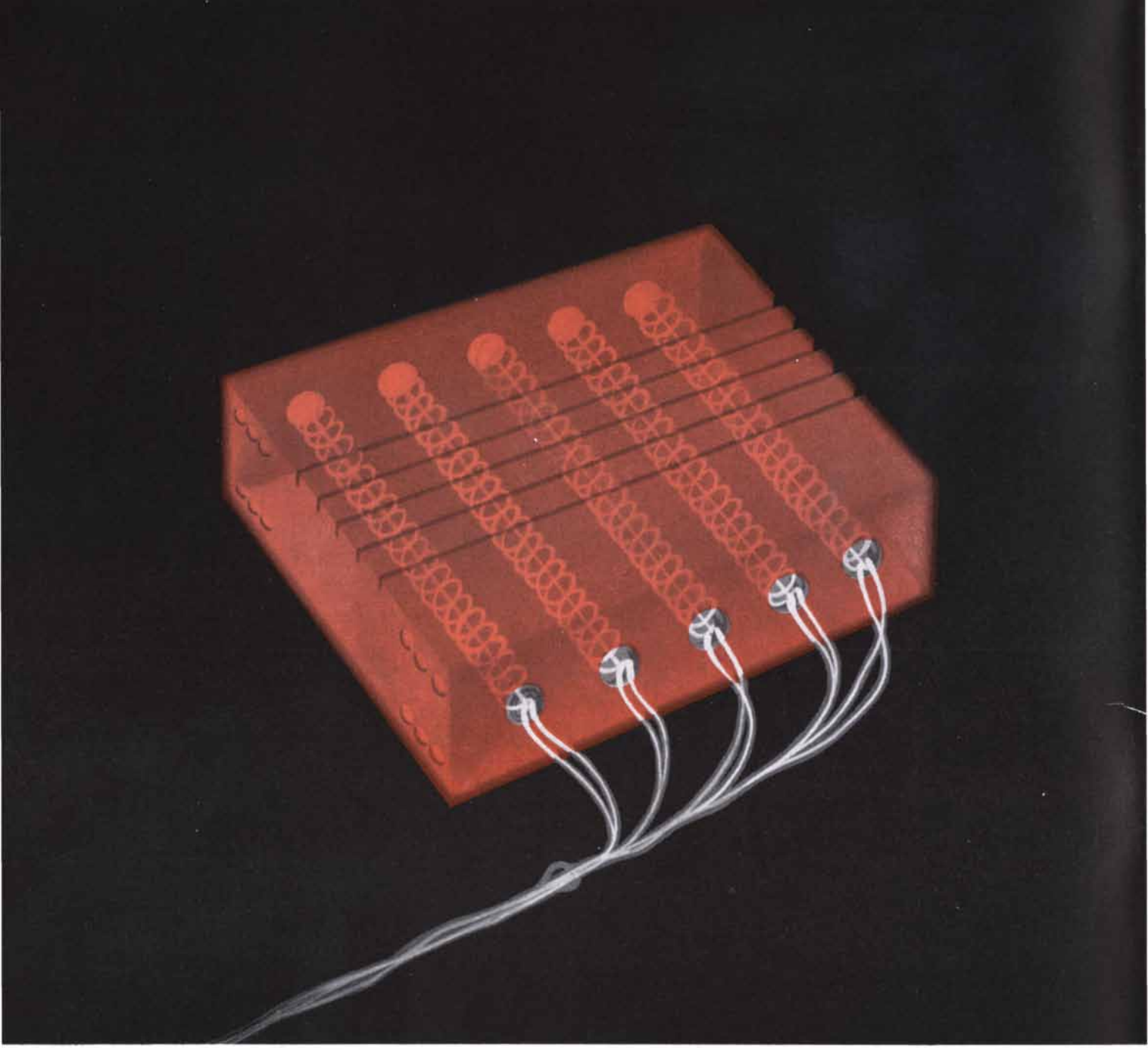
A good example of our activity in this area is our recent development of a heat- and radiation-resistant servo actuator for nuclear reactor controls. This actuator is designed to withstand massive radiation doses during operation at temperatures up to 1200°F.

Bendix research embraces a complete range of disciplines including acoustics, nuclear, data processing, microwave, fluid power, lasers and masers, guidance, electronics, solid state physics, and mechanics. Motivation: to develop new techniques and hardware for producing complete, integrated, advanced systems for defense, industrial and commercial applications. Inquiries are invited. We also invite engineers and scientists to discuss career position opportunities with us. An equal opportunity employer. Write Director, Bendix Research Laboratories Division, Southfield, Michigan.

Research Laboratories Division

THE Bendix CORPORATION

WHERE IDEAS UNLOCK THE FUTURE



THE INSIDE STORY: clean solution for a sticky problem

What you see above is a block of a Du Pont TEFLON fluorocarbon resin with imbedded heating elements, used to heat-seal candy wrappers. Almost nothing sticks to the TEFLON—not even the wet display inks that previously were smeared by cast-iron heat sealers.

A TEFLON resin makes an ideally useful material whenever you encounter the problem of handling sticky substances. The strong bonds within the molecules of TEFLON, together with the weakness of attraction they exhibit to dissimilar molecules, account for the inherent antistick nature of TEFLON resins, for their high resistance to heat and for their virtually complete chemical inertness.

In consequence, you can use TEFLON in the form of a solid, a liner, a coating or a spray to provide a low-friction, non-sticking, non-contaminating surface in contact with any number of tacky materials.

Are *you* free of such sticky problems? If not, write: E. I. du Pont de Nemours & Co. (Inc.), Dept. SA-6, Room 2526T, Nemours Building, Wilmington 98, Delaware. *In Canada:* Du Pont of Canada Limited, P.O. Box 660, Montreal, Quebec.

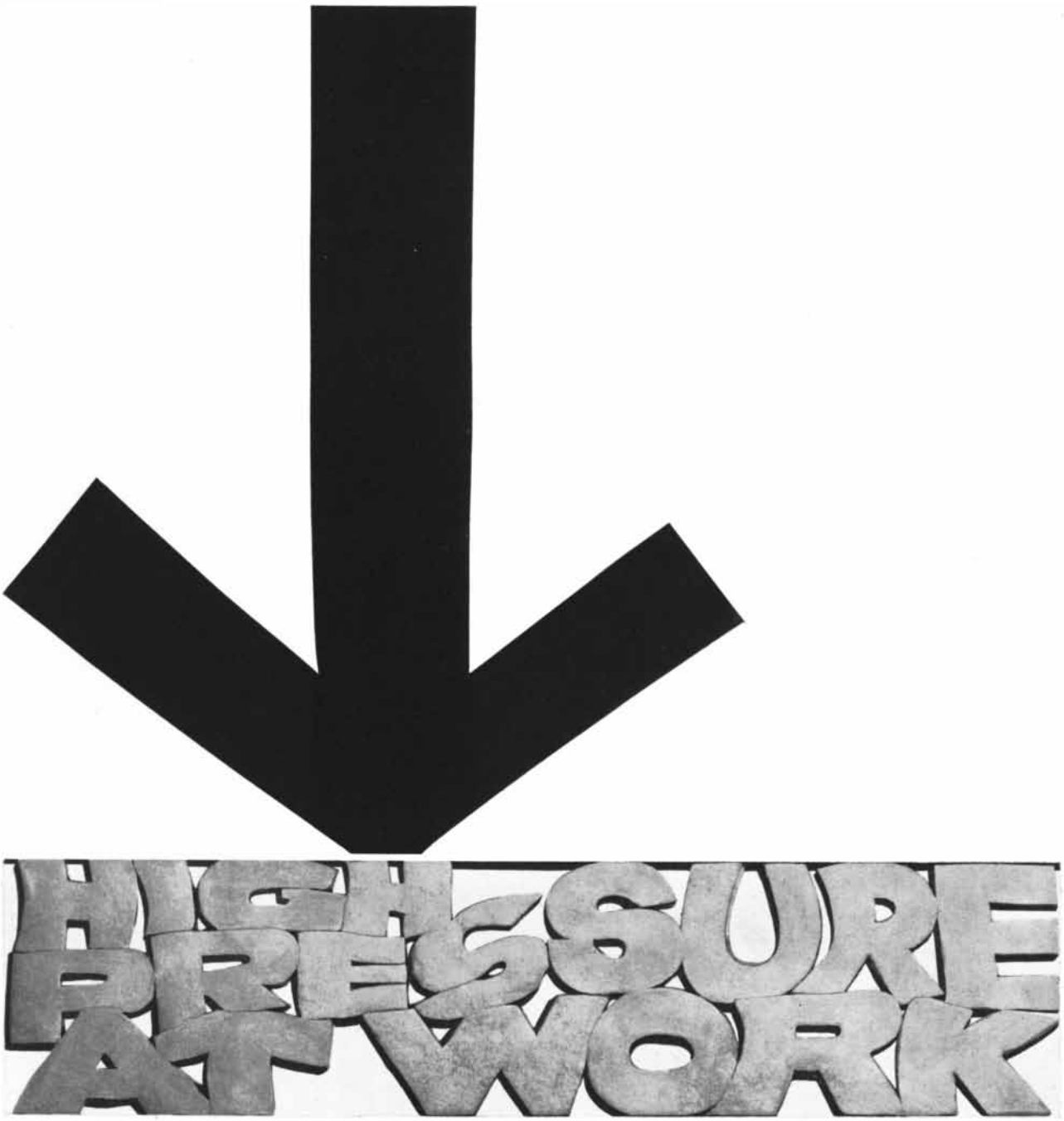
DU PONT

TEFLON®

FLUOROCARBON RESINS

TEFLON is Du Pont's registered trademark for its family of fluorocarbon resins, fibers and film, including TFE (tetrafluoroethylene) resins and FEP (fluorinated ethylene propylene) resins.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*



Do you need—or suspect you need—high pressures in your research or processing operations? Are you a bit unsure as to what kind of high pressure equipment is available, what each kind is best suited for, and how to select the proper equipment for *your* needs?

"HIGH PRESSURE—At Work!" is a kit designed for the designer and the researcher. It has been tailored by Autoclave Engineers, Inc., America's major manufacturer of high pressure autoclaves, reactors, valves and fittings, to lend confidence to the high pressure equipment user by putting at his disposal more than fifteen years of skill and experience in this field.

Getting started on the proper use of high pressure equipment is simple. Send the coupon to put the pressure on us!

AUTOCLAVE ENGINEERS, INC.

Autoclave Engineers, Inc.
Dept. SA
Box 4007, Erie, Pennsylvania, U.S.A.

Gentlemen:
Yes, I'd like "HIGH PRESSURE—At Work!"

Name_____

Title_____

Company_____

Address_____

City_____ Zone____ State_____

AT RADIATION, CHALLENGE IS OPPORTUNITY

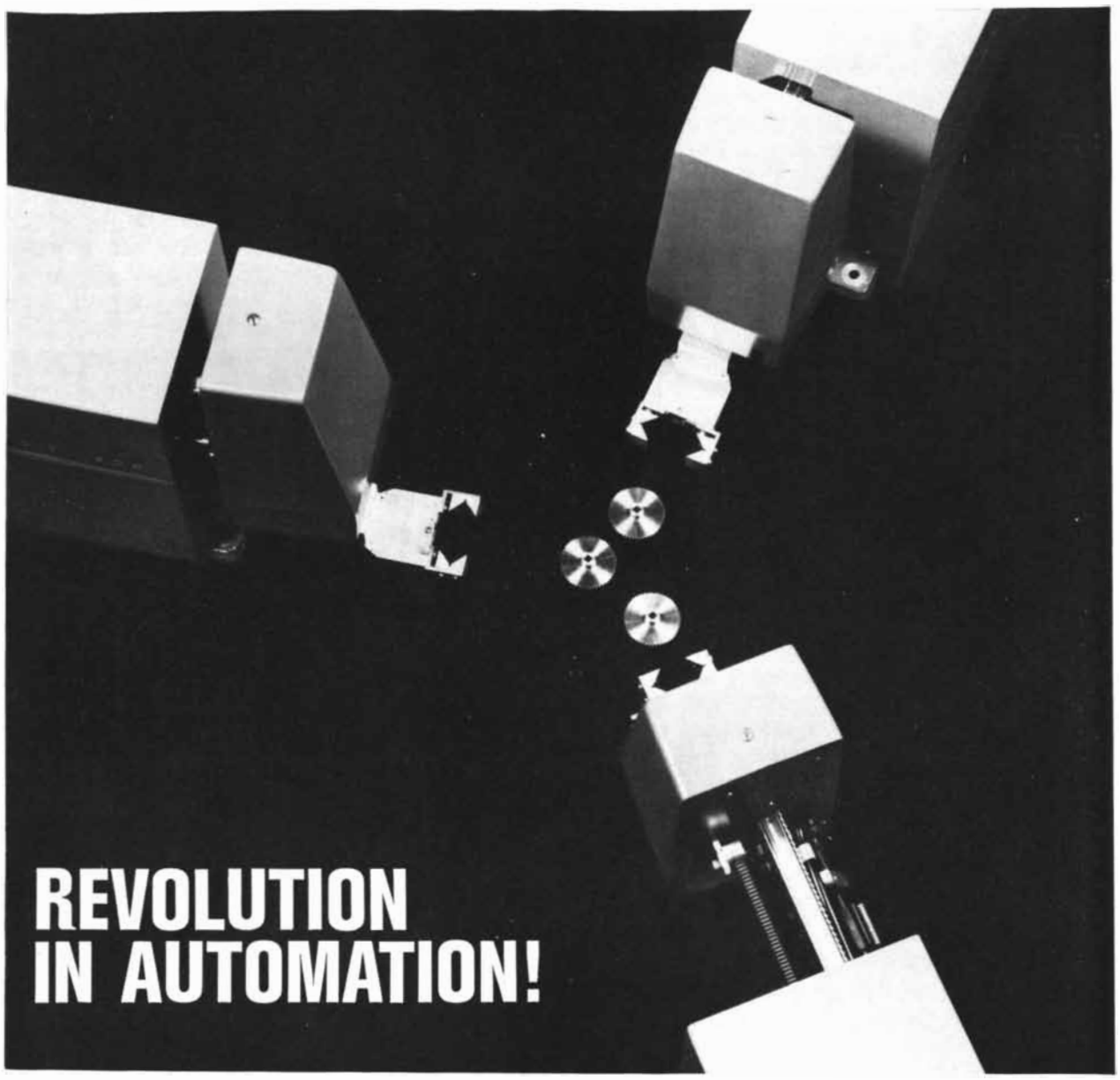
Example: Three satellites, three breakthroughs

PCM telemetry technology moves a step forward each time Radiation Incorporated engineers solve challenging telemetry problems of advanced projects. These include Nimbus, Telstar, and most recently, NASA's Orbiting Astronomical Observatory. This far-out "observatory" will provide astronomers with a vantage point unobstructed by our atmosphere.

The two-unit OAO PCM system is constructed with unique fail-safe redundant circuitry for long life and handles both experimental and operational information. Although it has a 688-channel capacity, the system requires less than 6 watts and weighs less than 60 pounds! The digital circuitry has a *satisfactory operating probability of 98% for one year in orbit.*

Radiation's unique capability in PCM and ground support equipment dates back to 1954 when our engineers pioneered the first airborne system. If *you're* the kind of engineer who wants the opportunity to work in an environment where creativity is welcomed, send your resume or write for details. Personnel Director, Dept. SA-6, Radiation Incorporated, Melbourne, Florida. *Radiation is an equal opportunity employer.*

RADIATION
INCORPORATED



For the first time, universal automation is practical! A revolutionary, "off-the-shelf" industrial robot—the USI TransfeRobot*—can operate on any production line under the direction of its self-contained electronic brain.

Versatile and dependable, the USI TransfeRobot performs virtually any repetitive task associated with hand and arm motions.

It is easy to teach the TransfeRobot a new task. A few simple cams and switches can be set for one operation today, an entirely different application next month, and still another next year.

Simple electronic controls couple any number of TransfeRobots together in synchronized cooperation, and direct the operation of presses, riveters and other production line tools.

A wide variety of mechanical, pneumatic, magnetic and other accessory fingers are available "off-the-shelf" to handle thousands of different components in any production situation.

TransfeRobots are now oiling clocks, machining automobile parts, assembling typewriters.

Write, wire or telephone to find out what USI TransfeRobots can do for you.

U.S. INDUSTRIES, INC. AUTOMATION DIVISION

12345 New Columbia Pike, Silver Spring, Maryland

*TM

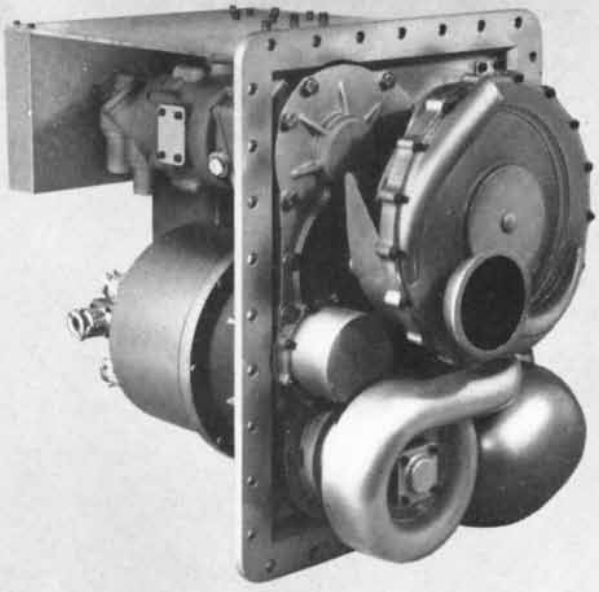
TRW **TAPCO**
Thompson Ramo Wooldridge Inc.

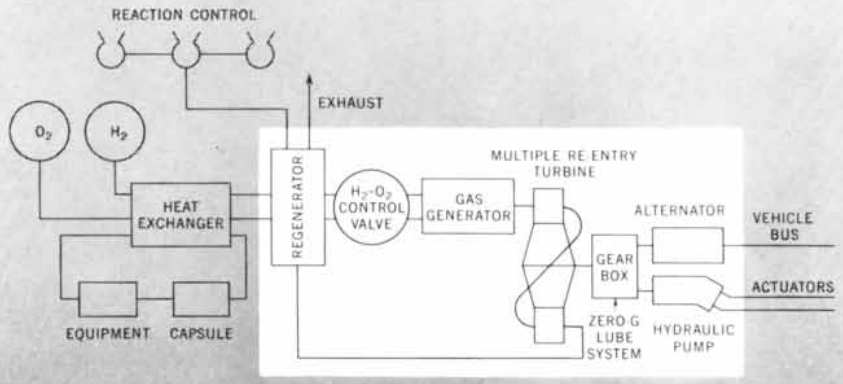
POWER SYSTEMS BY TAPCO — Combining extensive energy-conversion experience with a high degree of interface-systems intelligence, Tapco insures that trade-off studies will yield the most practical power system in terms of specific weight, reliability and operational flexibility.

TAPCO POWER-SYSTEM EXPERIENCE

ENERGY SOURCES
Solar
Chemical
Nuclear
Mechanical
Electromagnetic
Stored Thermal

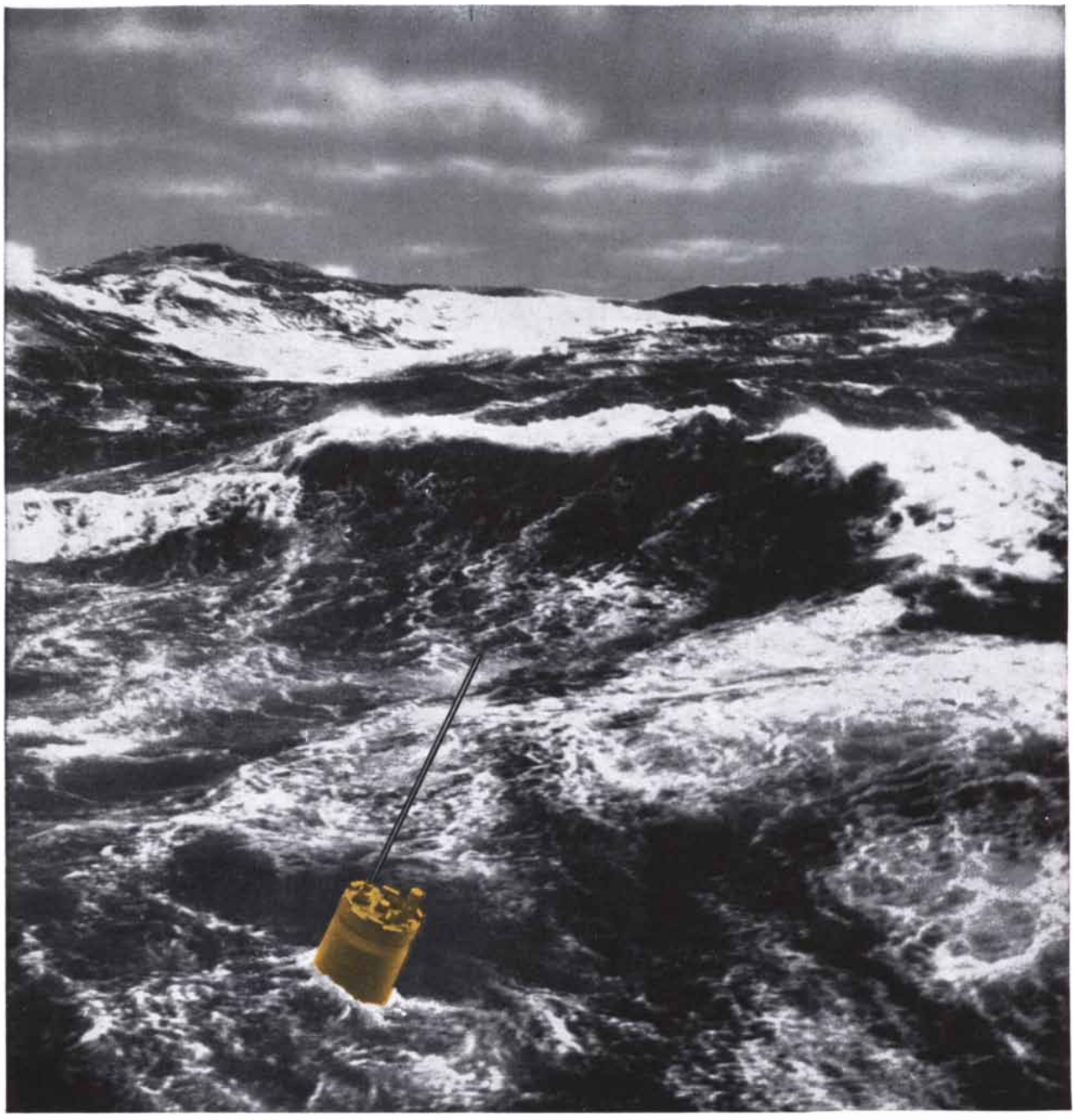
CONVERSION METHODS
Turboelectric
Piston Engine
Fuel Cell
MHD
Thermionic
Turbohydraulic





Cryogenic Regenerative APU: Chemically fueled, open-cycle, dynamic system integrated to provide electric and hydraulic power, reaction control and environmental cooling aboard manned space vehicles on moderate-duration missions. System is readily adaptable for outputs to 100 kw electric and 20 gpm hydraulic. Nucleus of system is unit shown above containing multiple re-entry turbine, alternator, hydraulic pump, lubrication and control subsystem. Turbine utilizes liquid H_2 and O_2 as energy source. By using H_2 as coolant, and exhaust regeneration, very low specific propellant consumption is achieved. Integration of energy source also provides all payload cooling, i.e., equipment and capsule. Performance of all system elements has been demonstrated. TAPCO, a division of Thompson Ramo Wooldridge Inc., 23555 Euclid Avenue, Cleveland 17, Ohio.

DESIGNERS / MANUFACTURERS FOR SPACE, MISSILE, AIRCRAFT, ORDNANCE, ELECTRONIC, NUCLEAR INDUSTRIES



Hearing Aids for the Ocean

One way to trap an enemy sub is to drop a pattern of Sonobuoys around it. Power for these detecting devices comes from special batteries activated by sea water. Silver foil and sheets of silver chloride, magnesium and calcium are vital components of the batteries.

Peerless Roll Leaf Company, a division of Howe Sound Company, long-time manufacturers of roll leaf and tissue-thin foils, cooperated in the successful development of salt water batteries. Peerless is now one of the leading producers of the sheets and foil used in batteries for Sonobuoys, torpedoes and similar applications.

This is an example of the progress in new techniques being made by Howe Sound companies—through generations of experience in metals. Howe Sound is a company you should know about. Howe Sound Company, 500 Fifth Avenue, New York 36, N.Y.

HOWE SOUND

DIVISIONS: ROLLING MILLS • DENTAL/SURGICAL • SUPERALLOY PRODUCTS • METALLURGICAL/REFRACTORIES • PRECISION PRODUCTS/TESTING

THE AUTHORS

L. DON LEET ("The Detection of Underground Explosions") is chairman of the Division of Geological Sciences at Harvard University, where he has directed the Harvard Seismograph Station since 1930. Born in Alliance, Ohio, in 1901, Leet received a B.S. in geology from Denison University in 1923 and a Ph.D. in seismology from Harvard in 1930. He joined the Harvard faculty in the same year. During World War II he was engaged in research first at Harvard's Radio Research Laboratory (on radar countermeasures) and later at its Underwater Sound Laboratory. He became chairman of the Division of Geological Sciences in 1951.

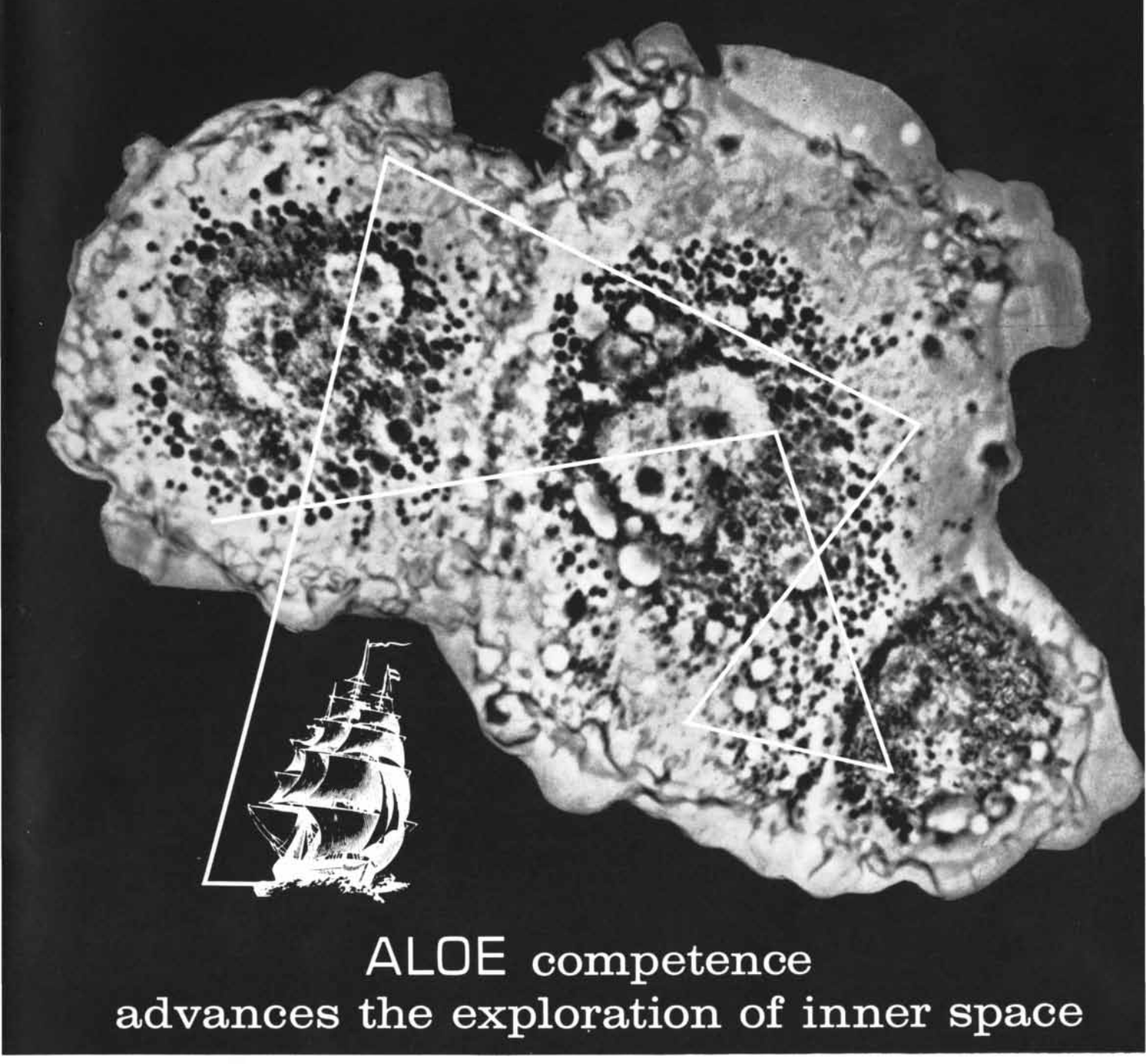
J. E. KUNZLER and MORRIS TANENBAUM ("Superconducting Magnets") are respectively head of the Metal Physics Research Department and assistant director of the Metallurgical Research Laboratories at the Bell Telephone Laboratories. Kunzler received a B.S. in chemical engineering from the University of Utah in 1945 and a Ph.D. in physical chemistry from the University of California in 1950. He was a research associate at California until 1952, when he went to the Bell Laboratories. There Kunzler established a low-temperature laboratory and began specializing in the precise measurement of the electrical, thermal and mechanical properties of solids at low temperatures. This led him to the study of superconductivity and superconducting magnets. Tanenbaum obtained an A.B. at Johns Hopkins University in 1949 and a Ph.D. in chemistry at Princeton University three years later. His first years at the Bell Laboratories, which he joined in 1952, were devoted to studies of the chemistry and physics of semiconductors. Tanenbaum's later interest in the structural and electrical properties of solids led to his association with Kunzler in work on the properties of superconductors in strong magnetic fields.

VICTOR H. YNGVE ("Computer Programs for Translation") is director of a group at the Massachusetts Institute of Technology engaged in research on the mechanical translation of language. Yngve studied physics at Antioch College, receiving a B.S. there in 1943, and at the University of Chicago, where he acquired a Ph.D. in 1953. While doing research on cosmic rays he became interested in the possibility of using digital computers for mechanical translation. Yngve became increasingly fascinated by the formidable language problems involved and by the possibility that scientific methods might lead to a greater understanding of the complex phenomena of language and human communication. He has been teaching and conducting research in mechanical translation at M.I.T. since 1953.

J. A. BASSHAM ("The Path of Carbon in Photosynthesis") is research chemist and lecturer in chemistry at the University of California, where he received his B.S. in 1945. Bassham did his doctoral research at the University of California under Melvin Calvin on the path of carbon in photosynthesis and received his Ph.D. in 1949. Since then he has been in Calvin's Bio-Organic Chemistry Group at the Lawrence Radiation Laboratory, except for a two-year tour of duty in the Navy and a year in H. A. Krebs's laboratory at the University of Oxford.

JEAN DE HEINZELIN ("Ishango") is professor of stratigraphic paleontology at the Geological Institute of the University of Ghent in Belgium. Originally trained in organic chemistry, de Heinzelin turned to geology and mineralogy after World War II. He took degrees in these subjects at the universities of Brussels and Paris in 1953 and 1955 respectively. Last year he was in the Sudan as a member of the Nubian Monuments Expedition sponsored by Columbia University.

HARVEY E. WHITE and PAUL LEVATIN (" 'Floaters' in the Eye") are respectively professor of physics at the University of California and chief of the department of ophthalmology at the Kaiser Foundation Hospital in Oakland, Calif. White received his Ph.D., specializing in optics, from Cornell University in 1929 and spent a year in Germany before going to the University of California, where he has been teaching college physics ever since. During World War II he directed research projects for the Office of Scientific Research and Development. In 1957 White taught a one-year high school physics course that was broadcast over a Pittsburgh educational television station and later distributed as a film. This led to his teaching the first nationally televised college credit course, in physics, on the program "Continental Classroom." White is the author or co-author of 11 textbooks in general physics and optics. A consultant to several pri-



ALOE competence advances the exploration of inner space

The men at Aloe Scientific are always on the lookout for the most advanced instrumentation available for the exploration of inner space.

Intelligent selection and careful testing of this laboratory equipment are indicative of Aloe competence.

Typical of the instruments which Aloe has brought to the attention of its customers is the de Fonbrune micro-manipulator developed for use in precise micro-biological and micro-physical investigations.

Its unique design permits a simplicity of operation and a flexibility of application not found in other apparatus.

There are many fine instruments in the Aloe line which are being used by scientists to help map boundaries of inner space. Contact Aloe Scientific for your laboratory needs.

Serving the Sciences that Serve Mankind

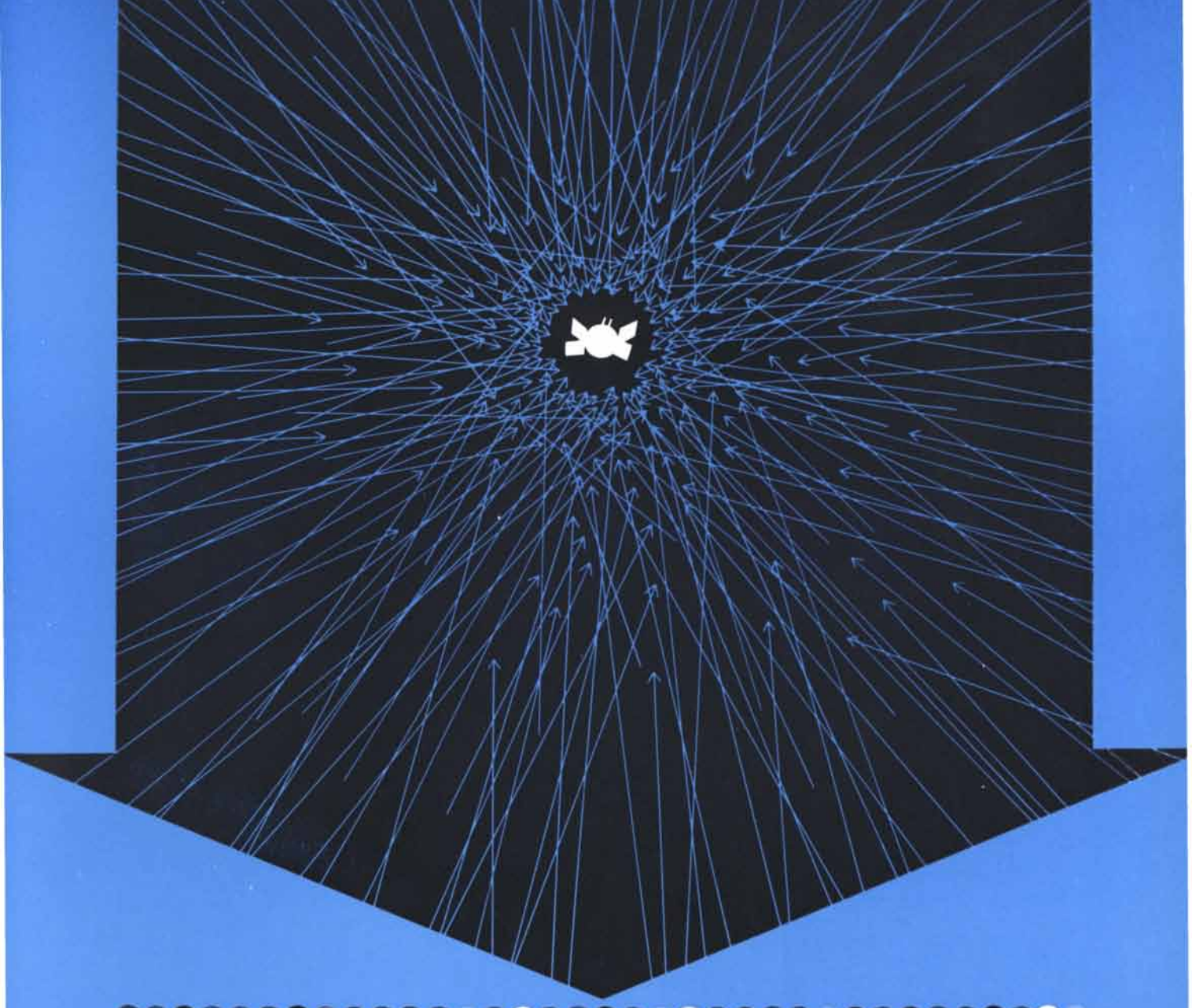
ALOE
SCIENTIFIC
DIVISION OF BRUNSWICK
ST. LOUIS 3, MO.

vate and governmental research organizations, he is currently director of the Lawrence Hall of Science at the University of California and vice-chairman of the physics department. Levatin was graduated from the Massachusetts Institute of Technology in 1934 and took a master's degree in chemistry there before attending Tufts College Medical School, where he received his M.D. in 1939. For the past 13 years he has been associated with the Permanente Medical Group at the Kaiser Foundation Hospital, and it was there that he operated on White for a detachment of the retina—the circumstance that led to his collaboration with White on the present article.

EVELYN SHAW ("The Schooling of Fishes") is research associate in the Department of Animal Behavior at the American Museum of Natural History in New York City. She was graduated from New York University in 1947 and received her Ph.D. there in 1952. From 1947 to 1954 she taught biology at Rutgers University; in 1949 she joined the staff of the American Museum. She writes that she has always been fascinated by the sea; her doctoral research was in the embryology and physiology of fishes. Since 1957 she has concentrated on the study of schooling, both at the museum and in the Caribbean, Mediterranean and Aegean seas.

MARY A. B. BRAZIER ("The Analysis of Brain Waves") is a neurophysiologist who holds a National Institutes of Health Career Professorship at the University of California at Los Angeles and a visiting professorship at the Massachusetts Institute of Technology. Although her primary field of interest has been electroencephalography, she has also been interested in the application of computer techniques to the biological and medical sciences. A native of England, she received a Ph.D. in biochemistry and a D.Sc. in neurophysiology from the University of London. She was on the staff of Maudsley Hospital in London from 1930 to 1940, when she came to the U.S. as research associate in neurology at Harvard University and neurophysiologist at the Massachusetts General Hospital. The investigation reported in her article was supported by the National Institutes of Health and the Office of Naval Research.

SERGE CHERMAYEFF, who in this issue reviews James Marston Fitch's *Architecture and the Esthetics of Plenty,* is professor of architecture at Yale University.



HOW TO LISTEN TO 160,000 SPACE MESSAGES–INSTANTANEOUSLY!

A satellite in orbit has a lot to tell. It sees the birth of a hurricane, feels the bombardment of radiation, peers into new space highways. Then it hurls this information to earth in the form of millions of electrical impulses. A Beckman system gathers and translates them to a common language, is capable of delivering 160,000 messages every second–without missing a one.

With a similar Beckman system you can check a prototype aircraft through its wind tunnel tests–improve on design long before actual flight. Or run continuous checks on a petroleum refinery–assure the quality of industrial output and the safety of workers. Other Beckman instruments analyze the mystic potions of a jungle witch doctor, balance the color in television receivers, and monitor the air in nuclear submarines. Beckman instruments, systems, and components are at work throughout the world in laboratories, production lines, and defense installations.

Remarkable what you–and a Beckman system can do.

If you have a problem in analysis, measurement, or control, write to our Director of Marketing.

Beckman® INSTRUMENTS, INC.
Fullerton, California

WHO SAYS YOU CAN'T CARRY WATER IN A SIEVE?

You can now, thanks to a startling new product called AM-9. It actually turns water solid in seconds.

Remember those wonderful childhood days at the beach? You scooped a hole in the sand. You watched, fascinated, as the hole filled with water. Then you bailed . . . and it filled . . . and you bailed . . . and it filled. Until you gave up and went for a swim.

Now picture this very same underground seepage on a giant scale and you have the problem that has faced many a harassed construction engineer.

Yes, although man may decide to sink a bridge footing here or dig a mine shaft there, Mother Nature quite often has other ideas. And she gets her way through *water*.

How? By the typically feminine maneuver of going underground. Beneath the topsoil lie layers and layers of substances, all of which have different properties. In tunneling through it, man has often, to his dismay, come upon layers of porous, sandy soil or fissured rock through which water flows easily. Trouble!

A problem like this is often solved by a technique called *grouting*. Grouting simply means that materials are pumped in to fill the voids in the sand or rock — like sticking thousands of tiny fingers in thousands of tiny dikes. In the past almost any inexpensive filler material was used. Cement. Clays. Even oatmeal. You pumped . . . and you hoped.

Then came AM-9* chemical grout.

It all began when a Cyanamid scientist synthesized a new compound named, with typical scientific brevity, *methylenebisacrylamide*. Step number two came when a group of other chemists, while exploring new uses for acrylics, uncovered a weird phenomenon. They found that when they mixed methylenebisacrylamide with another acrylic compound and certain catalysts in a glass of water—*the water turned solid!* So solid that it had to be cut from the glass with a knife.

At the time these first gels were being formed in the laboratory, an urgent, practical need had already been isolated. Water flowing through soil or rock formations caused costly problems and delays in construction and mining. Could this mysterious gel be the answer? It could—it was.

After refinement in Cyanamid laboratories came the big tests — exhaustive field trials. What emerged was AM-9 — a grouting material that could literally work wonders.

It transforms porous soil into impervious matter instantaneously. It halts cave-ins and underground seepages. It permits man to tunnel and excavate to his heart's content.

And AM-9 has still another string to its bow. So thin it flows wherever water can flow, it *waterproofs* just as well as it grouts. AM-9 halts chronic water infiltration in sewers and mines, was used to permanently waterproof the utility tunnels at the Plattsburgh Missile Complex.

With the development of this remarkable product, Cyanamid entered an entirely new field. Chemicals had long been known to improve the *agricultural* properties of the soil, but they had been thought to have little power over the soil's *engineering* properties.

Truly, AM-9 marks a breakthrough for the entire chemical industry.

And that is precisely what is so exciting about being in the *business* of science.

Cyanamid's twelve divisions are staffed with thousands of scientists, virtually all working toward the solution of some pressing problem. Yet the full realization exists that minds must be allowed to "putter." To stare aimlessly into space. To explore with no apparent direction.

Out of this "puttering" comes a variety of things. You get solutions to problems that do not yet exist, weird and seemingly worthless substances—that really work—like AM-9.

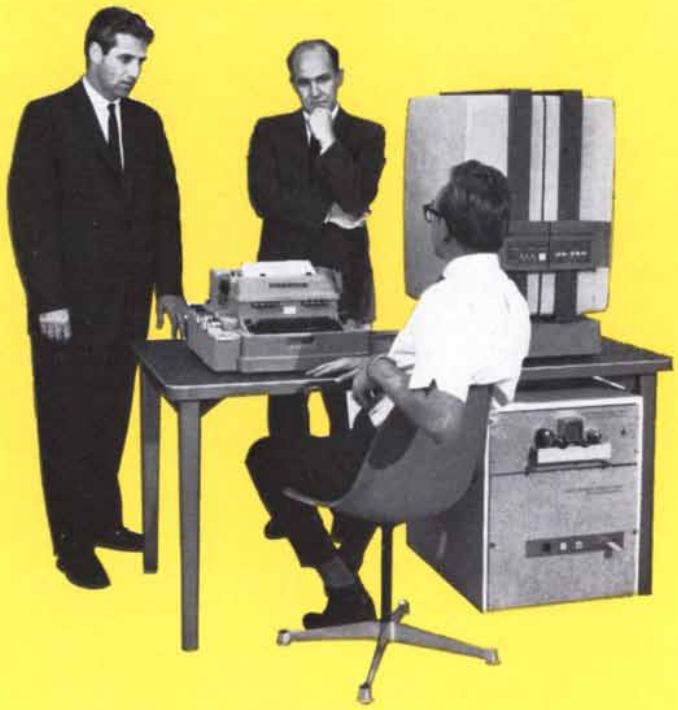
*T.M. American Cyanamid Company

CYANAMID
AMERICAN CYANAMID COMPANY

Agricultural / Building Products / Davis & Geck / Fibers / Formica Corporation
Industrial Chemicals / Lederle Laboratories / Organic Chemicals / Pigments
Plastics and Resins / Cyanamid of Canada Limited / Cyanamid International

PB250 COMPUTER

the most valuable engineering tool you can own!



At $1,200 per month the PB250 offers the greatest computing value available. Packing large scale power into a compact desk-size computer, the PB250 combines features previously found only in computers costing several times its low $40,000 purchase price. Why pay more?

The PB250 offers solid state reliability, a full complement of peripheral equipment, and software in abundance. It is backed by the resources of Packard Bell Computer Corporation (Subsidiary of Packard Bell Electronics).

SPECIFICATIONS: PB250 gp digital computer

Memory—expandable by plug-in from 2320 to 15,888 words

Word Length—21 bits plus sign

Command Structure—Single address with index register and next instruction location tag

Operation Times—Add/subtract—12 microseconds
Multiply—276 microseconds
Divide—252 microseconds
Maximum operation rate—41,666 instructions per second

Power Requirements—115 volts, 60 cps, 110 watts

Peripheral Equipment (connected by plug-in):
Magnetic tape units (up to six)
High speed paper tape punch and reader
Card reader
Line printers
Analog/digital converters
Multiplexers and commutators

This coupon will bring you all the facts you need to get the most productive computer, dollar-for-dollar, that you could possibly buy. Clip it now. Mail it today.

TO: Packard Bell Computer Corporation, 1929 Armacost Avenue, Los Angeles 25, California.

GENTLEMEN: Please send me literature giving full information on performance, flexibility, and applications of the PB 250 and optional peripheral equipment.

NAME..... **TITLE**.....

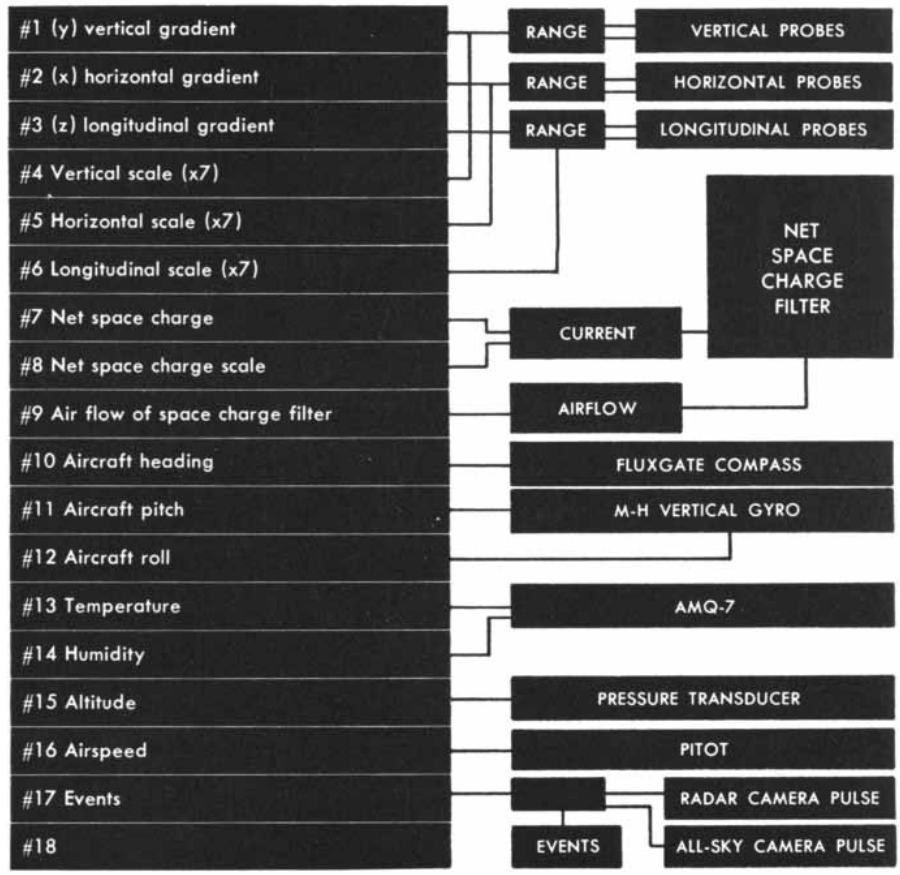
COMPUTER APPLICATION.....

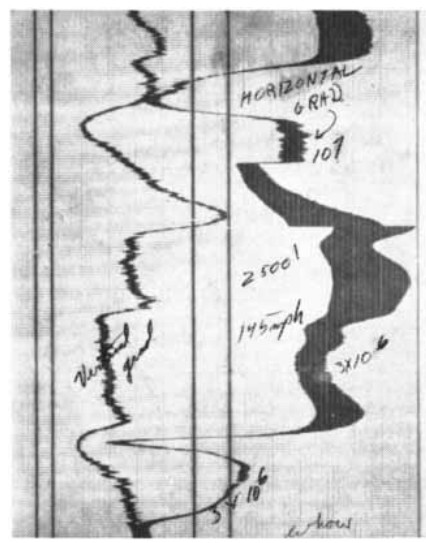
COMPANY.....

ADDRESS.....
(STREET) **(CITY, ZONE)** **(STATE)**

Which comes first... the lightning or the rain?

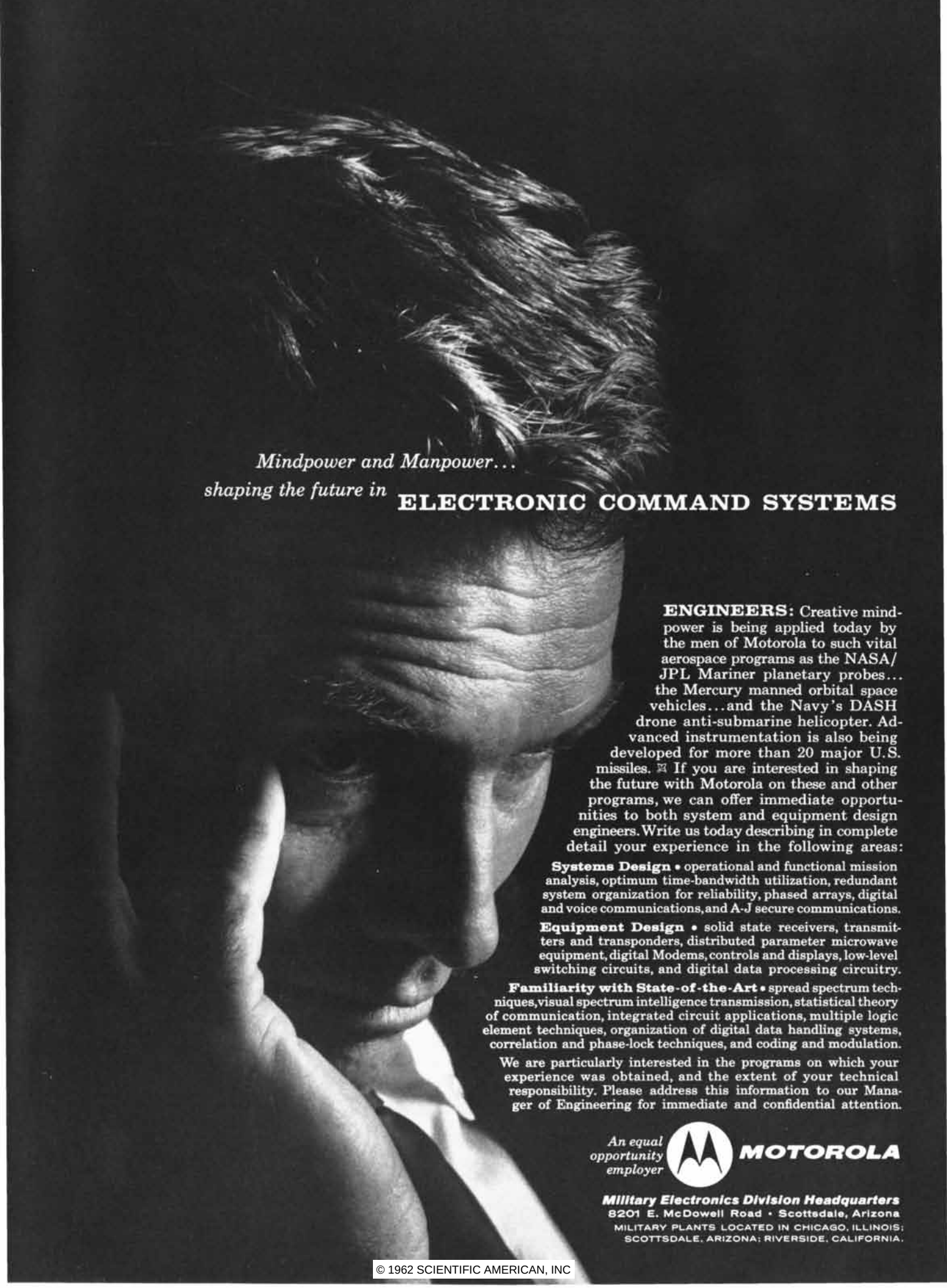
The Visicorder Oscillograph directly records electrical charges in the atmosphere. ☐ What effect do electrical charges on the atmosphere have on cloud formation? What causes cloud droplets to grow into raindrops? Why does one cloud produce rain while another does not? ☐ These questions are being answered in part by a Model 1108 Honeywell Visicorder Oscillograph, shock mounted in a C45 Beechcraft, flown at 15,000 feet over cloud formations above an electrically-charged airspace in Central Illinois. ☐ The Illinois State Water Survey has scattered a network of 50 rain gages across about 400 square miles downwind from 30 miles of small stainless steel wire stretched in a grid-like pattern 30 ft. above the ground. Seven power supplies energize the wire to about 20,000 volts with each supply having an output of 1 to 3 milliamperes. ☐ Time-lapse sky cameras, radar, and other observatory equipment make records of electrical fields, wind speed and direction. A low-flying Piper traces the plume of electrical charge as it rises from the ground; the Visicorder at 15,000 feet measures the movement of the charge in the higher air, how and where it scatters or dissipates, and what effect it has on the growth of cloud droplets. ☐ Maybe your research project is not as glamorous as these weather studies, but if it is at all complex, or requires high speeds or sensitivities, or if you need to record many parameters simultaneously—or directly—the amazingly versatile Visicorder can do your job. ☐ The schematic diagram of these cloud studies will give you an idea of the many capacities of the Visicorder. *For more details about the Model 1108 (24 channels) and other Honeywell Visicorders, write Minneapolis-Honeywell, Heiland Division, 4800 E. Dry Creek Road, Denver 10, Colorado. Our DDD phone number is 303-794-4311.*

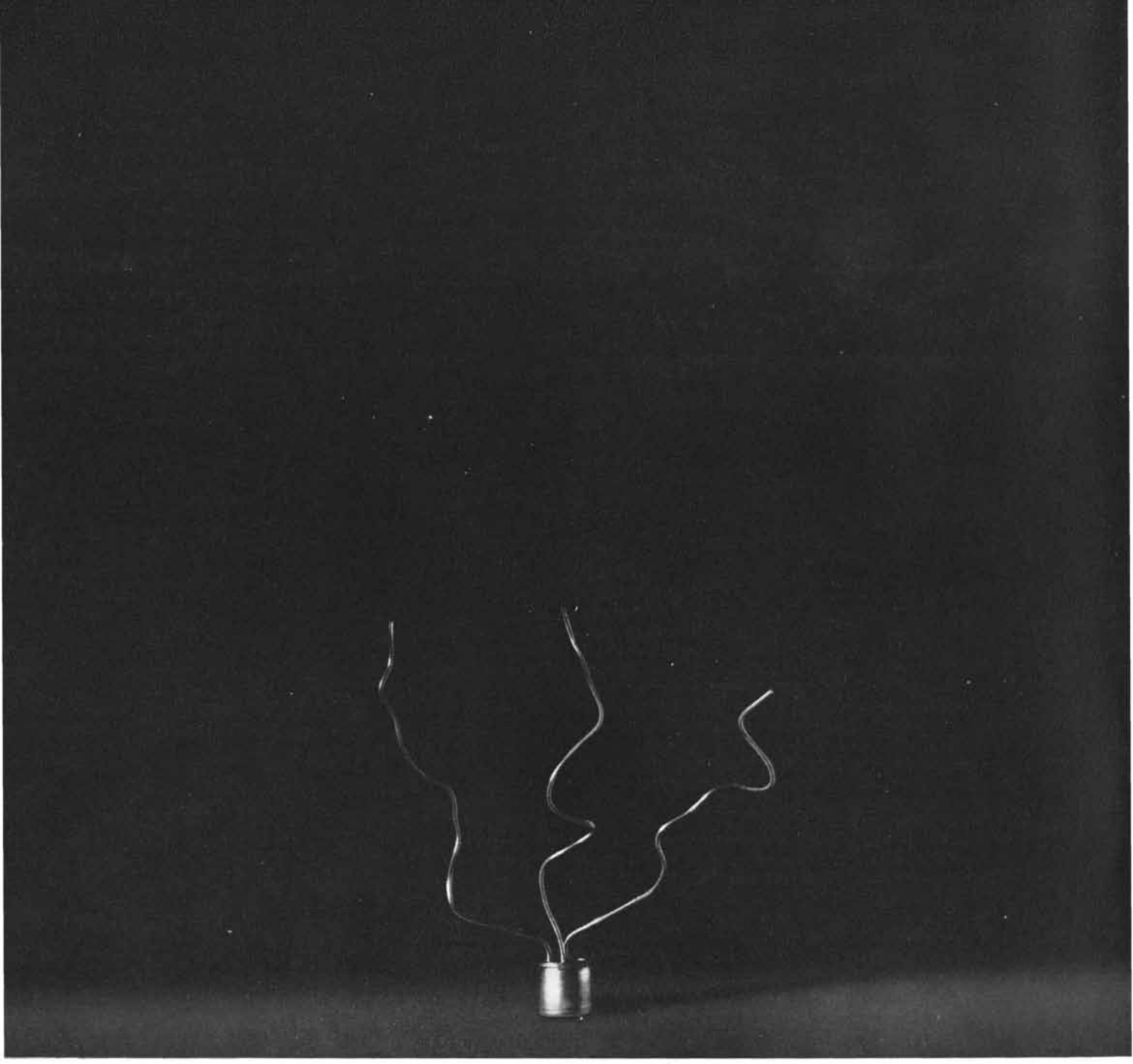




Honeywell

First in Control





Who killed this Fairchild transistor?

We did. It had already passed our standard tests... tumbling, centrifuge, radioactive leak detection. Then, as a sample of the week's production run, it was pushed to its limits... *and beyond*... in destructive testing. Forces 200,000 times greater than the pull of gravity. Extreme temperature, vibration, and shock cycles. Tests to determine the final breaking point. In actual application, no transistor would ever have to take such a beating. Even if shot to the moon. But this is one way we make sure at Fairchild. If there's any weakness in a production run, we want to be the first ones to know about it. *And the only ones.*

FAIRCHILD
SEMICONDUCTOR

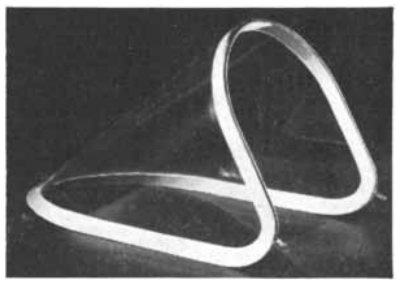
FAIRCHILD SEMICONDUCTOR/545 WHISMAN RD., MOUNTAIN VIEW, CALIF./YORKSHIRE 8-8161/TWX:MN VW CAL 853/A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

THIS IS GLASS

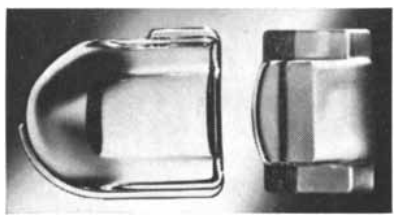
A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

Configurations to match concepts

Fret no more, if problems of shape have kept you from utilizing the chemical, dielectric, moisture, thermal, and transparency benefits of glass. We can give you all sorts of shapes in glass. To wit:

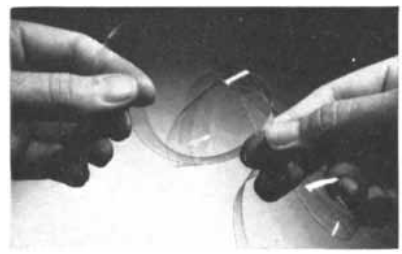


Here's a neat trick. We curve them 180° on an 18-inch radius, keeping a fine polish and holding distortion to barely measurable minimums. Then we laminate two panes of rugged borosilicate or aluminosilicate glass that can withstand 1000°F. We do this with a precision that also lets us separate curved ⅛-inch panes with an ⅛ inch of air. We developed this particular sag-molding technique with supersonic aircraft windshields in mind, but it may stir other ideas for you.

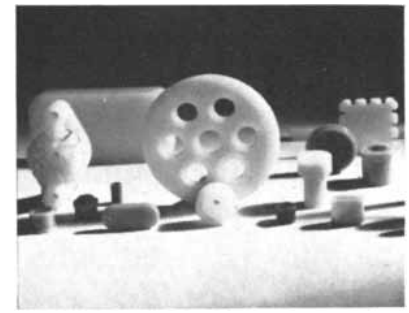


Here are two little gems representing the domestic and the exotic. On the left, a lens for a sewing machine lamp which simply transmits light attractively. On the right, a lens for entombment in the middle of a jet runway where it must withstand slams and bangs and freezings and scorchings. We use different glass compositions, but equal precision in designing their curves, angles, shoulders, and flanges. We press these lenses with such precision that there's no need for follow-up finishing. This is economic testimony to an accuracy with tolerances that might interest you.

What might you do with a rectangular tube? Or a square or triangular one? We can give you freedom from the restriction or boredom of the circle. You can get some glasses with the right precision to hold and measure an angular volume, for example. We think the only requirement on shape is that it be hollow. Also, there is considerable leeway as to the type of glass we can use. So, if you need real odd tubing with perhaps some unique properties, let us know. We will sure try.



This glass looks, acts, and feels like a ribbon. We call it ribbon glass, being practical in such matters. It provides a high dielectric constant and good optical quality in addition to sheer suppleness. Also, you can get it by the inch or by the mile. If area is of more interest than linearity, we can give you a glass in Micro-Sheets several thousandths of an inch thick. We've made such sheets up to 14 inches wide.



Let your fancy take wing, and all that sort of thing. Intricacy is of no moment —we can match most convolutions to ±0.005″. Size is no object—from the minuscules shown above to whatyouwills weighing 60 pounds. We can make these Multiform shapes from many glass compositions, which assures you the best combination of the properties you seek. Sealing Multiform glasses to Dumet, platinum, molybdenum, Kovar, etc., is no problem. If you've got a real oddie, this can be the real answer.

Found a problem-solver?

These are just some of the ways you can get all the advantages of glass in the shape you need. We know others.

If you're confounded by a configuration, tell us about it on the coupon and we'll try to help.

CORNING

CORNING GLASS WORKS, Industrial Components Dept.
4906 Crystal St., Corning, N. Y.

Please send more information on

.....

for an application that involves

.....

.....

Name .....

Company .....

Address .....

City ..... Zone ..... State .....

CONTROL DATA ANNOUNCES 3600 COMPUTER SYSTEM

TYPICAL SYSTEM **LEASE PRICE . . . . . $55,000 – $60,000**
PURCHASE PRICE . . . $2,000,000 – $2,500,000

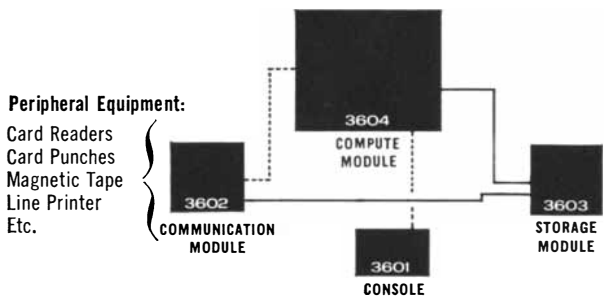
The Control Data 3600 brings to the industry a new order of speed, capacity, computing power, and machine sophistication for solving large-scale scientific problems and for handling large-volume data processing.

Again, Control Data Corporation is first in the industry to offer a computer with such superior system characteristics at a price substantially less than other computers approaching the capabilities of the 3600.

THE EXPANDABLE 3600 SYSTEM

The powerful design of the 3600 provides multi-programming and real-time capabilities for satisfying an extremely wide range of computing and data processing requirements – with the added benefit of a design which provides for smooth expansion to meet specific increased requirements as these arise.

The chart below shows the modular design of the 3600 . . . consisting of three physically separate but highly integrated elements called modules.



These modules provide:

- High-speed data communication via bi-directional data channels which may be expanded in modules up to 32 bi-directional data channels.
- High-speed magnetic core storage containing 32,768 48-bit words, expandable in modules of 32,768 words up to a total of 262,144 48-bit words.
- High-speed computation, the heart of the 3600 system, providing true double precision floating point arithmetic (25 decimal digits) as well as conventional fixed point arithmetic (11 decimal digits). All arithmetic operations are in the parallel binary mode.

HIGH-SPEED OPERATIONS

The high-speed magnetic core memory of the 3600 allows an information access of less than 1 millionth of a second with a total memory cycle time of 1.5 millionths of a second. In addition, there are special circuits in the 3600 employing tunnel diodes that operate at 4 billionths of a second. In summary, high-speed functions in the 3600 include:

- Fixed point add or subtract in 1.5-2.2 microseconds (670,000 per second)
- Single precision floating point add or subtract in 4 microseconds (250,000 per second)
- Single precision floating point multiply in 1-6 microseconds (167,000 per second)
- Double precision floating point multiply or divide in 2-26 microseconds (38,500 per second).

3600 SOFTWARE

An integrated software system designed for use with the 3600 will be oriented around a Master Control System (MCS) . . . which allows programming systems to be independent of particular system configurations as well as of types and numbers of peripheral equipment. Some of the important programming systems operating under the MCS will include

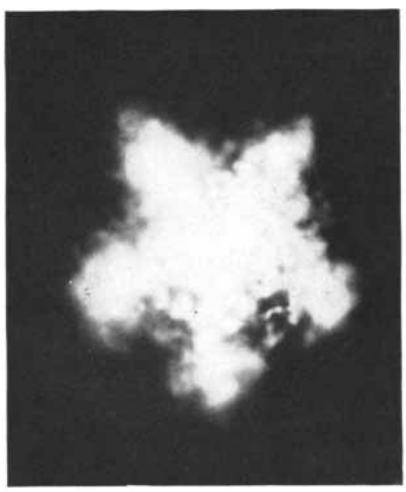
- FORTRAN
- COBOL
- Monitor System
- COMPASS
- 1604 Compatibility Package

For further information on the Control Data 3600, call the Control Data representative in your area, or write for Publication No. B-4B-62.

CONTROL DATA CORPORATION
8100 34th Avenue South
Minneapolis 20, Minnesota

News from Allied Chemical:

A star is created on Central Park West



Visit the American Museum-Hayden Planetarium in New York City these days and you'll see a fascinating exhibit of "The Chemistry of the Stars." Four big panels, with animated lighting effects, portray the birth of a star, the different kinds of stars, and how stars produce chemical elements.

Allied Chemical presented this display to the Planetarium in the sincere hope that it might prove useful in encouraging the younger generation to enter chemistry and the sciences.

Astral chemical laboratories

What's the relationship of chemistry to astral matters and why is Allied concerned with the stars? Simply this. A star, in its birth and evolution, is a giant chemical laboratory. It manufactures elements deep within itself. Elements—and what can be done with them—are the business of Allied Chemical.

Allied and the space age

There's another reason why Allied developed this particular exhibit to interest junior-level chemists and scientists. It relates so basically to our nation's current space interests. Nor is it surprising that Allied, maker of over 3,000 diversified chemical products, should have a lot to do with the space effort.

Section of "Chemistry of the Stars" exhibit, presented to the American Museum-Hayden Planetarium by Allied Chemical.

We have a number of products that are used in, or are being investigated for, space vehicles, missiles, and rockets: polyester resins for rocket casings, phenolic resins for impregnating missile parts, tungsten hexafluoride for coating rocket nozzles.

Allied Chemical also produces rocket oxidizers such as fluorine, fuming nitric acid, chlorine trifluoride, and nitrogen tetroxide.

There are many more, including SF_6, used in radar wave guide applications. And Nacconate® diisocyanates, a basic component used in the manufacture of the urethane foam insulation that lines an astronaut's helmet.

We hope you enjoy the exhibit. And be sure to take the children. Who knows? You may be grooming a future, famous scientist. Allied Chemical Corp., Dept. SA-6, 61 Broadway, N.Y. 6, N.Y.

Allied Chemical

BASIC TO AMERICA'S PROGRESS

This delivery could be two weeks late

Project management with a computer is a new technique for untangling "nightmare" projects. Through the maze of activities, the computer now lets you see the *key events that determine the project's completion date.*

Surprisingly, only 10 to 20 per cent of the activities in most projects really control the amount of time it takes to complete the job. Project management with a computer shows you exactly which activities to focus your attention on.

Building a plant; doing routine maintenance; starting a research and development project; planning a data processing installation; you can do it more efficiently with a computer. Your local IBM Representative would appreciate the opportunity to discuss this new technique with you.

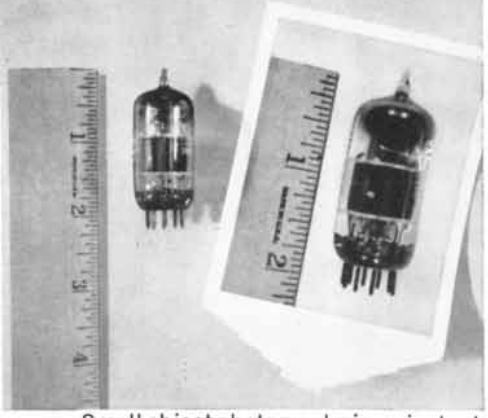
but the job still would be on schedule

■ You begin by examining all the activities in your project. Prepare a logical network, add time estimates, and punch all data into cards.

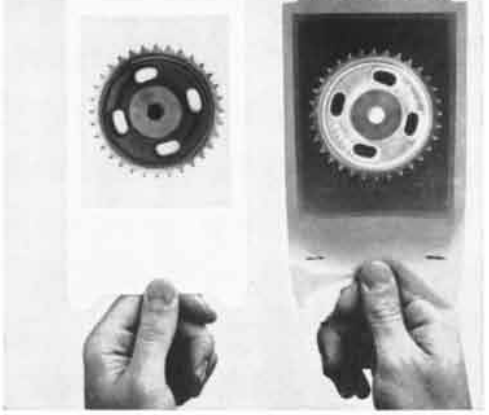
■ Enter cards into the computer. The computer checks your network and selects the chain of key events which determine your completion date.

■ For all other activities, the computer supplies you a report that tells exactly how much extra or "slack" time is available for the activity.

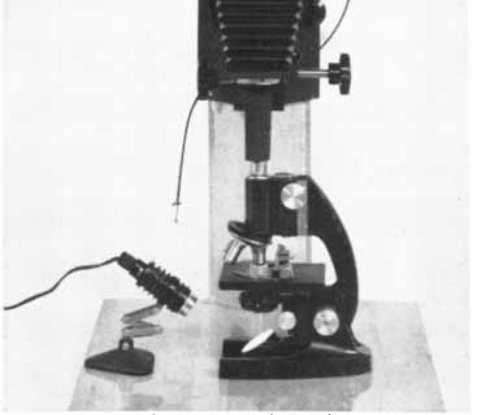
IBM®
DATA PROCESSING



Small object photographs in an instant

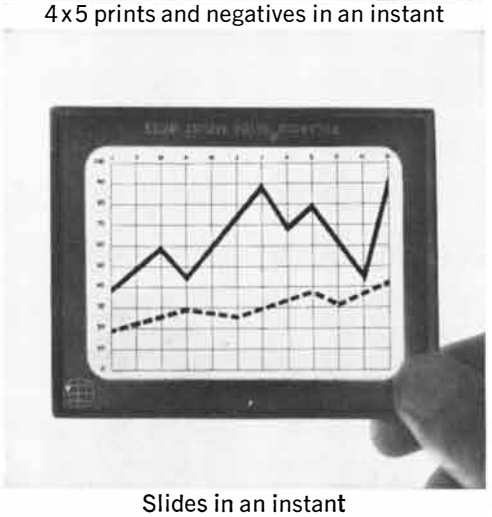


4 x 5 prints and negatives in an instant



Photomicrographs in an instant

Macrophotographs in an instant



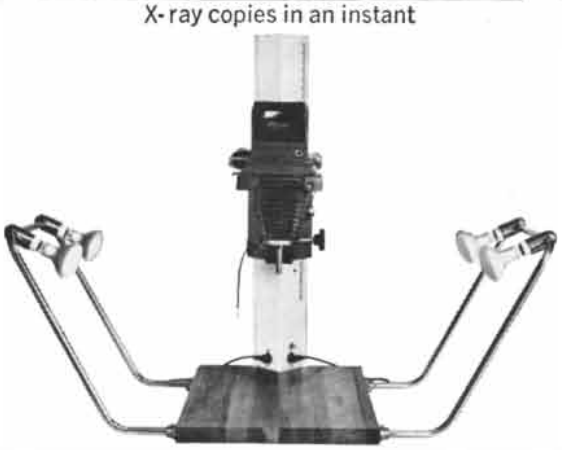
Slides in an instant

Wall chart copies in an instant

Copies in an instant

X-ray copies in an instant

Conventional 4 x 5 photographs in black and white or color



The new Polaroid MP-3 Industrial View Camera

With eye-level ground-glass viewing and focusing.

Send for 6 page brochure, Polaroid Corporation, Cambridge, Massachusetts.

POLAROID®

Established 1845 SCIENTIFIC AMERICAN June 1962 Volume 206 Number 6

The Detection of Underground Explosions

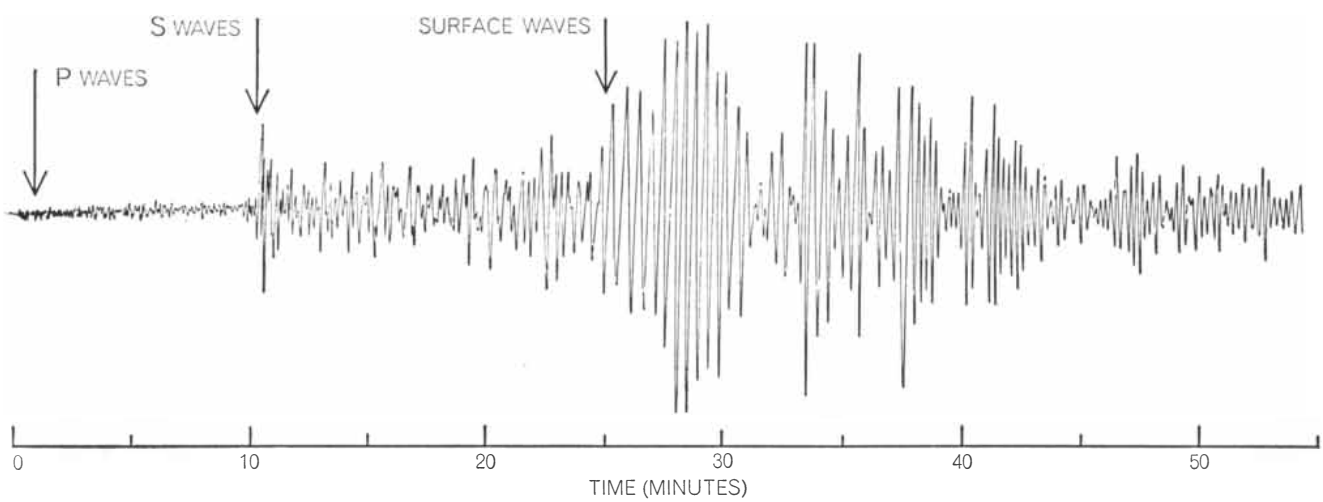
A seismologist suggests that underground nuclear explosions can be detected and distinguished from earthquakes by seismic records. He proposes criteria that might accomplish these aims

by L. Don Leet

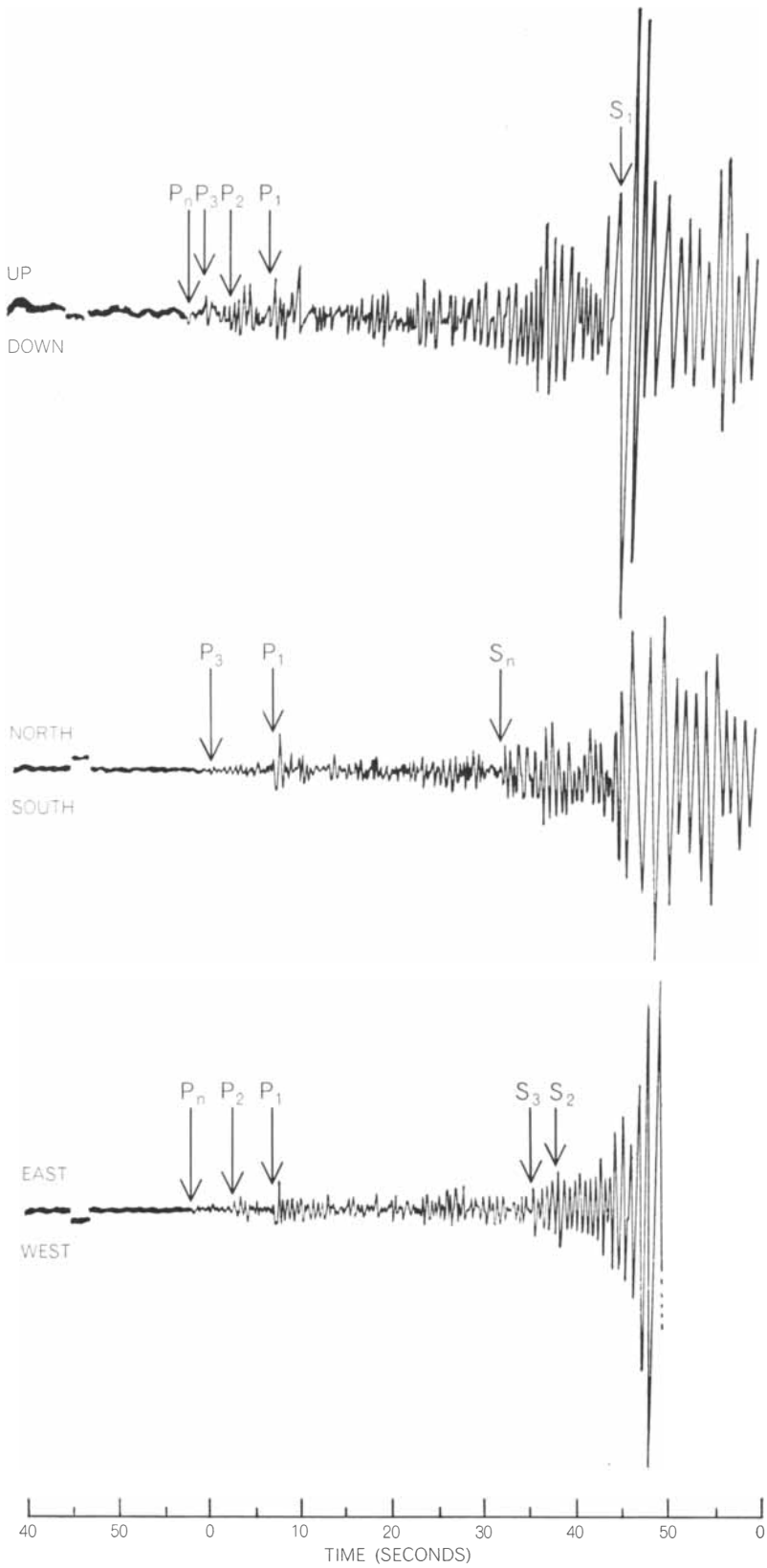
During the past few years one of the most troublesome questions of international affairs has been whether or not it is possible to detect and identify clandestine underground nuclear tests. For a time, at least, the question seemed to constitute the major obstacle in the way of an atomic test-ban agreement. To be sure, the nuclear explosions that have been set off in the atmosphere by both the U.S.S.R. and the U.S. strongly suggest that the underground problem has received more attention than it deserves. This is a matter I have no special competence to discuss. What I would like to consider briefly here is the question on its own merits. Actually there is not one basic question but three: Can a reasonable network of seismographic stations detect and locate underground explosions with an energy of a few kilotons (that is, an energy yield equivalent to that of a few thousand tons of TNT)? Can such a network differentiate explosions and earthquakes? Can it do these things with a high degree of reliability?

My first impulse, as a practicing seismologist, is to answer yes to all three questions. Several kilotons represents a substantial release of energy. We have recently heard that the "Gnome" explosion of December, 1961, announced by the Atomic Energy Commission as yielding "three kilotons plus or minus one kiloton," was recorded by some stations halfway around the earth.

A seismographic record is an expression of the extremely complex reaction of the body of the earth to an abrupt and severe local disturbance. People who deal regularly with such records have learned to extract a large amount of information from them. Some of the characteristics of the records have been accounted for theoretically. More are known only empirically. Undoubtedly there is a good deal that no one has yet



EARTHQUAKE WAVES were recorded at Harvard Seismograph Station, 8,500 kilometers (5,279 miles) from the epicenter in Turkey. The record shows the P (compression) waves arriving first, followed by S (transverse) waves and finally long surface waves. The quake was large and shallow. The tracing is reproduced here to show typical distribution of energy from such an event.



AMPLITUDE OF S WAVES is much greater than that of P waves in records made 326 kilometers from earthquake. Waves in all three dimensions are shown, starting at 12 hours 48 minutes 56 seconds universal time. Waves labeled P_n and S_n traveled through earth's mantle. The others moved through various layers of the crust. The various waves show up on all three traces but are identified only on those where they are most easily recognized. The P_n or first P wave is already weak and would not be recognized beyond about 500 kilometers.

learned to read at all. But in general the train of events traced out by a seismograph is related in a recognizable and at least partially understandable way to the event that set it in motion.

Explosions and earthquakes are two quite different kinds of event. It would be surprising if they did not set up different reactions in the earth. As a matter of fact, the problem of differentiating relatively small nonnuclear explosions from earthquakes is one that seismologists faced and solved some time ago. It is for these reasons that I would expect, a priori, a nuclear explosion to be also distinguishable from an earthquake.

It is true that small explosions are localized phenomena, seismologically speaking, whereas a nuclear explosion shakes the entire earth, or a large part of it. It is also true that much of the data on nuclear explosions has not yet been made generally accessible. Yet there is enough in the public literature to make at least a preliminary test of the position I am advancing. An examination of the record appears to me to confirm this position and even to suggest a method whereby detection and discrimination might be accomplished.

To follow the argument one must have a general picture of the types of motion set up by convulsions in the earth. An earthquake is a train of vibrations in the ground set up when masses of rock on opposite sides of a fracture slip with respect to one another. The energy released by the break is distributed through and around the earth by waves of four kinds. Two of them travel through the body of the earth: the primary waves (P waves) and the slower secondary waves (S waves). The other two move along the surface (that is, through the top 20 miles or so): Love waves and Rayleigh waves. Each wave is characterized by a different type of motion. P waves are trains of compressions and expansions, like sound waves; S waves are transverse, or "shear," waves, in which the matter through which they pass oscillates at right angles to the direction of their travel. Love waves are also shear waves, with the motion restricted to the horizontal plane. Rayleigh waves are elliptical: the particles of matter move around in closed ellipses as the waves progress. The direction of the elliptical motion is said to be retrograde. This means that in a wave traveling from left to right the elliptical motion is counterclockwise.

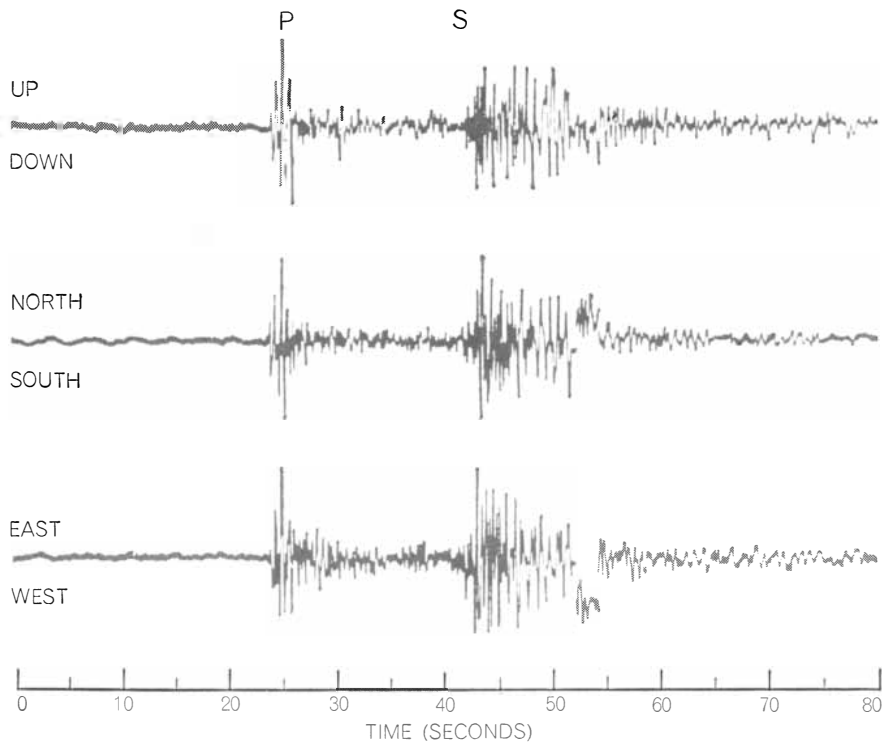
Because earthquakes are caused by a slipping or shearing motion of rock,

shear waves carry away more of the energy of an earthquake than do compressional vibrations. As the waves move farther and farther from their source the P waves die out first, then the S waves. Quite commonly only surface waves are recorded by a distant seismographic station.

Explosions also deliver energy to the ground, setting up vibrations that are distributed by seismic waves. The mechanism by which they deliver their energy, however, is quite different from that of earthquakes. Impact is practically at a point, and it is in the form of compression. Compression waves would be expected. But if the blast is buried in rock not too far from the surface, there are asymmetrical strains at the surface that produce shear waves as well.

In the case of an earthquake the initial P wave moves out from the center as a compression in some directions and an expansion in others. The first P wave from an explosion is a compression in all directions. This fact was the basis of an early proposal for distinguishing earthquakes from explosions. The idea was to record the direction of first motion of the first wave at stations surrounding the center. If all showed a compression, the event could be recognized as an explosion.

In my opinion this method is doomed to failure. Regardless of what the ground actually does, it has been known for years by people who read earthquake records every day that it is often impossible to be sure whether the trace on a seismogram moves up or down at the beginning of the records of even very large earthquakes. The same uncertainty has also been observed in the records of some nuclear explosions. Indeed, I believe that a search for any single, simple feature in the record cannot possibly succeed. The necessary information will come only from a synthesis of the great quantity of information that can be amassed by a worldwide seismographic network.



RECORDS OF DYNAMITE BLAST 152 kilometers from seismograph show P and S waves of roughly equal energy. Surface waves are very small. Time scale starts at instant of blast.

In 1934 the Harvard Seismograph Station started to investigate differences between records of earthquakes and those of blasts in quarries. We had installed a new, sensitive Benioff seismograph and the instrument began recording local disturbances in such numbers that we knew they could not all be earthquakes. We were recording the earth motion along three mutually perpendicular directions, an essential condition for determining the over-all motion of the ground. To depend on a single component such as the vertical, as is often done, is like photographing on black-and-white film a series of objects distinguishable from each other only by color. A systematic difference in the records showed up at distances between 100 kilometers and 170 kilometers. When all components of motion were taken into account, records of explosions showed greater amplitudes in the P-wave group with respect to the S-wave group than did earthquakes.

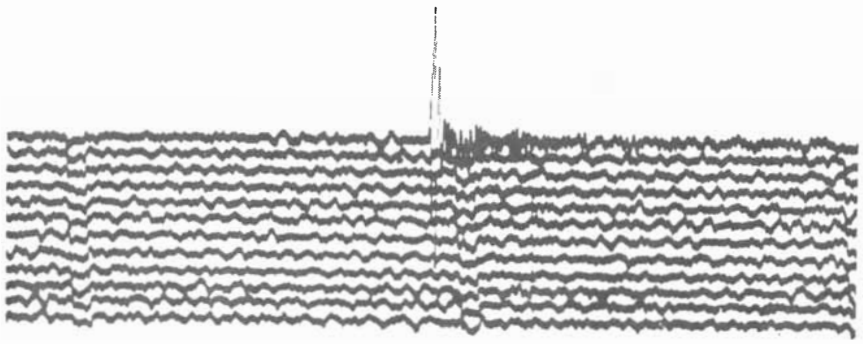
Explosions gave no data at distances greater than 190 kilometers at that time because there were no quarries farther away and still within range of our station. But at greater distances earthquakes continued without exception to show a spectacular predominance of S motion over P. When the earthquake centers were far enough from the station, the early P waves disappeared altogether, whereas there was still pronounced motion in the S group.

The first records of earth motion from an atomic explosion were obtained on July 16, 1945. The explosion, given the code name Trinity, was rated at 20 kilotons and was set off in the air 100 feet above the ground. It was recorded by seismographic stations as far away as 1,200 kilometers. At eight kilometers a Leet seismograph in which the tape was moved at a rapid rate to give a fine-scale recording showed two types of wave never seen in earthquake records. One of them, called H, was similar to the Rayleigh wave except that the particle movement was not retrograde: as the wave traveled from left to right, the particles of earth moved in a clockwise elliptical orbit. The second type, named C, was rather more complex: as the wave advanced, the ground moved back and forth along a straight line, but it was a line skewed with respect to the direction of travel. For example, if the wave was traveling forward, the particle motion might be forward, up and to the left, then backward, down and to the right. This mode represents the fact that all three mutually perpendicular components of the waves are traveling in phase, a situation that as far as I am aware is unique to earth movements from nuclear explosions.

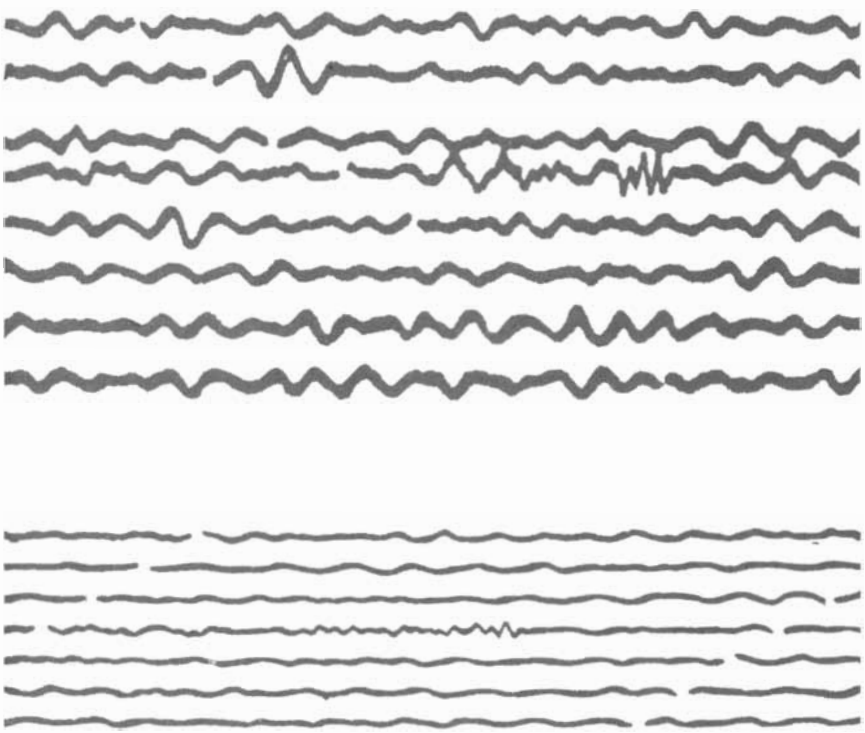
Instrumentation at greater distances from the Trinity explosion produced records from which it was not possible to determine whether the H and C waves traveled farther or not. To the extent that the total energy distribution could be computed, however, the traces showed the relative preponderance of P over S, and the earlier disappearance of S that is typical of smaller explosions compared with earthquakes.

A major discovery in the seismic study

"LONESOME P" WAVE was recorded by Charles F. Richter and Beno Gutenberg of the California Institute of Technology, 8,000 kilometers from the Bikini "Baker" test of July 24, 1946. This trace covers less than one minute. The P wave is the only wave that appeared.



ANOTHER LONESOME-P WAVE was recorded at College Outpost, Alaska, from the "Gnome" underground nuclear explosion near Carlsbad, N.M., on December 10, 1961. The relatively undisturbed traces below top line are parts of normal daily seismograph record made on a revolving drum. This record was furnished by U.S. Coast and Geodetic Survey.



SEISMOGRAPHS IN THE U.S.S.R. recorded lonesome-P waves from the 19-kiloton Project Blanca nuclear explosion set off in Nevada on October 30, 1958. The upper trace was made 8,300 kilometers from the blast, the lower 10,080 kilometers away. Blast waves appear in fourth line in each case. These tracings read from right to left. As these records demonstrate, lonesome-P waves are not always readily apparent. Seismological stations near a nuclear blast that detected a seismic event with suspicious characteristics could alert more distant stations to search a particular section of their records for lonesome-P waves. Having been advised where to look, a trained seismologist should be able to identify the phenomenon.

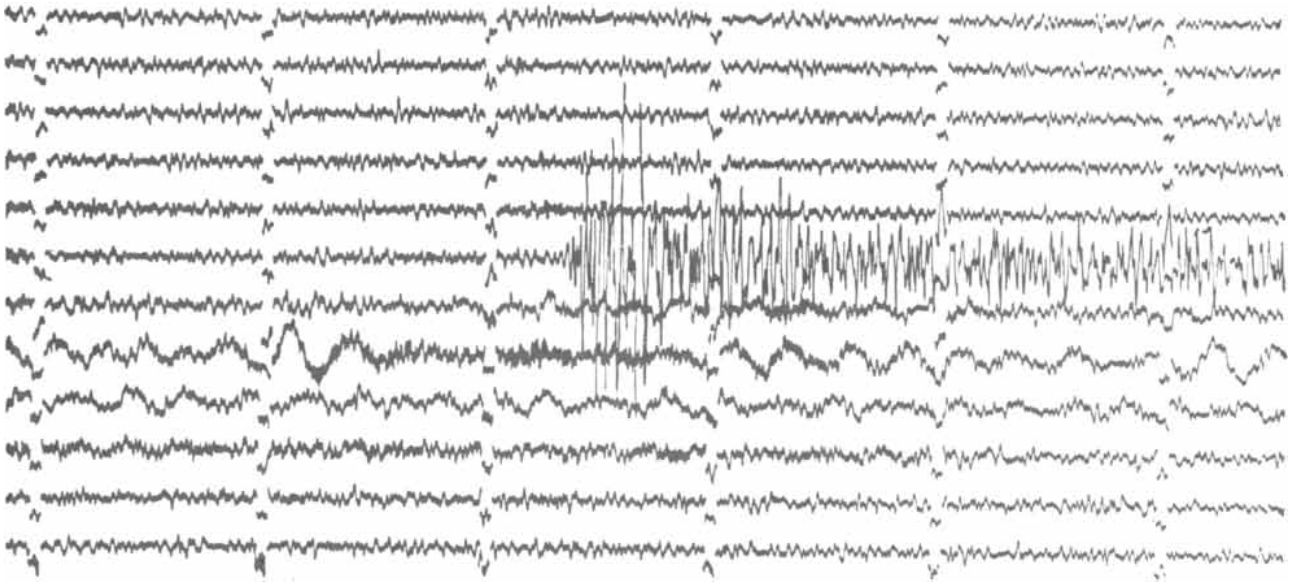
of nuclear explosions came out of the "Baker" test at Bikini on July 24, 1946. The 20-kiloton shot was fired under 100 feet of water in a lagoon. Beno Gutenberg and Charles F. Richter of the California Institute of Technology reported picking up the seismic waves on the West Coast of the U.S., 8,000 kilometers away. They printed a picture of one trace that showed highly unusual characteristics. From the time of the arrival of the first wave it could be identified as the initial P wave. But the disturbance was absolutely alone—unaccompanied by S waves. A few distant earthquake records have since been obtained with isolated oscillations of this type. But they have never been obtained with so much pure P energy, so far from the focus and from so weak a source of energy. In 1946 this phenomenon was totally unknown, and for many years it was regarded as a freak.

Now, however, the records of other distant nuclear explosions seem to confirm the existence of the "lonesome P," as I call it. What we are seeing here is the eventual limit of the trend, which begins near explosions, to a faster disappearance of S with respect to P. This combination appears to be a unique characteristic of distant seismic signals from nuclear underground explosions.

All this suggests a series of criteria for the identification of underground explosions. First we look at records from stations up to 1,000 or 1,500 kilometers from the suspected explosion location. We examine them for a reversal of the usual division of energy between P and S. Possibly they may also show H and C waves, although further research is required to establish how far these travel. At intermediate ranges, out to, say, 2,500 kilometers, the feature to look for is a progressive loss of surface and shear waves. If this criterion is met, we can look for the final indication—lonesome-P waves at distant stations. Taken altogether, these characteristics are a composite picture of a nuclear explosion.

The records from distant stations should also serve to locate the explosion accurately. The paths of waves to nearer points are proportionately more severely affected by local variations in the earth's crust and therefore may point back to a spurious starting point. At the distance of lonesome-P waves such anomalies have pretty well averaged out.

If these criteria prove sound, careful measurements will be required to establish their limits of sensitivity and discrimination. At the moment it would seem to me that an adequate network of



DIRECTION OF FIRST MOTION has been proposed as a criterion for distinguishing an earthquake from an explosion. On this rather typical earthquake record it is impossible to say whether the first motion of the recording instrument was up or down simply because it is impossible to pick out the first motion. The difficulty arises in records of many earthquakes, even the largest.

seismographic stations should be able to detect, locate and identify explosions down to the size of the Gnome shot. Records of this test showed H and C waves as prominent parts of the motion at a distance of 13 kilometers. The instruments at intermediate range, however, were inadequate for establishing the distance over which the waves persisted. The more general criteria of preponderance of P over S waves and of lonesome P at long distances were fulfilled.

The detection methods proposed here depend on extracting a large body of information from an ensemble of records made at varying distances and directions from the explosion or earthquake. In 1958, when a nuclear-test ban was first seriously discussed, a group of experts appointed by the governments of the U.S., the U.S.S.R. and the United Kingdom met in Geneva and proposed a network of 160 to 170 seismographic stations. Between 100 and 110 of them were to be located on continents, 20 on large oceanic islands and 40 on small oceanic islands. In areas of low seismic activity the posts were to be about 1,700 kilometers apart; in active earthquake regions about 1,000 kilometers apart.

After the report recommending this network was issued, the U.S. withdrew its support of the conclusions. New tests and "theoretical and operational advances in seismology," it was explained, indicated that "adequate control of underground nuclear testing is far more difficult than the Geneva experts thought in 1958."

A rough estimate leads me to believe that the Geneva network, or something close to it, would be adequate for the detection criteria I am proposing. The exact number and distribution of the stations might be shifted somewhat from that of the Geneva plan to meet the particular requirements of the method.

The discussion so far has not mentioned the well-publicized question of "decoupling," or muffling, underground explosions by setting them off in enormous holes. There is no doubt that such a stratagem would reduce the energy that finds its way into seismic waves. Although some estimates of the amount of such reduction have been published, I do not think anyone has an accurate idea of how much it would really be. Incidentally, it is worth recalling that the Trinity test, which was decoupled to the extent of being set off above ground altogether, was detected at a distance of 1,200 kilometers. It will be interesting to learn how far the current series of atmospheric explosions over the Pacific Ocean may be spreading seismic signals.

In any case, I find it hard to take the "big hole" idea seriously. It is perhaps conceivable that someone might take on the preparations for one, or even two, tests—the prodigious excavations and the spectacular engineering problem of shoring up the sides and top of the holes (a matter that does not seem to have had much attention). But it is almost impossible to envisage this preparation for the extended series of tests that seems to be required in weapons work. Indeed, it would probably be easier (and certainly cheaper) simply to wait for big earthquakes and set off the explosions while natural waves masked the disturbances resulting from the tests. But this too seems a rather unlikely way to undertake an orderly program of research and development.

In 1959 the U.S. established Project Vela, a seismological research program "aimed at restoring and if possible exceeding the estimated capability of the [1958 Geneva] 'experts' system.'" By August of 1961 more than $20 million in research contracts had been let under Project Vela. From this massive effort will doubtless come improved instrumentation and recording techniques as well as the discovery of still further clues to underground explosions in seismographic data. Each advance will help increase the sensitivity and reliability of an over-all system of detection.

Perhaps Project Vela has uncovered information to demonstrate that the detection criteria suggested in this article would be ineffective. But the evidence available to me strongly suggests that underground nuclear explosions set up seismic waves with positive and unique features that distinguish them from earthquake waves. I see no reason why existing instruments and recording techniques cannot produce records of those waves that would furnish a way to detect, identify and locate underground nuclear tests.

SUPERCONDUCTING MAGNETS

Magnets have now been made with superconducting coils through which current flows without resistance and heating. This indicates that it is possible to build very large magnets requiring very little power

by J. E. Kunzler and Morris Tanenbaum

Soon after Heike Kamerlingh Onnes discovered superconductivity in 1911 he considered building a superconducting electromagnet. A series of experiments had convinced the Dutch physicist that at temperatures near absolute zero the electrical resistance of certain metals vanished completely, and that literally no energy was needed to maintain a flow of current through them, once started. An electromagnet made of such materials would require only enough energy to cool it; for the rest, the current would circle endlessly and the magnetic field would be perpetually available. Onnes' experiments failed because his materials lost their superconducting property in the presence of a magnetic field of moderate strength. In other words, the electromagnets would have destroyed their own superconductivity.

In subsequent years the incentive for building superconducting magnets steadily increased as magnets grew more powerful and the prospect of not having to maintain their huge currents became more appealing. Today there are perhaps a dozen conventional magnets in existence capable of generating steady magnetic fields of 100,000 gauss. (The field between the poles of a toy horseshoe magnet is a few hundred gauss.) Such magnets are expensive and require enormous amounts of power. For example, a modified Bitter solenoid magnet at the Bell Telephone Laboratories, which is used in various physical studies, requires 1.6 million watts of power to produce a field of about 100,000 gauss. This is about a quarter of the power consumed by the entire laboratory. Moreover, nearly 1,000 gallons per minute of cooling water are needed to remove the heat generated in the magnet winding.

In principle no energy is neccessary to sustain a magnetic field once it is established; therefore all the energy converted to heat is a result of the resistance of the magnet winding. Obviously if a superconductor could be used for the windings, and if it remained superconducting in the maximum field to which it was subjected, the energy-dissipation problems could be avoided.

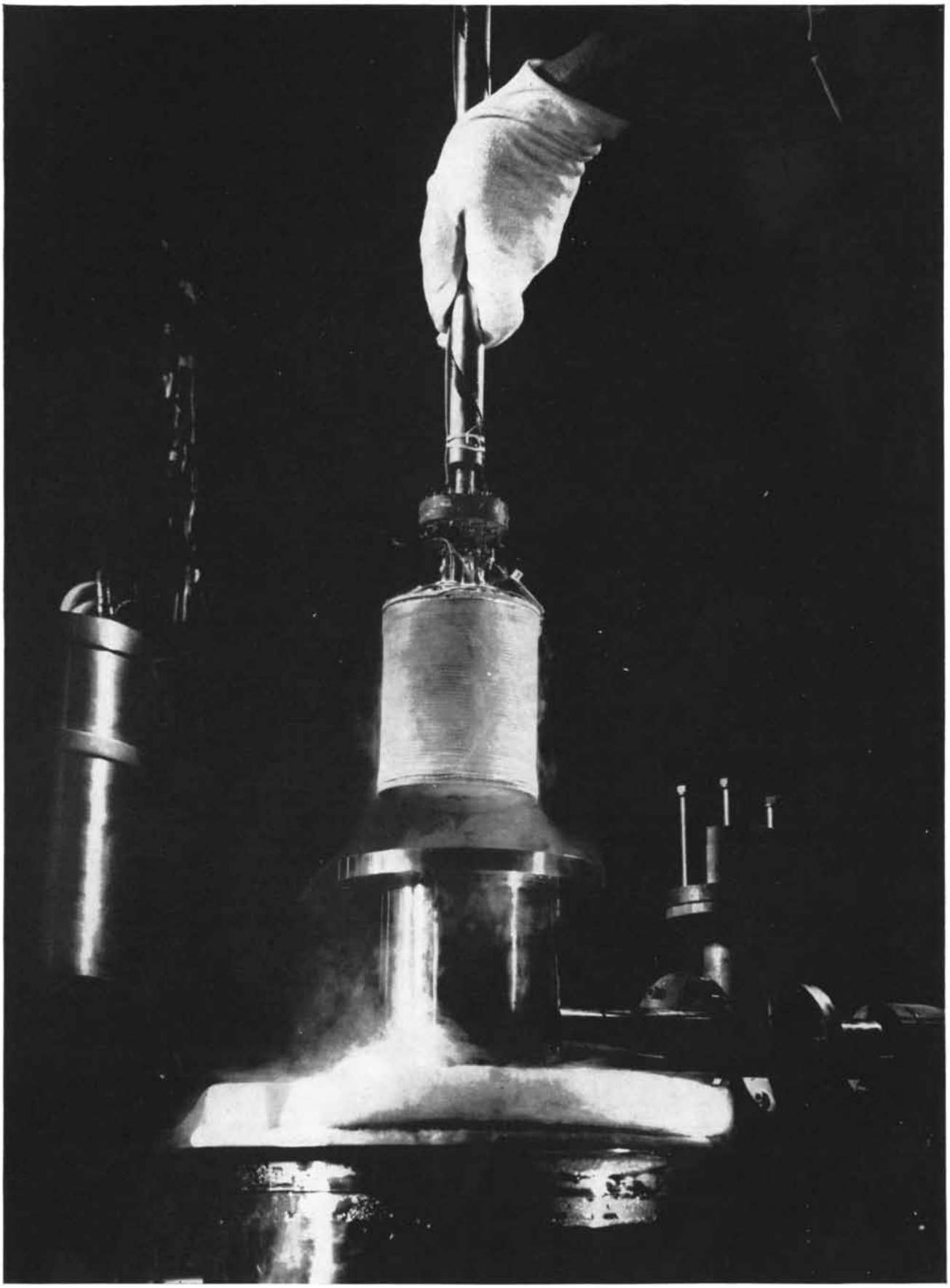
The maximum magnetic field in which a superconductor remains superconducting is known as the critical field. Its value varies with the material and depends on temperature. The critical field is at a maximum at a temperature of absolute zero, and for "ideal" superconductors it decreases with rising temperature on a parabolic curve. It is zero at the critical temperature of the superconductor: the temperature above which the material cannot be superconducting [*see top illustration on page 62*].

The superconductors available to Onnes and his immediate successors had low critical fields, of the order of a few hundred gauss or less. These materials acted as nearly ideal superconductors. It was also discovered that a sufficiently high current flowing through a wire could destroy superconductivity in the absence of an external magnetic field. For a time it appeared that the relation among critical field, critical current and temperature was reasonably well understood.

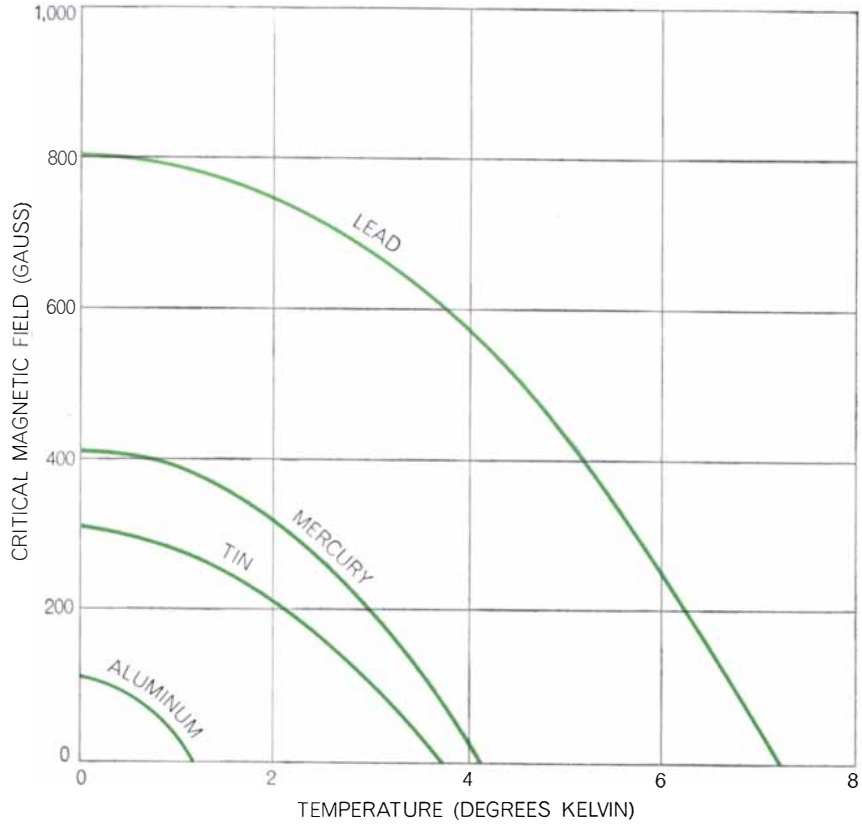
As alloys and mechanically hard superconductors came to be examined, however, it soon became apparent that these materials possess properties that are far from ideal. (The ideal superconductors became known as "soft" and the nonideal as "hard," chiefly on the basis of their mechanical properties. Although this correlation is a fair approximation, the names are misleading because there are many exceptions.) Among the hard superconductors traces of superconductivity persist in fields many times larger than those that had been expected from earlier studies.

Superconducting magnets narrowly missed becoming a reality during the early 1930's. W. J. de Haas and J. Voogd at the University of Leiden found that wires of a hard superconducting alloy of lead and bismuth remained superconducting in fields in excess of 20,000 gauss. De Haas and Voogd accordingly supposed that it was possible to construct a superconducting magnet capable of generating a maximum field of about 20,000 gauss. Further experiments discouraged them from going ahead. Their colleague W. H. Keesom measured the maximum, or critical, current that the wire could carry and remain superconducting in a magnetic field. Extrapolating from the comparatively low fields in these studies, Keesom concluded that at high field values the critical current would be too small to be useful. (We now know that the critical current of a lead-bismuth alloy in fields of 10,000 to 15,000 gauss is sufficiently high to make this material practical for superconducting magnets capable of generating fields approaching 20,000 gauss.) As a result of this and related work it was widely concluded that superconducting magnets capable of fields of even a few thousand gauss were impractical. The miscalculation was unfortunate; the successful construction of superconducting magnets at that time would have had an impact on technology that would be hard to overestimate.

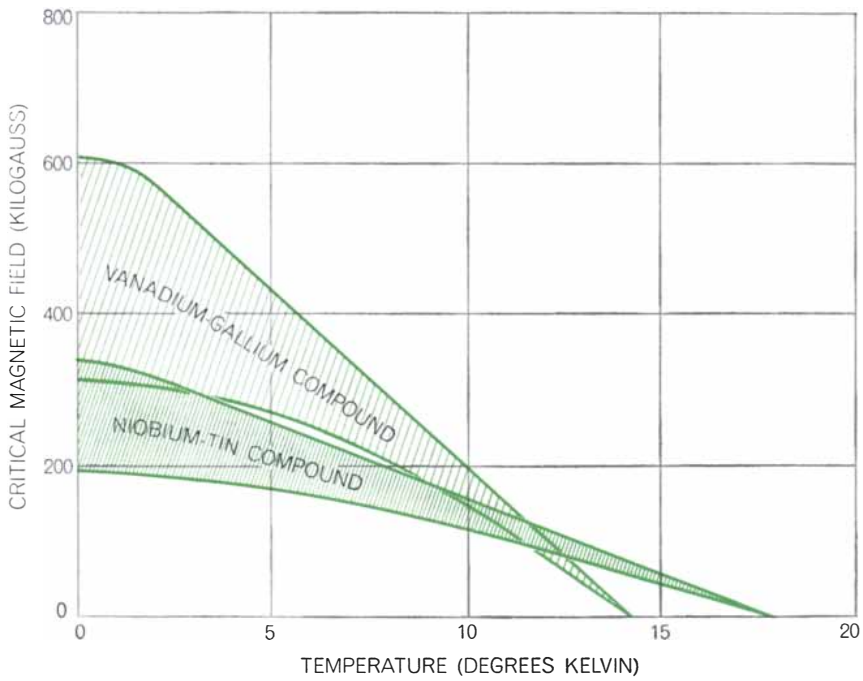
In 1934 Kurt A. G. Mendelssohn of the University of Oxford, making use of a theory of superconductivity developed by the physicists Fritz and Heinz London, was able to explain the existence of traces of superconductivity in fields of 10,000 to 20,000 gauss in terms of a



SUPERCONDUCTING MAGNET, the most powerful of several recently built at the Bell Telephone Laboratories, is shown being removed from a vessel containing liquid helium. When the magnet is running, the vessel is closed and the deeply chilled niobium-tin coils of the device allow electric current to flow without resistance, producing a field of 70 kilogauss (70,000 gauss) inside the magnet.



CRITICAL MAGNETIC FIELD is the maximum field in which a superconductor remains superconducting at a given temperature. The critical temperature is the maximum temperature for superconductivity at zero field. The interrelations are plotted here for four "ideal," or "soft," superconductors. They cannot be used for making high-field superconducting magnets because their superconductivity is killed by low current and low magnetic fields.

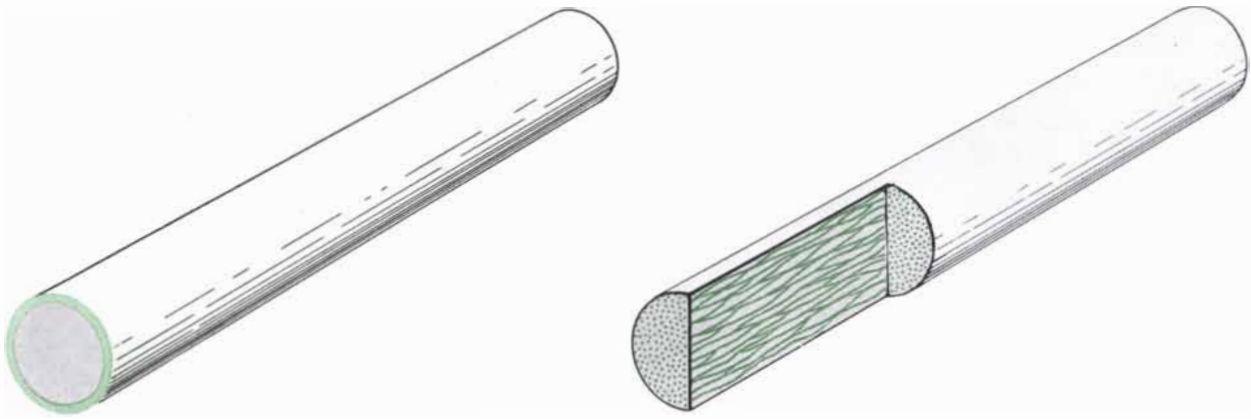


VERY HIGH CRITICAL FIELDS can be sustained by certain "nonideal," or "hard," compounds, such as those consisting of vanadium and gallium (V_3Ga) or niobium and tin (Nb_3Sn). Their critical fields can be estimated only between broad limits (*shaded*) because there are no magnets capable of testing their properties much above 100 kilogauss. These compounds have the virtue of remaining superconducting while carrying high currents.

spongelike or a three-dimensional filamentary structure. In an ideal superconductor the current is carried only within a thin surface layer, known as the penetration depth, with a thickness of the order of a few hundred angstrom units (ten-millionths of a millimeter). The theory predicted that for films of material having a thickness less than a certain critical amount, the critical field increased as the layers got thinner. In other words, a very thin film has a higher critical field than a piece of bulk material. Similar conclusions apply to thin wires. Therefore a three-dimensional network consisting of thin filaments, or thin films, with a thickness much less than the critical amount could be expected to remain superconducting in magnetic fields several times stronger than the critical fields for the corresponding bulk materials. Mendelssohn assumed that only a small fraction of the bulk of the hard superconductor is contained in the filaments. The magnetic field can penetrate both the nonsuperconducting part of the material and the filaments because they are so thin.

Even before Mendelssohn's work it had been known that the superconducting properties of some materials could be enhanced by deforming the superconductor mechanically. In 1955 G. B. Yntema, then at the University of Illinois, used this stratagem to make a small electromagnet with an iron core and a superconducting coil of niobium wire. Subsequently J. K. Hulm and his associates at the Westinghouse Research Laboratories successfully operated air-core niobium magnets. In 1960 Stanley A. Autler of the Lincoln Laboratory of the Massachusetts Institute of Technology described the first practical applications of a superconducting niobium magnet. Autler's magnet generated a field of 4,300 gauss when it was cooled to the boiling point of helium (4.2 degrees centigrade above absolute zero) and was used in a solid-state microwave maser.

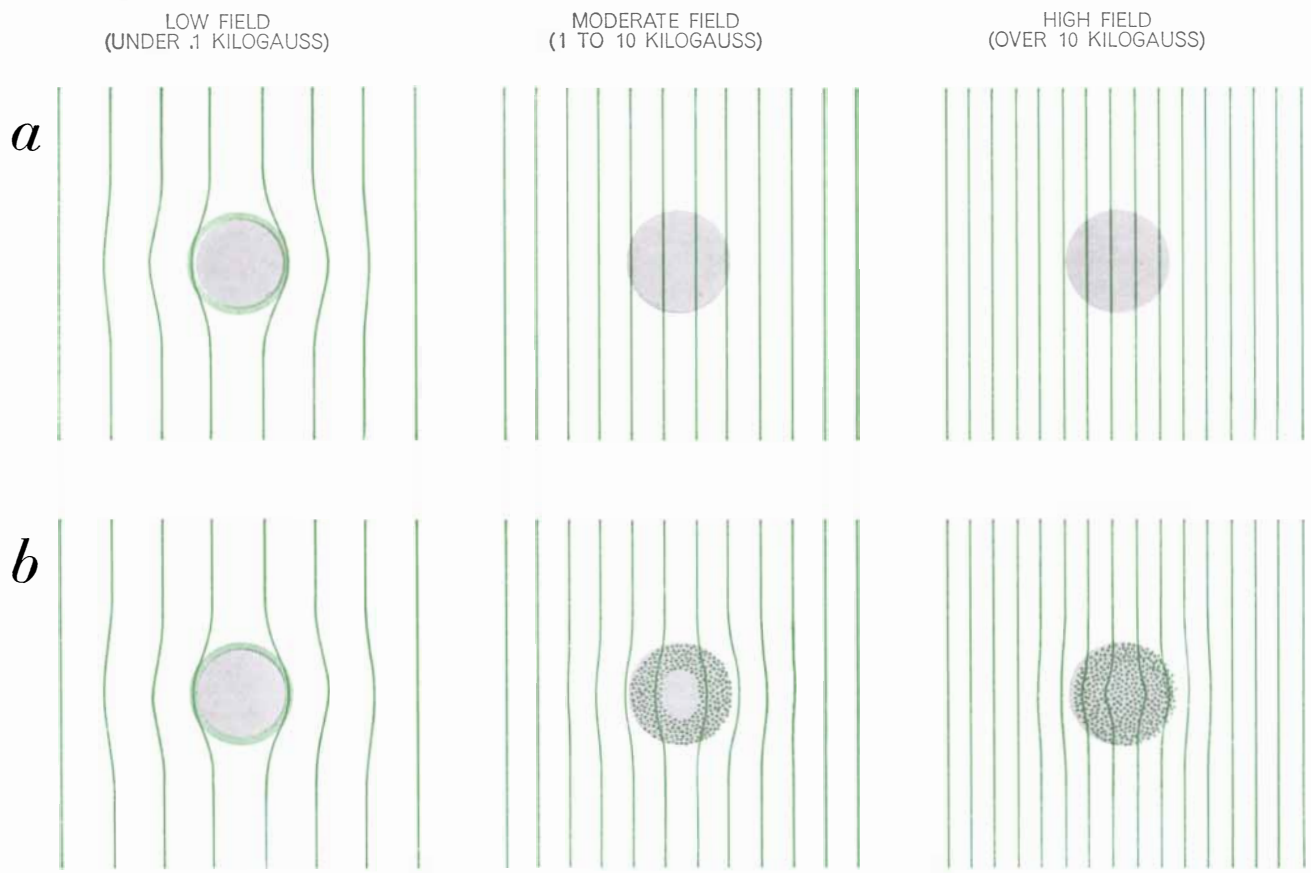
At the Bell Telephone Laboratories in 1960 B. T. Matthias suggested using an alloy of molybdenum and rhenium to make superconducting magnets. (Hulm had reported alloys of these metals to be superconducting five years earlier.) One of us [Kunzler], working with Ernest Buehler, F. S. L. Hsu and Charles Wahl, examined the critical current as related to the magnetic field in the alloys. The Bell Laboratories group was able to show that it should be possible to construct a solenoid, using molybdenum-rhenium wire, that would be capable of



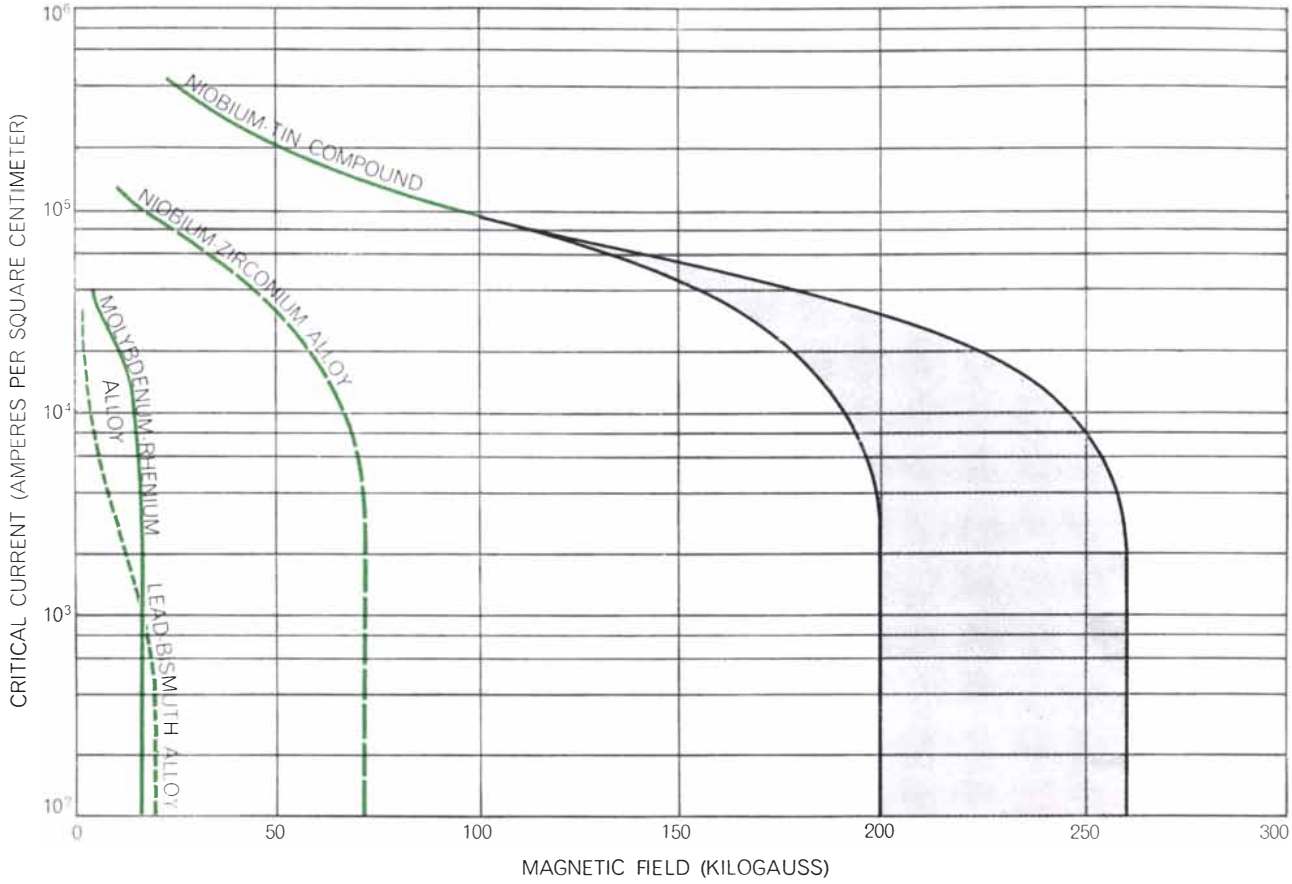
SOFT AND HARD SUPERCONDUCTORS differ in the manner in which they carry electric current. In a soft superconductor (*left*) current is carried only in a thin surface layer. In hard superconductor (*right*), such as niobium-zirconium, the current seems to be carried by filaments inside the material. Number of filaments can be increased by physically working the material.

producing a superconducting field of approximately 15,000 gauss. They then constructed such a solenoid and found that its operating characteristics were consistent with the measurements on small samples of the wire.

In 1954 Matthias, T. H. Geballe, Seymour Geller and Ernest Corenzwit reported the synthesis of niobium-tin (Nb_3Sn), a compound that becomes superconducting at 18 degrees centigrade above absolute zero. Today niobium-tin remains the material with the highest known temperature of transition from ordinary conductivity to superconductivity. In February, 1961, Kunzler, Buehler, Hsu and Jack H. Wernick pointed out that this compound satisfied spectacularly well the three essential requirements of a material suitable for construction of superconducting magnets: (1) The material must remain superconducting in a high magnetic field; niobium-tin was found to be superconducting in a magnetic field of 88,000 gauss. (2) The material must sustain a high current density in the high mag-



EFFECT OF MAGNETIC FIELDS on a typical soft superconductor (*a*) is different from that on a hard superconductor (*b*). When the field is low, under .1 kilogauss, both conduct current in a thin surface layer (*color*), and the field is excluded from the interior of the material. A moderate field, one to 10 kilogauss, penetrates a soft superconductor, thereby destroying its superconductivity. When a moderate field penetrates a hard material, however, superconducting flow appears to be transferred to thin filaments. In certain hard superconductors filamentary flow persists even in high fields of 10 to 100 kilogauss and beyond.



CRITICAL CURRENT DENSITY is the maximum current a superconductor can carry and still remain superconducting. When the superconductor is placed in an increasing magnetic field, the critical current density falls slowly at first and then precipitously, as shown by these four curves. A superconducting magnet requires a material that maintains a high critical current density in the presence of high magnetic fields. Plotted values are for materials cooled to the boiling point of liquid helium, 4.2 degrees Kelvin (*see top illustration on opposite page*). Magnets do not yet exist for measuring critical current density much beyond 100 kilogauss.

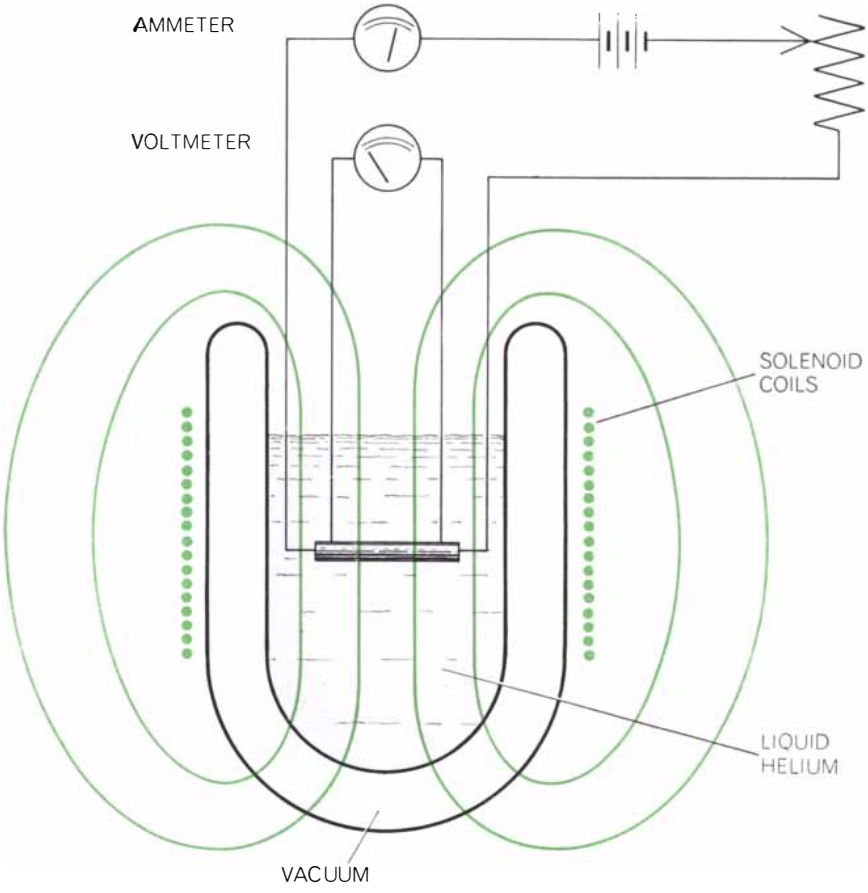
netic field; niobium-tin wire was shown to sustain a current density in excess of 100,000 amperes per square centimeter at 88,000 gauss. (3) The material, even if refractory, must be capable of being fabricated into a magnet; niobium-tin is extremely brittle, but it can be formed into solenoids by a special mode of manufacture that will be described later.

The observation that niobium-tin had exceptional properties was a surprise, but it came at a time when technology was ready to take full advantage of the fact. First, there was a need for superconducting magnets both as research tools and for devices such as the solid-state maser. The desire for a superconducting magnet to be used with a solid-state maser had stimulated Autler's work. It was a similar motive that had initially interested the Bell Laboratories workers in superconducting magnets. Second, a large amount of information on superconducting materials had accumulated, thanks to the work of Matthias and Hulm; one or the other of them discovered superconductivity in all the materials of greatest interest for magnet construction. Third, the tremendous recent advances in low-temperature technology make possible arrangements that would have been out of the question a few years ago. At that time liquid helium was a curiosity available only in a few laboratories. Today it can be bought commercially and is on hand in nearly every major laboratory.

In investigating the properties of superconductors and their possible application to magnets it is not practical actually to build a magnet of each of the possible materials. Most of the potentially interesting materials (such as niobium-tin) are not readily available in suitable form. In fact, they are usually quite difficult to prepare, and the development of fabrication procedures is warranted only if a material shows promise. The best test is to determine how the critical current density decreases as the applied magnetic field is increased. The sample is cooled to liquid helium temperatures and a transverse magnetic field is applied. Then current is passed through the material in gradually increasing quantity until a voltage suddenly appears across the sample. This signals the appearance of resistance and therefore the end of a continuous superconducting pathway.

Typical curves for four materials are shown above. All have the same general shape: a "knee" followed by a rapid decrease in critical current with increasing magnetic field. The maximum practical field for which a material can be used in magnet construction corresponds approximately to the field at the knee of the curve. This value has not been directly measured for many of the new compounds because sufficiently strong steady-state fields are not available. Niobium-tin has been tested in such fields only up to about 100,000 gauss, and the knee lies somewhere beyond this value. Some experiments indirectly suggest a value in the neighborhood of 200,000 gauss. Therefore niobium-tin magnets should be able to generate fields of about 200,000 gauss.

Niobium-zirconium, which forms ductile alloys, was first reported to be superconducting by Matthias in 1953. At the April, 1961, meeting of the American Physical Society, a group of Bell Laboratories workers drew attention to its high-



APPARATUS FOR EVALUATING SUPERCONDUCTORS requires the use of a variable magnetic field. Measurements are made on a sample held at right angles to field and cooled to temperature of liquid helium. As long as the sample superconducts it offers no resistance and the voltmeter reads zero. Raising either the current flow or the magnetic field, or both, ultimately destroys superconductivity, which is reflected by a voltage reading.

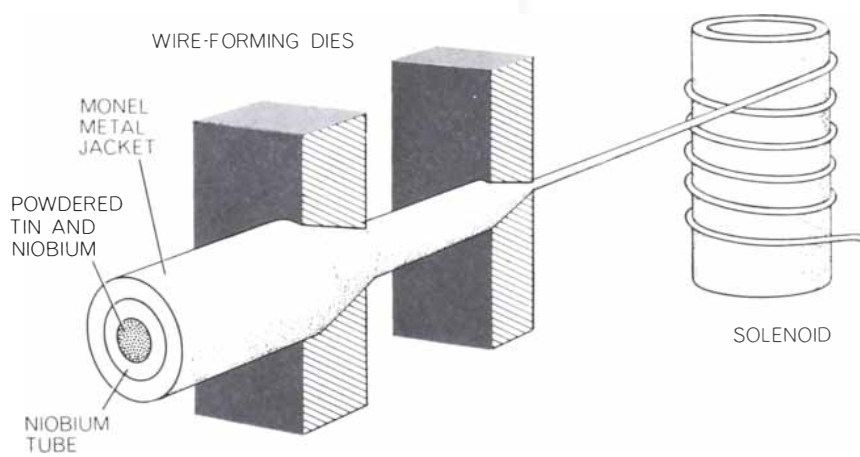
field superconducting properties and its usefulness for magnets. The position of the knee for niobium-zirconium alloys depends on the composition and increases with increasing zirconium content, up to a proportion of zirconium of about 75 per cent. The optimum critical current density, however, is found in a compound containing between 25 and 35 per cent zirconium. The maximum field for which these alloys may prove useful for magnets is between 80,000 and 100,000 gauss.

The critical current of any material is highly sensitive to its state of mechanical deformation. The greater the deformation that is brought about by cold-working, the greater, as a rule, the critical current-carrying capacity. On the other hand, the maximum field at which superconductivity persists near zero current density is not affected by the mechanical state of the materials. This and related evidence has provided a clue as to the origin of the filaments responsible for the existence of high critical fields. The filaments are thought to be associated with dislocations in the crystalline structure of the material: defects in the lattice of a crystal that increase in number when the crystal is deformed.

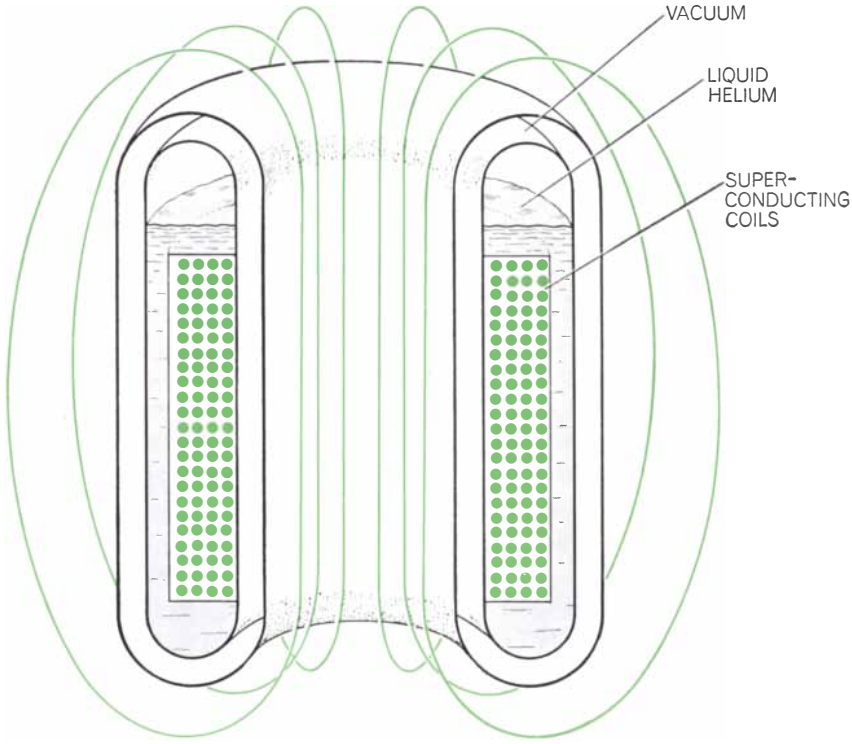
The structure of individual dislocations probably does not change with increasing deformation; their effective diameter does not increase, only their number. It is the diameter, however, that presumably determines the thickness of the filament and therefore the maximum field in which superconductivity can exist. Thus the increase in critical current density with mechanical deformation and the lack of increase in the limiting magnetic field are consistent with the dislocation interpretation. This model has the further appealing feature that dislocations do not terminate within one of the many single-crystal grains that make up a metal but can form a continuous and connected network between grain boundaries.

We have mentioned that special techniques are required to fabricate niobium-tin into magnets. A niobium tube is filled with an intimate mixture of finely divided niobium powder and tin powder. Then the ends of the tube are sealed with niobium plugs and the tube is drawn into "wire." In a typical wire the outside diameter of the niobium jacket is about .015 inch; the diameter of the core is about .006 inch. In this state the core still consists of a mixture of elemental niobium and elemental tin; the wires are ductile and can be wound to form a solenoid. In order to convert the niobium and tin mixture into the compound Nb_3Sn, the coil is heated in a furnace at 1,000 degrees centigrade. Once the compound core has formed, the wire is brittle and cannot be bent without damaging it. But it is already in the required shape. Several 10,000-foot lengths of shaped niobium-tin wire have been prepared by Karl M. Olsen, Robert F. Jack and Edward O. Fuchs of the Bell Laboratories in collaboration with the Superior Tube Company and the Wilbur B. Driver Company.

Because the wire must be heated to



NIOBIUM-TIN WIRE for use in superconducting magnets is made by drawing down a tube containing niobium and tin in the form of intimately mixed powders. The resulting wire is wound into solenoid coils. The coils are then heated to about 1,000 degrees centigrade, whereupon niobium and tin unite chemically to form Nb_3Sn, a highly brittle compound.



WARM-CORE SUPERCONDUCTING MAGNET could be built by isolating the low-temperature components. Core, containing the intense field, could then be any temperature.

so high a temperature in the process of fabrication, the problem of providing it with an insulating coating is not easy. It was found that covering the original cylinder with Monel metal not only insulates the drawn wire but also aids the drawing. Geballe first pointed out that a layer of metal would adequately insulate a superconductor. The resistance of the layer is infinite compared with that of the superconductor.

Thus when the insulated wire is formed into a solenoid coil and the flow of current through it reaches a steady state, all the current passes through the superconducting core and none through the Monel metal coating. When the current is first turned on, however, its build-up in the solenoid is impeded not primarily by electrical resistance but by inductance, or "electrical inertia." During the time that the current is increasing, the inductance of the superconducting core will force a large part of the flow into the Monel metal insulation. If the adjacent turns are in direct contact, the solenoid will be effectively short-circuited. To avoid this the layers of the Monel-metal-clad wire are separated by layers of quartz-fiber cloth.

At the time of publication of this article the general properties of niobium-tin and niobium-zirconium will have been known for only about a year. Already superconducting magnets of both materials have been constructed and operated in fields of approximately 70,000 gauss. At least three firms are offering for sale superconducting magnets capable of producing fields up to 50,000 gauss. A 70,000-gauss niobium-tin experimental magnet has been tested at the Bell Laboratories, and a 70,000-gauss niobium-zirconium magnet at the Westinghouse Research Laboratories. Atomics International (a division of North American Aviation, Inc.) and the Lincoln Laboratory are among the other organizations that have reported magnets capable of producing fields above 50,000 gauss. This is remarkable progress, yet it probably represents only a fraction of what can be accomplished in another year or so.

In the experimental magnets built so far the diameter of the working space inside the solenoid is usually a fraction of an inch. Such small dimensions do not reflect any fundamental limitation. These are early prototype magnets built primarily to test materials and design.

Although niobium-tin, with a potential field of about 200,000 gauss, will probably be used in the first superconducting magnets operating near 100,000 gauss, other materials offer the possibility of reaching even higher fields. One of the most intriguing of these is vanadium-gallium (V_3Ga). Like so many of the others, this compound was first made and found to be superconducting by Matthias. Wernick, F. J. Morin and their associates at the Bell Laboratories recently obtained experimental evidence indicating that the critical field of vanadium-gallium is in excess of 400,000 gauss. Since the study of high-field superconductors is still in its infancy, it seems reasonable to expect the discovery of materials with still better properties.

Although the vanadium-gallium data suggest that it is theoretically possible to construct superconducting magnets capable of generating fields of several hundred thousand gauss, there are many problems to be solved before such magnets become a reality. Not the least of these is to contain the forces that are generated. For example, a field of 300,000 gauss produces an outward pressure of about 50,000 pounds per square inch.

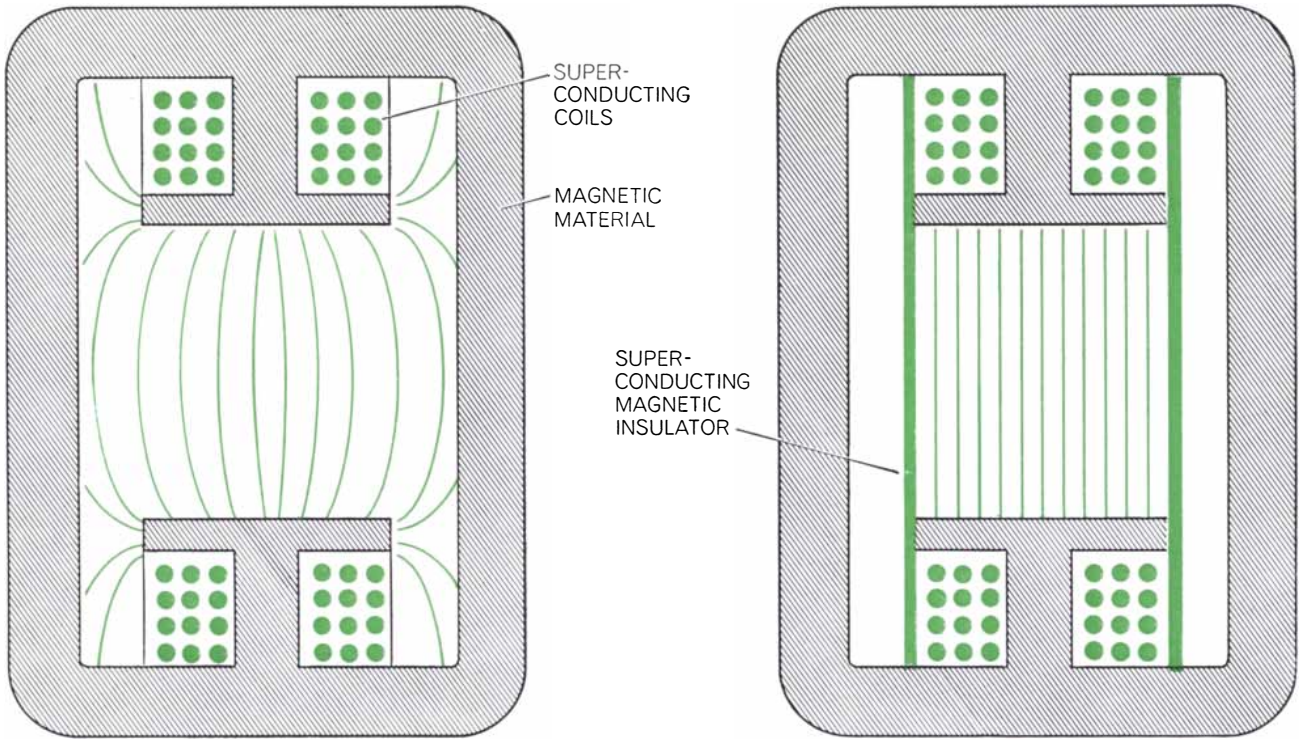
Since all known superconductors exhibit superconductivity only in the neighborhood of the temperature of liquid helium, it might seem at first that any device used in conjunction with a superconducting magnet would also have to be maintained at very low temperatures. This is not the case, however. It is not difficult to arrange a solenoid cooled by liquid helium so that its core is maintained at room temperature or at an even higher temperature.

Superconducting magnets appear to be potential candidates for almost every application involving large magnetic fields. Among the obvious possibilities are the furnishing of fields for solid-state physics research and communication devices, for particle accelerators such as cyclotrons, and for the bending of the paths of charged nuclear particles in detectors such as cloud chambers and bubble chambers. Superconducting magnets are particularly intriguing in the field of power generation, both for magneto-hydrodynamic devices and for controlled nuclear fusion.

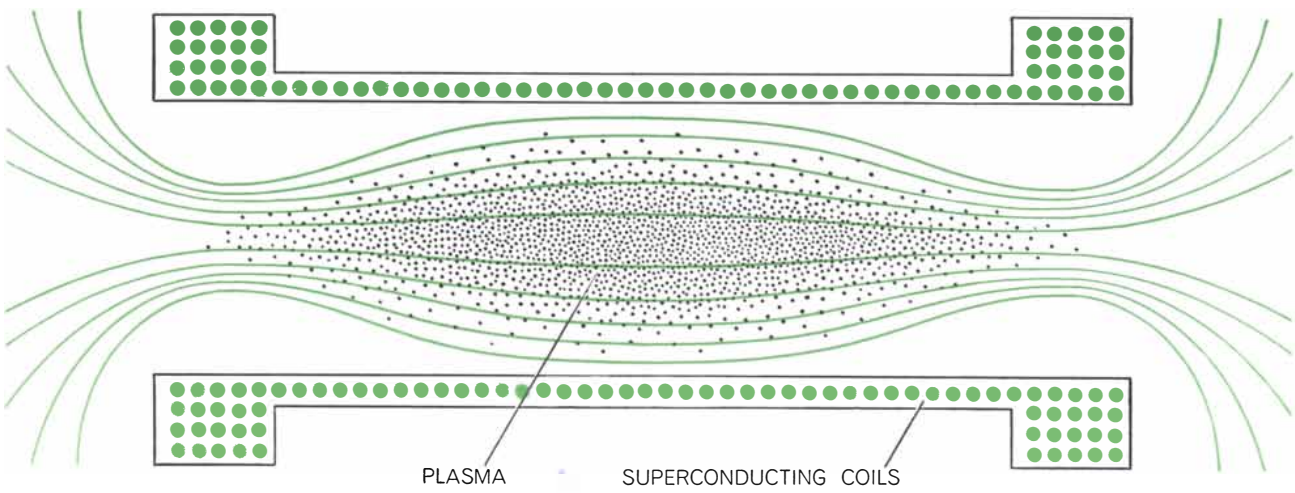
This last application is one of the most interesting and potentially the most important. There are many problems that must be solved before fusion power becomes a practical reality. One is the confinement of hot ionized gases, or plasmas, in some sort of container. Because the plasmas will be at temperatures in the range of 100 million degrees centigrade, no material substance can be used to contain them. They can, however, be confined by the force of a magnetic field. A longitudinal field can form a "magnetic bottle" and keep the hot ionized gases away from the walls of the physical container [*see lower illustration on opposite page*]. In order to

keep the plasma from escaping from the ends, a higher magnetic field is provided, forming constrictions in these regions. Until recently it was planned to use an ordinary good conductor, such as copper, for the magnet to provide the necessary fields. But such magnets would be massive—possibly several feet in diameter and tens of feet long—and they would have to create magnetic fields of several tens of thousands of gauss.

Estimates have shown that the amount of energy required to operate magnets of this size will exceed the output of the thermonuclear power generator unless it is made extremely large. Even then a tremendous amount of power will be required initially to start the generator, and the source of this starting power presents a problem. Current thinking involves the use of superconductors to provide the magnetic field. The power required to sustain the magnetic field will be negligible. Power will be required, it is true, to refrigerate the windings to liquid-helium temperatures. Although this power will be appreciable, it will be trivial compared with the power required for the conventional type of magnet.



SHAPED-FIELD SUPERCONDUCTING MAGNET was designed by P. P. Cioffi of the Bell Telephone Laboratories for use with a solid-state maser, a device for amplifying radio signals. The magnet, shown in cross section at right, combines superconducting coils with superconducting magnetic insulators. The latter shape the magnetic field by blocking its passage. If the insulators were not present, the field would take the form shown at left. The 10-pound superconducting magnet replaces a conventional one of 700 pounds.



"MAGNETIC BOTTLE," of the type employed in studying controlled thermonuclear reactions, could be built with superconducting coils. The purpose of the bottle is to confine ionized gas, or plasma, which has been heated to millions of degrees centigrade. The ionized particles are trapped by the magnetic lines of force and so are kept from touching the walls of the container. When the particles encounter the stronger magnetic fields at the ends of the container, they are "reflected" back toward the middle.

Computer Programs for Translation

A simple model for sentence construction, devised as a first step toward mechanical translation, is beginning to show why English and other languages are so ingeniously complicated

by Victor H. Yngve

A schoolboy studying his first foreign language sometimes asks: "Why do they say it that way?" Often the reply is: "Because that's the way it is in the language. Don't ask why, just learn it." As a matter of fact in many cases nobody knows the answer to such a question. Recently, however, a possible answer to some of the questions as to why language is the way it is has come from an unsuspected quarter: research on the mechanical translation of languages by electronic computer.

As long as we keep to our native tongue and are not obliged to explain its quirks to others, we rarely appreciate just how complicated language is. It appears that even widely different languages are complicated to much the same extent. The usefulness of some of the complications is clear. Word order or case endings frequently serve to indicate whether a phrase is playing the role of a subject, an object or something else. But then there is a seemingly endless catalogue of other complications with no apparent utility, and the traditional grammar book does little to point out the reason for these complications. Faced with the many complexities of language, about the best a grammar or language textbook can do is to justify certain usages "as a matter of euphony" and to condemn others as "awkward" or "stylistically poor." Such vague explanations are of little help to the student who has not yet developed a feeling for the language. They are almost useless to someone who is trying to analyze a language rigorously, with a view to mechanical translation.

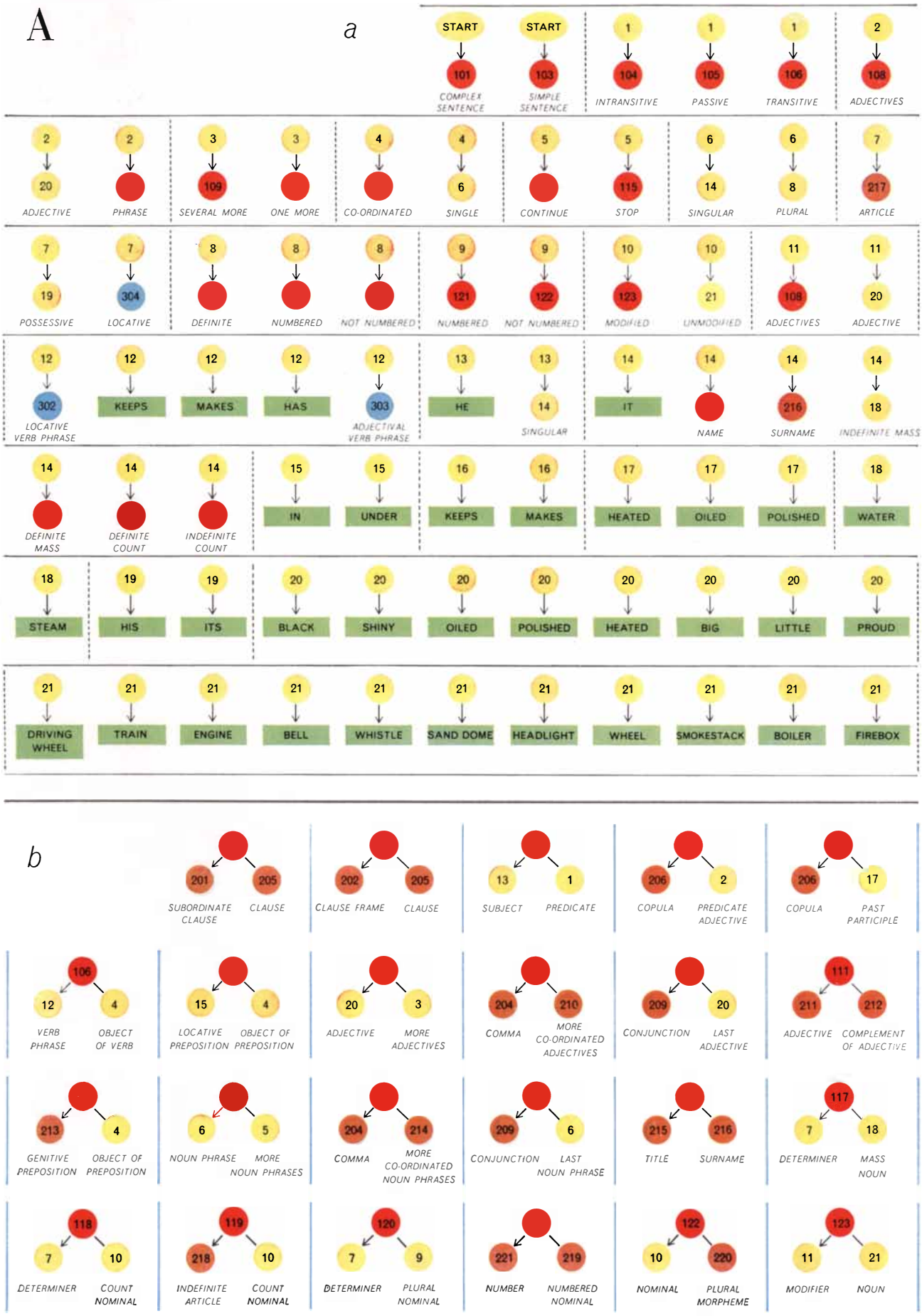
Why, for instance, do we say "He called *her up*" but not "He called *up her*," when we can say both "He called *the girl up*" and "He called *up the girl*"? Why do we have two ways of saying the same thing, for example, "He gave *the girl the candy*" and "He gave *the candy to the girl*"? Also we have "*The woodsman* chopped down *the tree*" and "*The tree* was chopped down by *the woodsman*," where the passive sentence appears to have the same meaning as the active one. Other anomalies concern the placement of modifiers. Adjectives generally precede the noun, but relative clauses follow. We say "a *worn-out* car" and "a car *that is worn out*." Some modifiers are actually split, part going before the noun and part after: "*too worn-out* a car *to drive*," "a *more priceless* possession *than jewels*" and "*the best* friend *in the world*." The list could fill a volume. It is remarkable that the human brain can cope with such a vast catalogue of complications. It sometimes seems as though language is just about as complex as it can be without making it impossible for an average individual to learn it in his preadult years.

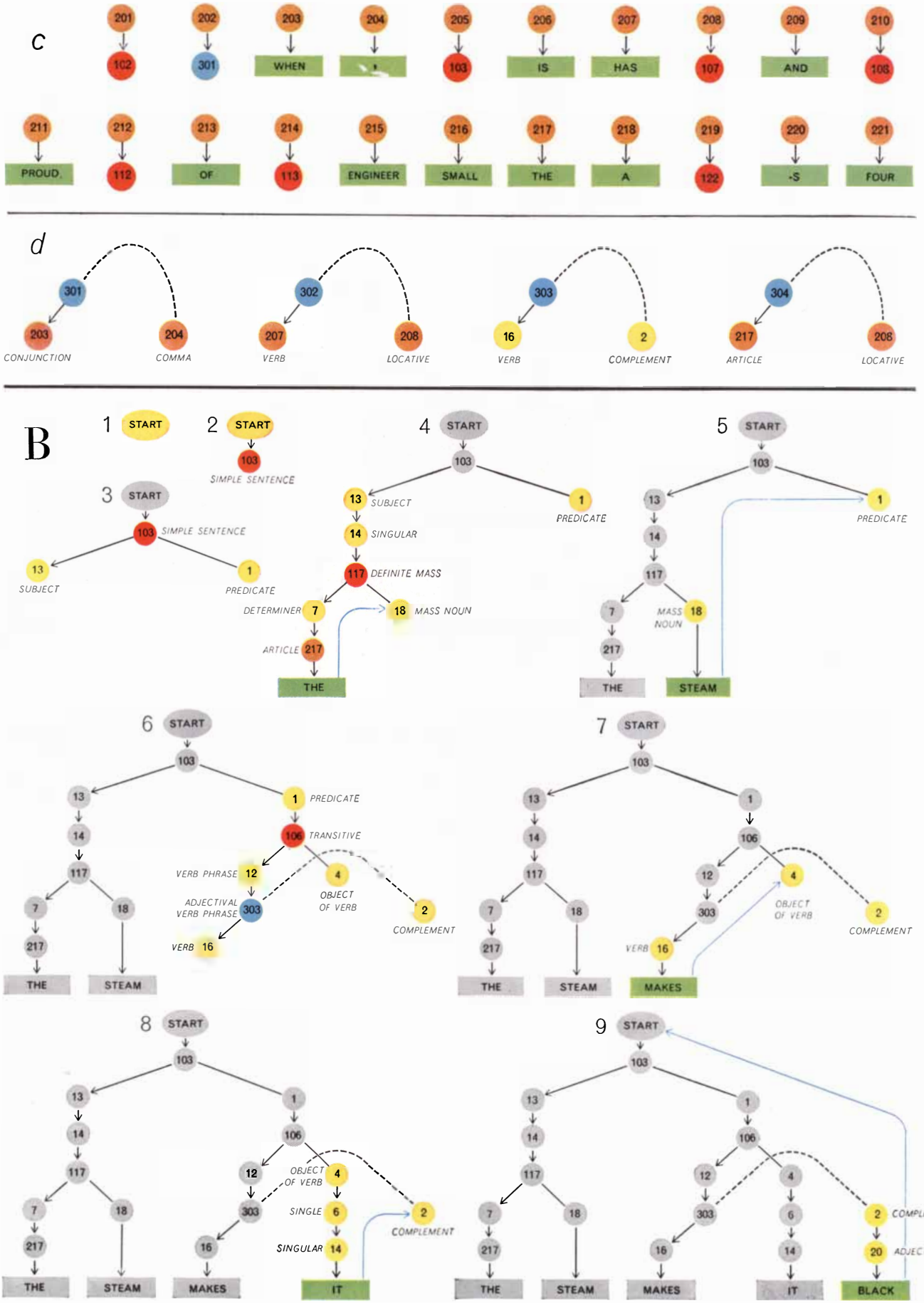
One would expect that a simpler language would have a utilitarian advantage. A basic puzzle is why English and other Western languages employ four major parts of speech: verbs, nouns, adjectives and adverbs. It can be shown by means of logical notation schemes that two parts of speech and a single rule for word order could provide, in principle, an artificial language as expressive as English. Why, then, is English so complicated? The usual explanation for the four main parts of speech does not stand up to careful examination. It is not invariably true that verbs express actions or states of being, that nouns are the names of persons, places or things, and so on. That is, even if one knows the semantic class of the thing referred to, one cannot invariably determine the correct part of speech to use. A given concept may at different times be referred to by different parts of speech: "They *projected* the pictures very clearly"; "The *projection* of the pictures was very clear"; "They were very clearly *projected* pictures."

Our main schoolboy question, therefore, is whether all these complications serve a useful function in the language or whether they are sheer dead weight. It is this question that research in mechanical translation may have elucidated. An answer to the question would do more than satisfy our curiosity. In view of all the complications of language, it seems almost too much to hope that we will ever be able to program machines to handle human language adequately unless we can achieve a deeper understanding of how and why languages operate.

The possibility of applying machines of the digital-computer type to the twin problems of mechanical translation and information retrieval has spurred an increasing number of workers to reexamine language. If we could perfect a translating machine, a great stride would have been made toward removing language barriers. If we could perfect an information-retrieval machine, the

SIMPLE GRAMMAR sufficient for the first 10 sentences of a children's book is described in *A* (*four tables on opposite page and at the top of page 70*) in terms of a series of building blocks. Each arbitrarily numbered circle is a potential "node," controlling one step in the sentence-building process. Table *a* lists the nodes at which the computer can choose among several possibilities; *b* indicates the constituents of various grammatical constructions; *c* gives the nodes at which the computer has only one choice; *d* lists discontinuous constructions.





wisdom accumulated in the libraries of the world would be made much more readily available. Effective indexing, abstracting and retrieval may require a deeper understanding of the languages used than anyone now possesses.

The history of mechanical-translation research is brief. Much of the early work, some 10 years ago, contemplated little more than word-for-word substitution. It was hoped that the output of such a word-for-word device would be good enough to be of some use to the scientist who wanted to know what was in an article written in a foreign language [see "Translation by Machine," by William N. Locke; SCIENTIFIC AMERICAN, January, 1956]. Presumably the reader's general knowledge of the subject matter would let him fill in wherever the output of the machine was obscure. That hope collapsed when it became obvious that a mere word-for-word translation was so poor as to be nearly worthless. Another approach, still in progress, is a pragmatic effort to improve the word-for-word translation by fixing up its most serious shortcomings, using any measures that seem to work. Those employing this approach hope to obtain, within a reasonable time, translations of practical value for some purposes. The results of such programs are often impressive, but looks are deceiving: in the flow of English words there lie many hidden inaccuracies and mistakes. It is becoming clearer that although 80 per cent of the translation problems can be solved rather easily with these crude methods, the remaining 20 per cent are very difficult, and it is this 20 per cent that make all the difference between an acceptable and an unacceptable translation.

It looks as though there are no short cuts. Nothing less than a careful and thorough study of the basic problems of grammar and syntax will do. One needs a complete catalogue of the structure of each language, a catalogue with a degree of explicitness never before achieved. This is because information for the use of an unthinking machine must be more tediously explicit than information for human use. Every "feeling" about language that the computer is to display must be first understood by the human programmer, then broken down into its elements and written into the machine program. With such a program one can hope to obtain translations much better than any obtainable by a pragmatic approach.

As a first step in this direction, I began thinking some time ago how one could prepare a catalogue of the intricacies of sentence structure that would fit the needs of a computer. Of course, a description of a language is static, and a computer program for handling language is dynamic. It seemed reasonable that the two could be separated. The computer would be provided with a description of the linguistic facts, stored in lists or tables, together with a program capable of referring to the stored facts while the computer carried out its translating operations on the text it was processing.

The separation seemed attractive because linguists had already considered how a language might be described. Most of the proposed methods of description are variations of what are known as phrase-structure or immediate-constituent models, where a sentence is divided successively into smaller and smaller parts. Commonly an English sentence is viewed as having two parts: a subject and a predicate. Each of these parts is viewed in turn as having two (or more) parts, until one gets down to words or to morphemes, the smallest units that have meaning.

Such analytical methods work quite well most of the time but run into complications when they try to deal with discontinuous constituents. For example, two or more words that form a single construction are often separated by other words in the sentence. Examples are *called up* in "He *called* her *up*," *can see* in "*Can* he *see* through the fog?," *what for* in "*What* did he use it *for*?" and *best at any price* in "the *best* car *at any price*." One of the problems is to specify just how much material is enclosed between the first and second part of each discontinuous constituent.

I have adopted a system for describing the facts of a language that is close to the better traditional ways of representing linguistic structure. The description is composed of four tables, which are reproduced on page 69 and at the top of the opposite page. The first table (*a*) reflects the freedom of choice existing in the language—between singular and plural, for example. Other tables indicate various kinds of grammatical construction, together with their immediate constituents. The way to represent adequately discontinuous constituents, shown in table *d*, became clear only after I had decided how a computer could be programed to construct relatively simple sentences using the basic description scheme. The tables shown, representing the first attempt at this method of description, include only enough of the structure of English to be able to handle the first 10 sentences of *The Little Train*, a well-known children's book written and illustrated by Lois Lenski.

The program for constructing sentences, designed for use in a general-purpose digital computer, is straightforward and operates well [*see illustration B on opposite page*]. Whenever there is a choice point in the program, the computer chooses at random. The resulting sentences conform only to the grammatical constraints represented in the tables, and if the sentences appear to be ungrammatical, one can go back and correct the tables. The program therefore turns out to be a valuable research tool for checking the accuracy of the descriptions. Without some such check it is practically impossible to produce an accurate, error-free description of a language.

A number of sample sentences, produced by a computer provided with a vocabulary of about 225 words, appear on the following page. The sentences embody improvements in language description suggested largely by the work of Edward S. Klima and added to the program with the help of George Monroe. (Klima and Monroe have been working with me at the Massachusetts Institute of Technology.) The sentences are of course lacking in meaning because the program is concerned only with sentence structure. If the program were adapted for language translation, the word choices would be governed by the text being translated. A more advanced

COMPUTER CONSTRUCTS SENTENCE by working its way from node to node as shown in the numbered sequence of steps in *B* on the opposite page. There is always a "current node," which controls the next step. The reader can follow the computer's procedure by noting the color and number of the current node, referring to that node in the proper table in illustration *A* and choosing the corresponding lower node, which becomes the new current node. If the node is yellow, a choice is available; the machine makes this choice at random. If the node is orange, only one choice is provided. If the node is red, the lower left-hand node under it becomes the new current node and the one at the right is a "remembered node." If the node is blue, the procedure is the same except that the remembered node must be delayed until later in the sentence. Each word in a green rectangle is a word in the sentence; after it is in place the next current node is found by moving up and to the right (*blue lines*) until the next remembered node is encountered, or back to *START* to begin a new sentence.

program for French is being developed by David A. Dinneen, and a good beginning of a description of Arabic has been made by Arnold C. Satterthwait as a part of his experimental program for translating Arabic into English. Other members of our group are working on a German program, which is already more complete than the English one.

Close examination of the properties of such programs reveals some rather interesting points. Although the grammar consists of a finite number of rules, the program can produce a sentence of any length, and therefore any sentence chosen from an infinite set of sentences. It can do this by making choices in such a way that it repeatedly returns to the same node number. An example of such repetition is shown at the top of the opposite page, where the node 108 (adjectives) can give rise to a potentially infinite string of adjectives. Node 113 behaves similarly, as does node 117 in a slightly more complicated way to produce "the water under the wheels under the firebox under the boiler." There are many examples of this sort of recursiveness in English ("I imagined him listening to the announcer reporting Bill catching Tom stealing third base"). Thus one sees that our grammar and program is satisfactory in this respect as a model for English.

COMPUTER PROSE shown in this read-out was produced by a digital computer programed as in the illustrations on pages 69 and 70 but with a larger vocabulary and more advanced grammar. Many of the sentences are nonsensical, although grammatical, because the program was concerned only with sentence structure and words were selected at random.

It is probably clear from the illustrations that the program operates with remembered nodes. Each time the computer embarks on the beginning of a construction (for example, a subject) it stores a remembered node (such as a predicate) so that it will be sure to follow the first part of the construction by an appropriate second part. But if indefinitely long sentences can be produced, how much temporary memory will have to be provided in the computer for storing the remembered nodes? An unlimited amount? Let us examine this question. The bottom illustration on the opposite page contains at the left a "regressive" structure. We call it regressive because the machine has to go down the stem expanding *1*, *2*, *3*, *4* and *5*, storing a number of nodes in its memory (here four); then it has to go back up, expanding in turn the branches growing from *a*, *b*, *c* and *d*. This regressive structure has a "depth" of four. The depth of a node is numerically equal to the number of remembered nodes when that node is about to be expanded. On the right side of the same illustration is a "progressive" structure. The machine can continue down the main stem, expanding as it goes, never retracing its steps and putting only one node away in its temporary memory at each step. After each expansion it returns to the main stem and expands the node remaining in its memory. It is clear that as regressive structures grow longer and longer they require more and more memory. Progressive structures, however, do not. They can continue indefinitely with a minimum of memory.

Let us consider what would happen if the memory had room for only three remembered nodes at a time. In this case

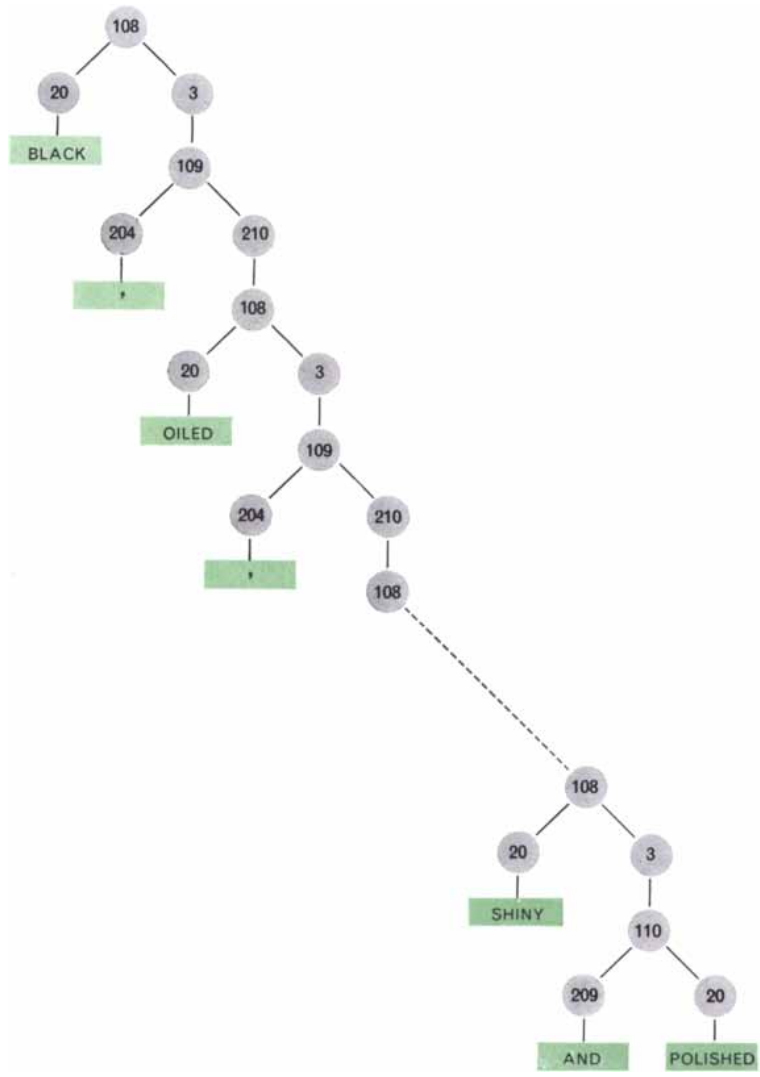
it could produce the sort of structure shown in the upper illustration on the following page, but it would not be able to produce any structure that would penetrate the broken line. If the machine is to have a limited temporary memory, it will have to have some means of restricting its operation if it is to function correctly. One possibility would be to add to the program an alarm much like a typewriter bell that would give warning when the temporary memory was nearly full. At this point the freedom of choice in the grammar could be restricted so that no more remembered nodes would be produced until there was room again in the memory. Another possibility would be to leave the program as it is, without an alarm, and restrict the grammar in such a way that its rules can be reapplied to produce arbitrarily long sentences of the progressive type, but not those of the regressive type beyond a certain depth. Restrictions of this kind could lead to severe complications in the grammar.

In order to determine whether either of these possibilities or some other possibility would be reasonable, I looked again carefully at some of the constructions of English and discovered that many of the previously puzzling complications of the language fall into place as devices in the grammar for restricting the depth of sentences to about seven. Many other complications evidently serve to maintain the expressive power of the language in the face of this rather severe restriction of depth. I framed the hypothesis that all languages will have grammatical and syntactic complications to serve the same purposes.

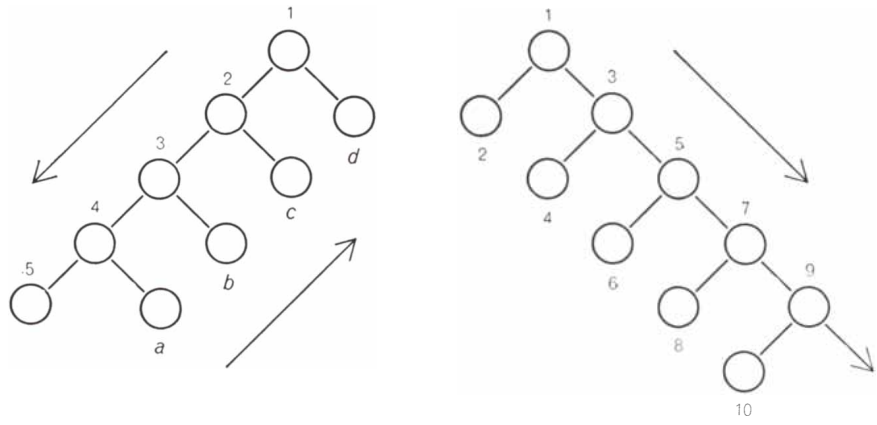
A limit of seven for the temporary memory in our model checks with the span of immediate memory measured by psychologists. We are able to memorize at a glance and repeat back correctly about seven random digits, or about seven nonsense words, or about seven items.

Such a depth limit would not apply to schemes of notation used in mathematics and logic because the mathematician or logician, working on paper, can look back at what he has written. He need not keep it all in his head. Thus workable mathematical and logical notations can have a simple structure.

There are many complications of English that appear to be related to a limited temporary memory. I shall discuss only a few illustrative examples. It is now possible to see the usefulness of the parts-of-speech system in English. It provides a method of tagging nodes to



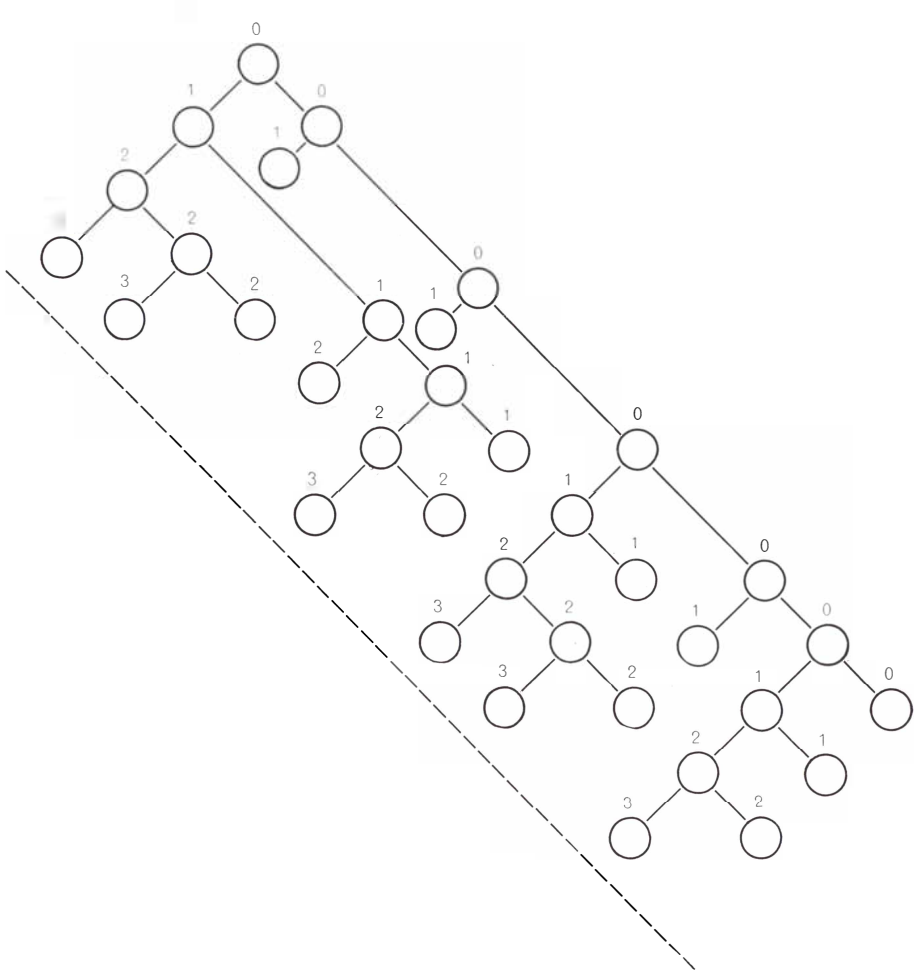
INDEFINITELY LONG sentences can be produced when the computer returns repeatedly to the same node. In this case node 108 ("adjectives") gives rise to a chain that continues until the sequence is interrupted when the computer happens to select 110 ("one more").



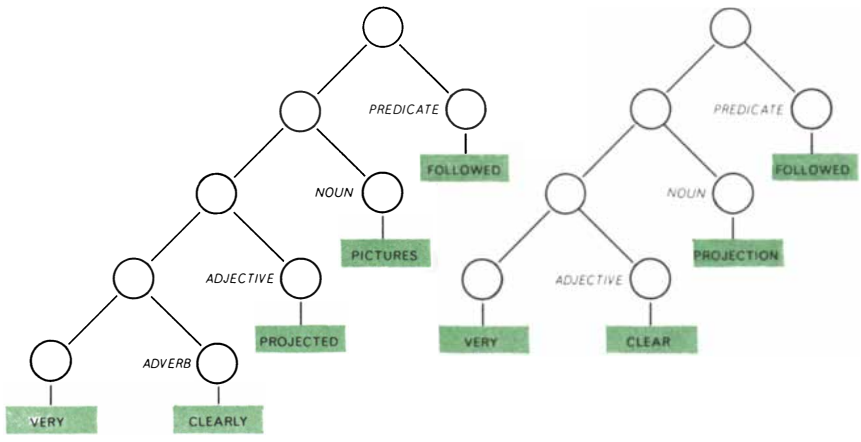
REMEMBERED NODES are stored to tell the computer what to do next. For example, a node for a predicate must be remembered while the subject is produced, a node for a noun while its modifiers are expanded. A "regressive" structure (*left*) requires that an additional node be stored in the memory with every step down, and then expanded in turn (*a, b, c, d*). At step 5 there are four remembered nodes; the structure has a "depth" of four. A "progressive" structure (*right*), on the other hand, never has more than one remembered node: a depth of one. (Vertical node-to-node lines are omitted in this diagram and the next one.)

keep track of depth. Construction can follow construction in the regressive direction only so far. One can say, for instance, "Very clearly projected pictures followed." Here a verb (*followed*) is preceded by a noun (*pictures*), which is in turn preceded and modified by an adjective. The adjective is itself preceded by an adverb, which is in turn preceded by a different kind of adverb. At this point the facilities of the language offer little opportunity for continuing in the regressive direction.

We can now see why it is that English allows object clauses within object clauses ("He knows what should have been included in what came with what he ordered") but does not allow subject clauses within subject clauses ("What what what he wanted cost in New York would buy in Germany was amazing"). The first is progressive; the second is regressive, and every new subject clause would introduce another predicate node into the temporary memory. There are apparently no nodes for producing it in the grammar. But when English does allow clauses within clauses in the regressive direction, a special device is used to count them out and prevent the number of remembered nodes from increasing indefinitely. We have "The family is leaving tomorrow"; "The family the woman told us about is leaving tomorrow"; "The family the woman we met yesterday told us about is leaving tomorrow." This is about as far as it can be carried. English uses special patterns of pitch, loudness, pause and speed in these cases to mark the regressive steps. The patterns allow for two or three regressive steps but no more.



DEPTH OF STRUCTURES that can be produced is limited by the number of nodes that can be stored in the temporary memory. In this case, with a limit of three remembered nodes, the structure is held to a depth of three and cannot penetrate the broken line. The numbers show how many remembered nodes there are when each current node is being expanded.



PARTS OF SPEECH provide a ladder for counting regressive steps and indicating the relations between words. The parts of speech change as words move up and down the ladder.

English also has various methods for conserving depth: getting as much expressive power as possible out of each regressive step. For example, when we say, "The boy loves the girl," we have the feeling—supported by linguistic analysis—that the sentence is divided into subject and predicate, and that the predicate (*loves the girl*) is then divided into verb and object [*see illustration on opposite page*]. The alternative of dividing the sentence immediately into three parts—subject, verb and object—would require in our model two remembered nodes (verb and object) rather than one (predicate). It has frequently been noted by linguists that language seems to prefer two-part rather than multipart constructions. This may be the reason.

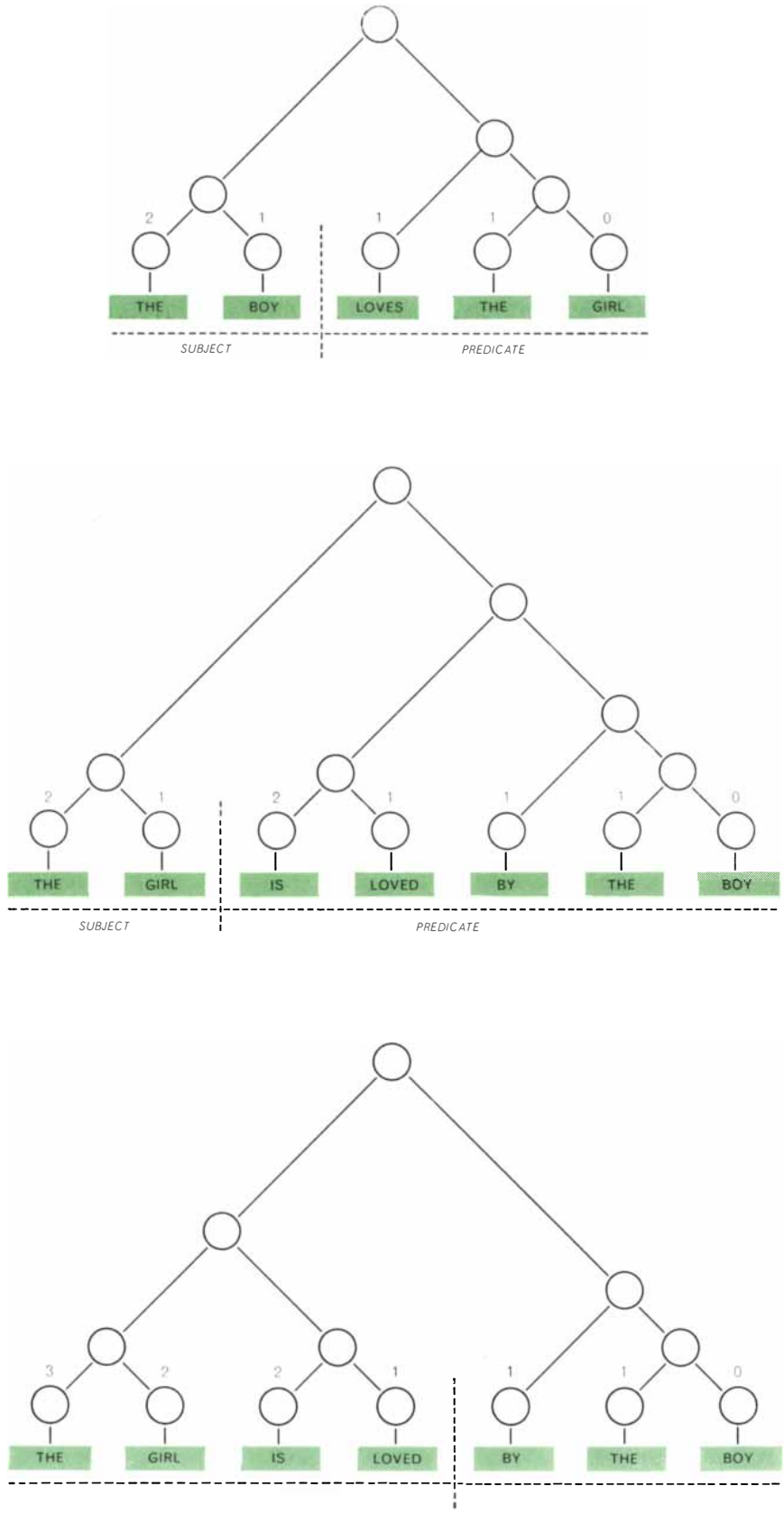
But when the sentence "The boy loves the girl" is changed to the passive sentence "The girl is loved by the boy," we do not retain the same connection between *girl* and *love* that we had in the active. The immediate constituents of the sentence are not *the girl is loved* and *by the boy*, which would require in our model that while the words *the girl* are being produced there would have to be two remembered nodes, one for *is loved* and one for *by the boy*. Instead the pattern of modification is changed back to the subject-predicate type, so that while *the girl* is being produced the program has to remember only one node for the entire predicate *is loved by the boy*.

Other means of conserving depth,

more prevalent in languages such as Turkish than in English or Chinese, are the phenomena of affixation and agglutination, which form long words out of various parts, including prefixes and suffixes. By these devices a regressive structure can be eliminated merely by replacing it with a single compound word. For instance, in English the phrase "to build again" follows a progressive construction and so presents no problem. The word "rebuilding," however, is made up of three elements that present essentially the same concept in regressive order, and we condense these elements into one word [*see upper illustration on next page*]. The importance of word-building for conserving depth in a language is related, of course, to the way the rest of the language is organized. In the evolution of a language, word-building tends in time to be resisted, otherwise the vocabulary would grow too large to be mastered.

In addition to methods for limiting the depth of sentences to about seven, and for conserving depth, English also has an extensive and complicated mechanism for maintaining the power of expression of the language in the face of the severe depth restriction. This mechanism saves depth by providing alternative means of expression. Frequently the order of phrases or clauses can be interchanged without a change in meaning. Of course the roles of the phrases must be suitably marked, since word order is not available now for this function. Thus we have "The boy loves the girl" and "The girl is loved by the boy," where the position of subject and object have been interchanged. We have "He gave the girl the candy" as well as "He gave the candy to the girl." We have strong grammatical or stylistic feelings that make us prefer one or the other alternative under certain circumstances. These feelings can be characterized as urging us to place the "light" construction first and the "heavy" (potentially deep) construction second, where it starts with one less item in the temporary memory. Hence we find it awkward to say: "He gave the candy he got in New York while visiting his parents between Christmas and New Year's to her." It is much simpler to postpone the long clause and move *her* forward: "He gave her the candy he got in New York. . . ."

The possibility of structure reversal provided by the passive construction often enables one to express complicated ideas that would be hopelessly deep if the active alone were available. Consider the following sentence, taken from a

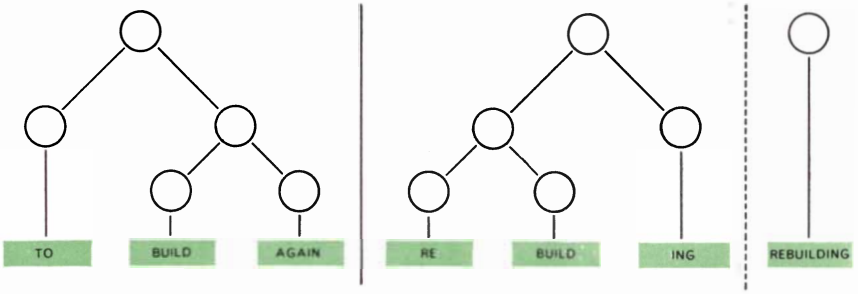


DEPTH IS CONSERVED by the conventional division of a sentence into subject and predicate (*top*) rather than into subject, verb and object. In the passive mood the subject-predicate division is preserved even though it means losing the relation between *girl* and *love* (*middle*). To do otherwise would require a depth of three instead of two (*bottom*).

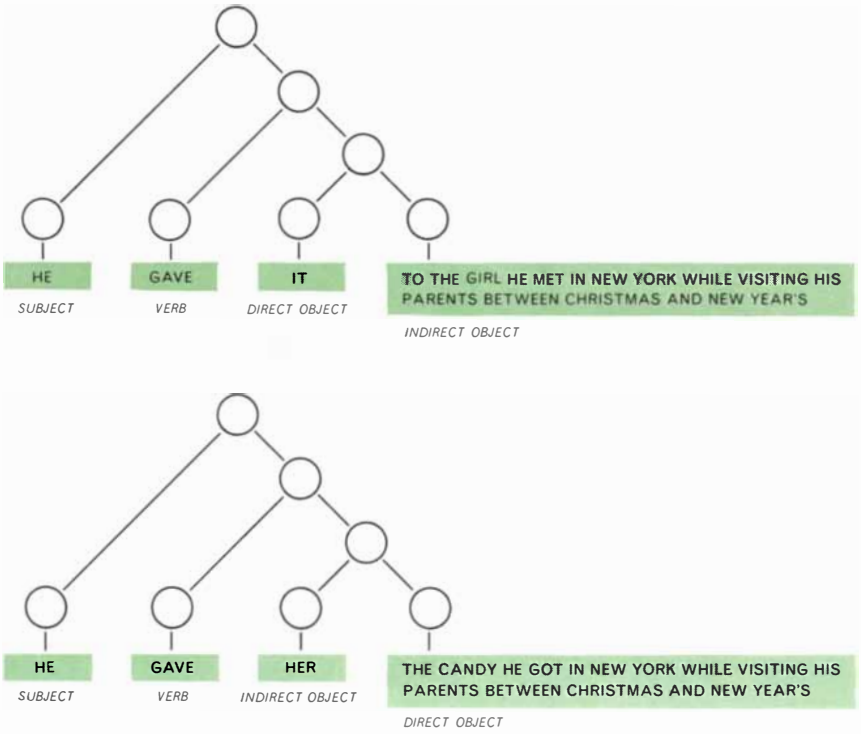
U.S. patent: "The said rocker lever is operated by means of a pair of opposed fingers which extend from a pitman that is oscillated by means of a crank stud which extends eccentrically from a shaft that is rotatably mounted in a bracket and has a worm gear thereon that is driven by a worm pinion which is mounted upon the drive shaft of the motor."

The main type of structure reversal used here is the passive construction, although other types are also represented. This sentence is admittedly extreme, but without structure reversal one would have the following monstrosity: "A pair of opposed fingers that extend from a pitman which a crank stud that extends eccentrically from a shaft which is rotatably mounted in a bracket and which a worm gear that a worm pinion which is mounted upon the drive shaft that the motor has drives is on oscillates operate the said rocker arm."

In addition to structure reversal we have another way of maintaining the expressive power of the language. Many of the complicated discontinuous constructions, which were puzzling to grammarians and which initially presented a programing problem, are now seen to serve the obvious function of postponing potentially deep constituents to a point where they start with an initial burden of one less remembered node. As an alternative to the ungrammatical "That that that they are both isosceles triangles is true is obvious isn't clear" one has "It isn't clear that it is obvious that it is true that they are both isosceles triangles." Here the anomalous discontinuous construction "*It* isn't clear that . . ." shows its true function of postponing a potentially deep constituent to a point of lesser depth. Instead of the already cited ungrammatical "What what what he wanted cost in New York would buy in Germany was amazing" one now has the possibility of "It was amazing what could be bought in Germany for the cost in New York of what he wanted." One is now in a position to explain why relative clauses follow their nouns, whereas single adjectives precede them. It is now clear that the function of postponement explains the utility of the discontinuous constructions in "too worn-out a car to drive" and "a more priceless possession than jewels."



WORD-BUILDING, another device for conserving depth, does not take place (nor is it necessary) when the elements form a progressive structure (*left*). But when the parts are regressive (*right*), conditions are favorable for affixation, or combination into one word.



FLEXIBLE WORD ORDER in English makes it possible to build sentences in such a way that a "heavy" construction is delayed, minimizing depth and maintaining the expressive power of the language. Here the order of the direct and the indirect objects is changed so that in each sentence the element containing an unwieldy subordinate clause comes last.

It remains to be seen how well the depth hypothesis applies to other languages. There are preliminary indications that depth phenomena consistent with the hypothesis may be found in Arabic, Turkish, Chinese and Japanese, as well as in Hidatsa and Mohawk (North American Indian languages), Shilha (a Berber language) and Toba-Batak (spoken in Sumatra).

In the meantime light has been cast on style in English. Perhaps it is not too much to hope that our machine-produced translations will be stylistically elegant as well as accurate and correct renditions of the original. But for accuracy and correctness purely syntactic programs will certainly not be enough. We are aware of great difficulties in the area of semantics—the precise definition of meaning—that must also be solved. But that is another story.

We are heartened by our effort to catalogue the manifold complexities of language; out of apparent chaos has come a glimpse of order. The architecture of language is truly amazing and beautiful. The balanced and complex interplay of various competing elements provides a superb instrument for human communication.

Kodak reports on:

why the earth now speaks more distinctly in color... improvements in pamphleteering since 1933... "films" and films... a little proposition for other manufacturers

Ruddy-faced fellow, isn't he?

He is showing a color photograph of terrain. A skillful photographer can do an excellent job in black-and-white of *suggesting* the color of a man's complexion. Terrain photography is another matter. There suggestion is worth an awful lot less than objective information. For geology, for forestry, for hydrography, for stream-pollution studies, and for just about every other field of photo-interpretation, few will dispute that color—and particularly color *change*—add several dimensions to information capacity.

A new KODAK EKTACHROME AERO Film has arrived, keyed to a set of processing solutions known as "Process E-3." Now the flying camera needs fewer special favors in return for the boon of color. Process E-3 makes it possible to photograph more detail in color for more hours of the day on more days of the year over more of the earth's surface.

More than what?

More than the original EKTACHROME AERO Film, the only color film until now that we have ever heard of as being specifically designed to magnify the pitifully short brightness range that we see when we look down through the hazy air. This density-range expansion was embodied in the film when it first came out in 1942.

Twenty years have taught us a few more tricks. By means of Process E-3, for example, we cut down a troublesome amplification factor when the silver image is converted to the dye image—troublesome because the silver halide crystals had to be relatively sparse to keep density from building up too high. Now we can have more crystals and thereby a finer structure in the image that is apparent at once to the man who has to interpret the picture. About the detailed reason-why he need not trouble his head.

The new color film is in good supply. Now one can tackle aerial photography that has been put off for years. A speed boost of ⅔ stop sounds modest, but it answers demands of modern equipment for shorter exposure and adds a great many flying hours to the year. Details from Eastman Kodak Company, Department GS, Rochester 4, N. Y.

Guide to photographic photometry

Send for the booklet "KODAK Plates and Films for Science and Industry" from Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

It tells how to use photographic emulsions for photometric purposes. It is the latest revision of a little book that has gone through many editions since first issued in 1933 under the title "Photographic Plates for Use in Spectroscopy and Astronomy." The title was broadened as photographic photometry spread beyond these two disciplines under the not inconsiderable influence of the little book itself. It has taught the ground rules to multitudes, few of whom ever point out that one can read so few pages to get so smart.

The latest edition goes at its task from a viewpoint that we should have adopted sooner. Come to think of it, one rarely faces the problem of being handed a box of plates and being asked to figure out something appropriate to do with them. On the contrary, one has a job requiring a certain combination of characteristic curves, image structure, spectral sensitivity, gradient-wavelength function, reciprocity effects, safe-light requirements, processing requirements, mechanical specifications—and wonders what product will best provide the combination. The data are now organized on the latter basis.

Notice it doesn't say above that the booklet is free, and yet it doesn't say how much to send. We do not propose to put large organizations to the annoyance of issuing purchase orders for the trifling sum. Nor will it be exacted from anybody else genuinely interested in the subject either for love or money. On the other hand, we would feel badly to spend the printing on one who contemplates no technical photography but hates to see the mail girl go by without stopping, or on one who reads this in a library next winter while thinking of little more than shelter from the cold. In those cases, the price of the book is $1.

Nutritious vinyl plasticizer

It is clear that KODAK Film is something one puts in a camera. Then a wisp of verbal fog appears.

When *other* manufacturers say "film" they don't necessarily imply that it has photographic emulsion on it. They can mean polyolefins, polyvinyls, polyesters, or poly-anything-else in the form of plain sheeting. Then it turns out that Eastman Kodak Company *also* makes plain sheeting of many kinds. Naturally, Kodak cannot call *those* "film." But they are first-class "films" nonetheless.

Now the fog starts drifting in thick sheets. There are two divisions of Eastman Kodak Company, namely Tennessee Eastman Company and Texas Eastman Company, that furnish polymers for our own film or "films." There is a subsidiary, Eastman Chemical Products, Inc., that sells the polymers from the two TECs to other extruders whose products slug it out in the marketplace toe-to-toe against Kodak's sheeting.

As we make good friends in the extruding fraternity, we notice that some of the boys insist on extruding polymers that we don't make, like polyvinyl chloride. For *them* we show our friendship by supplying various plasticizing esters which, by matching the polar strength of the polyvinyls, form stable solutions of favorable temperature-viscosity characteristics. This business is handled through the same Eastman Chemical Products, Inc. (Kingsport, Tenn.) that deals in the raw polymers.

Suddenly another of our divisions, Distillation Products Industries, turns up in the competitive fog with a discovery about one of the edible products it normally supplies to food processors. This division reports that its MYVACET Distilled Acetylated Monoglycerides, Type 9-40, makes a plasticizer for vinyls that does not lose its virtue in the freezer; that it may be found suitable at a lower level of usage than required of the similarly price-ranged non-nutritive esters, dibutyl and dioctyl sebacate; that this might well interest even those "film" makers who do not happen to be aiming for the food-packaging market.

The address of Distillation Products Industries, in case samples of this plasticizer are desired, is simply Rochester 3, N. Y. Mark you, the world supply of grape leaves may not suffice for the food-packaging needs of an exploding population.

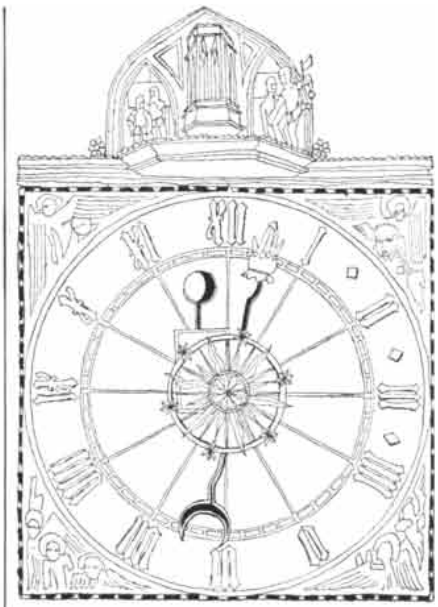
Hot and cold mirrors

Did you know that we are actively soliciting custom-manufacturing business in plane or focusing mirrors that we coat with interference layers either to reflect visible light and dispose of radiant heat by transmission or vice versa?

Negotiate with Special Products Sales, Apparatus and Optical Division, Eastman Kodak Company, Rochester 4, N. Y.

Price subject to change without notice.

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

Space News

An international Consultative Group on Potentially Harmful Effects of Space Experiments was set up by the Committee on Space Research (COSPAR) at its meeting in Washington in May. The six-man group will review experiments proposed by any nation to determine whether they would have adverse effects, particularly on other research activities. In setting up the panel COSPAR was responding to a recommendation of its parent organization, the International Council of Scientific Unions. Following an acrimonious debate over Project West Ford, the U.S. proposal to put a belt of small wires into orbit around the earth as a reflector of radio signals, the I.C.S.U. called for the establishment of a consulting body.

A new set of rules that restricts substantially the amount of information to be released on U.S. earth satellites is now in effect. No formal announcement of the policy was made; newspapers in April carried an Associated Press dispatch reporting that "the Pentagon has quietly curbed even further the already limited information on military space shots." The move was described as "one more step in a process that began right after the Kennedy Administration took over in January, 1961."

Henceforward the National Aeronautics and Space Administration (NASA) will report only on its own satellites and no longer include in its periodic summaries any reference to devices sent up by the military. In most cases information on military space shots will now be restricted to the fact that a satellite was launched. The purpose of withholding all other details is to make it impossible to tell when one of the "sensitive" Midas or Samos vehicles is put into orbit. (Midas is for detecting missile launchings and Samos is a photographic vehicle.) Spokesmen for the Navy indicated, however, that additional information on devices of scientific importance might be released at some time subsequent to the launching.

The first U.S. satellite launchings—the first Vanguard and the early Explorers—were under military auspices. With the formation of NASA late in 1958, the civilian space agency took over direction of most of the scientific earth-satellite and space-probe launchings. But the military services have continued to launch satellites with scientific implications, notably the Navy's Transit series (navigation), the Army's *Courier* (communications) and the Air Force's Discoverer series (satellite recovery and radiation experiments).

In the special case of the joint Army, Navy, NASA and Air Force geodetic satellite *ANNA*, scientists have won a battle against secrecy. They had argued that failure to announce details of its orbit would destroy its value. Those details are now to be made available as soon as possible after launching.

April was notable for an increase in space activity as well as a decrease in availability of information. The U.S.S.R. resumed its instrumented earth satellite program after a four-year layoff and by the end of the month had launched four large "Cosmos" vehicles, at least one of which was returned to earth. The U.S. crash-landed a capsule, *Ranger IV*, on the moon, but failed in the attempt to receive television pictures of the lunar surface or to land a package that would relay back seismic information. The first international satellite, *Ariel*, was placed in orbit from Cape Canaveral. It carried an instrument package for a British study of radiation in space.

Oral Polio Vaccine III

The U.S. Public Health Service has licensed for general use the oral (Sabin) vaccine against Type III poliomyelitis, completing the spectrum of live-virus vaccines against the three most common strains of infective paralytic

THE CITIZEN

polio virus. With "two effective weapons, the formaldehyde-inactivated vaccine and the oral vaccine . . . available for general use," the Surgeon General's advisory committee on the control of poliomyelitis has called for renewal of community-wide immunization programs to secure "early elimination of the disease."

Reviewing the merits of the live vaccine compared with the killed (Salk) vaccine that has been in general use for the past eight years, the Surgeon General and his advisory committee left it up to local health officials and physicians to decide which to use. "Availability," they said, "may be a determining factor." Where epidemics threaten in the coming summer months, they recommend administration of the live vaccine specific for the implicated infective virus. The Communicable Disease Center in Atlanta, Ga., is holding a supply of the vaccines in reserve against emergency demand.

With more than 400 million doses of Salk vaccine administered to date, the incidence of paralytic polio in the U.S. population has declined by more than 90 per cent. Some 65 per cent of preschool children and 70 per cent of young adults have nonetheless failed to receive the series of four injections recommended for full immunization. As a result outbreaks and even some severe local epidemics still occur.

Secure immunization by the oral vaccine also calls for four administrations. The three vaccines are taken separately at intervals of six weeks and then all together in a final dose after six months. Because other intestinal viruses may interfere with the effectiveness of the oral vaccine, and because these are more widely prevalent in the summer months, the Public Health Service recommends that the community-wide immunization programs using oral vaccine be undertaken in the autumn, winter and spring months.

Spate of Resonances

The big news in particle physics continues to be the appearance of more of the equivocal phenomena called pion resonances. The term is used in connection with certain particle reactions, each of which produces pions (pi mesons) in varying numbers, particularly two or

three. Until recently the distribution of energies of the pairs or trios of pions were expected to fall in a smooth curve. Now it is found that the curves contain resonances, or sharp peaks, at certain specific energies. One interpretation of the resonances is that the energy of each one comes from the decay of some extremely short-lived elementary particle, which exists too briefly to leave tracks of its own in cloud chambers or bubble chambers. In keeping with this point of view the resonances are also called mesons and have been given names: rho, omega, eta and so forth. Another approach to the theory of resonances is to regard them as being essentially compound objects made up of associations of particles already known.

Within the past few months a new two-pion resonance called the zeta meson has been found at an energy of about 550 Mev (million electron volts). This means that the kinetic energy of the two product pions, plus the energy represented by their rest mass, is 550 Mev. Only a short time earlier a three-pion resonance called the eta had also turned up at 550 Mev. (The rho and omega are in the neighborhood of 770 Mev.) The eta is neutral; the zeta occurs with both positive and negative charge.

At present workers in many laboratories are conducting a systematic search for further resonances across the entire energy spectrum. No results have been published yet; it takes considerable time to make sure that a bump in the energy curve is a real resonance and not merely a temporary statistical vagary. Nevertheless, there are preliminary indications of a number of new resonances at a variety of energies.

All this has induced a great deal of activity among theoretical physicists, who are trying to fit the new phenomena into some kind of conceptual framework. There are efforts—none of them successful as yet—to reach a deep understanding of the resonances. Most work, however, is on a more modest scale. A good deal of theory is required simply to compute various consistent sets of properties, such as quantum numbers, for the particles (or whatever they are) and to suggest tests of the calculations to experimentalists. Some theoreticians are coming to think that not all the resonances necessarily represent the same type of underlying event.

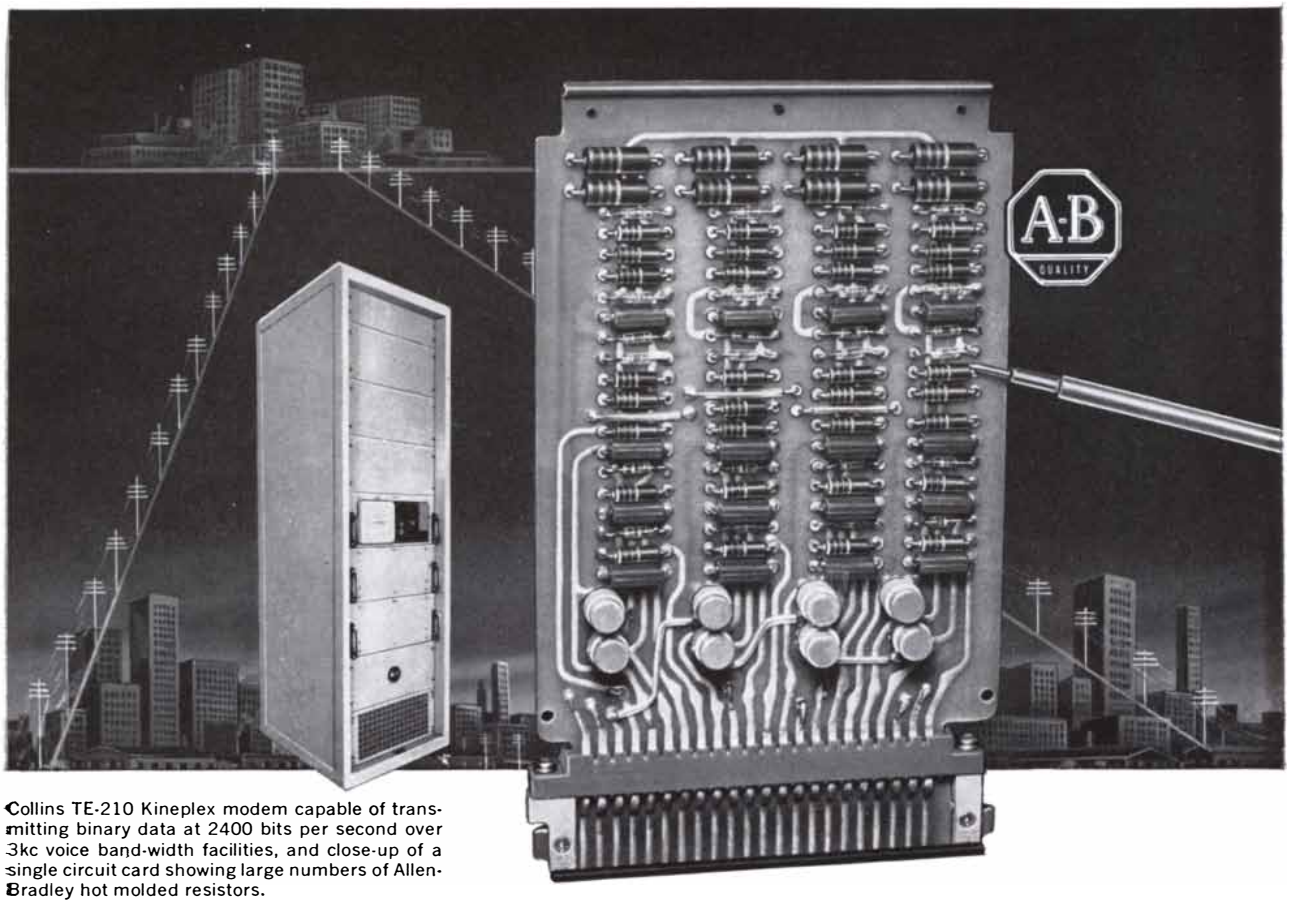
As to the eta and zeta, an engagingly simple proposal has just appeared in *Physical Review Letters,* put forward by Ronald F. Peierls of the Institute for Advanced Study in Princeton and S. B. Treiman of Princeton University. The rest mass represented by the energy of these resonances is almost precisely equal to that of four pions. Peierls and Treiman suggest that the eta and zeta are "loosely bound nuclei made up of four pions," implying "no more, and no less," than that the mesons are compound systems of elementary particles in the same sense that, for example, a helium atom is. The physicists have computed the quantum numbers and other properties that their model, together with the known behavior of the resonances, would imply. If experiments show the quantum numbers to be different, the theory will be disproved. If the predictions are verified, the theory will take its place along with other good ideas that a more basic understanding should eventually prove or disprove.

Removable Organs

The stomach, small intestine and even the heart of a dog can be removed and then put back again without apparent harm to the animal. Such "autotransplantations," performed by surgeons at the University of Minnesota and Stanford University, are raising intriguing questions in physiology as well as opening new possibilities in the treatment of disease.

The experiments began at Minnesota four years ago, when Richard C. Lillehei wished to determine how long blood flow could safely be interrupted during operations on the blood vessels supplying the small intestine. To avoid debate as to whether the blood flow had really been cut off, Lillehei took out completely the small intestines of a number of dogs, placed the intestines in refrigerated saline solution for up to five hours and then sewed them back in place. He restored blood vessel connections but not those of the nerves or lymph channels. Provided that the intestines had been properly handled and stored while out of the body, the dogs generally survived.

The success emboldened Lillehei to attempt a similar procedure with the stomach. This also proved feasible and has now been carried out on some 30 dogs; one animal has already survived for more than two and a half years since the operation. When the stomachs are restored, however, they no longer behave normally: their secretion of gastric acid and pepsin drops to very low levels. Gastric acidity rises again after a year, but the pepsin level seems permanently reduced. As far as the surgeons can tell this does not harm the dog. In human beings it might be a



Collins TE-210 Kineplex modem capable of transmitting binary data at 2400 bits per second over 3kc voice band-width facilities, and close-up of a single circuit card showing large numbers of Allen-Bradley hot molded resistors.

COLLINS KINEPLEX® brings greater speed and efficiency to communications

Allen-Bradley Hot Molded Resistors Guarantee Reliable and Continuous Performance for This Part of the System

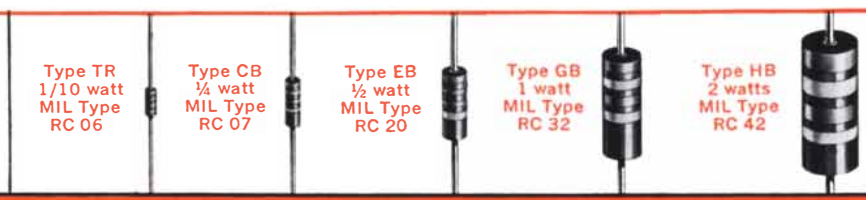
As today's communication equipment is called upon to handle far greater volumes of information quickly and accurately, uninterrupted operation becomes more and more important.

To obtain this needed reliability, modern high-speed transmission systems, such as the new Collins Kineplex, employ Allen-Bradley quality fixed resistors. Made by A-B's *exclusive* hot molding process, they are so remarkably uniform that their long term performance is accurately predictable in service. Also, where Allen-Bradley hot molded resistors are used, "catastrophic failure" is unheard of!

Always insist on Allen-Bradley hot molded fixed resistors—at least thirty years of field experience have demonstrated that they have no equal on the market. For full details on the complete line of A-B quality components, please write for Publication 6024.

Allen-Bradley Co. 1204 S. Third St., Milwaukee 4, Wisconsin • In Canada: Allen-Bradley Canada Ltd., Galt, Ontario

ALLEN-BRADLEY
Hot Molded Resistors are available in all standard EIA and MIL-R-11 resistance values and tolerances.



ALLEN-BRADLEY Quality Electronic Components

valuable effect: reducing secretion of pepsin is a highly effective means of treating stomach ulcers.

The isolated stomach has been found to tolerate doses of radiation more than 12 times greater than can be administered safely to the body as a whole. Consequently, Lillehei suggests, stomach cancer may someday be treated by removing the stomach for X-ray treatment in vitro and then restoring it to its owner.

The removal and reimplantation of the heart is the work of a Stanford group under Norman Shumway, which has so far operated on 12 dogs, keeping the heart out of the body for up to three hours. Nine dogs have survived for a year. Undertaken to test temporary removal of the heart as an aid to repairing complex heart defects, the procedure has already yielded results of interest to physiologists. As in the stomach and small-intestine restorations, the difficult task of re-establishing the links of the organ to the nervous system was not attempted; Shumway and his associates contented themselves with restoring the blood vessel connections. Shumway reports that the animals' hearts nevertheless respond well to the demands of exercise and other stresses. Therefore there exist means, apart from signals from the nervous system, for adjusting the performance of the heart to the body's needs.

Advancing Superconductivity

A group of physicists at the Bell Telephone Laboratories has demonstrated that molybdenum is a superconductor. The discovery fills in what had been a puzzling gap in the list of superconducting elements. No member of Column VI of the periodic table (comprising oxygen, sulfur, chromium, selenium, molybdenum, tellurium, tungsten, polonium and uranium) had previously demonstrated the property. To make molybdenum superconducting the physicists (T. H. Geballe, B. T. Matthias, E. Corenzwit and G. W. Hull, Jr.) found that it had to be very highly purified. This suggests that other elements not thought to be superconducting may also be prevented from achieving this state only by the presence of trace impurities.

A new application for high-critical-temperature materials such as niobium was announced by a group from the Jet Propulsion Laboratory of the California Institute of Technology at the April meeting of the American Physical Society in Washington. They have built a "flux pump," in which magnetic fields

MATERIAL CRYING FOR AN INVENTOR

Do any other epoxy resins promise such intriguing (and profitable) possibilities as these new developments from Dow?

Consider first, an extremely pure epoxy resin with a viscosity of 4,000—6,400 cps, and color 1 max. This is essentially the pure diglycidyl ether of bisphenol A without troublesome high polymer fractions. Or, the flame-retardant brominated epoxies which also provide top physical and electrical properties. Then there is an epoxy novolac with (1) unusually high chemical resistance, and (2) temperature stability up to 500° F.

All these, plus extremely high adhesion, low shrinkage during cure, resistance to thermal and mechanical shock, toughness, chemical inertness, moisture resistance and outstanding electrical properties. One of our secrets is the quality control we maintain, because we also make every single ingredient which goes into our epoxies.

You have the problems, we have the epoxies . . . many types. Why not see if they can help in your development work? Samples available. Write us c/o Coatings Sales Department 1641EQ6.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

can be compressed much as gas is compressed in an ordinary pump. One version consists of a block of niobium with two closed cavities connected by a fine duct. The block is placed in the field of a strong electromagnet, then cooled below its critical temperature, whereupon it becomes superconducting. The magnetic field now in the cavities is trapped there. (Magnetic fields cannot pass through superconductors.) One cavity contains a piston of superconducting niobium. When this is pushed in the right direction, all the flux flows into the second cavity, where the field strength then doubles.

A fancier design replaces the duct with a valve consisting simply of a thin wall of niobium. A small heater can raise the temperature of the wall above the critical point, thus opening it to the passage of a magnetic field; shutting off the heater makes the wall superconducting again and closes the valve.

The Jet Propulsion Laboratory physicists have already compressed fields as high as 23,500 gauss in their pump. They believe it should be possible to achieve a field of 100,000 gauss in a chamber big enough to hold a large particle detector or a space traveler, who would thus be shielded from charged particles.

Glassy Dirt

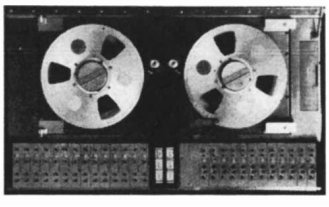
Tektites, the strangely shaped glassy stones scattered over many parts of the earth's surface, may have been formed from molten soil, according to Henry P. Schwarcz of the Enrico Fermi Institute at the University of Chicago.

During recent years evidence has accumulated that tektites are products of the impacts of giant meteorites on the earth. They were presumably formed by collisions energetic enough not only to melt rocks where the meteorite struck but also to splash droplets of molten material hundreds of miles from the site. The chemical composition of tektites, however, has posed a difficulty for this hypothesis. The principal types are more uniform in make-up than would be expected if they had really originated from the numerous different rocks that would be expected to occur at various impact points.

Schwarcz noted that soils often have uniform composition over wide areas and, moreover, are far more abundant at an individual location than any single type of rock. He accordingly checked the chemical composition of tektites from Texas, central Europe, Australia,

What can ride the rails and still record with laboratory precision? AMPEX CP-100.

What a life the CP-100 recorder leads. It even gets shock-mounted in a train to measure the flatness of the roadbed. And never a change in its true instrumentation quality performance. In fact, you'll find the CP-100 right at home in a down-range test van, nuclear submarine—or a clinical laboratory. (It can be rack-mounted.) It provides Direct, FM-Carrier and PDM recording. Is easily accessible: the entire transport assembly lifts up. And it operates on almost any standard source of power, including batteries. The CP-100 is perfect any time, anywhere you need a reliable precise portable. For more data write the only company providing recorders and tape for every application: Ampex Corporation, 934 Charter Street, in Redwood City, California. Sales and service engineers throughout the world.



southeast Asia and the Ivory Coast of Africa against analyses of Temperate Zone and humid zone soils. He made comparisons for 11 major constituents and 10 trace elements. With two exceptions, the agreement was very close. One discrepancy involves iron, which occurs in a more reduced state in tektites than it does in soil. Schwarcz points out that the iron would have been reduced during the melting of the soil. Many tektites also contain more magnesium than is found in soil. This excess could have come from an admixture of some material from the meteorite itself, if the latter had been of the magnesium-rich chondritic type.

Piggyback Penetration

Molecules ordinarily kept out of living cells by the cell's outer membrane apparently can get in by riding on particles engulfed in the process known as phagocytosis. Many cells engage in phagocytosis, wherein the membrane closes around a small particle, folds inward, then breaks loose from the rest of the cell wall and enters the interior of the cell. A team of investigators at St. Margaret's Hospital in Boston has been able to show that both small and large molecules can ride into leucocytes (white blood cells) on phagocytosed objects.

The investigation began two years ago when A. J. Sbarra of St. Margaret's noticed that leucocytes would absorb malonic acid, a substance to which they are ordinarily impermeable, under circumstances suggesting that they were also engaging in phagocytosis. Sbarra and his colleagues accordingly set up a series of experiments using white cells from guinea pigs, rabbits and human volunteers. Cells were suspended in a medium together with polystyrene spherules or insoluble granules of starch, both of which white cells readily ingest. Malonic acid, the molecules of which are small, was added to some of the preparations; gamma globulin, the molecules of which are large, was added to others. Both molecules found their way into the cells—but only when starch or polystyrene granules were present.

Sbarra and his associates W. Shirley and W. A. Bardawil, who describe the phenomenon in *Nature*, have named it "piggyback" phagocytosis. They believe it may be an important form of natural transport across the cell membrane; moreover, the process may be a way of introducing drugs into cells.

How to control the invisible nuisance in our atmosphere

No one has ever seen a water molecule.

Yet water vapor is everywhere. It permeates the earth and atmosphere. No life is possible without it.

But water can be a costly nuisance.

A single drop creates enough acid and sludge to foul up air-conditioning and refrigeration systems.

It condenses in transonic and supersonic wind tunnels.

It corrodes gasoline pipelines. Contaminates lube oils. Scrambles chemical reactions.

It contaminates commercial gases such as oxygen, hydrogen and carbon dioxide (makes them unfit for industrial use).

It gums up production in plants that process and package candy, food and drugs.

The economical, efficient answer to every dehydration problem is Alcoa® Activated Alumina.

Just use our *Liquid or Gas Dehydration Questionnaire* (available on request) to spell out your problems, and we'll do our best to solve them.

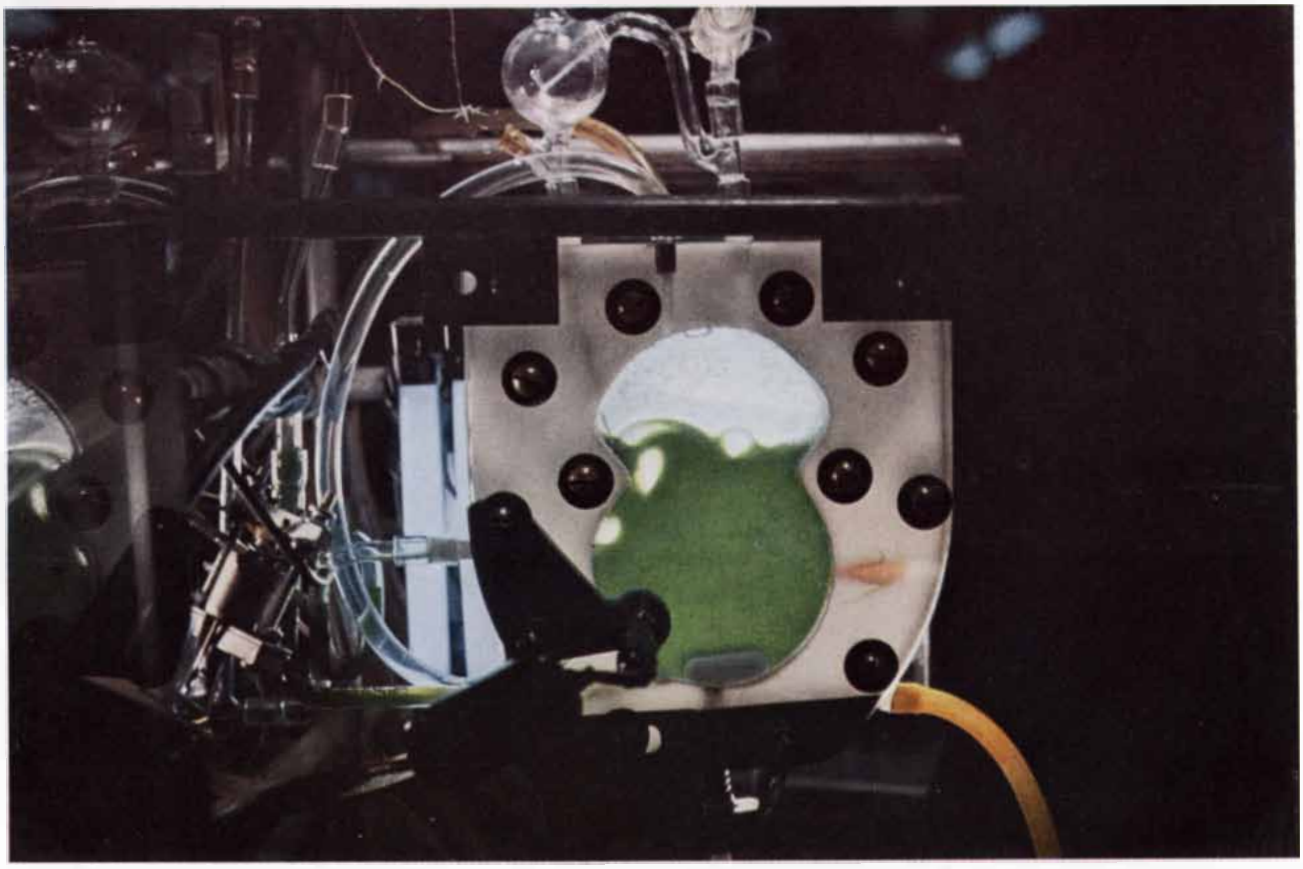
Write Aluminum Company of America, Chemicals Division, 965-F Alcoa Building, Pittsburgh 19, Pa.

Entertainment at its Best... **ALCOA PREMIERE** with Fred Astaire as host... Tuesday Evenings, ABC-TV

ALCOA CHEMICALS

ALUMINUM COMPANY OF AMERICA

THREE CULTURE TUBES are part of the continuous-culture apparatus used by the Bio-Organic Chemistry Group at the University of California to grow green algae under constant conditions in an aqueous medium. Two tubes are empty; the third contains algae.



"LOLLIPOP" is a thin, transparent vessel to which algae are transferred from culture tubes. Carbon dioxide containing radioactive carbon is bubbled through the algae suspension in experiments to determine the path taken by carbon in the photosynthetic process.

The Path of Carbon in Photosynthesis

The carbon atoms of the carbon dioxide assimilated by plants traverse an intricate cycle of chemical reactions. The immediate products are not only carbohydrates but also amino acids, fats and other compounds

by J. A. Bassham

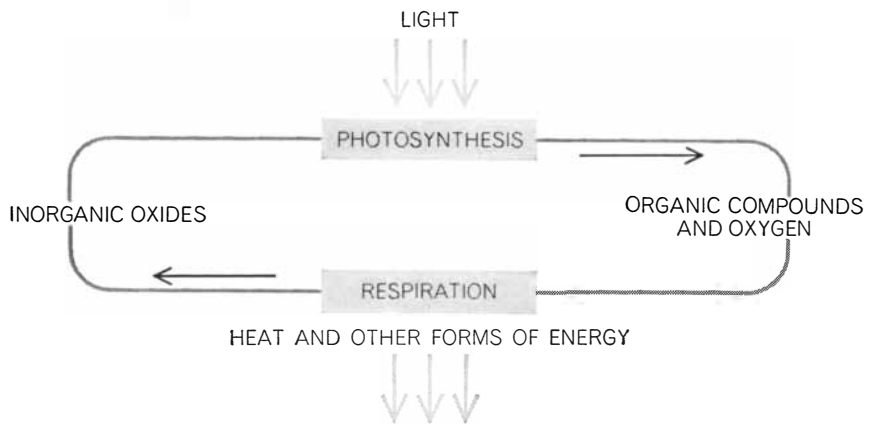
The processes of life consist ultimately of the synthesis and breakdown of carbon compounds. Because a carbon atom can bind four other atoms to itself at a time and is thereby able to link up with other atoms—especially other carbon atoms—in chains and rings, carbon lends itself to the construction of a virtually endless variety of molecules. These molecules derive their physical characteristics and chemical activity not only from their composition but also from their size and intricacy of structure. The rich variety of life suggests in turn that living cells have gone far in the elaboration of such compounds and the processes that make and unmake them. All these processes depend in the end on a first one. This is the process of photosynthesis, which takes carbon and several other common elements from the environment and builds them into the substances of life.

The plant finds most of these elements already bonded to oxygen in oxides such as carbon dioxide (CO_2), water (H_2O), nitrate (NO_3^-) and sulfate (SO_4^{--}). Before the plant can bind the elements other than oxygen together as organic compounds, it must remove some of the excess oxygen as oxygen gas (O_2), and this accomplishment takes a large amount of energy.

In the simplest terms photosynthesis is the process by which green plants trap the energy of sunlight by using that energy to break strong bonds between oxygen and other elements, while forming weaker bonds between the other elements and forcing oxygen atoms to pair as oxygen gas. For example, to make the sugar glucose ($C_6H_{12}O_6$) the plant must split out six molecules of oxygen in order to combine the carbon and half the oxygen of six carbon dioxide molecules with the hydrogen of six water molecules.

The glucose and other organic compounds taken up in the chemical machinery of the plants and the animals that live on plants serve both as fuel and as the raw materials for the synthesis of higher organic compounds. That considerable solar energy is bound by photosynthesis becomes apparent when wood or coal is burned. In living cells the controlled combustion of respiration extracts this energy to power the other processes of life. Both kinds of combustion take oxygen from the air and break down organic compounds to carbon dioxide and water again. In its end result photosynthesis can be defined as the opposite of respiration. Together these complementary processes drive the cyclic flow of matter and the noncyclic flow of energy through the living world [*see illustration below*].

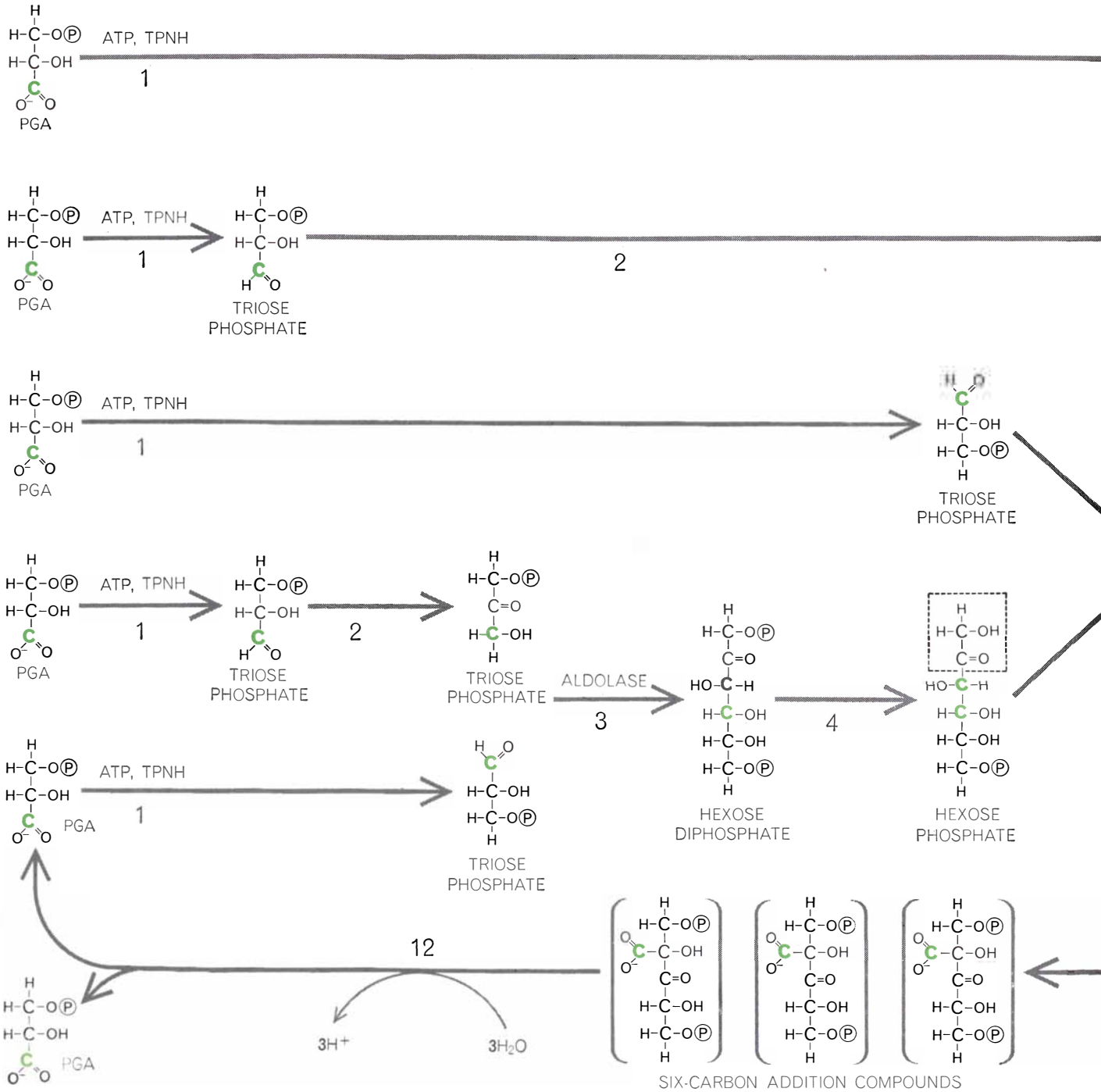
From such generalizations about the effect and function of photosynthesis in nature it is a long step to the explanation of how photosynthesis works. Yet much of the explanation is now complete. The work has been greatly facilitated by the earlier and more nearly complete resolution of the chemistry of respiration. The two processes, it turns out, are in some ways complementary on the molecular scale, just as they are on the grand scale in the biosphere. Each involves some 20 to 30 discrete reactions and as many intermediate compounds; half a dozen of these reactions and their intermediates are common to both photosynthesis and respiration. Only the first few steps in photosynthesis are driven directly by light. The energy of light is trapped in the bonds of a few specific compounds. These energy carriers deliver the energy in discrete units to the steps of synthesis that follow. The same or closely similar carriers perform corresponding operations in respiration, picking up energy from the stepwise dismemberment of the fuel molecule and



PHOTOSYNTHESIS AND RESPIRATION are the complementary processes that drive the cyclic flow of matter and the noncyclic flow of energy through the biosphere. Photosynthesis uses light energy to convert inorganic oxides to oxygen and organic compounds such as glucose. In respiration of plants and animals oxygen reacts with these compounds to produce the inorganic oxides carbon dioxide and water as well as biologically useful energy.

delivering it to the energy-consuming processes of the cell. Although the first, energy-trapping stage in photosynthesis remains to be clarified, it is now possible to trace the path of carbon from the very first step in which a single atom of carbon is captured in the bonds of an evanescent intermediate compound.

The term "carbohydrate" recalls the deduction of early 19th-century investigators that photosynthesis made glucose directly by combining atoms of carbon with molecules of water, as the formula for glucose suggests. In line with this idea it was thought that the oxygen transpired by green leaves came from the splitting of carbon dioxide. The progress of chemistry, however, failed to disclose any processes that would accomplish these results so simply. Accumulating evidence to the contrary became convincing some 30 years ago, when C. B. van Niel of Stanford University discovered that certain bacteria produce organic compounds by a process of photosynthesis similar to that in plants but with one important difference. These bacteria use hydrogen sulfide (H_2S) instead of water and liberate elemental sulfur instead of gaseous oxygen. The



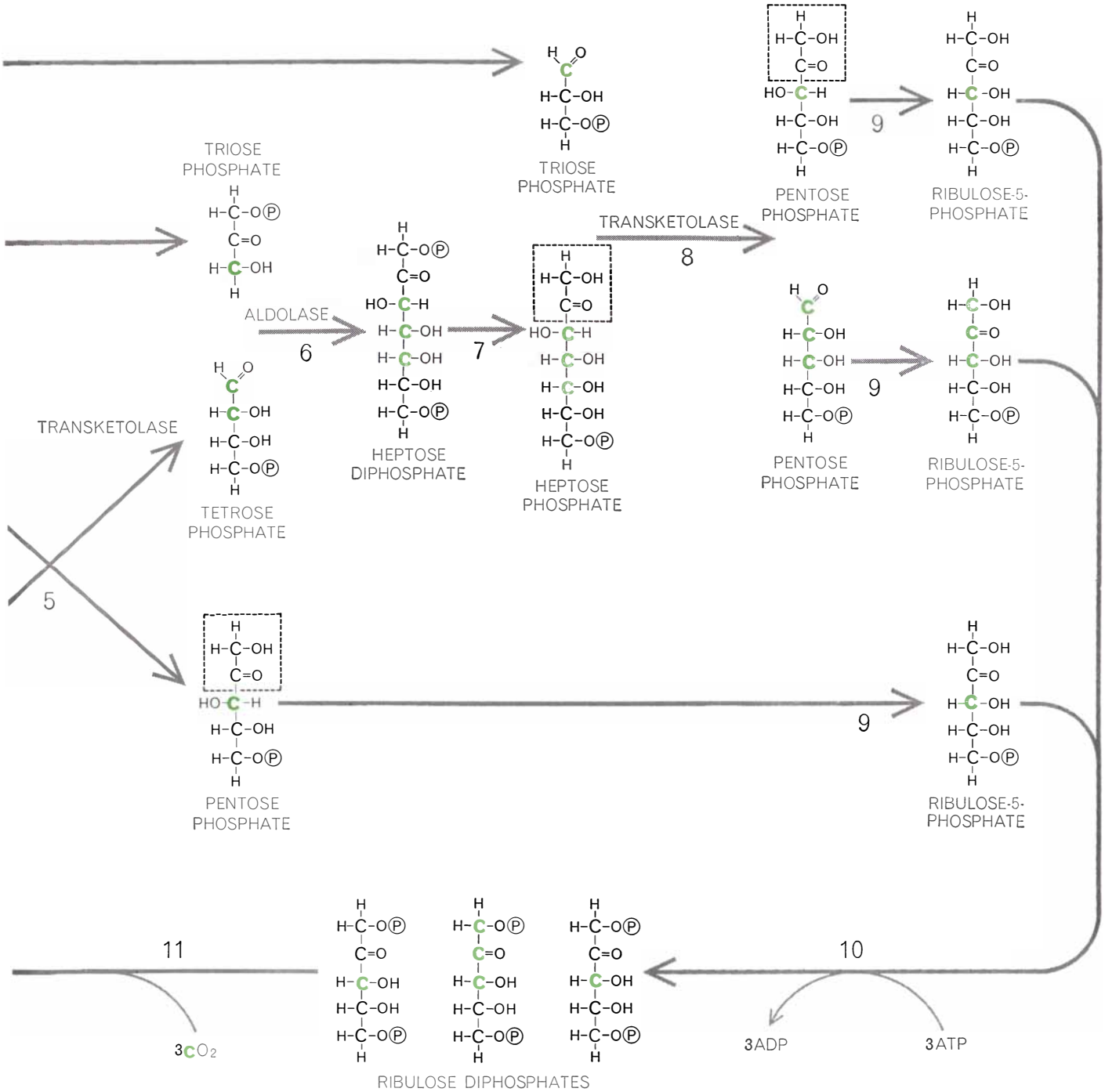
PATH OF RADIOACTIVE CARBON (*color*) **was determined from experiments described in the text. Five molecules of PGA, the first stable intermediate product to appear, are reduced** (*1*) **by cofactors ATP and TPNH to five triose phosphate molecules. A circled** *P* **represents a phosphate group (—HPO_3^-). Two of these are converted to a different type of triose phosphate** (*2*)**; the subsequent condensation of one of each kind of triose into hexose diphosphate** (*3*) **is mediated by the enzyme aldolase. Hexose diphosphate then loses a phosphate group** (*4*)**. Transketolase, another enzyme, removes two carbons from the hexose and adds them to a triose**

otherwise complete similarity of the two processes strongly suggested that the oxygen evolved by green plants must come from the splitting of water.

The Capture of Light

Photosynthesis could now be described in terms of familiar chemistry. The splitting of water would be accomplished by the process of oxidation (which means the removal of hydrogen atoms from a molecule), with oxygen gas as the product of the reaction. The free hydrogen atoms would then be available to carry through the equally familiar and opposite process of reduction (which means the addition of hydrogen atoms to a molecule). By the addition of hydrogen atoms (or electrons plus hydrogen ions) the carbon dioxide would be reduced to an organic compound.

It is during the first, energy-converting stage of photosynthesis that the water molecule is split. Initially the energy of light impinging on the plant cell is transformed into the chemical potential energy of electrons excited from their normal orbits in molecules of the green pigment chlorophyll and other plant pig-



phosphate (*5*), making one tetrose and one pentose phosphate. The tetrose condenses with a triose (*6*) to form a heptose diphosphate, which then loses a phosphate group (*7*). Transketolase removes two carbons from the heptose and adds them to a triose (*8*), making two more pentose phosphates for a total of three; these are converted to ribulose-5-phosphate (*9*), then to ribulose diphosphate (*10*). Addition of three carbon dioxide molecules (*11*) produces three unstable compounds (*brackets indicate unknown structure*) that begin the cycle again. Addition of three water molecules (*12*) results in six PGA molecules for a net gain of one in the cycle.

ments. A large part of this energy eventually goes into the splitting of water as electrons and hydrogen ions are transferred from water to the substance triphosphopyridine nucleotide (TPN^+), which is thereupon reduced to the form designated TPNH. The TPNH thus becomes not only a carrier of energy but also the bearer of electrons for the subsequent reduction of carbon dioxide. Along with the movement of electrons from water to TPNH, some energy goes to charging the energy-carrying molecule adenosine triphosphate (ATP), specifically by promoting the attachment of a third phosphate group ($-OPO_3^{--}$) to adenosine diphosphate (ADP), the discharged form of the carrier. Both ATP and TPNH belong to the family of compounds known as cofactors or coenzymes, which work with enzymes in the catalysis of chemical reactions. ATP, the universal currency of energy transactions in the cell, plays a significant role in respiration as well as in photosynthesis.

Needless to say, the manufacture of each of these cofactors involves an intricate cycle of reactions [see "The Role of Light in Photosynthesis," by Daniel I. Arnon; SCIENTIFIC AMERICAN, November, 1960]. Although the cycles are not yet fully understood, it is enough for the purpose of the present discussion to know that ATP and TPNH, or closely similar compounds, furnish the energy for the second stage of photosynthesis, during which the carbon atom of carbon dioxide is reduced and joined to a hydrogen atom and a carbon atom in place of an oxygen.

The process of reduction goes forward in small steps. Each reaction brings about some change in a carbon compound until the starting material is at last transformed to the final product. For each reaction there is therefore an intermediate compound. Since every life process involves a more or less extended series of intermediates, cells typically contain a large number of intermediates. Many of them turn up in two or more pathways leading to different end products. The tracing of the path of carbon in photosynthesis required first of all a technique for identifying the intermediates proper to it and for establishing their sequence along the path.

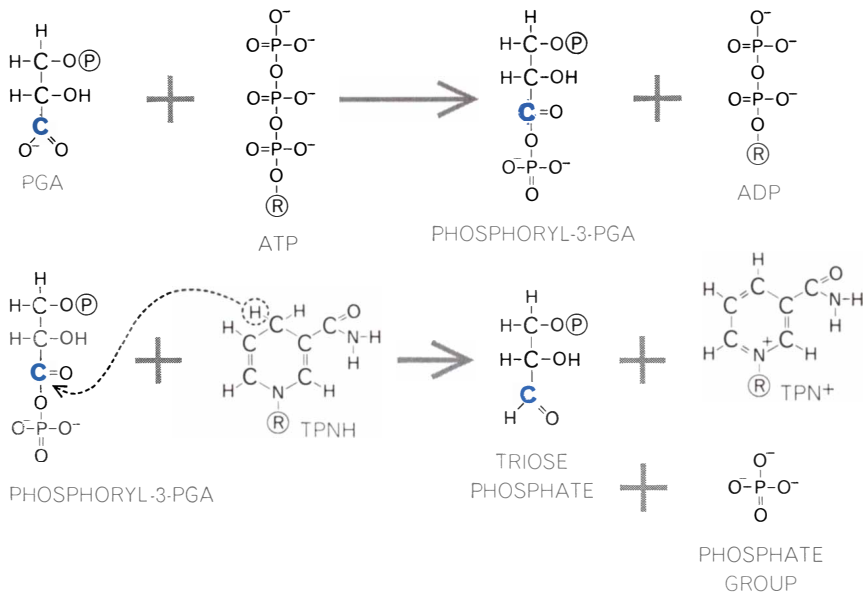
Samuel Ruben and Martin D. Kamen, then at the University of California, met this need some 20 years ago by their discovery of the radioactive isotope of carbon with a mass number of 14. This isotope has a conveniently long half life of more than 5,000 years; over the time period of an experiment, therefore, carbon 14 has an effectively constant radioactivity. Ruben and his colleagues recognized at once the potential usefulness of this isotope as a label for the identification of compounds in biological processes. They prepared carbon dioxide in which the carbon atoms were carbon 14. When they exposed green plants to an atmosphere containing this gas instead of normal carbon dioxide ($C^{12}O_2$), the plants took up the $C^{14}O_2$ and made compounds from it. The presence of the carbon 14 in these compounds could be detected by various devices, such as the Geiger-Müller counter, and by radioautography on X-ray film. Unfortunately this work was cut short by the war and by Ruben's death in a laboratory accident.

In 1946 Melvin Calvin organized a new group at the Lawrence Radiation Laboratory of the University of California with the primary objective of tracing the path of carbon in photosynthesis with $C^{14}O_2$ as one of its principal tools. Starting as a graduate student in 1947, I had the good fortune to participate in this work with Calvin, Andrew A. Benson and others.

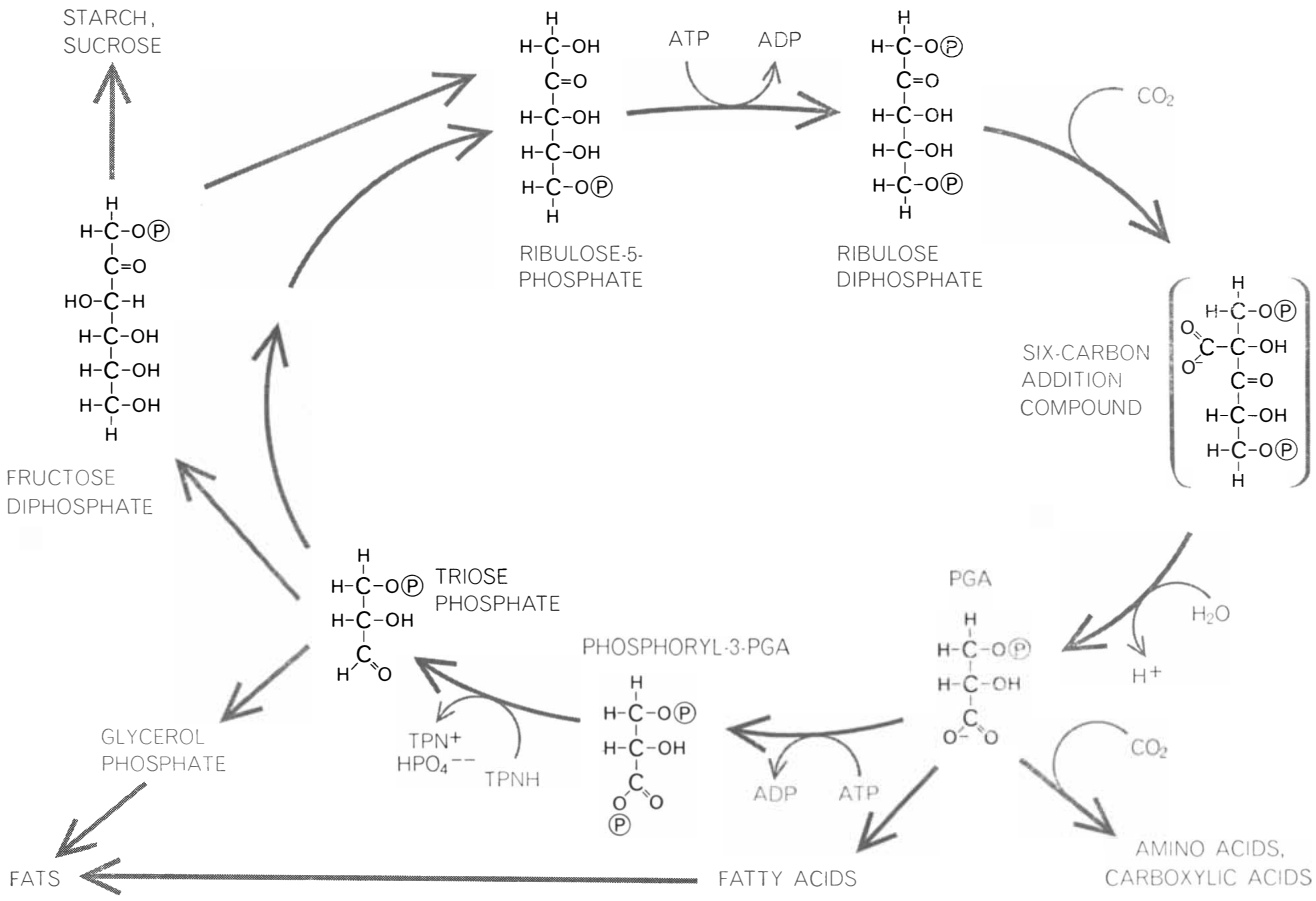
The early experiments were quite simply contrived. We used leafy plants and often just the leaves of plants. After allowing a leaf to photosynthesize for a given length of time in an atmosphere of $C^{14}O_2$ in a closed chamber, we would bring biochemical activity to a halt by immersing the leaf in alcohol. With the enzymes inactivated, the reactions converting one intermediate compound into another would stop, and the pattern of labeling would be "frozen" at that point. We soon discovered, however, that photosynthesis proceeds too rapidly for completely reliable observation by such a procedure. With a few seconds' delay in the penetration of alcohol into the cell, for example, the labeling pattern would be disarrayed and no longer representative of the stage at which we tried to halt the photosynthesis.

Since rapid and precisely timed killing of the plant is important, we adopted single-celled algae—*Chlorella pyrenoidosa* and *Scenedesmus obliquus*—as the subject for many of our experiments. In both species the plant consists of a single cell so small that it can be seen only with a microscope. Alcohol can quickly penetrate the cell wall and deactivate the enzymes. The algae offer another advantage: they can be grown in continuous cultures, assuring us a supply of material with highly constant properties.

An experimental sample is taken from the culture in a thin-walled, transparent closed vessel. Illuminated through the walls of the vessel and supplied with a stream of ordinary carbon dioxide, which is bubbled through the suspension, the algae photosynthesize at the normal rate. We shut off the supply of carbon dioxide and inject a solution of



REDUCTION OF PGA to triose phosphate requires both ATP and TPNH. At top ATP gives up its terminal phosphate group to PGA to produce phosphoryl-3-PGA. At bottom TPNH donates a hydrogen atom and an electron (*broken circle and arrow*), thereby displacing a phosphate group and forming triose phosphate. The second step is in reality more complex than shown here and involves other cofactors in addition to TPNH.



END PRODUCTS OF PHOTOSYNTHESIS are not limited to carbohydrates (e.g., sucrose and starch), as first thought, but include, among other things, fatty acids, fats, carboxylic acids and amino acids. Carbon cycle shown here is highly simplified; it involves at least 12 discrete reactions. Moreover, the steps from PGA to fatty acids and to amino and carboxylic acids have not been indicated.

radioactive bicarbonate ion (carbon dioxide dissolved in our algae culture medium is mostly converted into bicarbonate ion). After a few seconds or minutes the cells are killed. We then extract the soluble radioactive compounds from the plant material and analyze them.

The Reduction of CO_2

Calvin and his colleagues soon found that the carbon 14 label was distributed among several classes of biochemical compounds, including not only sugars but also amino acids: the subunits of proteins. As the exposure time was reduced to a few seconds, the first stable intermediate product of photosynthesis was found to be the three-carbon compound 3-phosphoglyceric acid (PGA).

The next step was to determine which of the three carbon atoms in the first generation of PGA molecules synthesized in the presence of radioactive carbon dioxide bears the carbon 14 label. We first removed from PGA the phosphate group [*see illustration on opposite page*] and then diluted the free glyceric acid with glyceric acid containing the stable carbon 12 isotope in order to have enough material for analysis by ordinary chemical methods. Treatment with reagents that severed the bonds between the carbons produced three different products, one from each carbon atom. By measuring the radioactivity of each of the products we were able to identify the labeled carbon.

In PGA from plants that had been exposed to labeled carbon dioxide for only five seconds we found that virtually all the carbon 14 was located in the carboxyl atom, the carbon at one end of the chain that is bound to two oxygens. This was not surprising because the carboxyl group most nearly resembles carbon dioxide. The carbon is bound to the oxygens by three bonds, however, instead of four; the fourth bond now ties it to the middle carbon in the PGA chain. The transfer of this bond from one of the oxygens to a carbon constitutes the first step in the reduction of the carbon dioxide. This was evidence also that the reduction is accomplished by some sort of carboxylation reaction, a reaction in which carbon dioxide is added to some organic compound. Ultimately, of course, the two other carbons of PGA must come from carbon dioxide. But it was some time before investigation disclosed the specific compound that picks up the carbon dioxide and the cyclic pathway that makes this carbon dioxide acceptor from PGA.

The discovery of the pathway intermediates was made much easier by a then comparatively new technique: two-dimensional paper chromatography, developed by the British chemists A. J. P. Martin and R. L. M. Synge. Closely similar compounds can be distinguished in this procedure by slight differences in their relative solubility in an organic solvent and in water. The extract from the plant is dropped on a sheet of filter paper near one corner. An edge of the paper adjacent to the corner is immersed in a trough containing an organic solvent; the paper is held taut by a weight and the whole assembly is placed in a water-

saturated atmosphere in a vapor-tight box. The solvent traveling through the paper by capillarity dissolves the compounds and carries them along with it. As they move along in the solvent, however, the compounds tend to distribute themselves between the solvent and the water absorbed by the fibers of the paper. In general the more soluble the compound is in water compared with the organic solvent, the slower it travels. If the compound is also absorbed to some extent by the cellulose fibers, its movement will be even slower. As a result the compounds are distributed in a row in one dimension. Depending on the solubility of the compounds and the nature of the solvent used, some compounds may still overlap one another. Repetition of the procedure, with a different solvent traveling at right angles

CHROMATOGRAM AND RADIOAUTOGRAPH used to corroborate the identity of amino acids produced by photosynthesizing algae appear at top and bottom respectively. The method of identifying such substances is described in the text. Areas of the radioautograph corresponding to colored areas in the chromatogram are alanine, glutamine, glutamic acid, serine and aspartic acid.

to the direction of the first run, will usually separate these compounds in a second dimension.

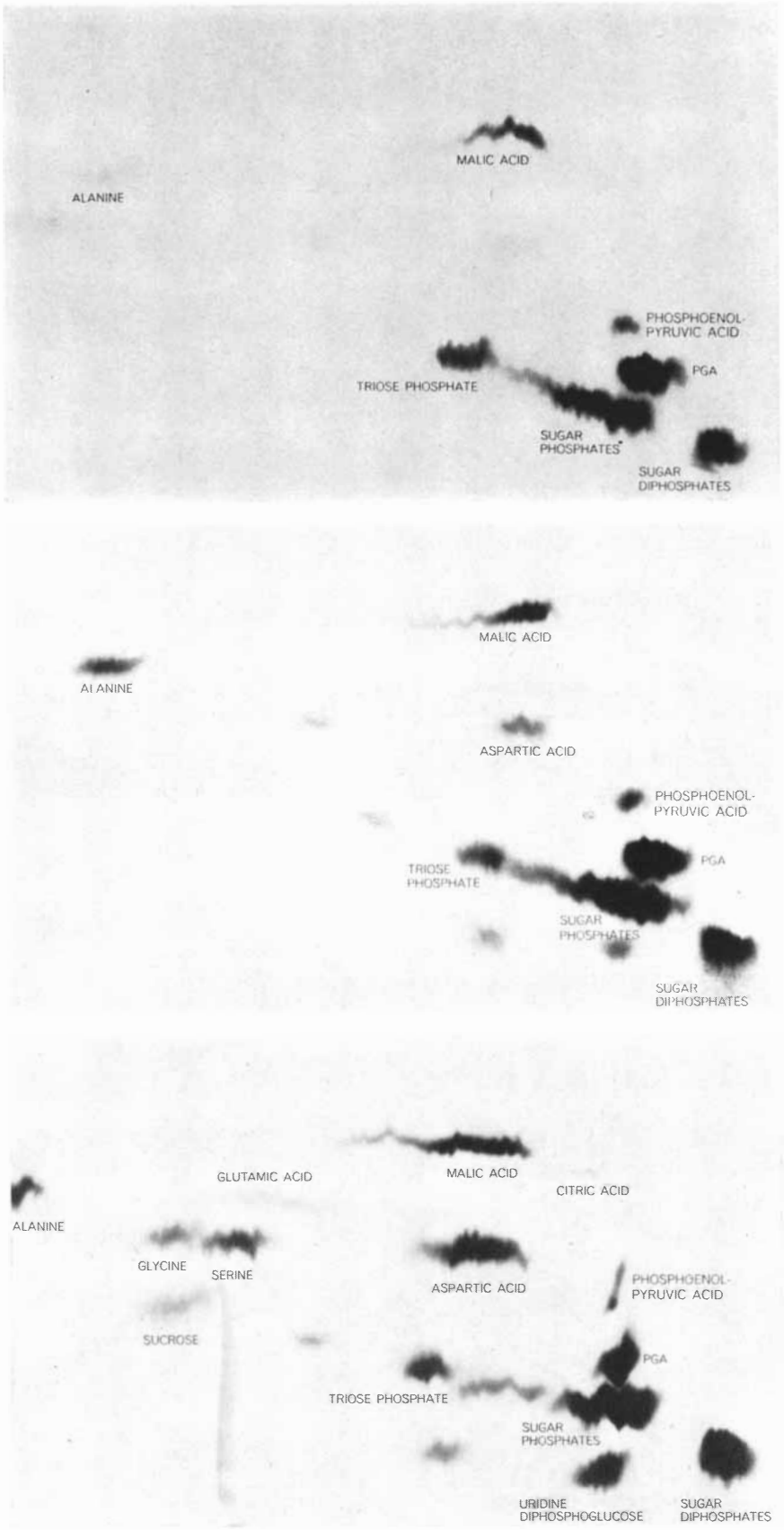
Since most of the compounds are colorless, special techniques are needed to locate them on the paper. Those that are radioactive will locate themselves, however, if the chromatographic paper is placed in contact with a sheet of X-ray film for a few days. The resulting radioautograph will show as many as 20 or 30 radioactive compounds in the substances extracted from algae exposed to carbon 14 for only 30 seconds [*see illustration at right*]. Clearly the synthetic apparatus of the plant works rapidly.

Chromatographs and Radioautographs

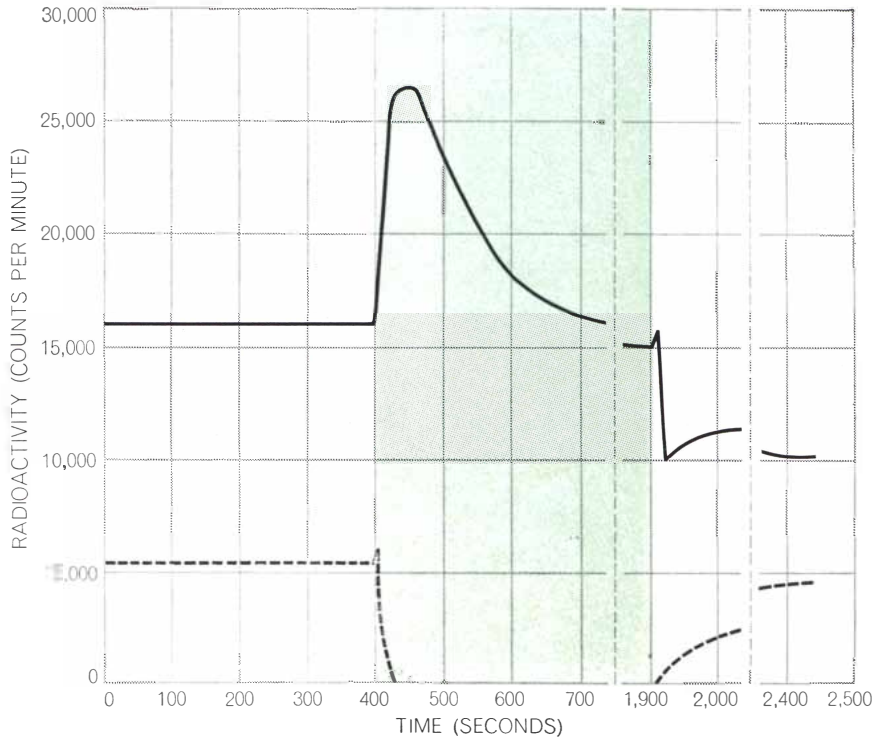
In order to identify these compounds we prepared a chromatographic map by running samples of many known compounds through the same chromatographic system and recording the locations at which we found them on the paper. The locations can be made visible in these cases by spraying the paper with a mist of some chemical that is known to react with the compound to produce a colored spot. Comparison of the radioautograph of an unknown compound with the map yields a first clue to its identity. This can be corroborated by washing the radioactive compound out of the paper with water and mixing it with a larger sample of the suspected authentic substance. The mixture is applied to a new piece of filter paper and chromatographed. With enough of the authentic material to yield a colored spot, comparison with a radioautograph of the same paper now shows whether or not the radioactive and the authentic material really coincide. The possibility that the authentic material and the radioactive material are still not the same can be tested by using different solvent systems in the preparation of the chromatograph and by other means.

Over the years these procedures have established the identity of a great many of the intermediate and end products of photosynthesis. Some of the sugar phosphates labeled by carbon 14 proved to be well-known derivatives of triose (three-carbon) and hexose (six-carbon) sugars. Others were discovered for the first time among the intermediates produced by our algae. Benson showed that among these are a seven-carbon sugar phosphate and also five-carbon phosphates, including in particular ribulose-1,5-diphosphate.

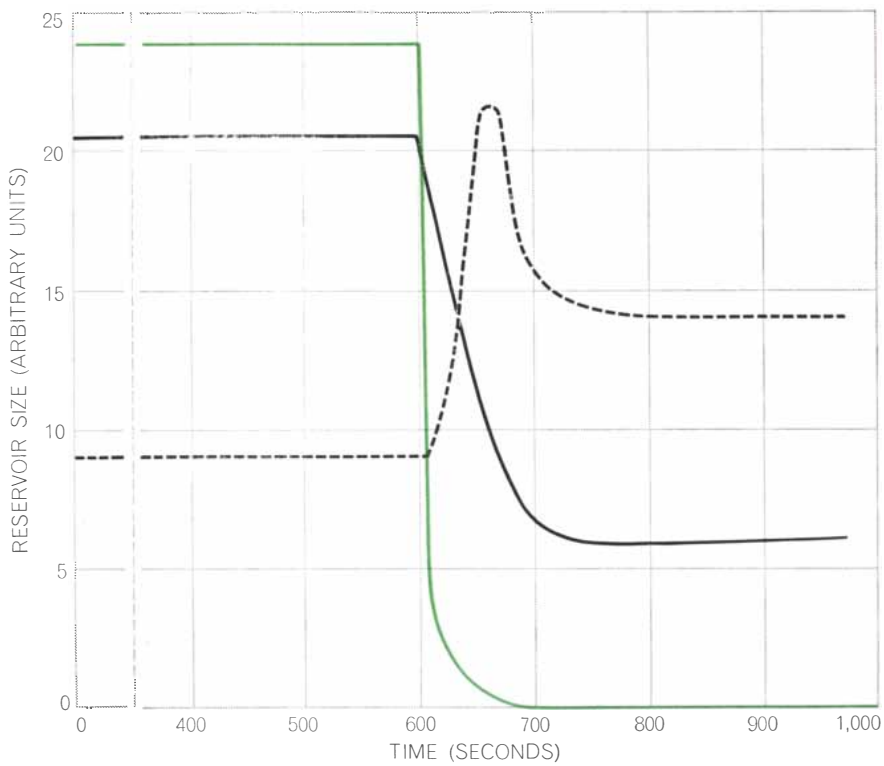
The rapid building of carbon 14 into the more familiar triose and hexose phosphates suggested certain biochemi-



THREE RADIOAUTOGRAPHS reveal the compounds containing radioactive carbon that were produced by *Chlorella* algae during five (*top*), 10 (*middle*) and 30 seconds (*bottom*) of photosynthesis. Alanine, the first amino acid to appear in the process, shows up very faintly at first (*top*); glycine, serine, glutamic acid and aspartic acid appear as photosynthesis progresses. These radioautographs were made at the author's laboratory by exposing X-ray-sensitive film to chromatograms of compounds extracted from three samples of algae.



EFFECT OF SUDDEN DARKNESS on PGA (*solid curve*) and ribulose diphosphate (*broken curve*) is shown here. The conversion of ribulose diphosphate to PGA continues after the light is turned off (*colored area*), so that the ribulose concentration drops to zero. The concentration of PGA, which is no longer reduced to triose phosphate by ATP and TPNH, increases momentarily before it is used up in the production of other compounds.



SUDDEN DEPLETION OF CARBON DIOXIDE (*colored curve*) slows the carboxylation of ribulose diphosphate to PGA. Because the light remains on after depletion, ribulose diphosphate (*broken curve*) continues to be formed and its concentration rises. PGA (*black curve*) is still reduced to triose phosphate, so that its concentration drops. "Reservoir size" refers to the average size of the "pool" of any one compound per unit quantity of algae.

cal pathways already established in studies of respiration. It seemed likely that PGA might be linked to these phosphates by the reverse of a sequence of respiratory reactions first mapped many years ago by the German chemists Otto Meyerhof, Gustav Embden and Jakob Parnas. In the respiratory pathway hexose phosphate is split into two molecules of triose phosphate, with the split occurring between the two carbon atoms in the middle of the chain. The triose phosphate is then oxidized to give PGA. The electrons from this energy-yielding operation are picked up by diphosphopyridine nucleotide (DPN^+), which is thereupon reduced to DPNH. The DPN^+ is a close relative of the TPN^+ that turns up in photosynthesis. In addition this oxidation yields enough energy to make a molecule of ATP from ADP and phosphate ion.

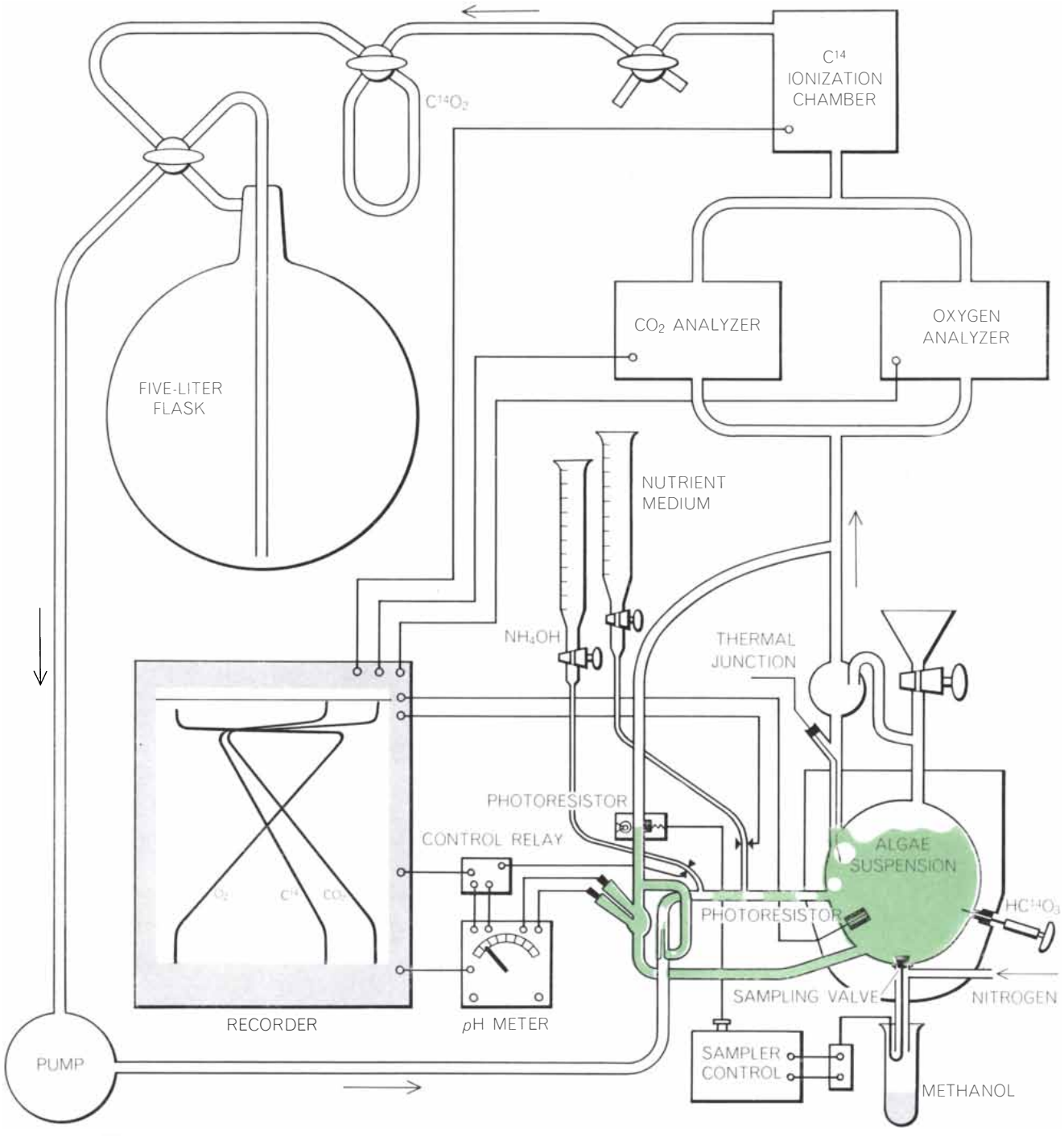
In the reverse pathway of these reactions in photosynthesis, Calvin concluded, the plant uses the cofactors ATP and TPNH, made earlier by the transformation of the energy of light, to bring about the reduction of PGA to triose phosphate. In the first step the terminal phosphate group of ATP is transferred to the carboxyl group of PGA to form a "carboxyl phosphate" (really an acyl phosphate). Some of the chemical potential energy that was stored in ATP is now stored in the acyl phosphate, making the new intermediate compound highly reactive. It is now ready for reduction by TPNH. This reducing agent donates two electrons to the reactive intermediate. One carbon-oxygen bond is thereby severed and the oxygen atom, carried off with the phosphate group, is replaced by a hydrogen atom. In this way the carboxyl carbon atom is reduced to an aldehyde carbon atom; that is, it now has two bonds to oxygen instead of three and one bond each to carbon and hydrogen [*see illustration on page 92*]. This is the point in the cycle at which the major portion of the solar energy captured in the first stage of photosynthesis is applied to the reduction of carbon.

The Unstable Intermediate

The next development in the plotting of the carbon pathway came from a series of experiments first performed in our laboratory by Peter Massini. He hoped to see which intermediates would be most strongly increased or decreased in concentration by turning off the light and allowing the synthetic process to go on for a while in the dark. In order to establish the concentration of the various intermediates when the reaction pro-

ceeds in the light, he bubbled radioactive carbon dioxide through the culture for more than half an hour. At the end of this period every intermediate was as highly radioactive as the incoming carbon dioxide. The radioactivity from each compound therefore gave a measure of the concentration of the compound. He then turned off the light and after a few seconds took another sample of algae in which he measured the relative concentration of compounds by the same technique. Comparison with the compounds sampled in the light showed that the concentration of PGA was greatly increased. This finding could be readily explained: turning off the light stopped the production of the ATP and TPNH required to reduce PGA to triose phosphate.

Of the sugar phosphates present, only one, the five-carbon ribulose diphosphate, was found to have changed significantly; its concentration dropped to zero. Because the PGA had simultaneously increased in concentration, it was apparent that ribulose diphosphate was consumed in the production of PGA. This finding was of great significance because it indicated for the first time that



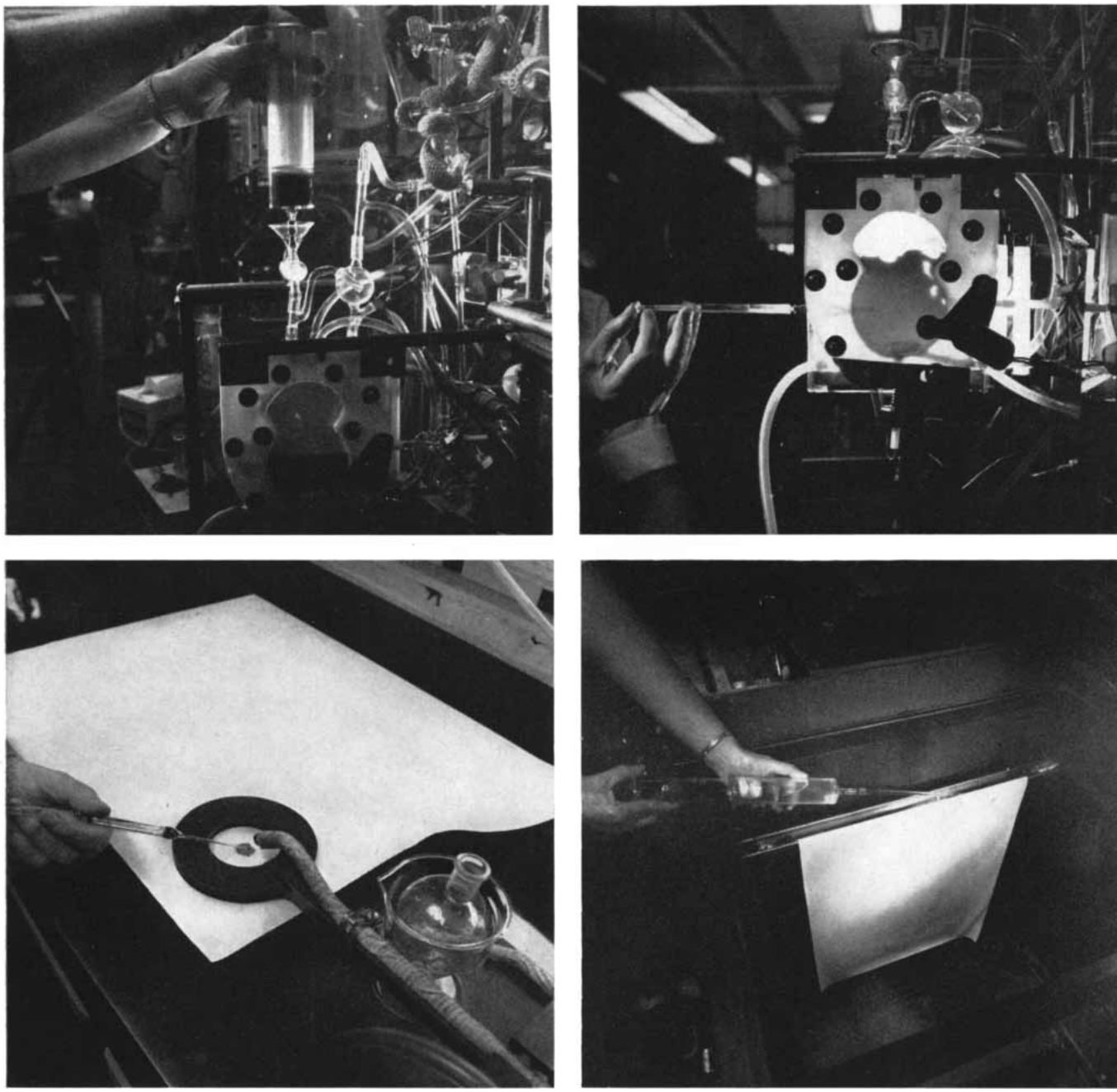
STEADY-STATE APPARATUS permits experimental control and study of photosynthesis. The algae are suspended in nutrient in a transparent vessel (*lower right*). A gas pump circulates a mixture of air, ordinary carbon dioxide and labeled carbon dioxide (when needed) to the vessel, where it bubbles through the suspensions. Labeled carbon can also be added in the form of bicarbonate ($HC^{14}O_3$). Measurements of the oxygen, carbon dioxide and labeled carbon levels in the gas are recorded continuously. The *p*H is maintained at a constant value by means of the *p*H meter. The sampler control allows removal of samples into the test tube.

ribulose diphosphate is the intermediate to which carbon dioxide is attached by the carboxylation reaction.

For this reaction ribulose diphosphate is prepared by an earlier reaction that goes on in the light and in which ATP donates its terminal phosphate group to ribulose monophosphate. The more reactive diphosphate molecule now adds one molecule of carbon dioxide by carboxylation. The details of this reaction remain obscure because the resulting six-carbon intermediate is so unstable that we have not been able to detect it by our methods of analysis. As its first stable product this sequence of events yields two three-carbon PGA molecules.

Massini's experimental results were confirmed by a parallel experiment devised by Alex Wilson, then a graduate student in our laboratory. Instead of turning out the light Wilson shut off the supply of carbon dioxide. In this situation one might expect to find an increase in the concentration of the compound that is consumed in the carboxylation reaction; ribulose diphosphate showed such an increase. Correspondingly, one would look for a decrease in the concentration of the product of this reaction; PGA did in fact decrease in concentration.

The first steps along the path were thus established. The photosynthesizing plant starts with ribulose monophosphate and converts it to ribulose diphosphate, using chemical potential energy trapped from the light in the terminal phosphate bond of ATP. Carbon dioxide is joined to this compound, and the resulting six-carbon intermediate splits to two molecules of PGA. With energy and



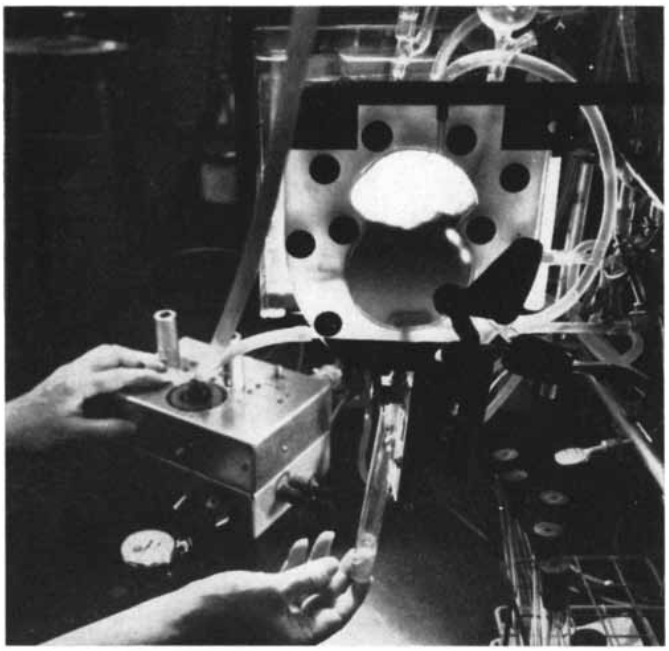
EXPERIMENT to determine the path of carbon in photosynthesis is outlined. After removal of an algae sample from its culture tube, the sample is placed in a transparent vessel (*top left*). At start of experiment labeled bicarbonate is injected into the vessel (*second from top left*). A sample is then removed by pressing a button on the sampler control (*third from top left*); alcohol in the test tube kills the algae. The sample is concentrated by evaporation in a special flask to which a vacuum has been applied (*top right*)

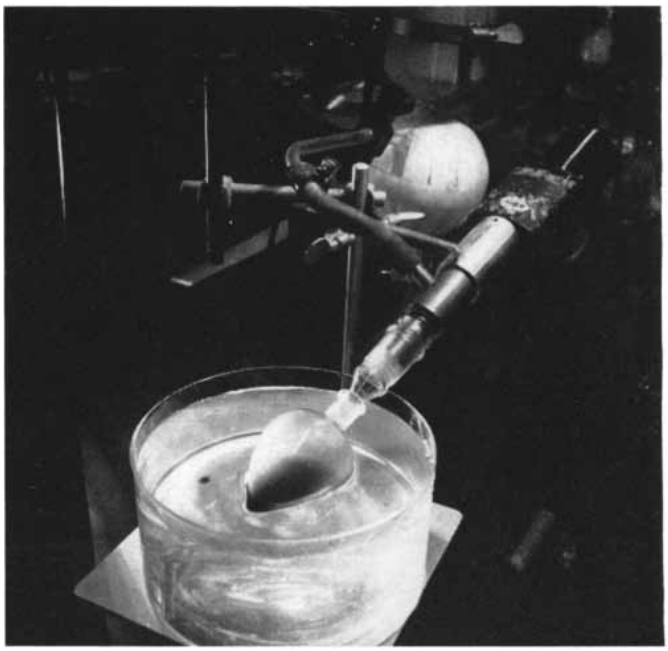
electrons supplied by ATP and TPNH, PGA is reduced to triose phosphate. In the next step, it was apparent, two triose phosphates must be joined end to end in the reverse of a familiar respiratory pathway to form a hexose phosphate. The pathway from hexose to pentose phosphate remained to be uncovered.

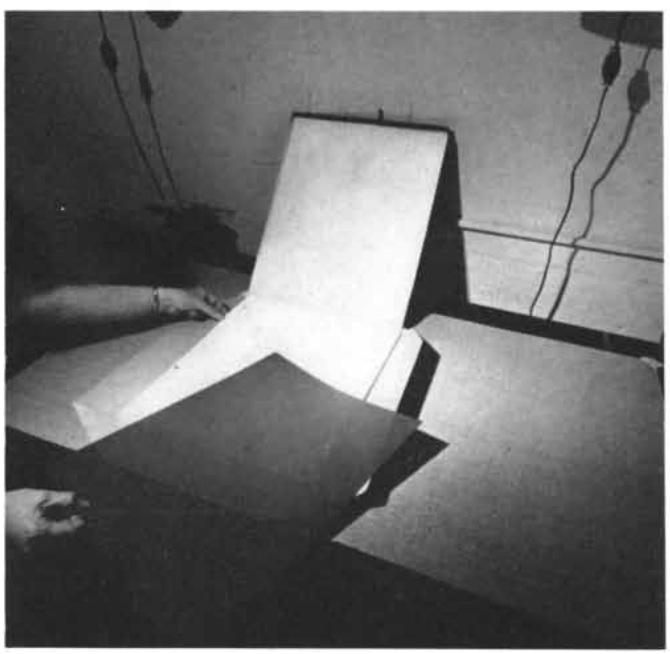
We continued the carbon-by-carbon dissection and analysis of these chains by the methods that had earlier shown the carbon 14 in PGA to be located first in the carboxyl carbon. In the hexose molecules we had found the labeled carbon concentrated in the two middle carbons, just where it should be if two triose molecules made from PGA were linked together by their labeled ends. We also took apart the seven-carbon and five-carbon sugar phosphates to establish the position of the carbon 14 atoms in their chains. As the result of these degradations we were able to show that the overall economy of the photosynthetic process starts with five three-carbon PGA's, variously transforms them through three-, six-, four- and seven-carbon phosphate intermediates and returns three five-carbon ribulose diphosphates to the starting point [*see illustrations on pages 90 and 91*]. From the carboxylation of these three chains and their immediate bisection, the cycle at last yields six PGA molecules. The net result, therefore, is the conversion of three carbon dioxide molecules to one PGA molecule.

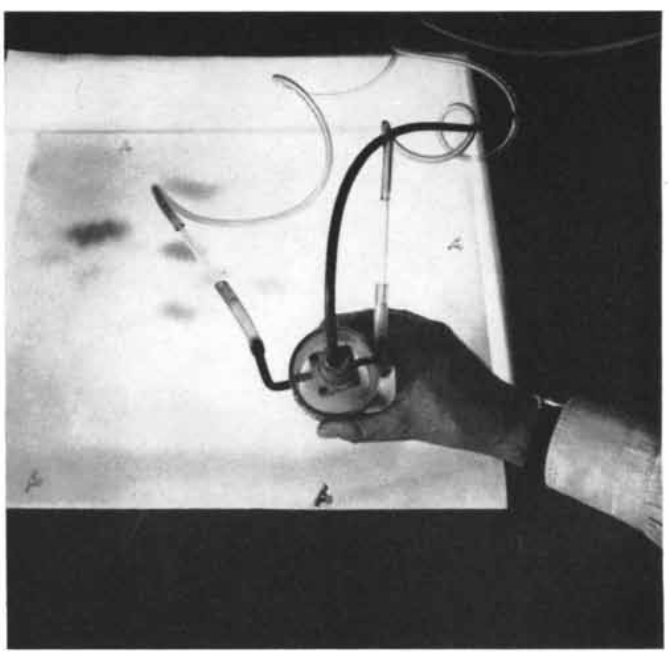
The Calvin Cycle

With these steps filled in, the carbon reduction cycle in photosynthesis, called the Calvin cycle, was complete. The in-









and the extract applied to chromatogram paper (*bottom left*). The paper is placed in a trough of chromatographic solvent (*second from bottom left*), which diffuses through the paper; after eight hours the paper is turned at right angles and the process is repeated. A radioautograph is made by exposing X-ray-sensitive film to the chromatogram (*third from bottom left*). The radioactivity of the compounds in the chromatogram is then measured (*bottom right*), using the radioautograph as a guide to their location.

termediates formed in the cycle depart from it on various pathways to be converted to the end products of photosynthesis. From triose phosphate, for example, one sequence of reactions leads to the six-carbon sugar glucose and the large family of carbohydrates.

Because the cycle had been established primarily by experiments with algae and the leaves of a few higher plants, it was important to see whether or not the cycle prevailed throughout the plant kingdom. Calvin and Louisa and Richard Norris carried out experiments with a wide variety of photosynthetic organisms. In every case, although they found variation in the amounts of particular intermediates formed, the pattern was qualitatively the same.

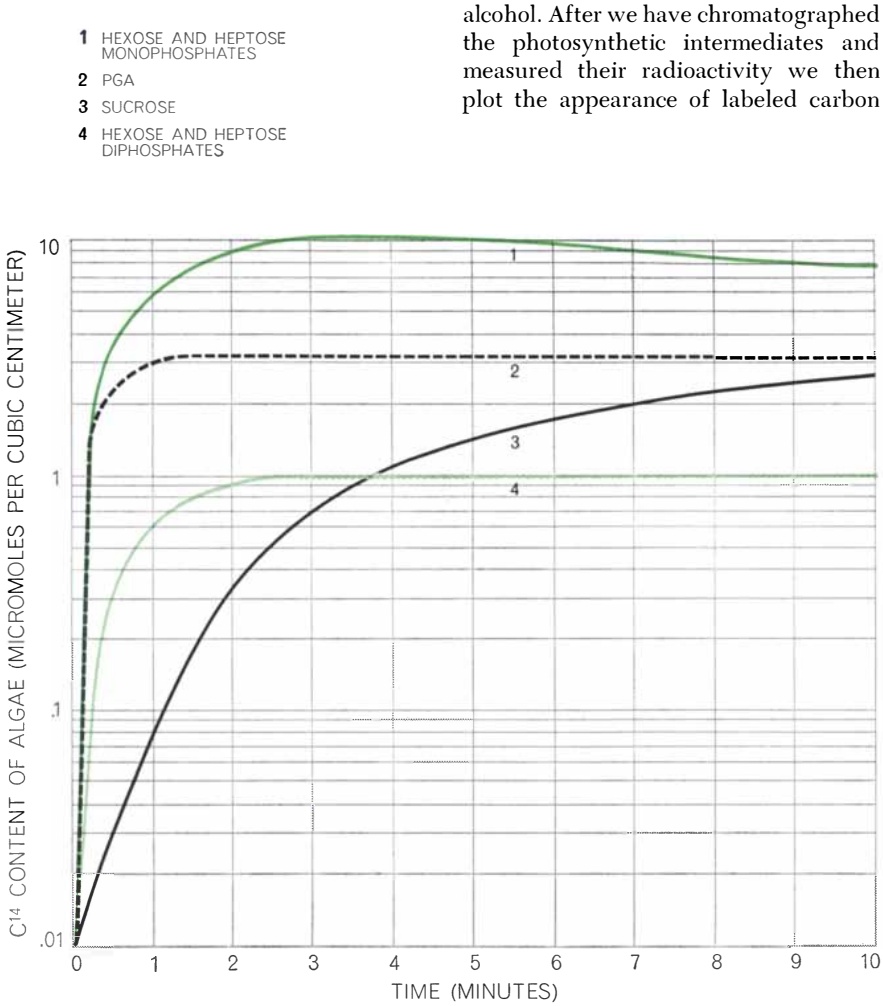
It also had to be shown that the pathway we had traced out is quantitatively the most important route of carbon reduction in photosynthesis. To this end Martha Kirk and I undertook an intensive study of the kinetics of the flow of carbon in photosynthesis. Our study has helped to solve other general problems, particularly the question of how carbon enters into the pathways leading to the synthesis of proteins and fats. The biological materials for this work are supplied by an algae culture system under automatic feedback control. In this apparatus we are able to maintain the photosynthetic process in a steady state, with nutrients supplied at a constant rate and with temperature, density, salinity and acidity held within narrow limits.

At the start of a run we inject radioactive bicarbonate ion into the culture medium along with radioactive carbon dioxide gas and so bring the ratio of carbon 14 to carbon 12 immediately to its final level in both the gas and the liquid phase. An automatic recorder measures the rate at which carbon is absorbed by the photosynthesizing cells. We take samples every few seconds and kill the cells immediately by immersing them in alcohol. After we have chromatographed the photosynthetic intermediates and measured their radioactivity we then plot the appearance of labeled carbon in each of these compounds as a function of time.

By the end of three to five minutes, our records show, all the stable intermediates of the cycle are saturated with carbon 14. Taking the total amount of carbon thus fixed in compounds and comparing it with the rate of uptake of carbon in the culture, we found that the cycle accounts for more than 70 per cent of the total carbon fixed by the algae. A small but significant amount is also taken up by the addition of carbon dioxide to a three-carbon compound, phosphoenolpyruvic acid, to give four-carbon compounds.

From the earliest work with carbon 14 in our laboratory, it had been apparent that carbon dioxide finds its way rather quickly into products other than carbohydrates in the photosynthesizing plant. This was at variance with traditional ideas about photosynthesis that regarded carbohydrates as the sole organic products of the process. It was important to ask, therefore, whether fats and amino acids could be formed directly from the cycle as products of its intermediates or whether these noncarbohydrates were synthesized only from the carbohydrate end products of photosynthesis. Our kinetic studies show that certain amino acids must indeed be formed from the intermediates and must therefore be regarded as true products of photosynthesis. The amino acid alanine, for example, shows up labeled by carbon 14 at least as rapidly as any carbohydrate; it would be labeled with carbon 14 much more slowly if it were made from carbohydrate, since the carbohydrate would have to be labeled first. We have been able to show that more than 30 per cent of the carbon taken up by the algae in our steady-state system is incorporated directly into amino acids. There is some evidence that fats may also be formed as products of the cycle.

The discovery that plants make these other compounds as direct products of photosynthesis lends new interest and importance to the chloroplast, the subcellular compartment of green cells that contains pigments and the rest of the photosynthetic apparatus. It has been known for some time that this highly structured organelle is responsible for the absorption of light, the splitting of water and the formation of the cofactors for carbon reduction. More recent studies have shown that it is the site of the entire carbon-reduction cycle. Now the chloroplast emerges as a complete photosynthetic factory for the production of just about everything necessary to the plant's growth and function.



CALVIN CYCLE (*see illustration on pages 90 and 91*) **was shown to be the most important route of carbon reduction in photosynthesis in studies by the author and Martha Kirk. As seen here, all stable intermediates of the cycle become saturated with labeled carbon within three to five minutes. Comparison with the rate of carbon uptake in the algae culture showed that the cycle accounts for more than 70 per cent of the carbon fixed in compounds.**

Holding the line . . . for a richer harvest

Boll weevil, codling moth, leaf rollers, thrips and beetles . . . these are only a few of the thousands of insects that chew up millions of dollars worth of farm crops each year. Fortunately, however, they are no match for a new Union Carbide product called SEVIN insecticide. In the United States and many other countries, the use of SEVIN has already saved such staple crops as cotton, corn, fruits and vegetables from destruction by ravaging insects. ▶ You can now get SEVIN insecticide for your own garden as part of the complete line of handy EVEREADY garden products that help you grow healthy vegetables and flowers. SEVIN comes from years of research in Union Carbide laboratories and at an experimental farm in North Carolina where scientists prove out their latest agricultural chemicals. ▶ This is only one area in which chemicals from Union Carbide help improve everyday living. The people of Union Carbide are constantly at work searching for better products that will meet the needs of the future.

A HAND IN THINGS TO COME

UNION CARBIDE

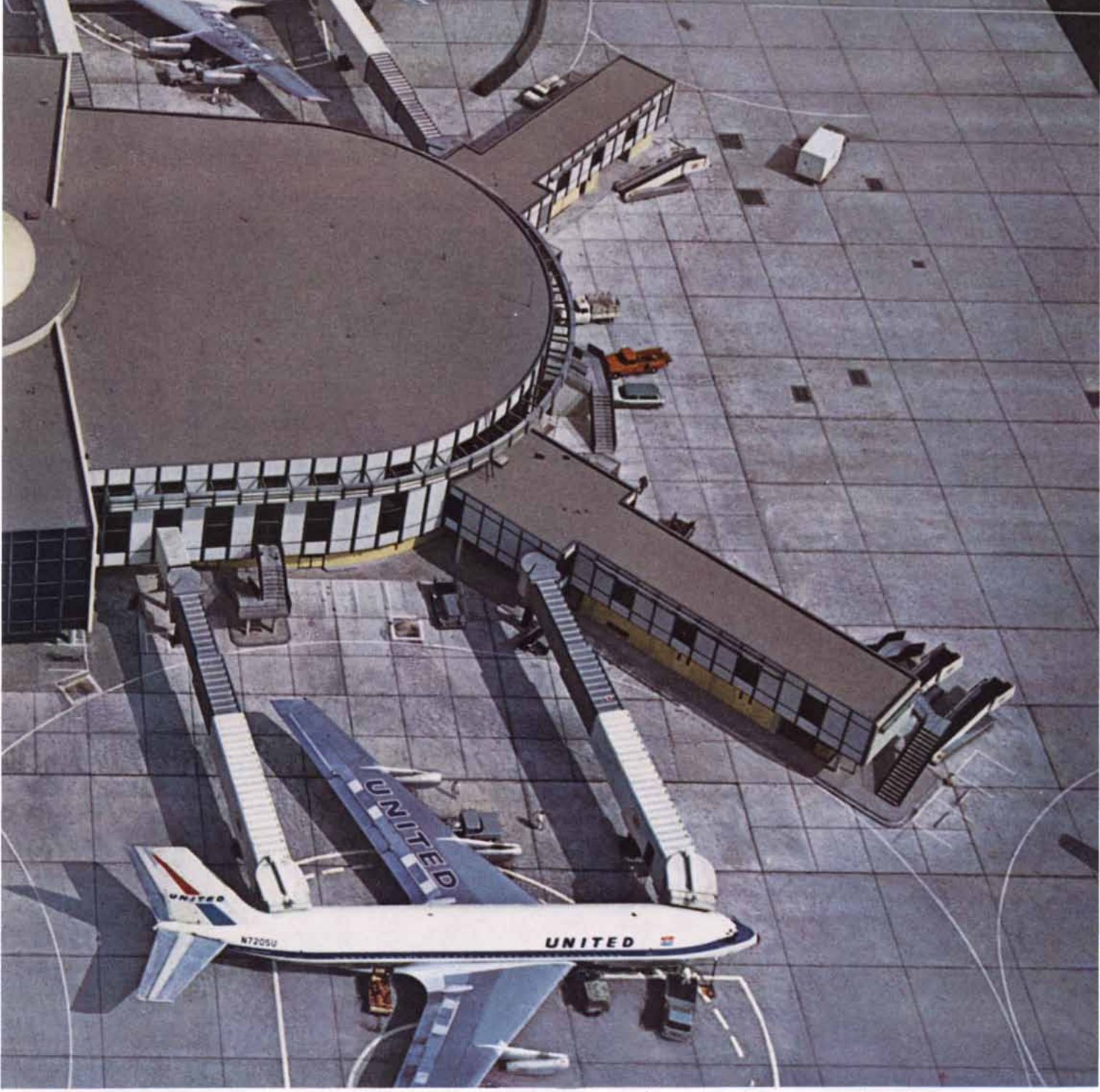
LOOK for these famous Union Carbide products—SEVIN Insecticide, EVEREADY Garden Chemicals, "6-12" Insect Repellent, LINDE Synthetic Emeralds and Stars, PRESTONE Car Care Products. Union Carbide Corporation, 270 Park Avenue, New York 17, N.Y. In Canada, Union Carbide Canada Limited, Toronto.

Today, United Air Lines has the world's largest and most complete jet fleet. Each Jet Mainliner® in United's fleet—the great DC-8, the more powerful DC-8 Mark IV, the versatile 720, and the captivating Caravelle—was designed with Extra Care to provide special comfort and convenience for you who travel with us. Next year, United will add still another new jet—the 727 Jet Mainliner—to the big fleet that is already so far ahead.

THE BIG FLEET

This is United Air Lines' Satellite Terminal at Los Angeles International Airport . . . surrounded by gleaming Jet Mainliners.

Just leaving the Satellite is a DC-8 Mark IV nonstop to New York. The DC-8 is the big jet in United's big jet fleet . . . the Mark IV is especially designed for transcontinental service with more powerful engines that provide greater speed, range and reserve power for on-time dependability.



Outstanding, too, is the service aboard the DC-8 Mark IV. There's a new kind of Red Carpet Service featuring the same leisurely course-by-course dining that has delighted those travelers who have flown with United to Hawaii.

And even in the Custom Coach section—economical as it is—you enjoy the speed and comfort of the DC-8 Mark IV Jets... and dine on a delicious meal prepared in United's own flight kitchens by our European trained chefs.

The United jets you fly and the service aboard them differ only in degree. The important and essential ingredient is the Extra Care we aim to take in everything we do. And that you have a right to expect from United whether you fly First Class or Custom Coach... on any plane in the big fleet that is so far ahead.

WORLD'S LARGEST JET FLEET

UNITED

THE EXTRA CARE AIRLINE

Mark IV is United Air Lines' designation of the advanced DC-8 model equipped with more powerful JT-4 and turbofan engines.

Let's make toys kids can't hurt—and *vice versa*

Too many children's plastic toys just can't stand the gaff. They have sharp edges, too! So you're either picking up pieces or bandaging little fingers. You'd gladly pay more for *good* plastic toys that are smooth, safe, and realistic . . . that are firm but don't scratch or cut . . . that last long enough to pass on to small brothers and sisters. There *are* such toys today, handsomely made of CYCOLAC® Brand Plastic Polymers, a versatile plastic developed by Marbon Chemical Division of Borg-Warner. New Cycolac is so rugged, yet so workable, that it adds long-lasting beauty to parts for automobiles, typewriters, luggage, radios . . . plus countless other items like color telephones and heavy-duty pipe (and kid-proof toys, of course). Modern plastics, like new Cycolac, are still another example of better products through creative research and engineering by Borg-Warner.

B-W

***The 7 Hats of Borg-Warner** are (from the top, left to right) national defense; oil, steel and chemicals; agriculture; industrial machinery; aviation; automotive; home equipment. Their benefits are with you everywhere.*

BORG-WARNER

200 South Michigan Avenue • Chicago 4, Illinois

Better products through creative research and engineering

ISHANGO

The men who lived at this site in Africa more than 8,500 years ago appear to have been inspired inventors. They independently devised the harpoon, and may even have created a number system

by Jean de Heinzelin

About 30 years ago explorers in central Africa came across a number of bone harpoon points scattered along the bottom of the steep cliffs bordering Lake Edward at Ishango in the Congo. The pieces seemed to date from a prehistoric era. In 1935 the Belgian biologist H. Damas sank a test pit into the cliffs and sent back the material collected to the University of Brussels. Examining the samples, François Twiesselmann found a most peculiar fossil fragment. It was part of the jaw of a man-like individual, but a jaw that seemed to belong to one of man's more primitive ancestors rather than to a member of the species Homo sapiens. Yet no one believed that pre-sapiens creatures could have fashioned a tool as advanced as a harpoon. Moreover, the geological evidence indicated that the age of the site was less than 10,000 years, a time when the prehuman hominids had given way to man.

There matters rested until 1950, when Victor van Straelen, head of the Institute of National Parks of the Belgian Congo, put me in charge of a full-scale archaeological expedition to investigate the remains at Ishango. The mystery of the jawbone soon evaporated: additional fossil fragments showed that Ishango man, although he is no longer extant, was undoubtedly a true Homo sapiens of the Mesolithic era, the stage of culture between the Paleolithic and Neolithic eras. But the artifacts have proved far more interesting than we could have hoped. In fact, the complete picture

EXCAVATION SITE AT ISHANGO lay along the shore of Lake Edward in the Congo. Ishango was occupied between 9000 and 6500 B.C. The remains of its culture include tools, weapons and bones, found in the top layers of the 40-foot cliffs bordering the lake.

suggests that the site was an important way station in the road to "civilization."

Lake Edward, about 50 miles long and 30 miles wide, is fed from the east by the rivers of Uganda and from the south by the rivers born on the Virunga volcanoes; its outlet is the Semliki River, which flows northward into Lake Albert, the headwater of the Nile. Not far from the lake is a mountain range with peaks that have been active volcanoes for many thousands of years. Their eruptions have greatly increased the content of carbon 12 (the abundant nonradioactive isotope of carbon) in the lake, thereby upsetting the usual ratio of the carbon isotopes there and rendering old shells unfit for accurate dating by the carbon 14 method. Moreover, no charcoal was found at Ishango, so that there were no nonaquatic samples to which the method could be applied. The best archaeological and geological evidence date the site from some time between 9000 B.C. and 6500 B.C. It appears to have existed as a stable settlement for perhaps as long as a few hundred years before a volcanic eruption buried the entire countryside.

Fortunately a good record of the Ishango culture remains. Three distinct layers of sediment were deposited on the floor of Lake Edward during the period of the occupation, when the lake water was at a high level. Now the waters have receded and these layers are exposed near the top of the 40-foot cliffs that border the lake.

Time has not preserved any of the wood or leather articles that the Ishango people undoubtedly made and used, and the site does not contain any plant remains at all. Since we found not a single potsherd, it is obvious that Ishango represents a prepottery culture. Nevertheless, the length of the occupation itself, and the articles that actually were manufactured, bespeak a comparatively high level of culture. The people of Ishango were not nomads but members of a settled or semisettled community. It seems reasonable to assume that they had many more possessions than those that have been preserved, probably including rafts, ropes, cords and various other things made of leather and wood. On the whole their cultural habits seem comparable to those of their contemporaries in Europe.

There is, however, a rather remarkable exception to this general statement. It consists of the hundreds of quartz tools of various shapes and sizes that we found at Ishango. Consisting both of "cores" of larger pieces of quartz and of flakes chipped from such pieces, they are extremely crude and completely unlike any unearthed at other African sites dating from the same period or even earlier. Their style shows no variation from one layer of sediment to another and all of them resemble tools of the Paleolithic far more than those of the Mesolithic.

These primitive implements are in sharp contrast to the grinding and pounding stones found in large numbers at the Ishango site. The latter argue for a relatively advanced stage of culture: man only began to use them when he had learned to grind pigments for decorative purposes and to pound seeds and grain for food.

Although plant foods in all probability formed part of Ishango man's diet, he apparently ate much more meat and fish. We found thousands of fishbones and hundreds of animal bones scattered through the strata of the cliffs. Most of the animal bones—from such mammals as the hippopotamus, antelope, buffalo and pig—were broken, probably to extract the marrow.

The weapons used in hunting and fishing also indicate a fairly advanced technology. Moreover, a study of their development at Ishango and a comparison with weapons found in other parts of Africa suggest that this site may have been the fount from which one technique of manufacture spread over a considerable area.

The Ishango hunters relied chiefly on two types of weapon: the spear and the harpoon. The harpoon must have been thrown at the prey with the point embedding itself and the shaft then coming loose. One end of a line, presumably made of a vine, was tied to the harpoon point and the other was held by the thrower. All that now remains of the spears and harpoons are the barbed bone points. The shafts, which were probably made of wood, and the lines have rotted away. But from the distinctive workmanship of the bone pieces found in each of the three layers at the site we were able to trace the evolution of the weapons.

The lowest of the three layers, exposed

BLOCK DIAGRAM represents a 10½-mile section of the northern shore of Lake Edward. The elevation is exaggerated 20 times. The cross in center foreground represents the excavation site. To its left is the Semliki River, which flows northward to Lake Albert.

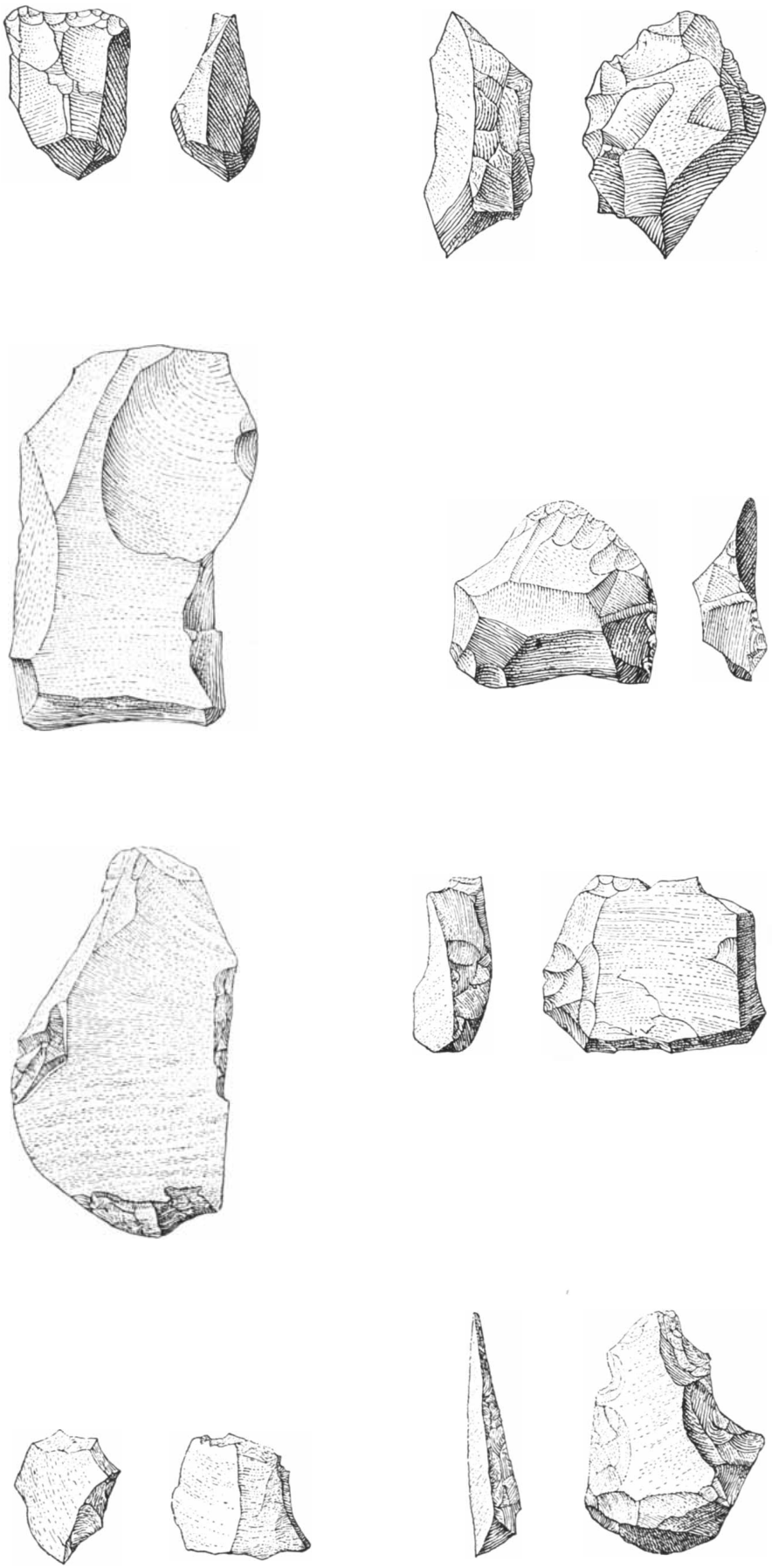
by our excavations, contains the earliest examples. Here we found points of both spears and harpoons. Although the two look much alike—both have barbs along each side—they are distinguishable from each other by differences in the shape of the base [*see two points at bottom of colored area in illustration on pages 110 and 111*]. The base of the spear point was so formed as to enable it to be fixed firmly in its shaft; the base of a harpoon point fitted loosely into its shaft. In addition, notches in the base of the harpoon head provided a point at which to attach the line.

The harpoon would have been far more useful than the spear for many purposes. Examining the weapons found in the lowest layer, one can almost see the idea developing among the men of Ishango. In addition to points that are obviously either spear points or harpoon points, we found a large number intermediate between the two. The intermediates give the distinct impression that the technique of making weapons with detachable points was not imported to Ishango from elsewhere in Africa but developed there as an independent invention, just as it developed independently in many other places throughout the world.

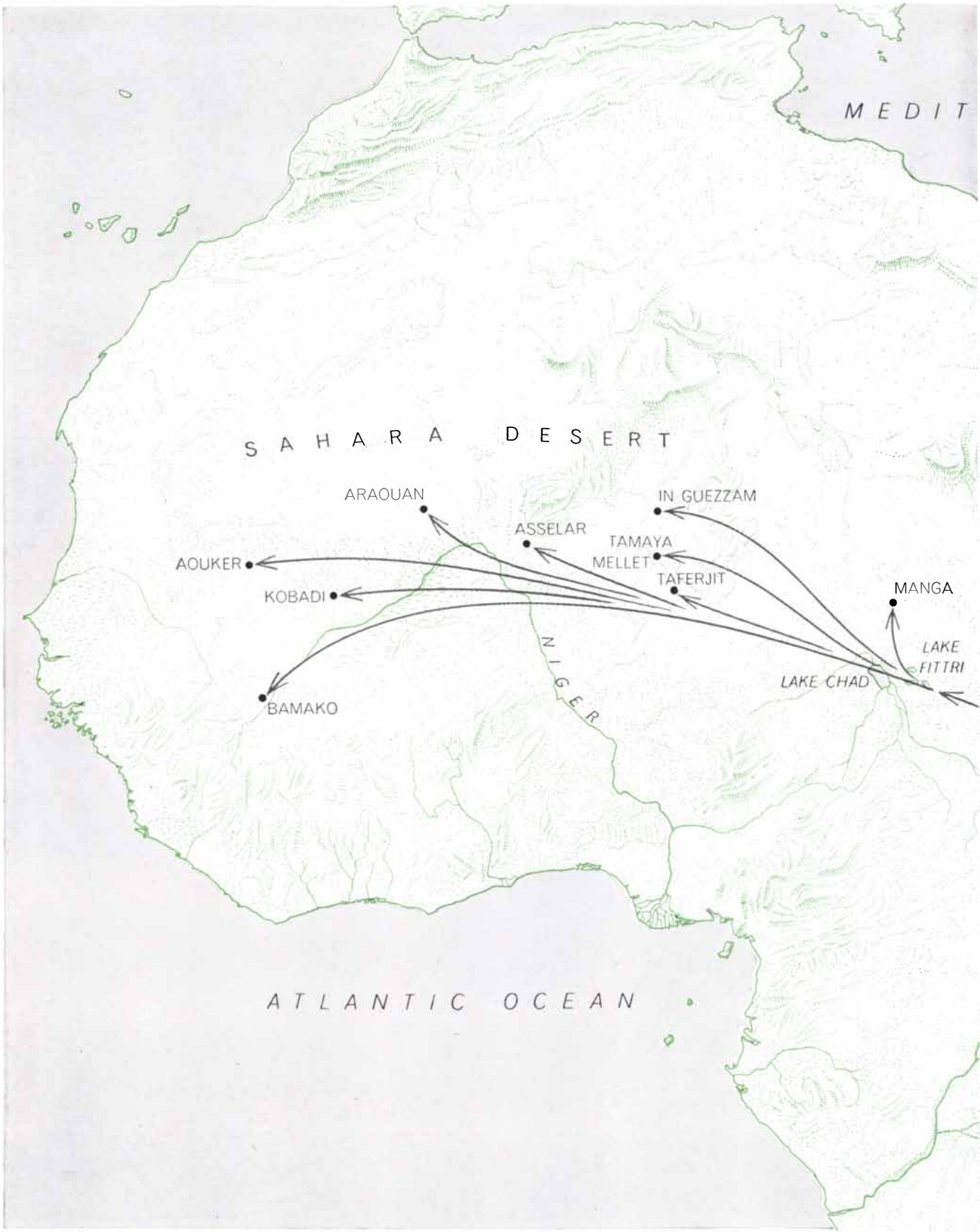
In the second layer were many harpoon points but no spear points at all. By this time the designers had become more sophisticated and were using a wide variety of styles. All the harpoon points retained the double row of barbs and all had notches for fixing the line.

The third layer from the bottom showed a further advance in technology. Now both spear points (which reappear in this layer) and harpoon points had a single row of barbs instead of two. This represents a considerable advance. The points are easier to make and equally effective in use. Although the earlier versions of these points were too long and poorly balanced, the makers soon evolved a better technique. In time they turned out a standard, rugged and well-balanced point that compares favorably with those made by Mesolithic peoples in Europe.

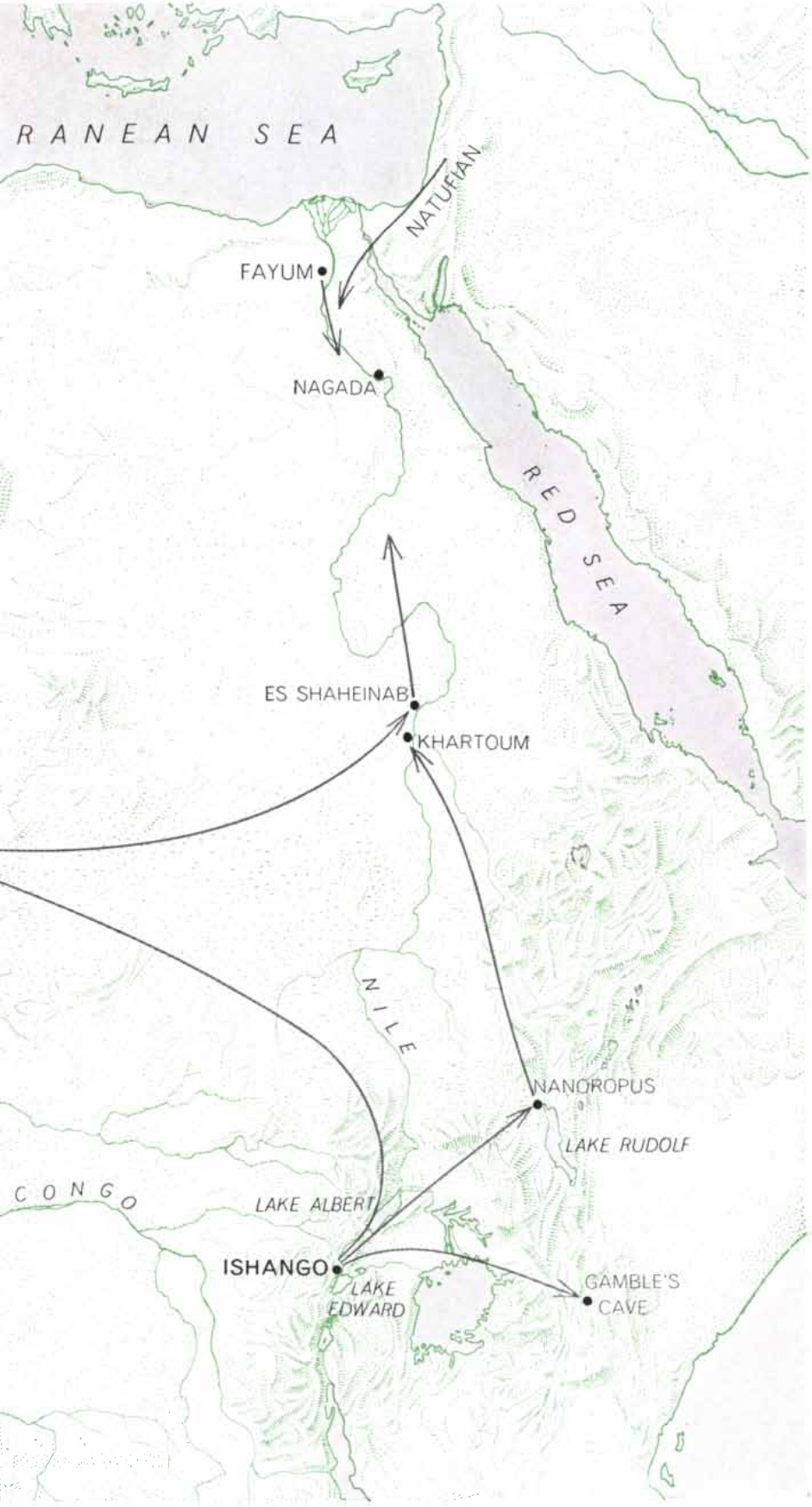
The process of manufacture of all the bone implements found at Ishango—chisels and other tools as well as harpoon and spear points—did not change through the entire span of the occupation. This fact lends further weight to the belief that the weapon points were invented on the spot. They were all made of the long bones of antelopes, split lengthwise and then chipped and trimmed along the edges. Next they were ground and polished—probably with



STONE TOOLS at Ishango were made of crudely chipped quartz. They are seen here one and a quarter times actual size. All but the two largest ones are seen in both front and side views.



MAP OF NORTH AND CENTRAL AFRICA shows the excavation sites at which harpoon points have been found. The arrows suggest possible routes by which the Ishango technique of manufacture may have spread from its place of origin, at bottom right, to more northerly places on the Nile and more westerly ones on the southern border of the Sahara Desert. The Ishango harpoons date from the



Mesolithic era; the others were made later. At Egyptian sites some harpoons show the influence of traditions from the Near East. At all others the harpoons derive primarily from those at Ishango. Illustration on next two pages shows harpoons found at all the sites.

sandstone—until surface irregularities were evened out. As a final step the barbs were cut into the points with quartz tools.

Just as one can follow the technological sequence at Ishango itself, it is also possible to trace the influence of the Ishango technique on other African peoples by examining harpoon points at other sites [*see illustration on next two pages*]. The nearest ones are at Gamble's Cave in Kenya and at Nanoropus on Lake Rudolf. At both locations harpoon fragments have been found that in all likelihood are of more recent manufacture than any at Ishango. These points were clearly inspired by the later ones made at Ishango.

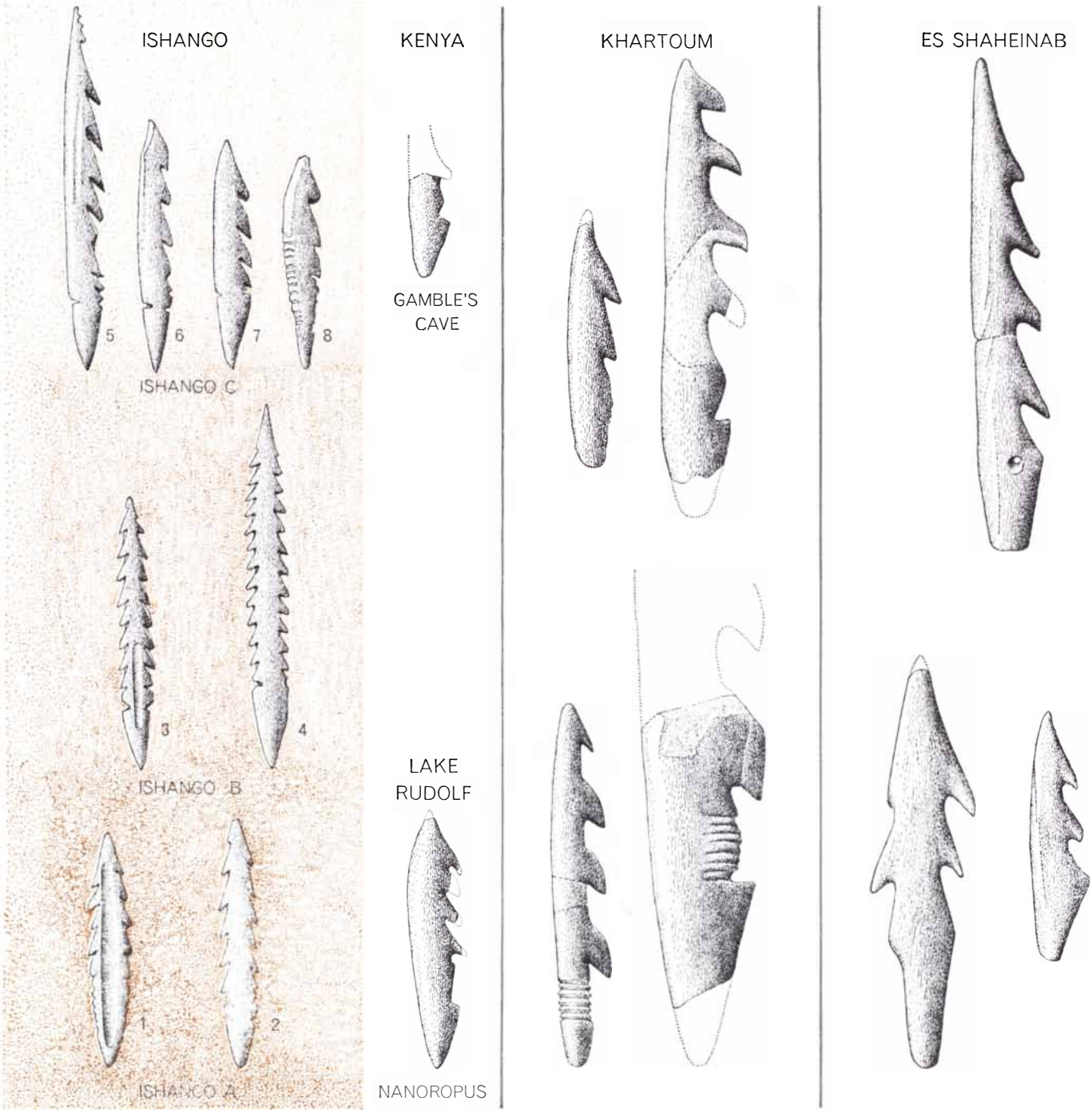
From central Africa the style seems to have spread northward. At Khartoum near the upper Nile there is a site that was occupied considerably later than Ishango. The harpoon points found there show a diversity of styles. Some have no special device for attaching the line. Others have a hole that must have served this purpose. But still others have the notches that seem to have been invented first at Ishango. Near Khartoum, at Es Shaheinab, is a Neolithic site that contains harpoon points bearing the imprint of Ishango ancestry; from here the Ishango technique moved westward, along the southern border of the Sahara. The points found in this section seem to have been used primarily for fishing. (Although the area where they were found is now arid, it was dotted with lakes during Neolithic times.) In addition to the characteristic Ishango notches, some of them have a hole at the base of the point.

The technology also seems to have followed a secondary branch northward from Khartoum along the Nile Valley to Nagada in Egypt. This site has both bone and copper harpoons. Made in the Neolithic period before the Egyptian dynasties began, many of them are notched at the head. Others show the influence of the Near Eastern Natufian technique and the Fayum technique, which is closely related to it.

The most fascinating and most suggestive of all the artifacts at Ishango is not a harpoon point but a bone tool handle with a small fragment of quartz still fixed in a narrow cavity at its head. In the first place, its shape and the sharp stone in its head suggest that it may have been used for engraving or tattooing, or even for writing of some kind. Even more interesting, however, are its markings: groups of notches arranged in three dis-

tinct columns [*see illustration on page 114*]. The pattern of these notches leads me to suspect that they represent more than pure decoration. When one counts them, a series of number sequences emerges. In one of the columns they are arranged in four groups composed of 11, 13, 17 and 19 individual notches. In the next they are arranged in eight groups containing 3, 6, 4, 8, 10, 5, 5 and 7 notches. In the third they are arranged in four groups of 11, 21, 19 and 9.

I find it difficult to believe that these sequences are nothing more than a random selection of numbers. The groupings in each column are quite different from one another and each column contains internal relationships unlike those found in either of the others. Take the first column, for example: 11, 13, 17 and 19 are all prime numbers (divisible only by themselves and by one) in ascending order, and they are the only prime numbers between 10 and 20. Or consider

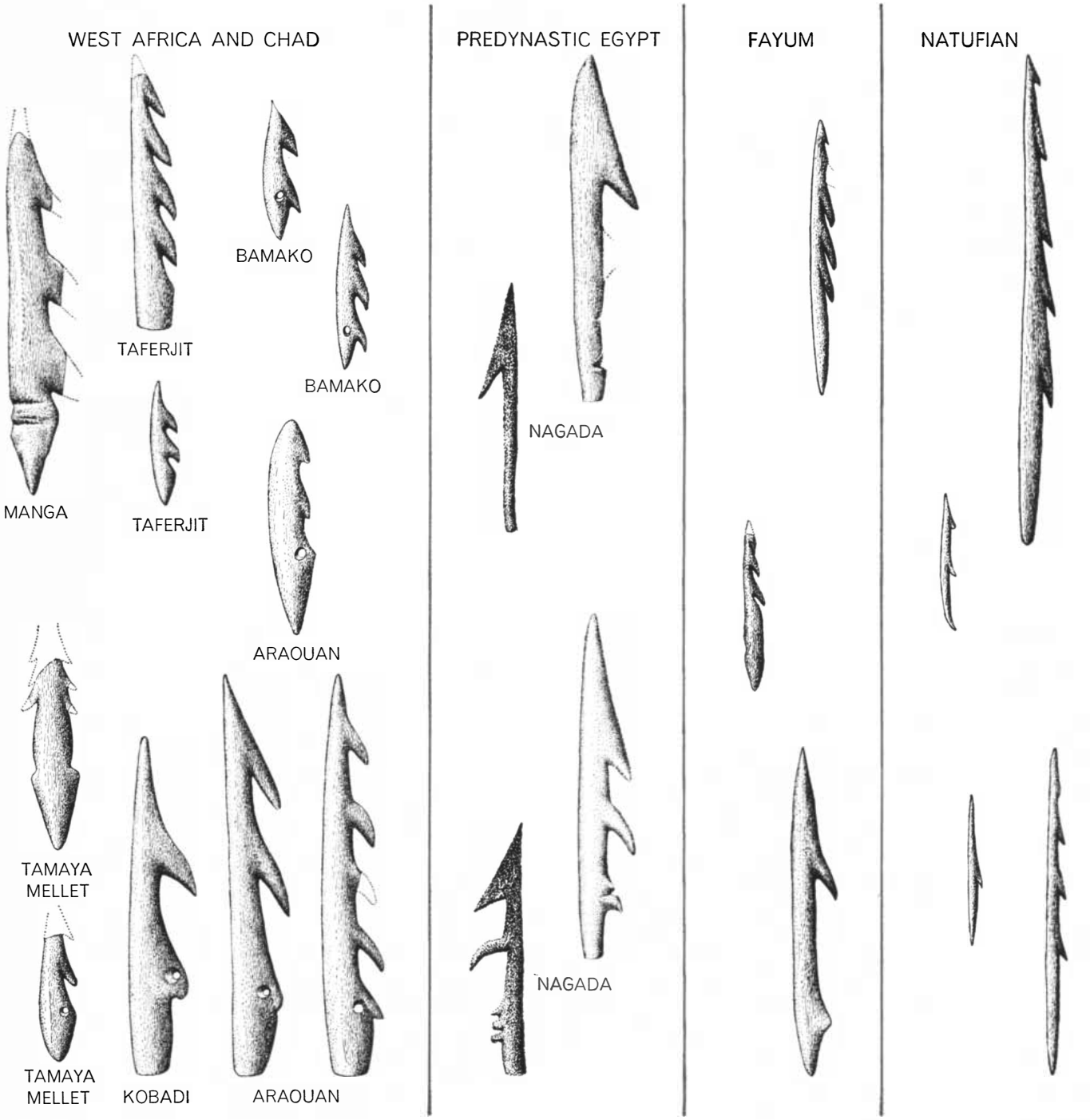


HARPOON AND SPEAR POINTS from various African sites are classified. At *1* is a spear point from the lowest level of the Ishango excavation; at *2* is a harpoon point from the same level. The difference between the two can be seen in the notches at the base of the harpoon point, to which a line could be attached. At *3* and *4* are harpoon points from the middle Ishango level. At *5*, *6*, *7* and

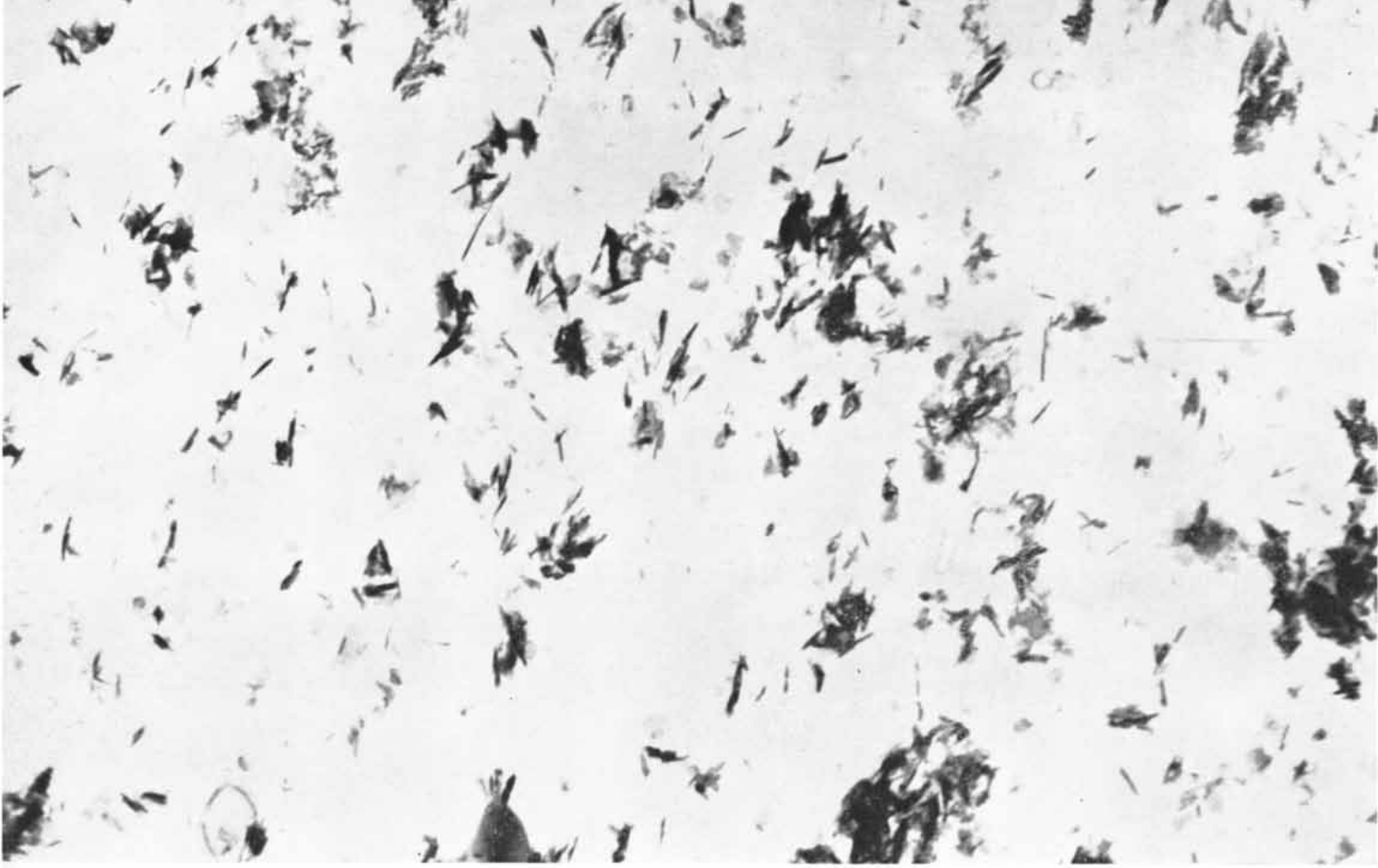
the third: 11, 21, 19 and 9 represent the digits 10 plus one, 20 plus one, 20 minus one and 10 minus one. The middle column shows a less cohesive set of relations. Nevertheless, it too follows a pattern of a sort. The groups of three and six notches are fairly close together. Then there is a space, after which the four and eight appear—also close together. Then, again after a space, comes the 10, after which are the two fives, quite close. This arrangement strongly suggests appreciation of the concept of duplication, or multiplying by two.

It is of course possible that all the patterns are fortuitous. But it seems probable that they were deliberately planned. If so, they may represent an arithmetical game of some sort, devised by a people who had a number system based on 10 as well as a knowledge of duplication and of prime numbers.

What did Ishango man look like? The 70-odd bits of human bone we found at

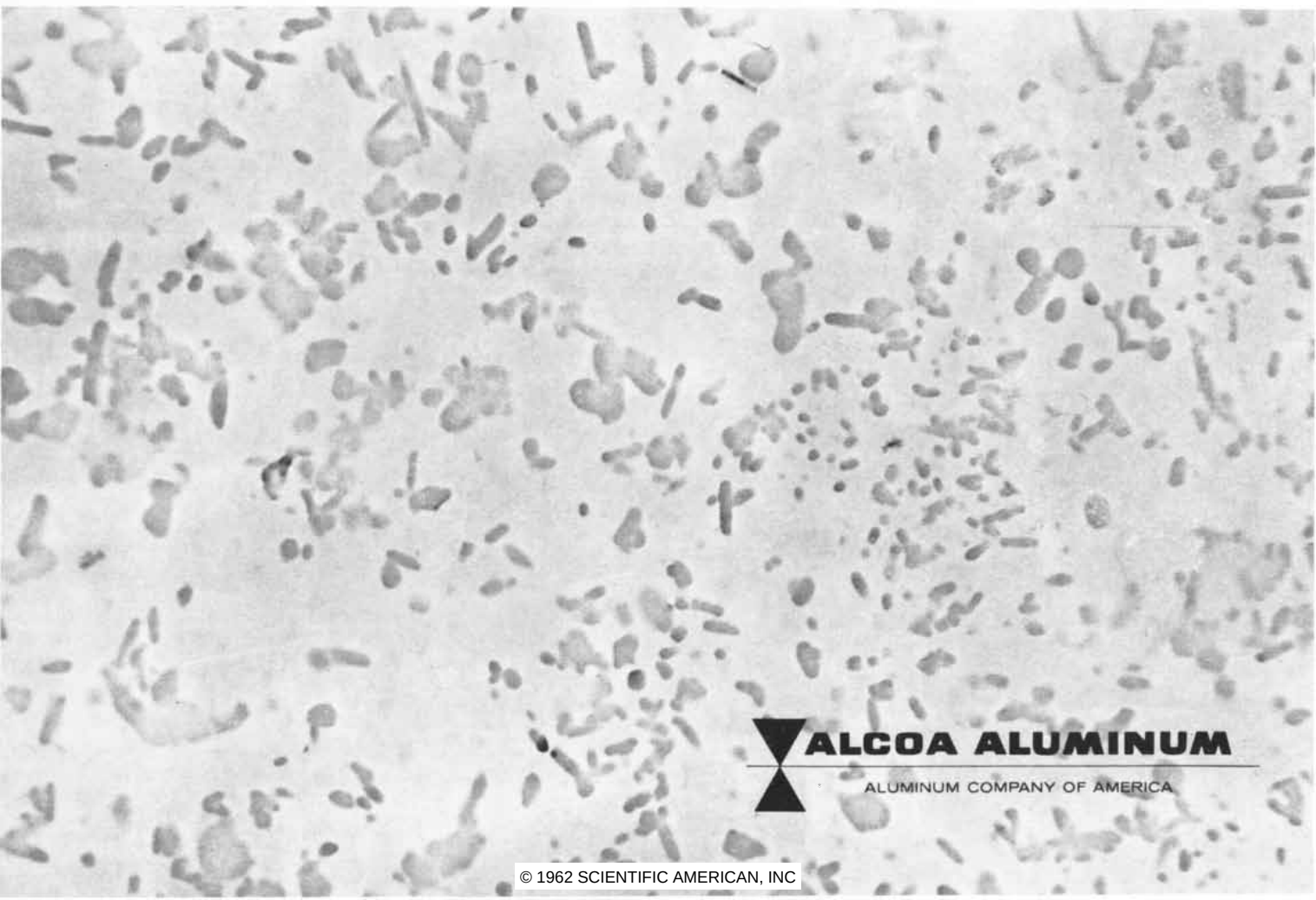


8 are harpoon and spear points from the third level, where all the weapons had one row of barbs. Many of the points shown in the other drawings were inspired by those made at Ishango. Those from Egypt also show the influence of the Natufian and Fayum traditions. Most of the points are made of bone. The lightest one is ivory; the darker ones are copper. All points are drawn one-half of actual size.



Typical aluminum powder metallurgy alloy dispersoids are so fine they require 25,000X magnification to examine.

TOP: Alloy XAP001—6 per cent Al_2O_3.
BOTTOM: Alloy M486—8 per cent Fe plus, 2 per cent each V, Zr, Cr, Ti.



ALCOA ALUMINUM

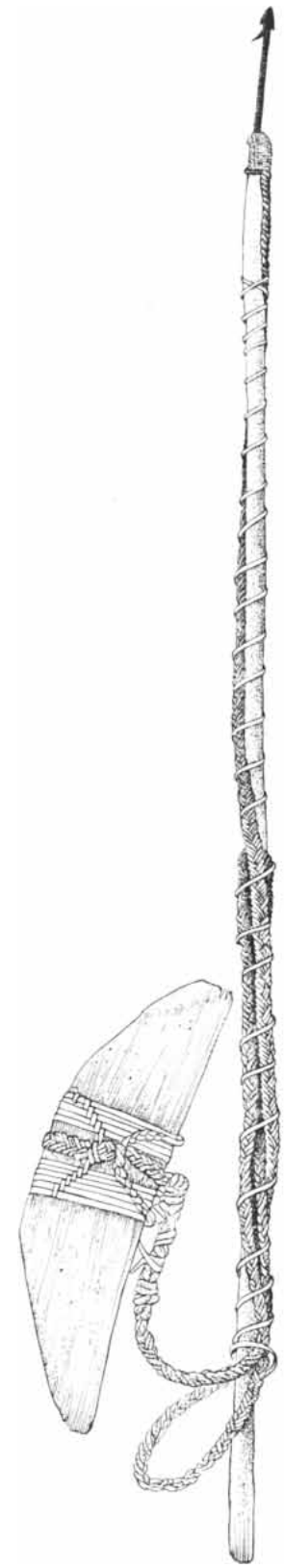
ALUMINUM COMPANY OF AMERICA

the site all seemed to come from a homogeneous group of people. These people may have been the harpoon makers, but it is not certain. The fact that the bones are part of the kitchen midden, and that many of them, like the animal bones, were broken as if to extract the marrow, suggests that they are the remains of another tribe or group that was captured and eaten by the toolmakers. On the other hand, some of the toolmakers may simply have eaten others; cannibalism was not uncommon among Mesolithic peoples. In any case, the remains do provide a picture of one type of early Mesolithic man in central Africa.

Most of the bone fragments come from some part of the head, but there are not enough of them to enable us to reconstruct Ishango man's skull in its entirety. We do know, however, that his jawbone was very large and heavy—a characteristic of Heidelberg man and of many other species that preceded Homo sapiens but not of modern man. This is one of the reasons that Twiesselmann and his colleagues at first assumed that Ishango man was probably prehuman. The size of the teeth would have given added weight to this assumption: some of the molars we found were as large as those of *Australopithecus*, the prehuman "man-ape." Moreover, the skull bones were thick—as much as three-eighths of an inch thick in many of the adults. This is approximately the thickness of Neanderthal skulls. All these features pointed to a pre-sapiens species.

On the other hand, Ishango man did not have the overhanging brow of Neanderthal and the other earlier forms. By the time he emerged, the supraorbital ridge had disappeared from the frontal bone of the skull. In addition his chin was shaped much like the chin of modern man, as was his ramus: the bone that rises from the lower jaw to join with the skull. Finally, the long bones of his body were quite slender.

All this adds up to a unique picture. No other fossil man shows such a combination of characteristics. Primitive and even Neanderthaloid in part, Ishango man was nevertheless a true Homo sapiens, possibly Negroid, who represented the emergence in Africa of an indigenous Negro population from an older Paleolithic stock. This interpretation of his place in history fits quite well with contemporary views of human evolution. Most students now believe that modern man did not descend from any single stock but from a mingling of many stocks that arose independently

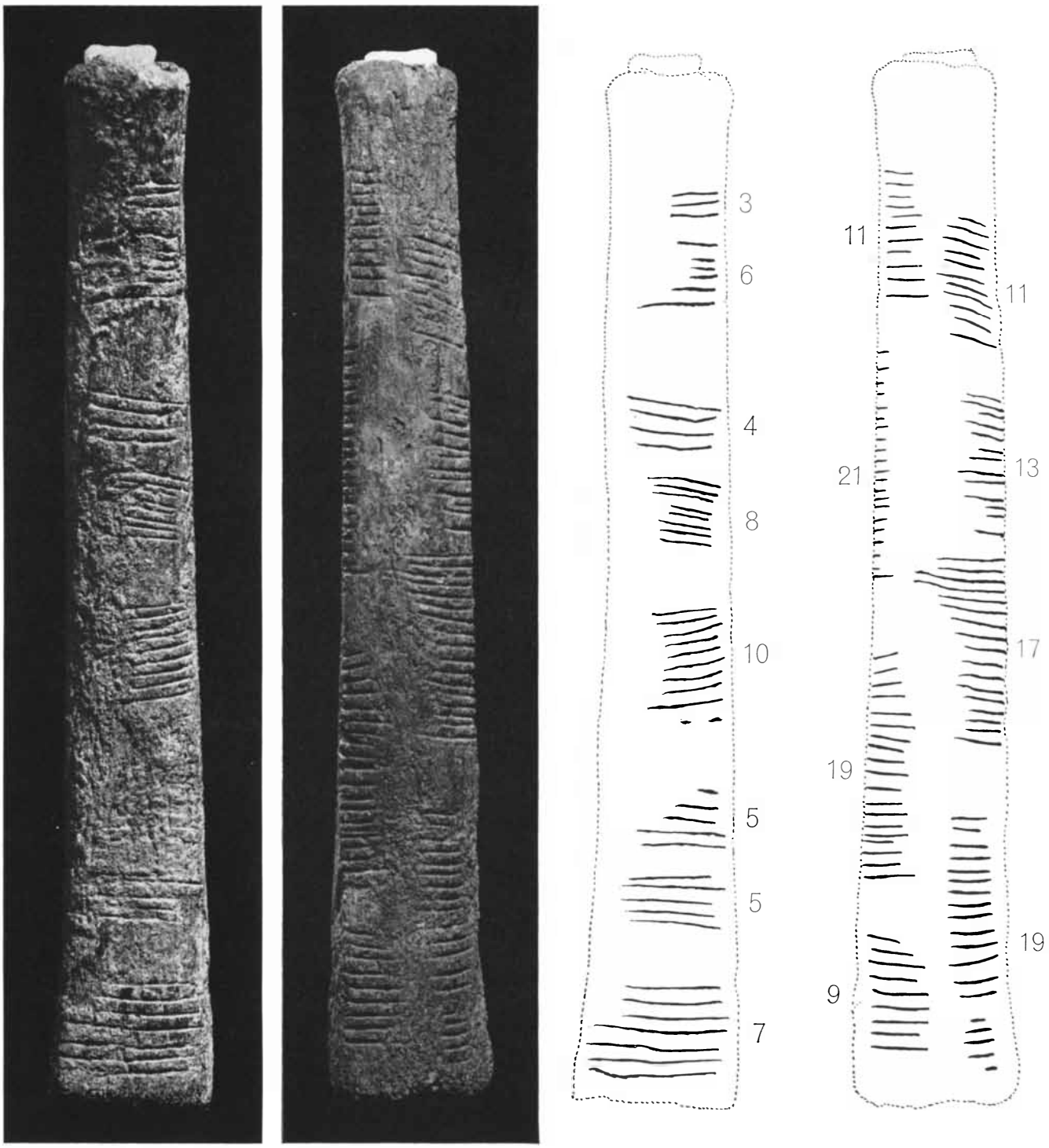


MODERN HARPOON is used in the Congo to hunt hippopotamus. The Ishango harpoons were probably constructed on a similar principle. In this harpoon the line is attached to the base of the weapon's iron point (*top*) and secured to the wooden shaft by windings made of vine. The free end of the line is tied to a float, seen here at left.

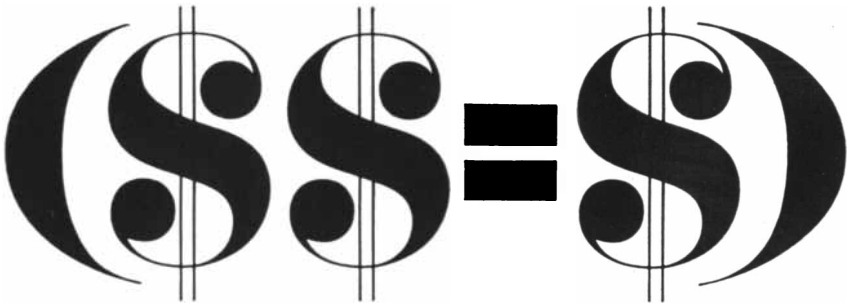
in a number of Paleolithic communities.

Some of the fossils we discovered at Ishango showed clearly that a second human population lived at the site hundreds of years after the volcanic eruption drove the first away. Although these later inhabitants were of the same physical type as Ishango man, the archaeological evidence indicates that they possessed few of his techniques. They had, for example, forgotten the use of the harpoon, but since this knowledge diffused through Africa by the paths already traced, this was a loss only to them and not to other peoples.

There is no evidence that they retained any knowledge of the numerical system that may have been invented at Ishango. Yet this knowledge too may have spread northward. The first example of a well-worked-out mathematical table dates from the dynastic period in Egypt. There are some clues, however, that suggest the existence of cruder sys-



NOTCHED BONE TOOL HANDLE found at Ishango is seen in two views. It is the earliest artifact to suggest knowledge of a number system. The drawings at right of the photographs indicate how the notches were arranged. Column seen in drawing at left is notched to suggest a knowledge of multiplication by two. Columns seen in drawings at right are notched to suggest that 10 was the base of the number system and that the concept of prime numbers was understood. The tool handle is photographed actual size.



YOU CAN GET ANOTHER COMPUTER TO DO WHAT THE

RPC-4000

DOES—FOR ONLY TWICE AS MUCH MONEY.

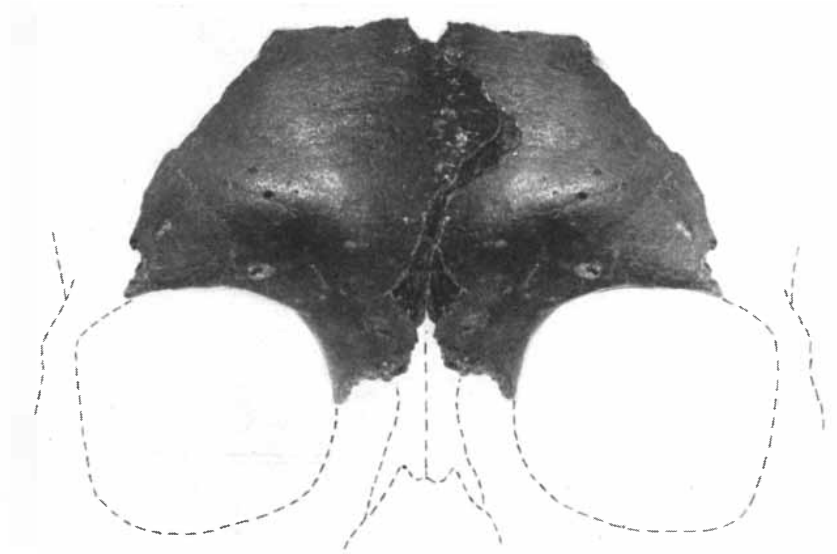
These performance specifications need no elaboration. □ 8008 word, 72,000 digit memory with special fast access features. Computer speeds of up to 230,000 operations per minute. 30,000 characters per minute input – 18,000 characters per minute output. □ Which adds up to the largest memory, greatest problem-solving capacity and flexibility in the low- or medium-priced field. It's actually a desk-size transistorized computer with room-size computer capacity. □ Performance is formidable—operation isn't. Even non-technical personnel can program and operate the RPC-4000 at optimum levels. You can easily master it yourself in one day—and free yourself forever from dependence on a computer specialist. (More than 3000 students were taught programming in less than one day with PINT, an interpretive routine developed especially for the RPC-4000 by Purdue University. A film of this training will be shown on request). The RPC-4000 plugs into conventional outlet, requires no expensive installation. □ All this plus a Library of Programs for the RPC-4000. It is the most extensive in this computer class – and may well include the program you need. Programs for Fortran and other computer languages also ready to go, as well as PERT programs. Here alone are possible

major savings. □ Only one other desk-size computer gives so much value per dollar. And that's the LGP-30 – little brother (or sister) to the RPC-4000 and the most powerful, biggest memory, complete computer system in its class, at $1100 per month rental. For more information about rental or purchase, write Commercial Computer Division.

GENERAL PRECISION

COMMERCIAL COMPUTER DIVISION / GENERAL PRECISION, INC. / BURBANK, CALIFORNIA

tems in predynastic times. Because the Egyptian number system was a basis and a prerequisite for the scientific achievements of classical Greece, and thus for many of the developments in science that followed, it is even possible that the modern world owes one of its greatest debts to the people who lived at Ishango. Whether or not this is the case, it is remarkable that the oldest clue to the use of a number system by man dates back to the central Africa of the Mesolithic period. No excavations in Europe have turned up such a hint.



FRONTAL BONES of Ishango man were reconstructed from fragments of the right half found at the excavation site. The left half was duplicated by symmetry. Broken lines indicate the shape of the eye sockets and the nasal bone. The bones are shown here actual size.

JAWBONES of Heidelberg man and Ishango man are compared. Heidelberg jaw (*top*) dates from Middle Pleistocene. Ishango jaws (*middle and bottom*) date from Mesolithic. Bottom jaw is from second population to live at Ishango. All bones are two-thirds actual size.

WE'VE BROUGHT CLEOPATRA'S BARGE UP TO DATE

In our picture, you'll notice Cleo's eyes are quite wide. They should be, for we've loaded her barge with a few thousand things she never heard of . . . but which modern industry is producing from Sinclair petrochemicals.

For example, in the plastics and synthetic fibres industries Sinclair petrochemicals are indispensable raw materials being used in the development of countless new and exciting products. Even when you add the new developments in paints, fertilizers, insecticides and detergents, you've only scratched the surface of profitable opportunities.

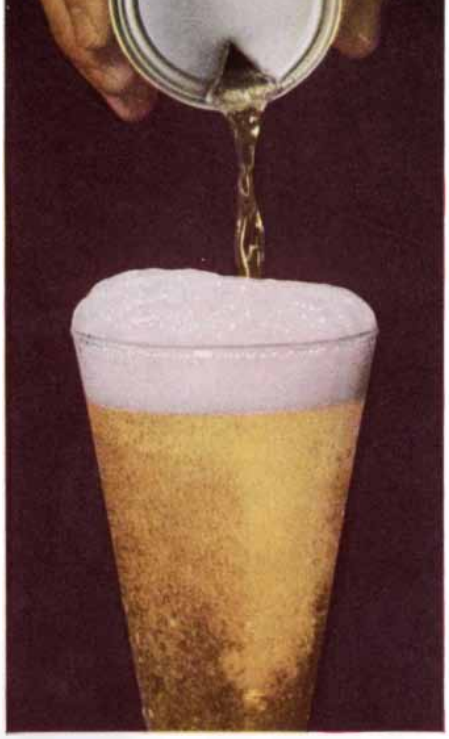
Sinclair supplies quality petrochemicals in quantity. Shipping and production schedules are set up to meet the most stringent demands. The purity of Sinclair petrochemicals sets industry standards.

SINCLAIR PETROCHEMICALS, INC.

600 Fifth Avenue, New York 20, N.Y. • 155 N. Wacker Drive, Chicago 6, Ill.

Sinclair

PARAXYLENE—PROPYLENE (99+%)—ORTHOXYLENE—HEPTENES—NONENES—DURENE (1,2,4,5-TETRAMETHYLBENZENE)—AROMATIC SOLVENTS—TOLUENE (NITRATION GRADE)—XYLENE (FIVE DEGREE)—ALIPHATIC SOLVENTS—ODORLESS SOLVENTS—MINERAL SPIRITS—VM&P NAPHTHA—RUBBER SOLVENT—ANHYDROUS AMMONIA—AQUA AMMONIA—AMMONIUM NITRATE SOLUTIONS—NITROGEN FERTILIZER SOLUTIONS—SULFUR—LUBE OIL ADDITIVES



TWELVE MICRONS SEPARATE "AH-H-H!" FROM "PFUI!"

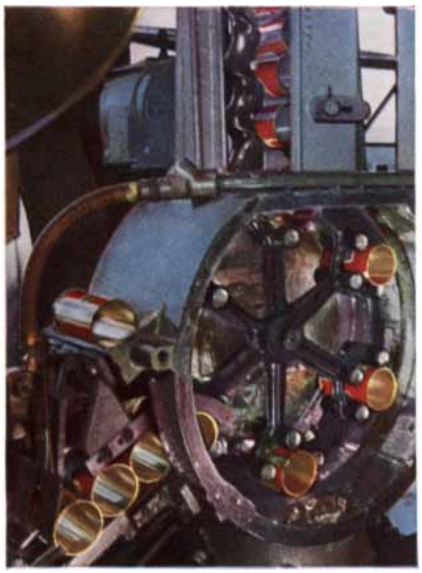
Between a flavorful beverage and its metal container, Glidden can coatings only .0005" thick make the difference between a tasty treat and an unappetizing disappointment.

Concentrated research by Glidden chemists on petroleum monomers provided the basis for a new can coating system that gives full protection and meets FDA and consumer requirements.

Butoxy base coats provide highly impervious can linings that are applied by existing coating equipment, yet cost up to one-third less. New Glidden vinyl top coats are readily applied over the base coat for complete protection of beverage from taste and appearance failures.

1 Copper sulfate test shows up any eyeholes or breaks in the coating as black spots. Glidden-developed coating completely protects test can end (at top) even after fabrication, processing and extended storage.

2 In the Glidden can coatings laboratory, this 15-inch roll-coater, one of only six in the nation, enables Glidden chemists to duplicate coating methods to be used on customers' production lines.



3 Retractable spray-gun deposits continuous coatings of Glidden taste-inert vinyl top coat over entire inner surface of the can body. Glidden technical service personnel work closely with customers' technical and production men to assure that coating is perfectly suited to application equipment.

4 At six Glidden Industrial Finishes plants, formulations of special can coatings to highest quality-control standards are produced in batches from a few drums to tank-wagon lots.

If your product requires a finish, a coating, or a resin, Glidden is ready to work with you. To obtain the formulation best suited to your product and application methods, write or phone:

Glidden QUALITY PRODUCTS

GLIDDEN

THE GLIDDEN COMPANY • COATINGS AND RESINS DIVISION
900 UNION COMMERCE BUILDING • CLEVELAND 14, OHIO
In Canada: The Glidden Company, Ltd., Toronto, Ontario

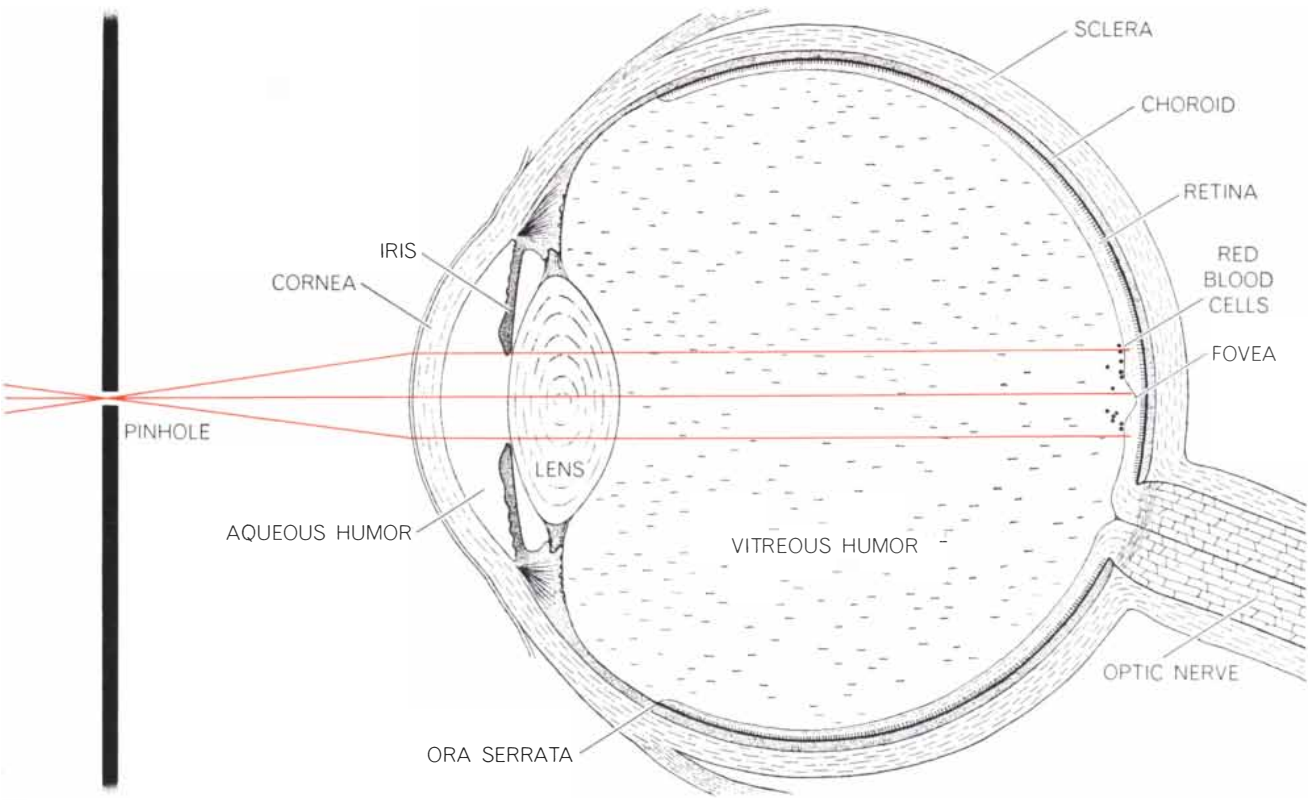
"Floaters" in the Eye

They are the spots that most people occasionally see before their eyes. The authors propose that floaters are usually diffraction patterns cast on the retina by red blood cells

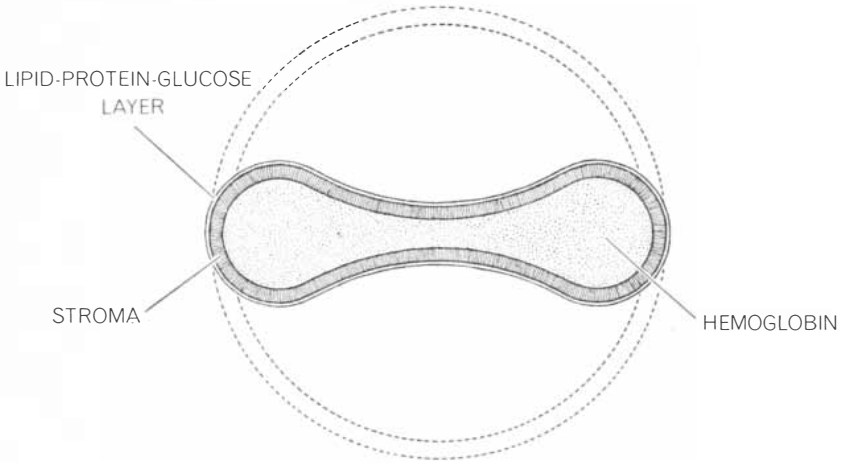
by Harvey E. White and Paul Levatin

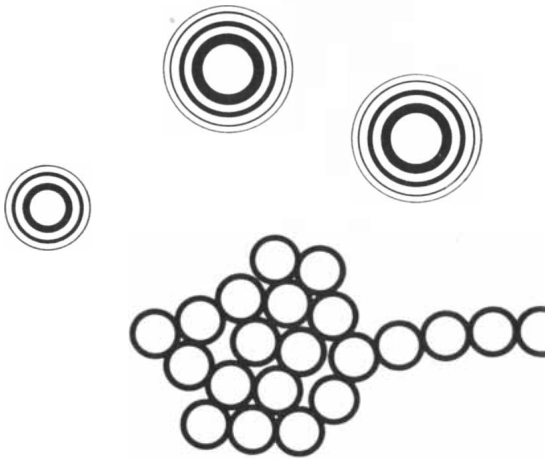
Most people at one time or another see spots before their eyes—small, hazy specks and hairlike objects that drift across the field of vision with the movement of the eyes. Often when one is not conscious of their presence, these "floaters" can be brought into view by staring at a bright, uniform background, such as the sky. They are for the most part extremely mobile and glide away elusively as one attempts to fix them in sight, whence their traditional name *muscae volitantes* (flying flies). Sometimes floaters remain fixed in the direct line of vision; these can be annoying until they either disappear or the brain learns to suppress and ignore them.

The authors of this article, a physicist and a surgeon, were drawn into a collaborative study of floaters quite by chance, when the surgeon (Levatin) operated on the physicist (White) for a detachment of the retina in his left eye. The operation was uneventful and recovery has been complete. On the third day after surgery, however, a small hemorrhage occurred in the eye. When the bandages were removed temporarily two days later, the only symptom was a yellow-orange tinge in the vision of the left eye. The color disappeared within 48 hours and was attributed to the diffusion of hemoglobin from the red blood cells into the fluids of the eye. Later in the course of recovery, when the patient



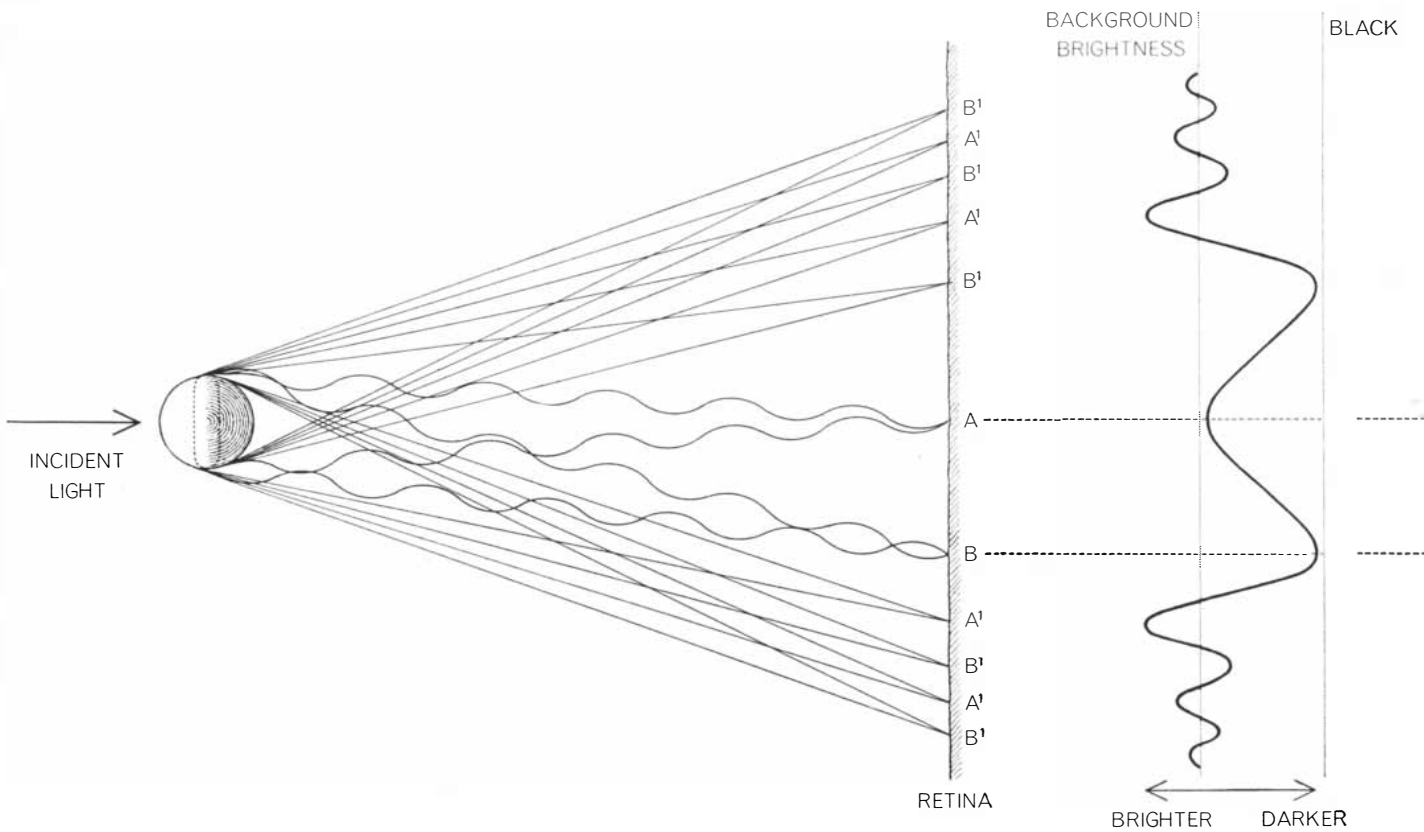
PARTS OF EYE involved in floater formation are shown in this somewhat schematized cross section. Light entering the eye through a pinhole is rendered essentially parallel by refracting media: the cornea, aqueous humor, lens and vitreous humor. If red blood cells are present in the vitreous humor as shown, the light could cast a diffraction pattern of the cells on the sensitive retina.



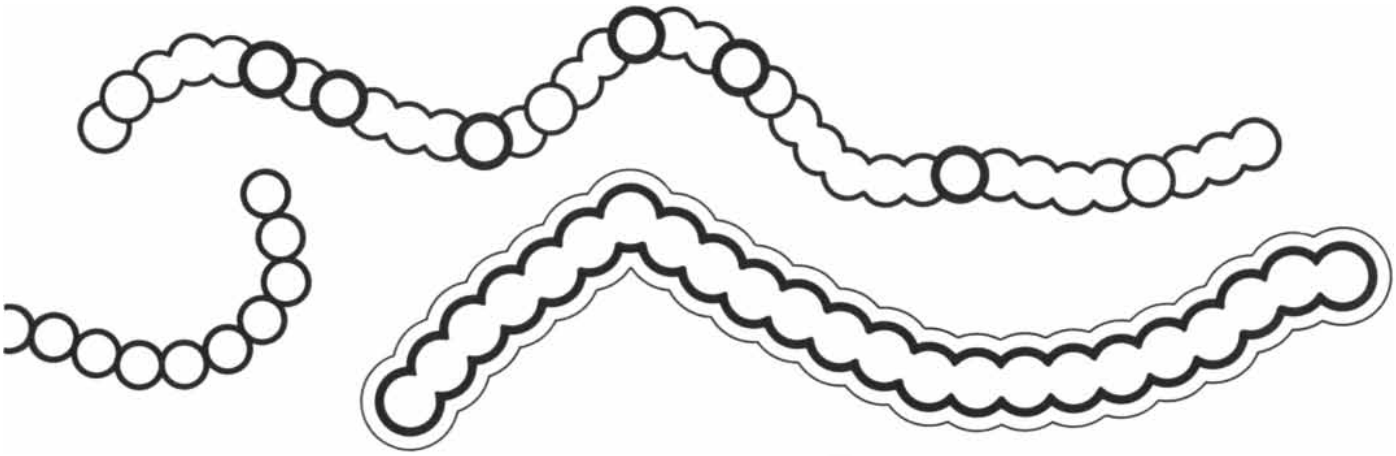


HUMAN ERYTHROCYTE, or red blood cell, is illustrated along with the diffraction patterns and necklace-like floaters for which it is apparently responsible. The cell is normally a flattened disk (*left*) but may swell into a sphere (*broken lines*) as it loses its hemoglobin in the watery environment of the eye. In either case its circular cross section, some eight microns (.008 milli-

was still wearing the pinhole goggles prescribed to restrain motion of the eyes, a thin veil appeared in the central visual field of the repaired eye. The veil swirled first this way and then the other when he moved his eyes. Seen through the pinhole against a bright blue sky, it appeared as an assemblage of tiny rings or pearls. The patient was given the assurance that this was a floater, that in the opinion of ophthalmologists most floaters consist of cellular debris, that the debris in this case came from the operation and that the condition would clear up in due time. In his enforced contemplation of the structure of this floater through the days that followed, the patient went somewhat deeper into the matter. As a result we are able to present here what we believe to be a plausible description of the nature and



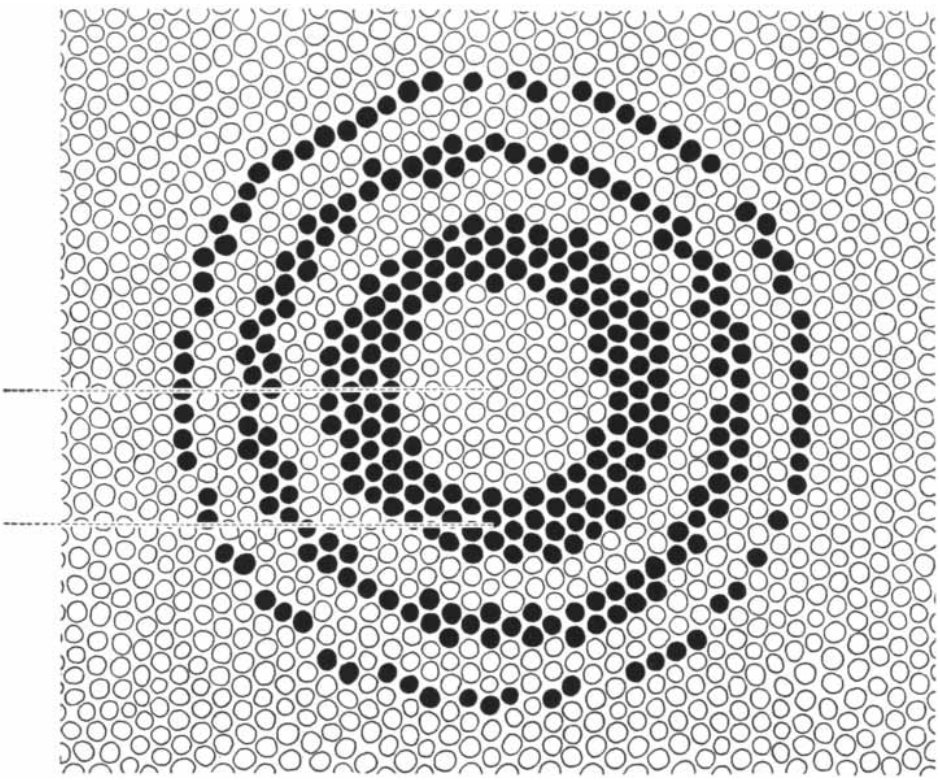
SINGLE BLOOD CELL would diffract light and form an image on the retina in the manner shown here. Light rays bend when they pass an opaque object. Rays from the edges of the cell (*left*) travel the same distance to the center of the pattern and arrive there in phase, forming a bright central spot at *A* on the retina. Rays traveling different distances arrive at the retina out of phase (*B*) and form the inside dark ring. The same relations apply at all points A^1 and B^1. The broken lines show how points *A* and *B*



meter) in diameter, would cast on the retina a diffraction pattern composed of a series of rings (*center*). The dark interior ring in individual floaters observed by the authors ranges from 25 to 40 microns in diameter. Chains of erythrocytes sticking together can give rise to a wide variety of floater images, of which the three versions shown in the middle and at right are typical examples.

origin of the kind of floater that is perhaps most commonly observed in normal eyes. Incidental to this study we have apparently approached a determination of the limit of the acuity of human vision and identified the anatomical structure that sets this limit.

The eye is an organ designed for the appreciation and understanding of a physicist. It is the living analogue of optical instruments that are among the principal tools of his trade, consisting of a light-bending, or refracting, system that brings images into focus on a light-sensitive screen. Light entering the eye passes successively through the cornea, the tough, transparent window of the eyeball; the aqueous humor, the fluid that fills the small forward chamber of the eye; the crystalline lens, the active refracting element in close vision; and the jelly-like vitreous humor that fills the large rear chamber of the eye [*see illustration on page 119*]. At the light-sensitive screen—the retina—the light impinges on the rod and cone cells, which transform light energy into nerve impulses for transmission to the brain.



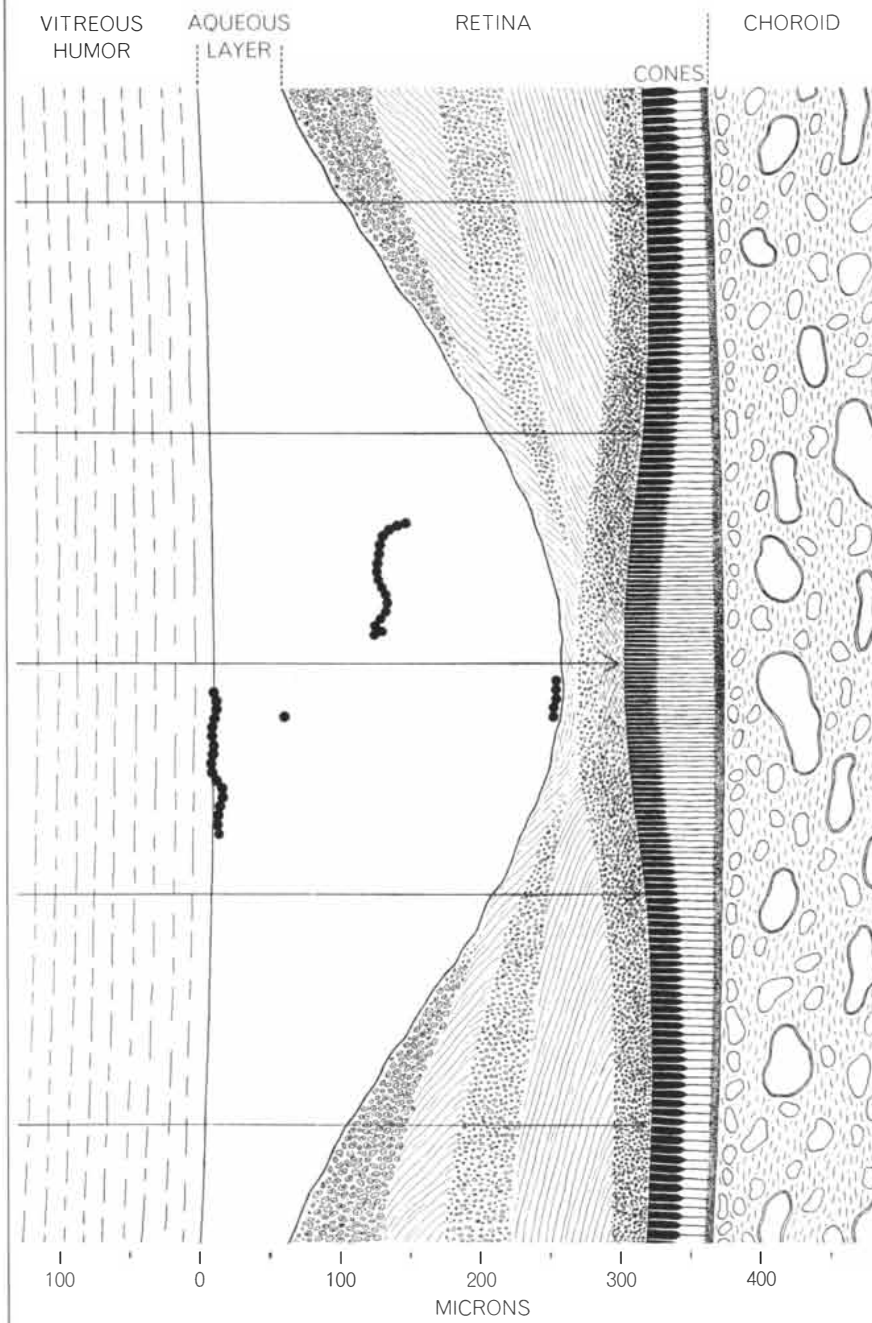
correspond to positions of greater and lesser brightness on a graph of the intensity of light reaching the retina (*middle*) and to the pattern formed on the retina (*right*). The diffraction pattern illuminates some of the sensitive cone cells and leaves others dark. The resolution of the outer rings of the pattern is limited by the number of cones between them.

In the center of the retina is a yellowish area called the *macula lutea* (yellow spot), and near its center is a small depression called the *fovea centralis* (central pit). The fovea is the center of visual acuity, containing a large number of densely packed cone cells and no rods. It is on this spot that the eye focuses the letters and words on this page, one after the other, and it is this spot that sees the floaters most sharply when they make their distracting passage across the field of vision.

When one considers that the retina is about the size of a postage stamp and not much thicker, it is surprising that today surgical repair of detachments of the retina is about 75 per cent successful. The retina becomes detached when fluid from the vitreous humor seeps behind it and lifts it from its bed in the choroid, the blood vessels of which supply nourishment to the rod and cone cells. Such detachment is usually due to a tear or hole in the retina, and this must be closed to effect a cure. To reattach the retina to the choroid, surgeons most commonly employ a technique first

developed some 30 years ago. A tiny electric needle that partially penetrates the sclera, the eyeball proper, produces electric "burns" in the sclera around the site of the tear. The irritated blood vessels of the choroid exude a sticky fluid that in a period of weeks becomes a fine, tough scar binding the retina to the choroid again. During surgery the surgeon peering into the pupil of the eye through a powerful ophthalmoscope sees tiny white coagulation spots in the retina that result from the mild heating by the electrode; he thus has a visual cue to guide him in applying the electrode to the site of the retinal hole. At the end of the operation tiny perforations are made through the sclera with a longer electric needle to allow the subretinal fluid to escape.

Both at the onset of detachment and during the weeks after the operation, vision is likely to be troubled by the appearance of floaters in the affected eye.



CHAIN OF BLOOD CELLS may attach themselves to the rear surface of the vitreous humor or float through the watery layer between it and the retina, as shown in this cross section of the foveal depression. The size of the diffraction patterns, and hence the observed size of the floaters, varies with the distance between the cells and the tops of the cone receptors. Note that the thickness and the spacing of the cones decrease toward the center.

In the present case the slight hemorrhage that followed the operation, the transitory yellow-orange tinge to the light and the ring- or pearllike detailed structure of the veil that appeared some days later in the patient's field of vision—all suggested that this floater might be an aggregation of red blood cells. The cells liberated by the hemorrhage had evidently migrated around behind the mass of the vitreous humor into the region of the fovea.

The normal red blood cell is shaped like a dented disk; its enclosing membrane is elastic and tough and quite sticky. When a red cell is placed in a solution with a lower osmotic pressure than its own protein-rich contents, as in the watery fluids of the eye, it will swell into a sphere, giving up its hemoglobin in exchange for the surrounding fluid. The colorless, translucent "ghost" cell will then cohere with other such ghosts in clusters and chains. Accordingly we postulated that each ring or pearl in the floater was a shadow cast on the retina by a red cell or its ghost.

The patient made a test of this idea by comparing the size of the rings in the floater with the width of the mullion of the window through which he looked at the sky. A rough calculation based on the estimated width of the mullion and distance to the window indicated that the diameter of the rings was indeed comparable to the diameter of human red blood cells, which is about eight microns (a micron is .001 millimeter).

This result encouraged the physicist to undertake a more exact measurement. On white cardboard he drew a series of circles ranging in diameter from 10 millimeters down to one millimeter, and he viewed this test pattern under bright light from a distance of eight feet. By looking at a floater in his left eye through a pinhole goggle, and at the test pattern with his right eye, he was able to superimpose a floater ring on the circle that most closely matched it in apparent size. He could then calculate the diameter of the floater ring by simple trigonometry, with a correction for the known average refractive index of the eye. To his surprise, calculation showed the floater rings to be from 25 to 40 microns in diameter, or three to five times the size of a red blood cell.

This unexpected result showed that the ring patterns could not be the shadows of red blood cells in direct contact with the retinal surface, as had first been supposed. It suggested, furthermore, that another optical principle might be involved. This is diffraction, the bending

Just like $103 million in the bank

In the past 4½ years, Hughes has put more than 7,000 cost improvements into practice—saving $103 million in defense and space dollars. Prudent management *avoided* these expenditures.

Savings like these in money, materials, time and human energy don't just happen. At Hughes, cost improvement is a corporate way of life. From top to bottom, in all plants and departments, employees submit ideas and suggestions without thought to personal gain. A comprehensive, fully organized program encourages these ideas, evaluates them and makes them work.

Typical ways in which cost improvements were applied: Machining time on a wave guide was cut from 3½ hours to 32 minutes each—saving $41,201. Application of a Preferred Parts Program simplified specifications and rationalized tolerances and performance standards—result, $40,000 saved the first two months. One radar reflector dish was redesigned to fit two different units—saving $117,000.

Each improvement results in lower contract costs. Some of the major defense programs that benefit include the Polaris, Titan, Falcon and Mauler missiles, new 3-D radar-computer systems now in service on Navy ships and automatic armament controls for Air Force interceptors.

And new Hughes space projects—the Surveyor moon landing vehicle, the Syncom communications satellite, the ion engine for long space journeys—all will deliver full value for every dollar.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

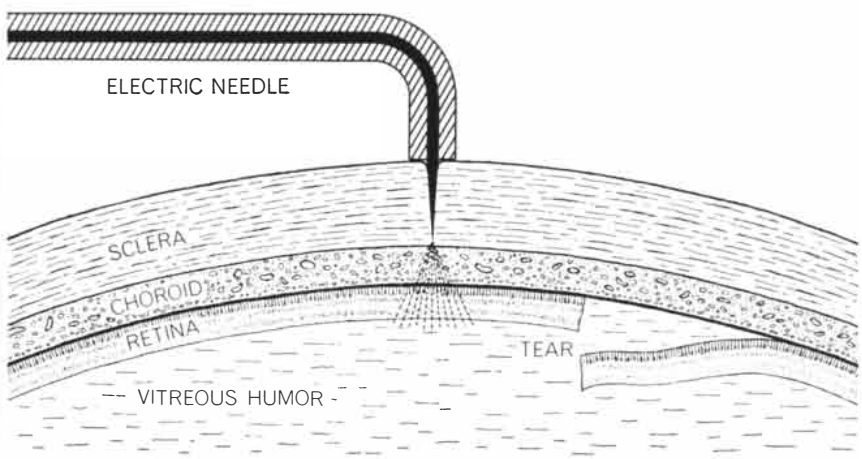
of light waves that occurs at the edges of objects. Light waves that are diffracted on passing through a pinhole or around a tiny object will produce a characteristic interference pattern of concentric rings of light and shadow. In diffraction around a tiny circular object such as a red blood cell, the light produces a pattern with a bright spot at its center [*see bottom illustration on pages 120 and 121*]. The diameters of the rings provide a basis for calculating the size of the object, since they depend on its diameter, the wavelength of the light and the distance to the screen on which the diffraction pattern is projected. With diffraction in mind, the patient took another look at the floater rings and saw that the distinct, bright central circle was surrounded by multiple outer rings of light and shadow.

The evidence for a diffraction effect required us to take into account a fine point in the anatomy of the eye. The vitreous humor is attached most firmly to the retina around the circumference of the optic nerve and in a band some two millimeters wide at the edge of the retina. When the eye moves quickly from one point of attention to another, the inertia of the vitreous body causes momentary distortions of its elastic mass. The points most distant from the areas of strong attachment return somewhat sluggishly to their equilibrium position. With age there sets in a partial liquefaction of the vitreous humor, which usually begins at the back surface and probably first fills the foveal pit with a watery fluid. By cutting down the areas of close approximation of the vitreous body to the retina, liquefaction may lead to increased risk of detachment of the retina. Moreover, instead of being squeezed against the retina by the vitreous body, floaters may be actually floating in suspension in the watery layer. This is undoubtedly the situation in the eye of an older person.

In the foveal pit the watery layer may have a depth of from 200 to 300 microns, and the tops of the cone receptor cells lie another 40 to 60 microns below the surface of the retina in that area. Cell ghosts may therefore be suspended as much as 250 to 350 microns above the cones as they migrate across the fovea. Calculation shows that the innermost dark ring of the diffraction pattern from an eight-micron object at such distances should have a diameter of from 30 to 45 microns.

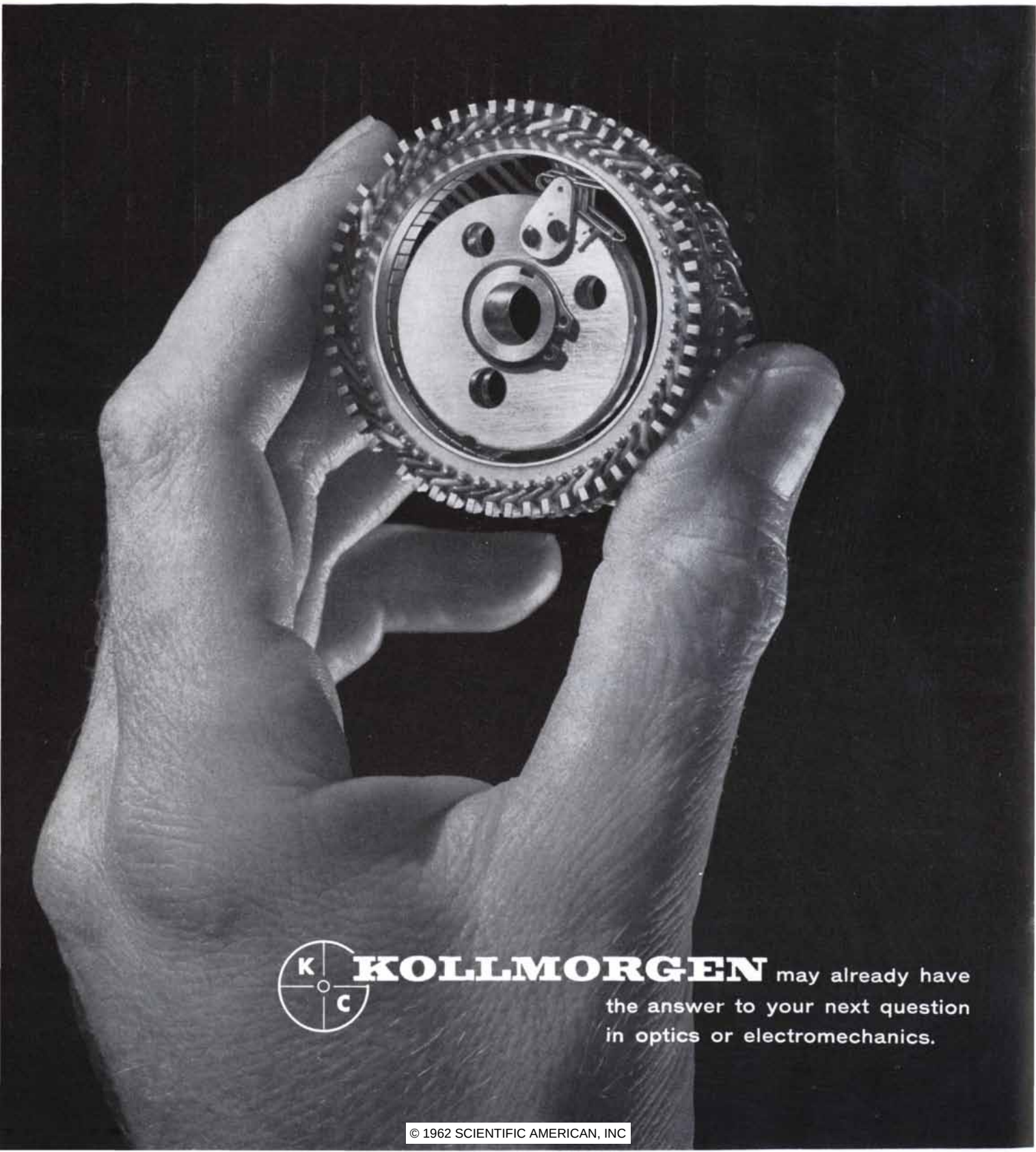
This is satisfactorily close to the size of the floaters the patient had observed. We have concluded that the ghosts of blood cells spilled into the eye by the postoperative hemorrhage drifted through the watery layer into position over the fovea, perhaps becoming attached to the rear surface of the vitreous body. There they formed the veil that swirled across the patient's field of vision as he moved his eyes.

The majority of the floaters seen in the normal eye can be explained on the basis of these findings. Most of them, on close inspection, show diffraction rings in the detail of their structure. Some disturbance such as a blow to the head or excessive pressure on the cornea or elsewhere on the eyeball can cause a tiny blood vessel in the retina to exude a string of red blood cells and close again. Because of their sticky coating



DETACHMENT OF RETINA can occur when vitreous fluid seeps through a hole or tear in the light-sensitive innermost layer of the eye. The fluid is drained off and the tear is "tacked down" by a circle of scars created with a fine electric needle. It was an operation of this sort that led to the two authors' collaboration on a study of floaters.

Q. Who has the facts about getting four billion signals out of a rotary switch?



these cells form a flexible chain or, if there are enough of them, a cluster. Some apparently adhere to the surface of the vitreous body and diffuse into its central mass, where they cast only a vague shadow on the distant retina. Others migrate freely through the thin aqueous layer between the vitreous body and the retina and, because of their proximity to the retina, become visible floaters. The typical floater appears in one part of the visual field and migrates quickly, with an intermittent motion associated with normal eye movements, across the field until it disappears at the periphery. The fact that these fast-moving floaters are seen by children as well as by older people suggests that liquefaction of the vitreous humor may begin at an early age.

Although hazy floaters are often seen with the naked eye, their structure can be examined in detail only if a pinhole aperture is used to make the light rays parallel. The reader can make such a device for precise observation of his own floaters. Simply glue a piece of aluminum foil over one end of a spool; punch a tiny hole in the center of the foil with the sharp point of a needle, being careful not to make the hole too large. Hold the spool with the foil end close to one eye and, with the other eye closed, look toward a bright light or through a window at the open sky. If a floater lies anywhere near the fovea, structures similar to those shown at the top of pages 120 and 121 will probably be observed. In the case of single isolated cells, look for fine outer rings surrounding the pronounced dark inner ring. Frequently the light ring just outside this innermost dark ring will appear even brighter than the background, as is characteristic of ideal diffraction patterns.

Most often when one is observing a floater with the attention fixed on some stationary point in the external field, the floater will be seen to drift downward slowly, as if settling through a liquid of high viscosity. Such motion immediately follows any shift of the gaze to one side and then back again. The drift is rapid at first and then slows down, and it stops in 20 or 30 seconds. If one lies supine, the motion of the floaters can be stopped completely. The loose cells may then settle into the aqueous pool in the foveal crater. When this happens, floaters as small as 10 microns in diameter can be seen.

The predominant downward drifting of floaters in the visual field would seem to be correlated with the pull of gravity. It should be recalled that retinal images of objects outside the eye are inverted by the lens system, just as they are in a camera. They must be reinverted by the brain. Since the cell ghosts are inside the eye and close to the retina, any apparent downward motion of the floaters must represent an actual upward movement of the cells.

This upward movement can be accounted for by the fact that any quick movement of the eye disturbs the equilibrium of the vitreous body and, in disturbing it, raises its center of gravity. The pull of gravity then causes the mass of the vitreous body to settle, forcing the less viscous margins of the vitreous body and the fluid in the aqueous layer behind it to flow upward. As the brain interprets the information coming to it from the retina, however, the floaters carried upward by the motion of the aqueous layer appear to move downward.

Our discovery that floaters perceived by the eye are diffraction images of blood cells made it possible to attempt a determination of the ultimate limit of the acuity of human vision. The eye's ability to distinguish small, closely spaced objects is qualified on the one hand by the refracting system and on the other by the fineness of the mosaic of cones in the fovea. The floaters in effect provide a test pattern within the eyeball, unaffected by image aberrations arising in the refracting system, with which one can test the resolving power of the fovea.

The rings of a circular diffraction pattern become thinner and more closely spaced with increasing distance from the center. In many careful observations of floaters we have been able to make out only three or possibly (it is hard to be sure) four rings. The space between the second and third rings we estimate to be not more than four or five microns.

The diameter of the cone cells decreases progressively toward the center of the fovea. In the most closely packed area of this center of visual acuity the average center-to-center distance between cone cells is one and a half to two microns. When the diffraction pattern of a floater falls on a patch of the central fovea, it illuminates some of the cones in the mosaic and leaves others dark [*see bottom illustration on page 121*]. The four-micron space between the outer rings of the pattern that is resolved by the fovea is approximately equal to two cone widths. It would appear that two lines in a pattern must be two cone widths apart if they are to be seen as separate. This anatomical requirement would specifically limit the resolution of which the eye is capable.

THE SCHOOLING OF FISHES

What influences make a fish join others of the same species to form a school? The question is studied partly by observing the developing behavior of young schooling fishes in a special laboratory aquarium

by Evelyn Shaw

For sea gulls, fishermen and other predators the propensity of certain species of fish to assemble in large schools is a great convenience. A school of fish is something more, however, than a crowd of fish; it is a social organization to which the fish are bound by rigorously stereotyped behavior and even by anatomical specialization. Schooling fishes do not merely live in close proximity to their kind, as many other fishes do; they maintain, during most of their activities, a remarkably constant geometric orientation to their fellows, heading in the same direction, their bodies parallel and with virtually equal spacing from fish to fish. Swimming together, approaching, turning and fleeing together, all doing the same thing at the same time, they create the illusion of a huge single animal moving in a sinuous path through the water.

This peculiar social organization has no leaders. The fish traveling at the leading edge of a school frequently trade places with those behind. When the school turns abruptly to the right or left, the fish on that flank become the "leaders," and what was the leading edge becomes a flank. Except in the execution of such a turn and during feeding—when the school formation may break up completely—the fish swim parallel to one another. The distances between fish may vary as individuals swim along at different and changing speeds, particularly in a slower moving, loose school. When a school is startled, for example by a predator or an observer, it closes ranks immediately and the fish-to-fish spacing becomes equal and fixed as the entire school takes flight.

Even in schools of as many as a million fish, all members are of a similar size. Speed increases with size and the fish of a species therefore tend to sort themselves out by size and by generation in the sea. Schools can take many shapes and usually have a third dimension, being a few fish or many fish deep. From above they may appear rectangular or elliptical or amorphous and changeable. Some species form schools of characteristic shape. The Atlantic menhaden, for example, can be easily recognized from the air because their schools move through the water like a giant amoeboid shadow, often changing course but never breaking apart.

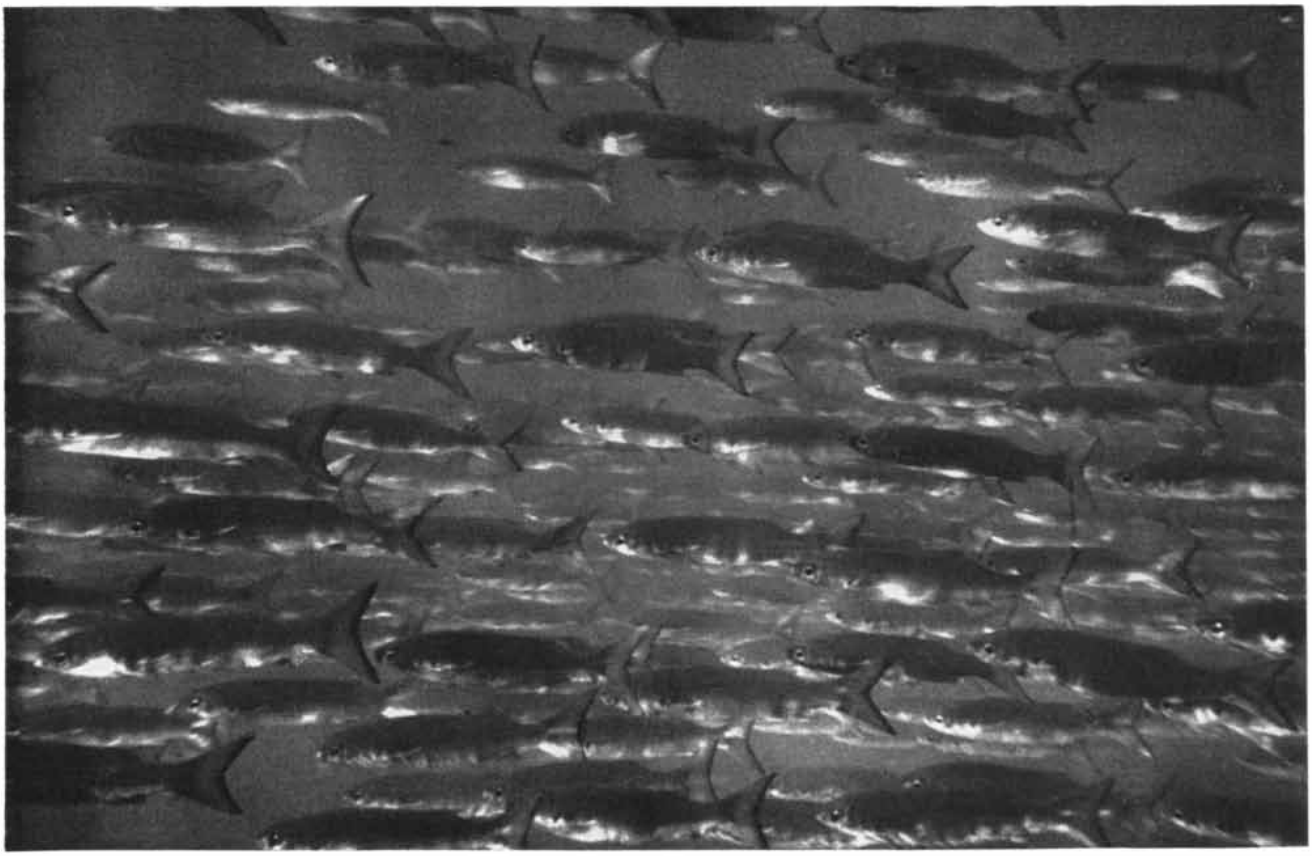
The speed and synchronization of response, the parallel orientation and the constancy of spacing among members of a school inevitably suggest that their behavior is integrated by some central control system that makes each "think" of changing course at exactly the same moment. Of course, there is no such central control system. Nor is it possible to explain the simultaneity of the members' actions as response to external stimuli from the environment. From time to time the fish do respond, as other animals do, to such stimuli as food and change of light intensity. Environmental conditions, however, do not explain the high degree of synchronized parallel movement that the members of a school display moment after moment, day after day. In fact, the great stability of schools, persisting through the most varied environmental conditions, suggests that the school organization must be dominated by internal factors.

Schooling is easily enough explained as an instinct. The term implies a causal factor—saying, in effect, that fishes school because they have an instinct to school. This tautology does not explain much, even when it is amplified by the more sophisticated statement that the behavior is inborn, unlearned and characteristic of the species. Many animals exhibit clear-cut, species-specific patterns of behavior, and it is useful to seek these out and compare them as they appear in related species. Such inquiry leaves equally interesting questions unanswered. In the present instance it does not explain what brings about the concerted action of the fish in a school. This requires, above all, study of the behavior as it unfolds in the developing organism. With growth and particularly with the maturation of the sensory system, the relation between the organism and its environment changes. The life history of the individual, however typical of its species, has a profound role in the molding of the behavior of the mature animal and holds the principal clues to the mechanism that governs its interaction with its social and physical environment. So far this approach to the schooling of fishes has only made the mystery more intriguing.

With progress on the question of how fishes school, one can also hope for some light on why fishes school. No other line of study has disclosed what function this highly organized social behavior serves in the perpetuation of the species that have adopted it.

In my own work at the Marine Biological Laboratory at Woods Hole, Mass., at the Woods Hole Oceanographic Institution, at the Bermuda Biological Station and at the Lerner Marine Laboratory on Bimini in the Bahamas, I have attempted to overcome the difficulty of study in the field by bringing fishes into the laboratory for observation and experiment. Life begins for most species of schooling fish in the plankton, where the eggs drift untended and abandoned by the school that laid and fertilized them in its passage. The eggs develop into embryos and the embryos into larvae, or "fry," which are capable of some feeble swimming movement. They grow, they ma-

SCHOOL OF HERRING was photographed by Ron Church near San Diego, Calif. The majority of herring caught in the Pacific Ocean are used to make fish oil and fish meal. This school, originally headed straight for the camera, has begun to turn to its right.

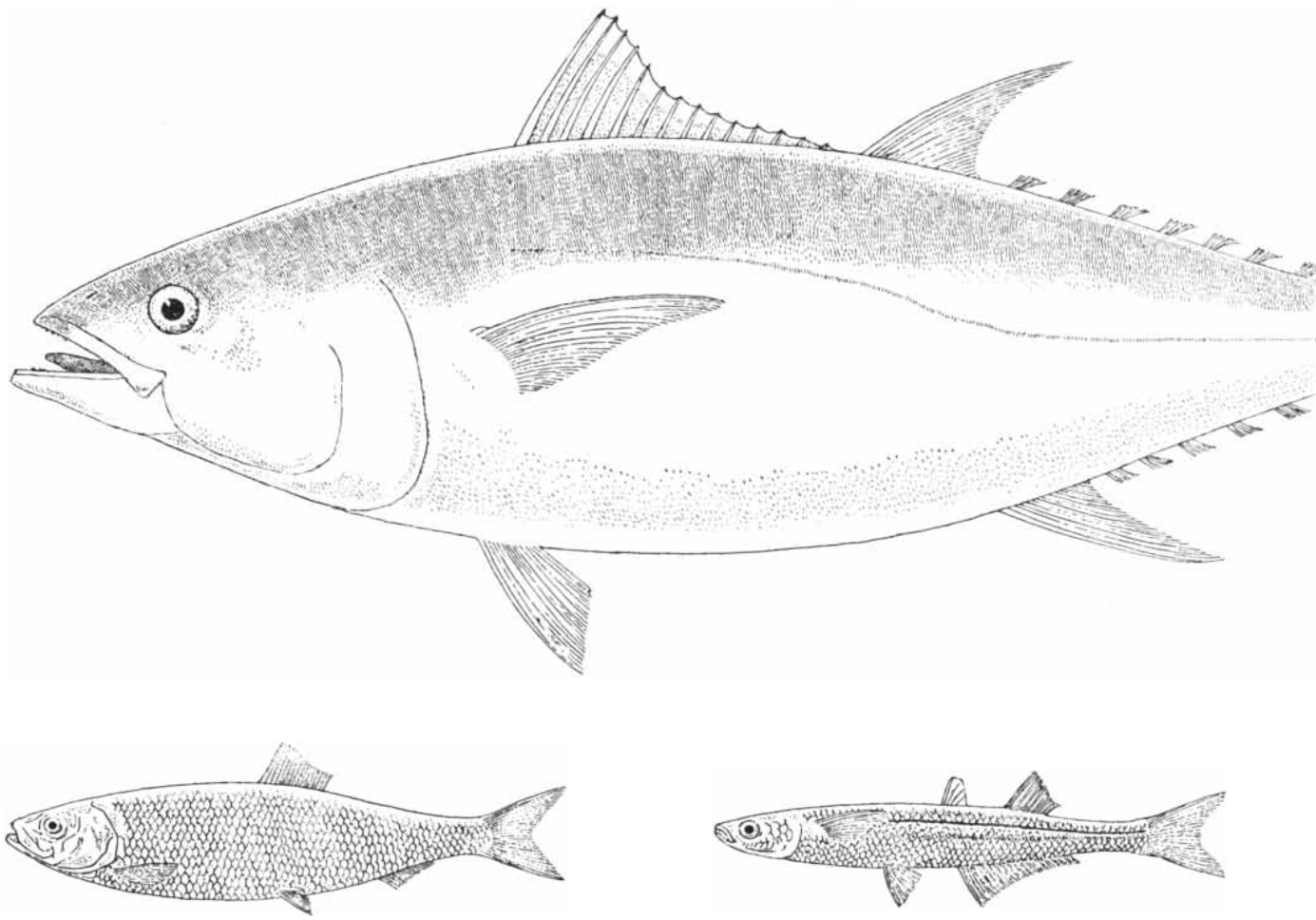


SCHOOL OF MULLET, which are common in the waters off Florida, was photographed there by Jerry Greenberg. A member of the order Mugiliformes, the mullet is an oceanic fish, and its distribution is primarily on both sides of the temperate South Atlantic.

ture and at some point during their early lives come together and form schools. One would like to be able to observe them during this epochal period. The only way to find the fry in the open oceans is to gather them in a plankton net, and the net necessarily disrupts the normal pattern of their behavior. My field studies have therefore been restricted to species that can be found as fry near the shore. But the fry are so tiny that crucial stages in the unfolding of their behavior in their natural habitat must go unseen.

In the waters around Cape Cod I have worked in particular with two species of *Menidia*, known commonly as whitebait, spearing or silversides. During late spring and early summer they spawn heavy eggs that adhere by sticky threads to rocks and to the stems of marine grasses and algae. On hatching, when they are no more than five millimeters (about a quarter of an inch) in length, they become part of the plankton. In spite of patient search I have never observed fry this small in open waters. When they grow to seven millimeters or longer, they become easier to find in the plankton. I have seen fry seven to 10 millimeters long randomly aggregated in groups but not yet schooling or showing any sign of parallel orientation to one another. As the season progresses and as they grow from 11 to 12 millimeters in length, they can be observed forming schools for the first time, lining up in parallel, with 30 to 50 fry to the school. During the summer of 1960 my associates and I observed an estimated 10,000 of these tiny fishes in the plankton of the shallow waters near Woods Hole and collected many of them.

From these observations one could deduce that schooling begins when the fry reach a certain length. We could not tell, however, whether schooling develops gradually or happens suddenly. We accordingly proceeded to rear some 1,000 *Menidia* from the egg in the laboratory. For the study of these fry we set up a doughnut-shaped tank with a channel three inches wide, having observed that schools tend to break up when they approach the corners of a rectangular tank. We took care also to observe them in constant light and through a one-way mirror. We were reassured to find that under these condi-



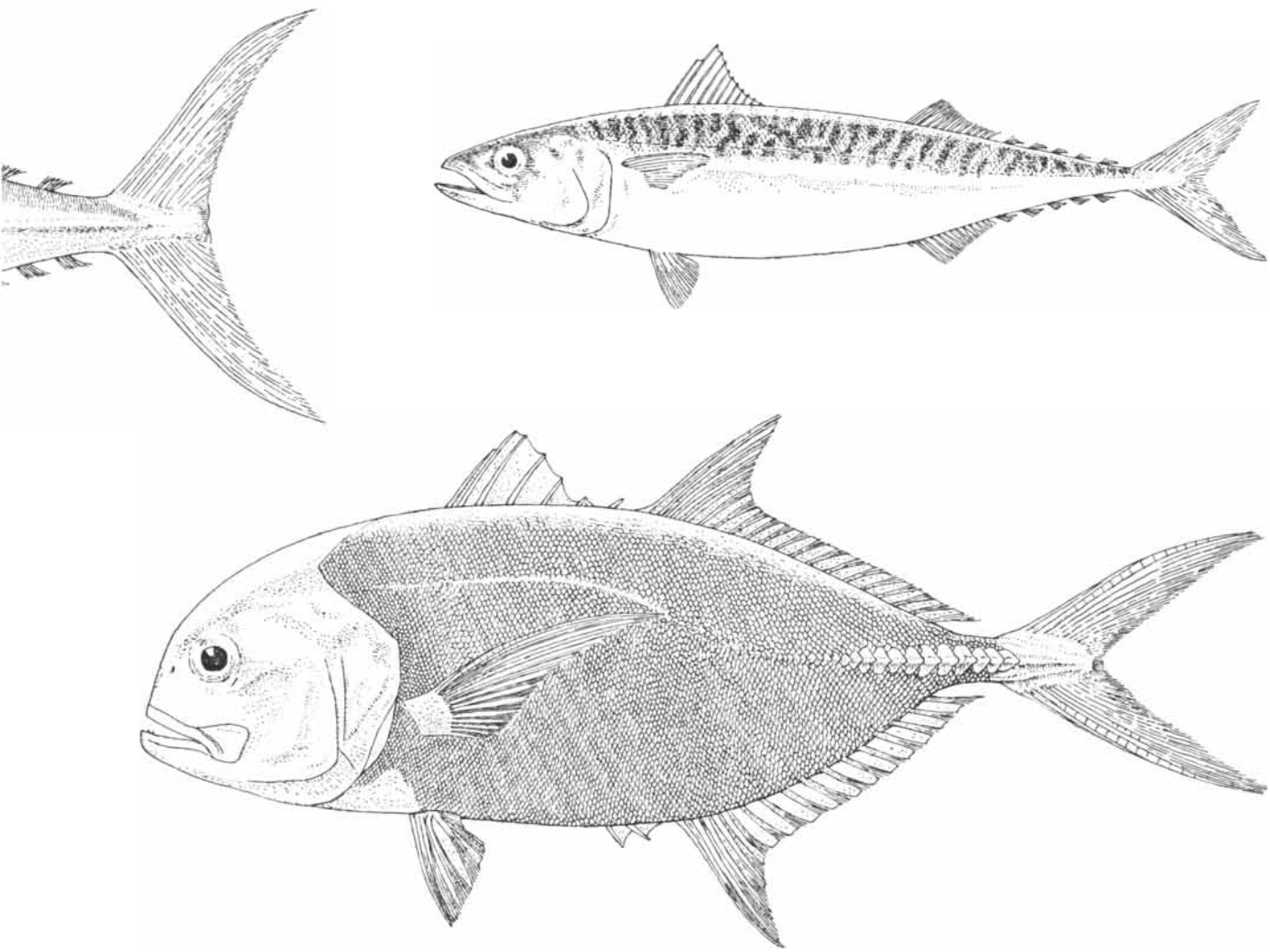
REPRESENTATIVE SCHOOLING FISH shown on these two pages are a tuna (*Thunnus thynnus*), at top left; a herring (*Clupea harengus*), at bottom left; a silverside (*Menidia menidia*), second from bottom left; a mackerel (*Scomber scombrus*), at top right; and a

tions schooling appeared in laboratory-reared fry when they grew to the same size as the smallest schooling fry observed in the sea.

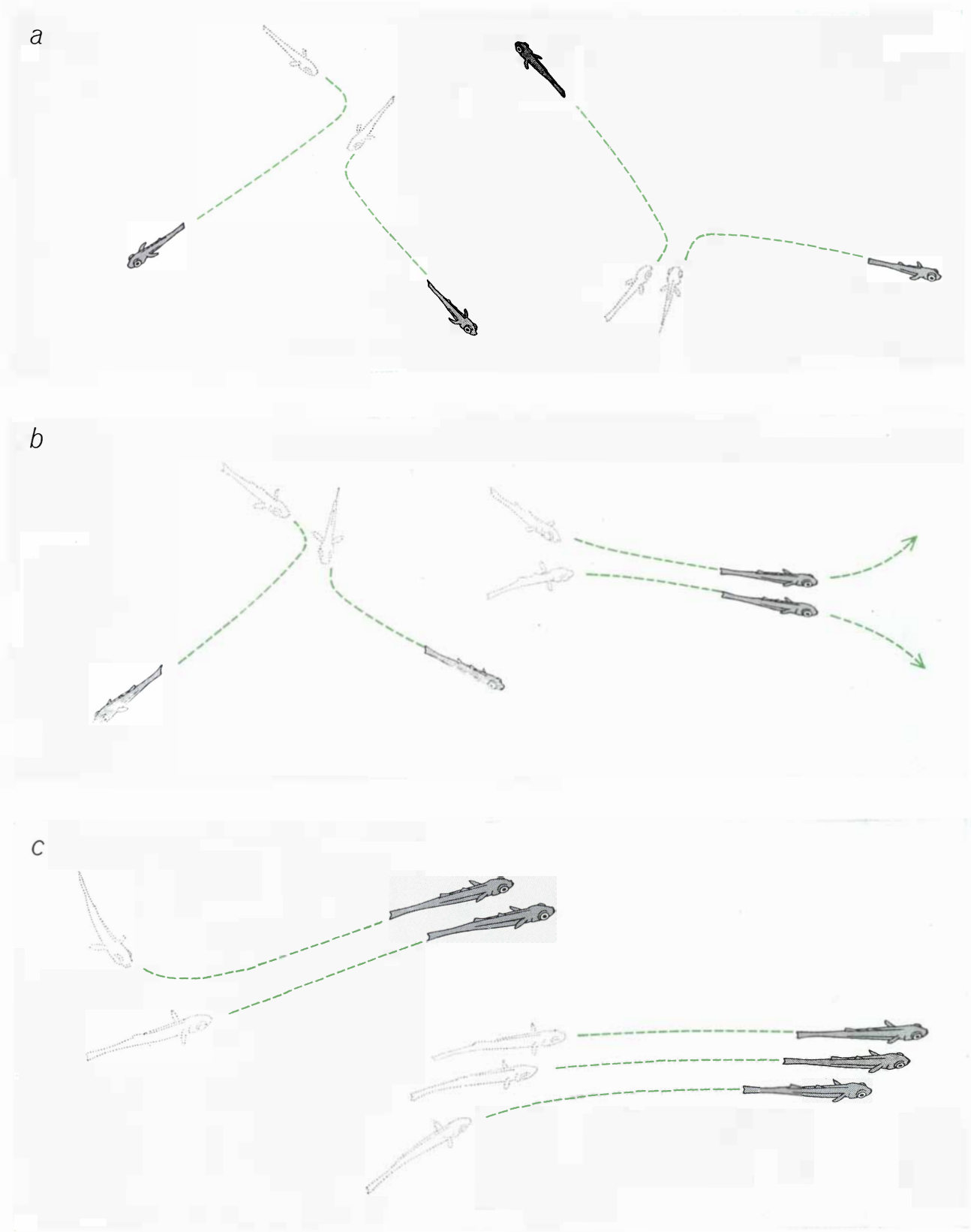
The close-up and constant surveillance in the laboratory showed that schooling unfolds gradually in characteristic patterns of fish-to-fish approach and orientation. Newly hatched fry, five to seven millimeters in length, would approach the head, the tail or the side of other fry to within five millimeters and then dart away. At eight to nine millimeters in length, a fry would approach the tail of another fry and, when the two fry were one to three centimeters apart, they would swim on a parallel course for a second or two. If either fry approached the other head on at an angle, however, each would dart off rapidly in the opposite direction. At about nine millimeters in length the head-to-tail approach became predominant, and the fry would now swim on parallel courses for five or 10 seconds. When they reached a length of 10 to 10.5 millimeters, one fry would approach the tail of another and both fry would briefly vibrate their entire bodies. This curious behavior would terminate with the two fry swimming off in tandem, or in parallel, for 30 to 60 seconds, occasionally joined by three or four other fry in the formation of a recognizable little school. The number that would engage in this behavior increased to 10 or so when the fry reached a length of 11 to 12 millimeters. With the distances from fish to fish ranging from 10 to 35 millimeters, the school was a ragged one. By the time the fry had grown to 14 millimeters the fish-to-fish spacing became less variable, ranging from 10 to 15 millimeters, and there was less shifting about in the school.

Schooling behavior can therefore be described as developing initially from the interaction of two tiny fry. As they grow older and larger, the head-on approach gives way to the head-to-tail approach; the two fry tend to swim forward in parallel instead of fleeing from one another, and they are joined by increasing numbers of individuals in the formation of the incipient school.

At this point some speculation is in order, particularly if it suggests specific hypotheses for exploration by observation and experiment. During the head-on approach, one may suppose, each fry sees a changing visual pattern:



jack (*Caranx hippos*). The fish are not drawn to scale. Tuna have been known to reach a length of 14 feet. The mackerel averages 14 to 18 inches, and the jack about two feet. The silverside grows to six inches; the herring may reach a length of 12 inches.



SCHOOLING ACTIVITY OF JUVENILE FISHES, or fry, develops as they grow. When newly hatched fry five to seven millimeters in length (*top*) approach the head, tail or side of other fry to within five millimeters, they dart away. At eight to nine millimeters (*middle*) two fry school momentarily if one has approached the tail of the other, but a side approach or one to the head still makes them dart away. As the fry grow from a length of about nine millimeters to 10.5 (*bottom*), the head-to-tail approach becomes predominant and two fry will school for five to 10 seconds; they later begin to school for short periods in threes and fours.

an oval mass (the head) and bright black spots (the eyes) coming closer and closer. The stimulus becomes too intense and each fry veers off in flight. The tail-on approach, in contrast, presents a quite different, although changing, pattern. This time it is a small silvery stripe and a transparent tail, swishing rhythmically and steadily moving away. The approaching fry follows. The leading fry may see, out of the rear edge of its eye, only a vague image of the follower. In each case the visual stimulus is moderate to weak in intensity, and the two fry swim forward together.

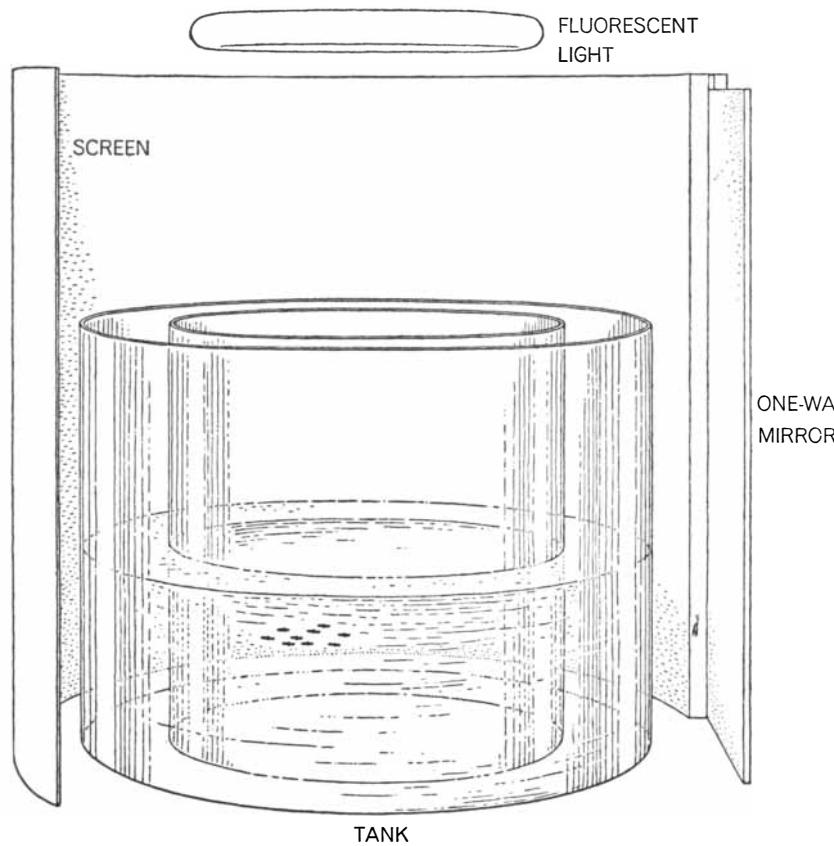
T. C. Schneirla of the American Museum of Natural History has postulated that, in general, mild stimuli attract and strong stimuli repel, and that most animals tend to approach the source of a mild stimulus and withdraw from the source of a strong one, even if they have had no prior experience with these conditions. Our fry had had considerable time to accumulate experiences of mutual encounter. We could not be certain, however, about the nature and impact of such experiences. A natural question therefore arose: Is such experience essential to the nature of schooling behavior? Or, to let the question suggest an experiment: Will fishes show schooling if they are taken away from their species-mates and raised in isolation? One must be cautious, however, in interpreting the results of such an experiment. On finding that a given behavioral trait appears in an animal that has been reared in isolation, some students of animal behavior are ready to conclude that the trait must be innate or instinctive and to close the book on further investigation at that point. Perhaps the pitfall lies in the word "isolation." No animal can grow up in a total vacuum of experience. In the case of the fry we proceeded to rear away from their species-mates, it was clear that each one had experience of itself (although we coated the bowls with paraffin so that the fry could not see their own reflection), of the water in its bowl, of the *Artemeia* shrimp on which it dined and of such stimuli as reached it from the world outside its bowl.

The mortality among the fry we isolated in this fashion proved to be extremely high. Only four out of 400 survived to schooling size in the first season and only nine out of 87 in the second. Apparently the fry need one another in the earliest larval stage, but we do not yet know why. The one noticeable difference between those reared in the community of their fellows and those reared alone seems to show up in the initiation of their feeding behavior. The fry in our laboratory communities began to feed two or three days after hatching, while they still carried a large yolky sac on their abdomen, whereas their siblings in isolation evidently starved to death. When we placed fry in isolation a week after hatching and after they had begun feeding, we secured a somewhat higher survival rate and, it turned out, a different and still enigmatic result when it came to observing the emergence of their schooling behavior.

As soon as the first four fry reared in isolation reached schooling size, we placed them in the company of schooling fish in community tanks. At first they showed disorientation; they bumped into their species-mates and occasionally swam away from the school. At the end of four hours, however, these fry could not be distinguished in behavior from the others. What this experiment showed is that fishes reared in isolation will soon join a school. It did not answer the question of whether or not schooling behavior would appear in fishes so reared.

With a more adequate supply of fry reared in isolation and in semi-isolation during the summer of 1960, we found that they would indeed form schools. The fry that had never had any contact with species-mates schooled within 10 minutes after being placed together in the test chamber. Those that had spent the first week after hatching in the company of species-mates also formed schools, but it took some of them at least 150 minutes to do so. What is more, we found that the shorter the time they had spent in isolation, the longer it took them to form a school. This suggests that their early experience with species-mates—at the period when the fry are still approaching one another at odd angles and darting away—may have set up some inhibitory process.

Although these experiments indicate that isolation in infancy does not keep these fishes from forming schools, the role of experience deserves further study. In this connection it should be added that schooling behavior was established



FISH TANK used by the author to study the development of schooling behavior in *Menidia* fry is doughnut-shaped and has a three-inch-wide channel in which the fry can swim continuously without reversing direction. The tank is completely encircled by a screen (*here cut away*). The fry are observed either from above or through the one-way mirror.

TURNING OF SCHOOL makes the relative position of the leading fish with respect to the school change. These fish (*gray*), which are originally at the leading edge (*left*), gradually shift around to the flank as the school turns (*middle and right*).

in our control communities when the fry were still a good deal smaller than the size at which we exposed our few precious isolates and semi-isolates to one another's company.

Another set of experiments with our laboratory fry produced evidence that the visual attraction of one fry for another develops in parallel with the emergence of schooling behavior. Very young fry showed no response at all to another fry swimming on the other side of a glass barrier. As the fry approached schooling age and size, however, they responded more and more actively to the visual image of the other fry. Finally they began to orient themselves in parallel to the fry on the other side of the barrier and were even observed to vibrate their bodies as they did so.

In a similar experiment with adult schooling fishes the visual attraction of one for another becomes readily apparent. Placed on each side of a glass partition, they swim toward each other immediately. In fact, fishes that cannot see cannot school. A fish blinded in one eye approaches and lines up with another fish on the side of the intact eye; a pair of fish blinded in different eyes swim at random when their sightless eyes are turned toward each other and school normally when they approach on the side with sight.

Just what visual cues are decisive in the mutual attraction of schooling fishes remains to be determined. Various experiments have shown that movement is important and that movement outweighs color and species, especially in attracting the initial approach. Albert E. Parr, now at the American Museum of Natural History, proposed in 1927 that fish-to-fish distances in schools might be explained by a balance of visual attraction and repulsion. According to Parr, the fish are repelled when they come too close together and attracted when they swim too far apart; the typical spacing in the school would thus represent the equilibrium of these two forces.

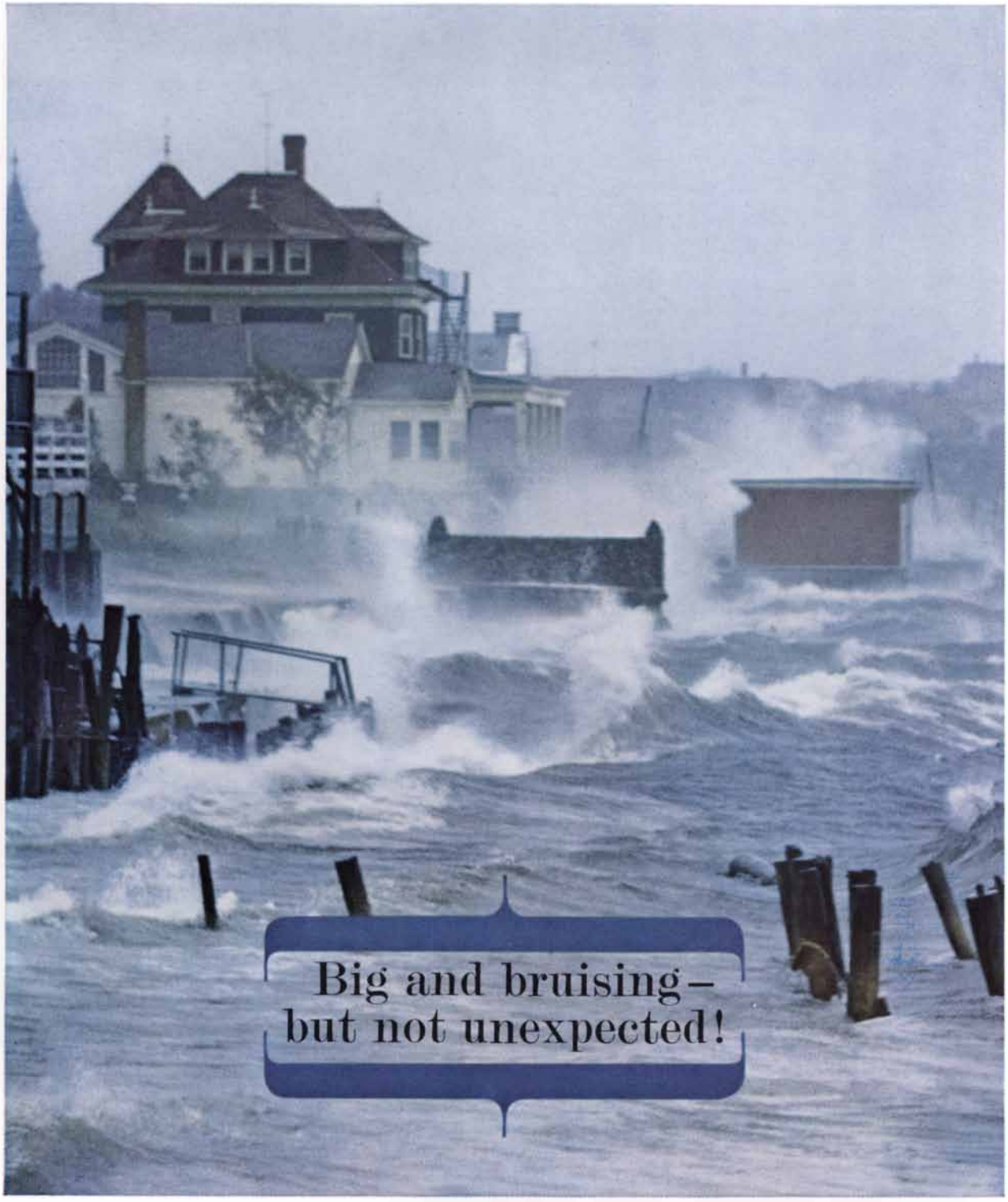
In a study of the schooling species around Cape Cod, Edward R. Baylor of the Woods Hole Oceanographic Institution and I found that many of these fishes are farsighted and that their retinas are therefore presented with a somewhat fuzzy image. The distribution of rod and cone cells in their retinas indicates, on the other hand, that their eyes may be well adapted for enhanced perception of contrast and so of motion against the hazy underwater background. This kind of vision would be highly adaptive in schooling behavior. Baylor and I also tried to modify the fish-to-fish schooling distance in pairs of fish by placing contact lenses over their eyes, but we observed no conclusive effects.

Although it appears that the visual apparatus is dominant in schooling behavior, there is also evidence that it does not serve as the exclusive channel of mutual attraction among fish. M. H. A. Keenleyside of the Fisheries Research Board of Canada has observed, for example, that *Pristella*, a species that sometimes schools, would respond to fish on the other side of a glass barrier by swimming back and forth along the barrier but would gradually lose interest, wandering away from the barrier more and more frequently and finally not returning at all. Sensory cues other than visual ones are most likely involved in establishing the parallel orientation and the fish-to-fish distances that give the school its ordered structure. It is difficult to determine which cues, because the experimenter cannot control for vision—a fish deprived of sight cannot make the initial approach so essential to the rest of the process.

Hearing, taste and smell have all been implicated, although inconclusively. James M. Moulton of Bowdoin College found that different schooling species produce different sounds, mostly of hydrodynamic origin, as the fish stream and veer through the water. Such sounds, in Moulton's opinion, may help to maintain the total school. There is no evidence, however, that sound helps to keep an individual fish oriented in position in the school. There is even less to be said for taste and smell, particularly in the case of oceanic fishes. Such odors as the fishes might produce would be diluted in the sea; although they might act on individuals at the trailing edge of a school, they could play little role in the behavior of those in the vanguard.

The one sensory system that would seem to be designed to play a role in the orientation of fish to fish is that associated with the lateral line—the nerve and its associated branches that are distributed over the head and run from head to tail along each side. It is thought that this organ is responsive to vibrations and water movements. Willem A. van Bergeijk and G. G. Harris at the Bell Telephone Laboratories have reported evidence indicating that the lateral line is sensitive particularly to "near field" motion of the water produced by propagated sound waves. Parallel orientation may well be facilitated by information about the movements of nearby fish picked up by the lateral line. The approach of one fish to another induced by visual attraction might also be checked by the increasing force of lateral-line perceptions of the movements of the same companion at closer range.

That schooling is a successful way of life can be judged from the fact that so many fishes have adopted it. Some 2,000 marine species school, and there

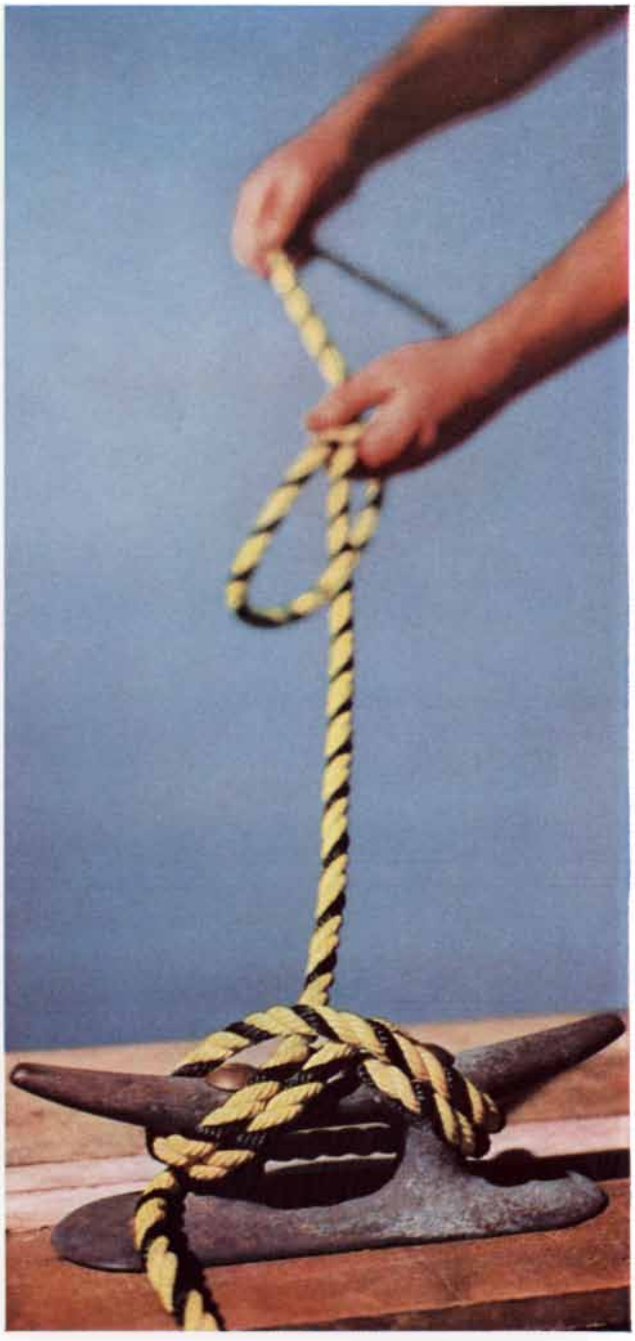


A revolution is taking place in weather forecasting. Satellites equipped with television cameras are helping meteorologists plot the courses of oncoming hurricanes, thereby saving lives and minimizing property damage. To pick up this valuable weather data, sensitive tracking antennas are used to monitor these satellites. An important component part of the antennas is high frequency coaxial cable made by Phelps Dodge. In applied electronics, in communications, in power transmission, in so many areas that are vital to America's progress, Phelps Dodge is playing a basic role.

Deep in the process of shaping the future!

PHELPS DODGE COPPER PRODUCTS

CORPORATION • 300 Park Avenue, New York 22, New York



To line a ditch or hold a hitch, call on Enjay skills

When a new secretary asked her Enjay boss what "technical service" meant, he didn't know where to start. One day we may be working on a way to help farmers conserve precious water by developing a better irrigation ditch liner of Enjay Butyl rubber; the next, helping rope manufacturers offer a better product at lower cost with Escon® polypropylene.

In solving such problems, Enjay can call upon one of the world's largest research organizations, made up of 2900 highly trained technical experts, many of whom are nationally recognized authorities. Enjay sales offices across the country are also staffed by experts, able to serve you in both technical and marketing matters.

Competent technical assistance from Enjay has sometimes made the vital difference in a critical development program. If your company uses chemicals, plastics, rubber or petroleum additives, we're ready to go to work for you. For further information please write to Enjay, 60 West 49th Street, New York 20, New York.

ENJAY CHEMICAL COMPANY, a division of Humble Oil & Refining Company ENJAY

is a major group—the Cypriniformes, consisting mainly of fresh-water fishes—that contains 2,000 more schooling species; among them are the common fresh-water minnows, or shiners, and the familiar characins of the tabletop aquarium. It is evident that these fishes must have converged on the schooling way of life by diverse evolutionary pathways. Of the marine fishes the best-known schooling orders are three that rank among the most numerous in the sea and constitute a vast portion of the world's fish supply. They are the Clupeiformes, the well-known herrings; the Mugiliformes, which include, in addition to the schooling mullets and our laboratory silversides, the solitary barracuda; the Perciformes, comprising the schooling jacks, pompanos, bluefishes, mackerels and tuna and the occasionally schooling snappers and grunts as well as numerous families of nonschoolers. Anatomically the Clupeiformes and the Mugiliformes are rather primitive fishes, whereas the Perciformes are advanced. Although unrelated, these fishes do have significant features in common. Like many other schooling fishes, they are generally sleek and silvery. Significantly, they also have the same small and flattened pectoral fins actuated by musculature that does not permit much mobility. As C. M. Breder, Jr., of the American Museum of Natural History was the first to observe, these fishes cannot swim backward. When they make a pass at a bit of food and happen to miss it, they must come around on a wide turn for another attempt. This limitation on their maneuverability must nonetheless be an advantage in the maintenance of a school, because it tends to keep them all moving forward.

Since the schooling families include anatomically primitive as well as advanced forms, the evidence from living species does not show whether schooling is a primitive or an advanced adaptation. The fossil record is equally inconclusive on this score. Herrings are found in great number in Eocene deposits and one may reasonably speculate that they were schooling then. But fishes were evolving long before the Eocene, and it is impossible to determine one way or the other whether the fishes of those times schooled.

In spite of all the indications that schooling is an effective adaptation, no student of the subject has been able to show why it is so effective. Many advantages can be cited in favor of the behavior, but none seems critical to survival. It is said, for example, that the school creates for its predators, as it does for human observers, the illusion that it is a huge and formidable animal of some kind and so frightens off the predator. No real evidence supports this idea, and one can more plausibly see the school as providing easy prey. If the predator misses one fish, there is always another. In an experiment with goldfish, on the other hand, Carl Welty of Beloit College found that the fish consumed fewer *Daphnia* when they

SCHOOL OF ATLANTIC MENHADEN in Long Island Sound was photographed from the air by Jan Hahn of the Woods Hole Oceanographic Institution. The menhaden, which is a species of herring, forms schools containing as many as a million members.

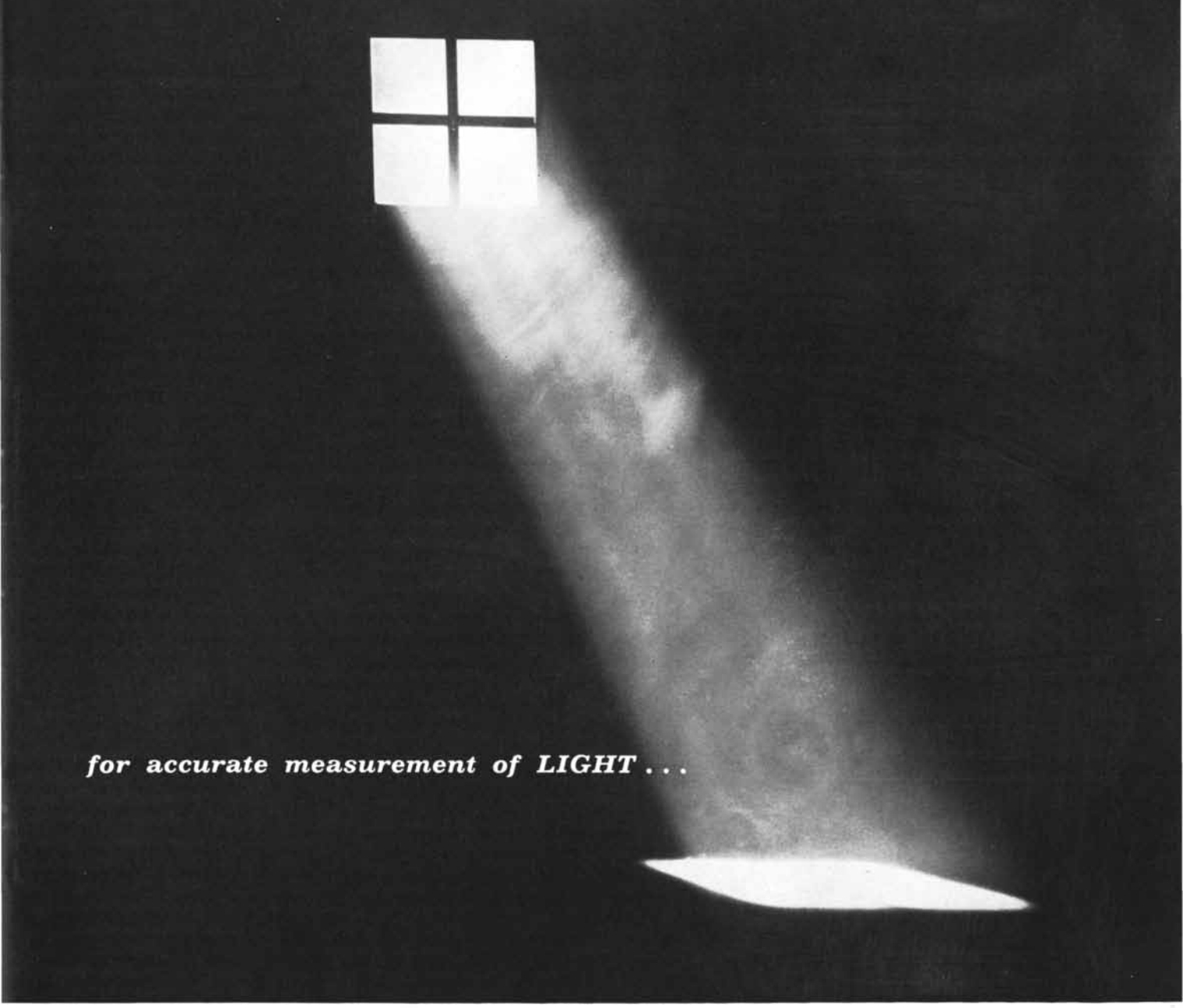
were fed too many than they did if they were allowed a smaller number. Welty suggested that large numbers of prey might "confuse" the predator. This idea finds support in a mathematical analysis by Vernon E. Brock and Robert H. Riffenburgh of the University of Hawaii, which shows that a school cannot be decimated by attackers once it exceeds a certain number. But one must then ask: Why do some predators school?

Another rationalization for schooling holds that it facilitates the finding of food. When it comes to the search itself, however, only the fish on the school's periphery will be in a position to locate the food; the talents of those in the center of the school are wasted. Of course, once the food is sighted, all may partake. The young of many fishes travel in schools, and their social feeding seemingly promotes more rapid growth. As our efforts to raise fry in isolation would indicate, the sight (or taste and smell) of other fish feeding induces fish to feed. Again, one must doubt that this advantage could account for the evolution of schooling behavior in so many different species.

Another advantage, often cited, has to do with the reproduction of the schooling species. When it is time to reproduce, there is no courtship behavior, no mate selection; as Parr observed some years ago, the males and females of schooling species are usually indistinguishable on casual inspection. The fishes simply shed their eggs and sperm in almost countless numbers into the plankton and leave the spawning site. This certainly enhances the probability of successful fertilization. In some of my collecting, however, I have found schools that were either all male or all female!

To the list of potential adaptive advantages I would like to add another one. Hydrodynamic considerations argue that schooling provides a more efficient way to move through the water. The exertion of each fish may be lessened because it can utilize the turbulence produced by the surrounding fish. Although the fish at the leading edge of the school may have to expend no less energy than solitary fish, the followers may receive enough assistance to help reduce their expenditure of energy. The attainment of maximum efficiency may dictate an optimum fish-to-fish distance in the school.

Study of the schooling of fishes has asked more questions than it has answered. But the questions have now begun to suggest fruitful programs of observation and experiment.



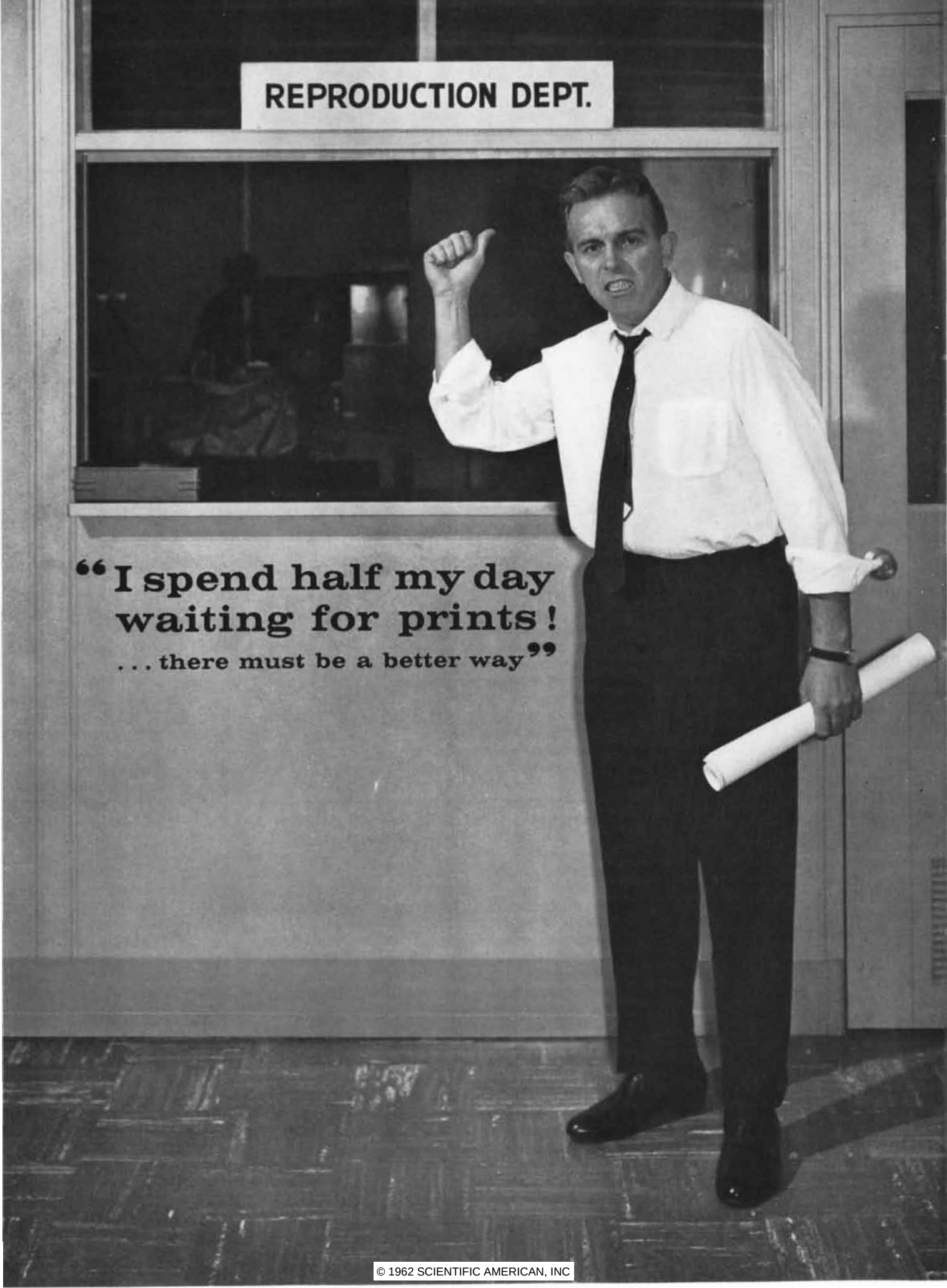
Instrumentation by General Electric

Whether interpreting light values for perfect film exposures or for precise color analysis, General Electric instruments achieve the ultimate in sensitivity and accuracy. In addition to pioneering progress in light measurement, General Electric research helps build industry's profits by creating other reliable instruments and instrumentation systems for equipment manufacturers, plant users, utilities and the aerospace industry.

For our 16-page color bulletin, "A Profile of Instruments Capability," contact your G-E sales representative, or write General Electric Co., Section 594-02F, Schenectady 5, N. Y.

INSTRUMENT DEPARTMENT

GENERAL ELECTRIC



There is!... Put your print file on card-mounted microfilm. Then you can fill print requisitions immediately by xerography. You get dry, positive prints on ordinary paper, ready for immediate use. They're easy to write on with pen or pencil. Quality is excellent and prints are so inexpensive they can be discarded after use.

Xerographic printers offer the fastest, most economical way to get sharp, clear prints from microfilm . . . size for size or reduced. Just push the button... and copies flow! Prints may be on vellum or offset paper masters, as well as ordinary paper.

Still another bonus: your storage space can be drastically reduced. Microfilm aperture cards require only 5% of the filing space required for conventional reproducibles.

Get complete information on this modern reproduction system that eliminates costly waiting for engineering prints. Write for booklet X-300 today. XEROX CORPORATION (formerly Haloid Xerox Inc.), 62-88X Lyell Ave., Rochester 3, N. Y. Branch offices in principal U. S. and Canadian cities. *Overseas:* Rank-Xerox Ltd., London.

XEROX
CORPORATION

The Analysis of Brain Waves

By rapid averaging and other procedures, electronic computers are helping investigators to extract much new information from the complex recordings of the electrical activity of the brain

by Mary A. B. Brazier

The electrical activity that can be recorded from the surface of the human head is probably the most baffling cryptogram to be found in nature. It is therefore not surprising that electrophysiologists have turned to electronic computers for help. First observed in animals by the English physiologist Richard Caton in 1875, the surface waves reflect the rich and constantly changing electrical activity of the brain. The first recordings from the human brain were made in 1924 by Hans Berger, a German psychiatrist who, because of his oddly secretive nature, withheld publication of his "electroencephalograms" until 1929. The reception was at first skeptical, but the electroencephalogram, or EEG, soon demonstrated its value in the diagnosis of epilepsy and other brain damage. Now, within the past 20 years, physiologists have made a start at decoding the EEG and have begun to show how it is related to the functioning of the nervous system.

For analyzing the electrical activity of the brain the electronic computer has emerged as an instrument of great power and versatility. One of the principal uses of the computer is to extract meaningful signals from the background electrical noise generated by the brain, which normally makes any single recording undecipherable. Although analyses of this sort are usually performed with magnetic-tape records of the brain's activity, the computer becomes even more useful when it is designed to make its analyses in "real" time, while the subject is still connected to the recording apparatus and while the investigator is still able to manipulate the experimental variables. Employed in this way, the computer becomes a subtle new tool for the studies of neurophysiology.

In man the fluctuating potential difference between leads on the unshaved scalp is commonly between 50 and 100 millionths of a volt, or about a tenth the magnitude of electrocardiographic potentials. These waves are most prominent at the back of the head over the visual-association areas of the brain; waves recorded there are called alpha waves. The alpha rhythm, which has a frequency of between eight and 13 per second in adult subjects, is most conspicuous when the eyes are closed. The alpha waves disappear momentarily when the eyes are opened.

Because of the regularity of the alpha rhythm, its frequency characteristics received most of the attention in the early days of electroencephalography. Physi-

ELECTRODES ON SCALP detect brain waves. This subject, in an isolated room, is viewing brief flashes of light at regular intervals. A special computer simultaneously analyzes the brain waves from the visual region in back of head, producing the record seen in illustration on page 150. The photograph was made at the Massachusetts Institute of Technology.

ologists reasoned that if these waves were analyzed mathematically, using the technique known as Fourier analysis, components might be uncovered that were hidden to the unaided eye. The principle behind Fourier analysis is that any periodic wave form, however complex, can be resolved into elementary sine-wave components. Unfortunately the brain emits so many irregular and nonperiodic potential changes that the usefulness of this well-known principle is open to challenge.

During World War II W. Grey Walter of the Burden Neurological Institute in England spearheaded the development of the first practical instrument for making an automatic frequency analysis of consecutive short segments—each arbitrarily limited to 10 seconds—of an EEG trace. The Walter analyzer reports the mean relative amplitude at each frequency over the whole period being integrated but cannot indicate the time sequence in which the frequencies occur. A short wave train of high amplitude has the same effect on the integrating device as a long train of low amplitude. Also lost is all information about phase relations between trains of waves.

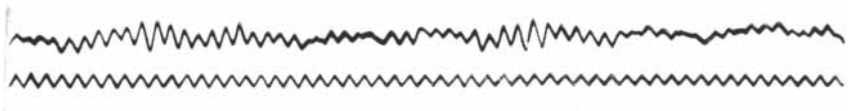
This type of analysis proved especially valuable when coupled with the finding that the frequency characteristics of the human EEG can often be controlled by having the subject look at a flashing light; the technique, called photic driving, was discovered in the early 1940's. Subsequently it was found that flashes of specific frequency will induce epileptic seizures in some epileptic patients. This is an example of a physiological finding reaching over into medicine to become a clinical diagnostic test. The Walter analyzer, which can be regarded as an early form of computer, still provides the simplest and most practical method for obtaining the average frequency spectrum of an EEG trace.

The rapid development of high-speed general-purpose and special-purpose computers in the past decade has opened up many new ways of analyzing the brain's electrical activity. At the same time techniques have been perfected for recording from electrodes implanted within the unanesthetized brain and left in place for weeks or months. Although used primarily with animals, the technique has been extended to man for diagnostic and therapeutic purposes.

It is therefore now possible to study the relation of the brain's electrical activity to behavioral performance and, in the case of man, to subjective experience. After a long period of concentrating on the rhythm observable when the subject was at rest with the eyes closed, electroencephalographers began to divert their attention from "the engine when idling" to the "engine at work," thereby examining how the brain responds to various stimuli.

Many types of stimulation can be used —sounds, odors, flashes of light, touch and so on—and their effect can be traced in brain recordings made both at the surface and deep within the brain. When such studies were first attempted in unanesthetized animals and man, it was soon discovered that the specific responses were largely masked, in the unanalyzed trace, by the ongoing EEG activity of the normal brain, activity that

AVERAGE RESPONSE COMPUTER (ARC) was designed by W. A. Clark, Jr., of the Lincoln Laboratory of M.I.T. It samples the brain waves for a prescribed interval after each stimulus, adding and averaging the samples. Oscilloscope face on computer (*left*) displays trace of average as the experiment proceeds. Reels of magnetic tape (*center, rear*) permanently record all the raw data. In the foreground, beside the laboratory technician, is an "X-Y plotter," which makes pen tracings of the averaged data.



FIRST PUBLISHED ELECTROENCEPHALOGRAM (EEG) of man appeared in 1929. The recording was made by the German psychiatrist Hans Berger from the scalp of his young son. Upper channel is the EEG, lower one an artificial sine wave used as a marker.

had been conveniently depressed by the anesthetic agents in the earlier studies. Since the electrodes used must be small enough to discriminate between neuronal structures less than a millimeter apart, appropriate computer techniques are essential for detecting the faint signals that are all but lost in the roar of biological noise that is the normal milieu of the active brain.

The principal means for increasing the signal-to-noise ratio is simply to have the computer add up a large number of responses—anywhere from a few dozen to a few hundred—and calculate an average response. One can then regard this average response, or certain features of it, as the characteristic "signal" elicited by a given stimulus. In applying this technique the neurophysiologist must necessarily make certain assumptions about the character of the biological phenomena he regards as signal and that which he chooses to call noise.

In the usual averaging procedure the brain's potential changes, as picked up by several electrodes, are recorded on multichannel magnetic tape, in which one channel carries a pulse coincident with delivery of the stimulus. Since the stimulus may be presented at irregular intervals, a pulse is needed as a time marker from which the responses are "lined up" for averaging. In the averaging process only those potential changes that occur with a constant time relation to the pulse are preserved and emphasized. Those unrelated in time cancel out in the averaging process, even though in any single record they may be of higher amplitude. In this way responses never before detectable at the surface of the human skull not only can be found but also can be correlated with the subject's report of his sensations.

For example, the lightest of taps on the back of the hand is found to evoke a clear-cut response in one special area on the opposite side of the head [*see illustrations on page 148*]. Other computer analyses show that a click in the ear gives a decipherable response in another location on the scalp. A flash of light not only evokes an immediate sharp response in the visual area at the back of the head but also gives rise to a long-lasting train of waves, all time-locked to the flash [*see illustration on page 150*]. It has been shown, moreover, that clinical patients who report a disturbance in their subjective sensation of touch, hearing or sight produce EEG traces that reveal distortions when analyzed by computer.

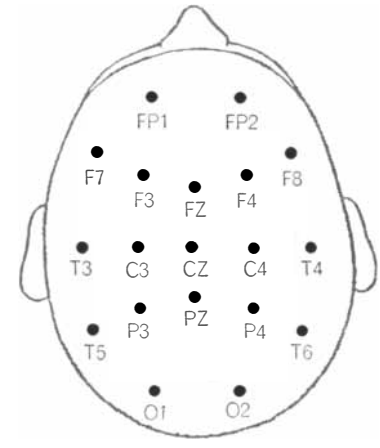
The long-lasting train of waves evoked by a flash of light raises a number of questions. Is this the electrical sign of further processing of the initial message received by the eye? Is it the sign that the experience is being passed into storage, initiating in its passage the cellular changes that underlie memory? There is already evidence that under conditions that retain the initial sharp response but obliterate the subsequent wave train all memory of the experience is expunged. Two such conditions, which support this suggestion in human experiments, are anesthesia and hypnotically induced blindness.

Valuable though computers can be for averaging taped EEG records, they still leave the investigator feeling somewhat frustrated. Hours, and sometimes days, may elapse between the experiment and the completed analysis of the recordings. When he sees the results, the investigator often wishes he could have changed the experimental conditions slightly, perhaps to accentuate a trend of some sort that seemed to be developing, but it is too late. The experimental material of the biologist, and particularly of the electrophysiologist studying the brain, is living, changing material from which he must seize the opportunity to extract all possible information before the passage of time introduces new variables. The computers familiar to business and industry have not been designed with this problem in mind.

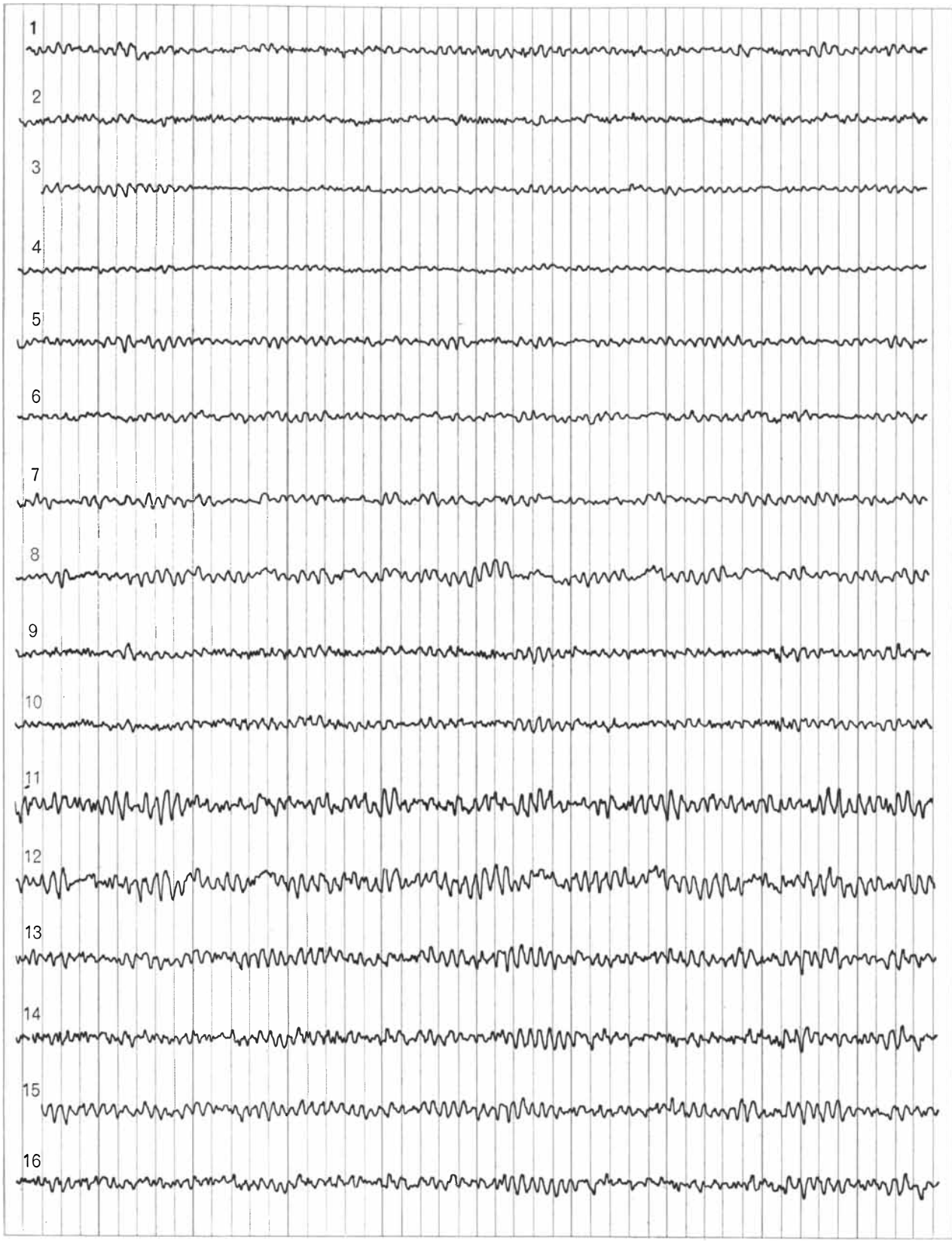
To meet the needs of the neurophysiologist a few computers have now been built that process brain recordings virtually as fast as data is fed in from the electrodes. The investigator can observe the results of his manipulations on the face of a cathode-ray tube or other display device and can modify his experiment at will. One of the first machines built to operate in this way is the Average Response Computer (ARC), designed by W. A. Clark, Jr., of the Lincoln Laboratory of the Massachusetts Institute of Technology [*see illustration on preceding page*]. ARC is a simple-to-operate, special-purpose digital computer that requires no programmer as a middleman between the biologist and the machine.

When searching for an evoked response, Clark's computer samples the EEG at a prescribed interval after the stimulus, converts it into a seven-digit binary number proportional to the amplitude and sends the number into one of the many memory registers. This particular register receives and adds all further numbers obtained at the same interval after each stimulus. ARC is equipped to sample the EEG at 254 different time intervals and to store thousands of samples at each interval. Only rarely, however, is the full capacity of the register required. The cumulative sums in each register are displayed on an oscilloscope after each stimulus [*see illustration on page 146*]. The investigator watches the cumulative display and stops the stimulation when he sees that he has enough signal-to-noise discrimination to satisfy the needs of the experiment. He can then photograph the face of the oscilloscope or have the cumulative wave form printed out graphically by a plotter.

What might one see if one were to watch the build-up of summed re-



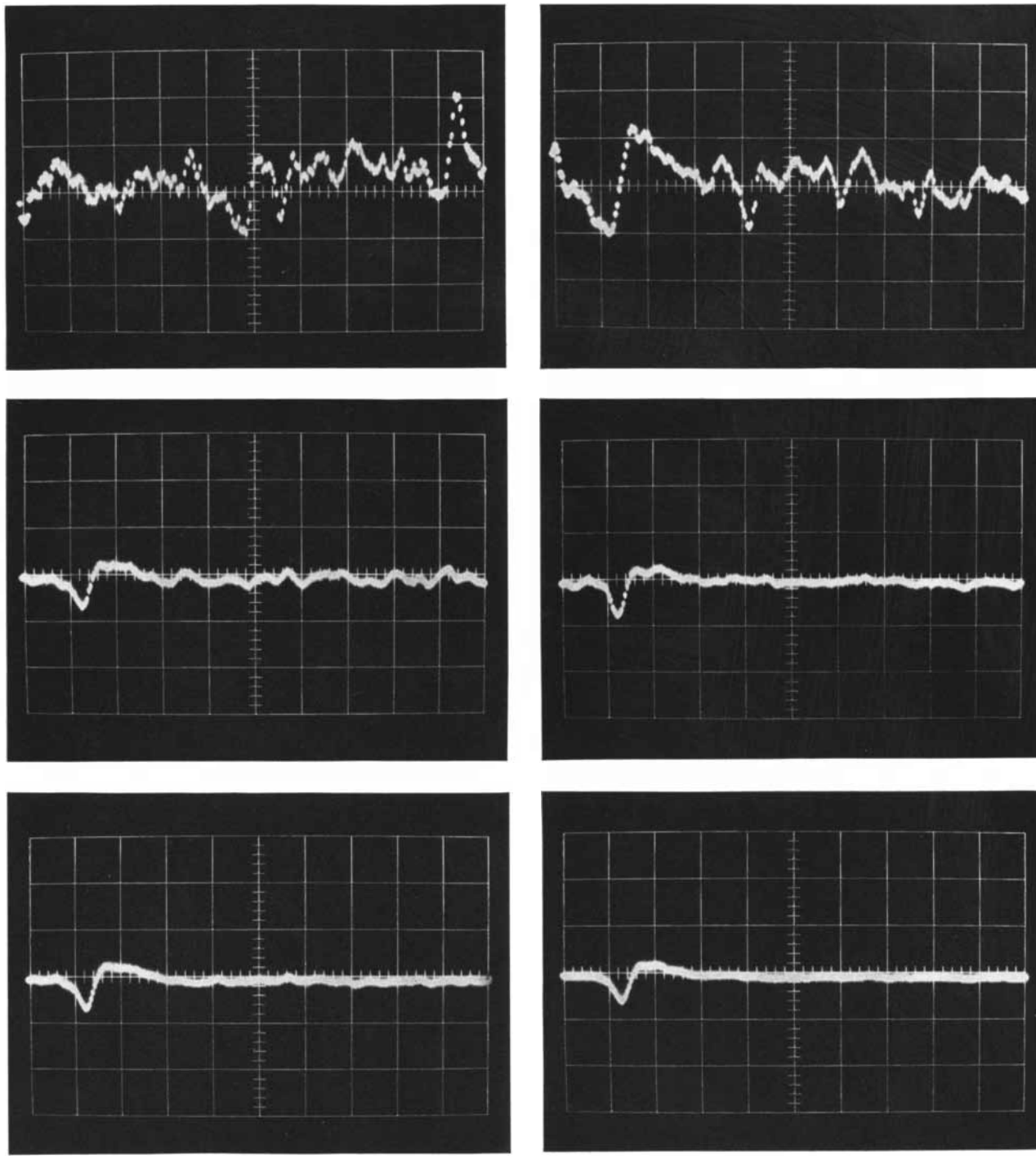
TYPICAL MODERN EEG shows that different regions of cortex give rhythms that differ widely. Berger thought the whole brain



emitted only one rhythm. Today as many as 16, 24 and even 32 channels can be used. The great complexity obviously makes computer analysis desirable. Each EEG trace records changes in electric potential between two electrodes. Thus line 1 came from electrodes FP1 and F7 on head as diagramed at left, while line 10 came from FP2 and C4. This data has not been processed by a computer.

sponses? If the man or animal being studied were anesthetized, the response would be markedly stereotyped; the averaged sum of 100 responses would look very much like the average of 50 responses. This is not so if the subject is unanesthetized. Responses to a series of clicks or flashes of light may show great variation, both in wave shape and in amplitude, and may require many samples before the characteristic signal emerges clearly from the background noise.

Operating in another of its modes, ARC can give an amplitude histogram, or profile, at any chosen interval after the stimulus. Such histograms indicate the degree of fluctuation of the response and its complexity. They supply the investigator with important clues to the behavioral state of the subject, to his level of wakefulness, to the degree of attention he is paying to the stimulus and to the feelings the stimulus arouses.



OSCILLOSCOPE TRACES of responses as averaged by computer appear while experiment is in progress, enabling experimenter to observe in "real time." As a result he can change conditions and stop when he has enough data. The traces (*left to right, top to bottom*) are averages of 1, 2, 32, 64, 128 and 512 responses. These traces appeared during an experiment by Nelson Kiang of the Eaton-Peabody Laboratory of the Massachusetts Eye and Ear Infirmary in Boston. The subject was responding to a long series of clicks.

When ARC is operated in the histogram mode, the memory registers are set to count the number of times the amplitude, or voltage, of the EEG falls within a certain preset range. Each register is set for a different range and the results are finally written out as a histogram for the chosen interval [*see top illustration on page 152*]. By analyzing other intervals similarly one can put together a composite survey.

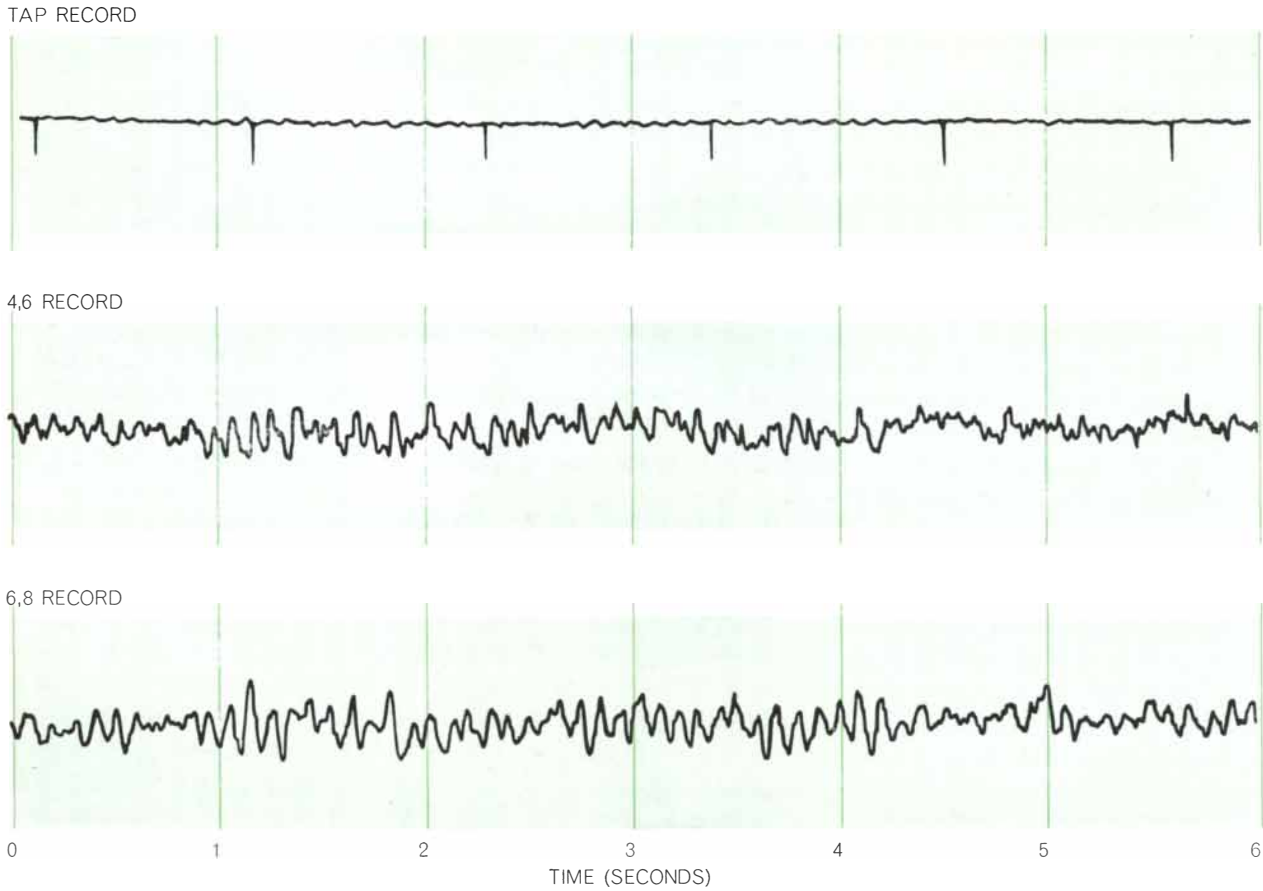
The study of such records may reveal little dispersion of amplitude at some particular interval after the stimulus and a much greater dispersion at some other interval. This may be a clue that the neuronal message in the first case has traveled over a nerve pathway containing few synapses, or relays, and thus has been subject to little dispersion, whereas in the second case the message has reached the recording site after traveling through multiple paths that finally converge. The complex wave train evoked by a single flash of light is susceptible to this interpretation. The initial deflection is caused by impulses that have traveled through a few synapses only and by means of the large, rapidly conducting fibers of the specific visual system. The subsequent shallower waves—so clearly revealed by the computer—reach the cortex through the more slowly conducting, indirect, nonspecific system with its many relay stations. The histogram of the earlier event, being more stereotyped, shows less dispersion around the median than does the histogram of the later events. Still more elaborate processing of histograms can show whether the amplitudes follow a normal, bell-shaped distribution pattern or are skewed in some manner.

If a physicist were to analyze the results of a series of complex experiments in his field, he would normally expect to find the results to be invariant. The biologist, working with an unanesthetized animal or man, can search in vain for an invariant response. It is precisely this subtlety of variation that electrophysiologists have recently identified as the concomitant of behavioral change. One such change is known as habituation. Early workers in electrophysiology could perceive, in their unanalyzed records, subtle changes in the shape of an EEG trace when the subject had been repeatedly exposed to the same stimulus. Computer analyses have now revealed clearly that under such conditions significant changes take place not only in the EEG as recorded outside the skull but even more markedly in

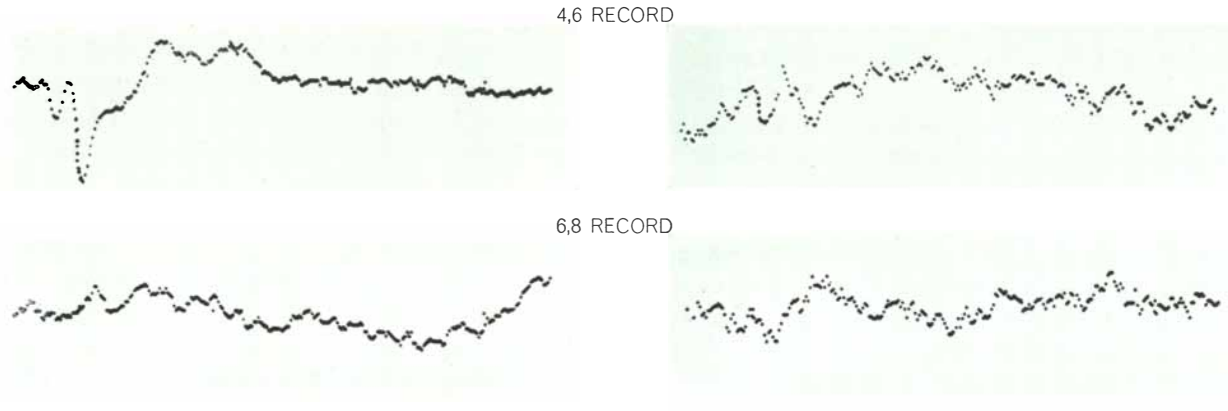
recordings made deep within the brain.

For example, the Average Response Computer has been used to analyze the electrical activity recorded from a particular relay station in a nucleus located deep in the mid-line region of an animal's brain. The nucleus, in turn, lies within the portion of the brain called the thalamus. Until a dozen years ago little except its anatomy was known about this mid-line region of the thalamus and its inflow from the portion of the brain stem called the reticular formation. The thalamic region and the reticular formation together constitute the nonspecific sensory system mentioned earlier.

In 1949 H. W. Magoun (now at the University of California in Los Angeles) and G. Moruzzi (now at the Uni-



REGULAR TAPS ON LEFT HAND, indicated by top trace, do not show up in standard EEG (*next two traces*). Ongoing activity of brain drowns signal even though electrode 4 (*see diagram of head on opposite page*) is over area that receives nerve inflow from hand.



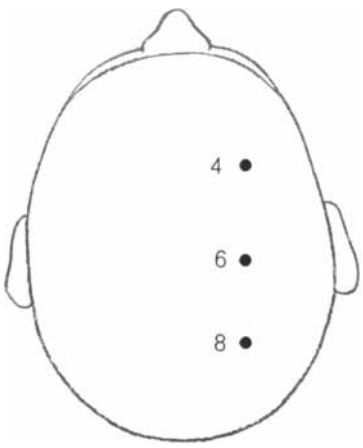
AVERAGED RESPONSE after 90 taps, however, tells a different story. Upper trace at left, from electrodes 4 and 6, shows that the brain definitely reacts to the taps. The computer also detects a faint response when the right hand, which is on the same side of the body as the electrodes, is tapped. (Nerves on the left side of the body are connected with the right side of the brain and vice versa.)

versity of Pisa) jointly discovered that the reticular system is crucially concerned with the organism's state of alertness and with the behavioral nuances that lie in the continuum between vigilant attention and the oblivion of sleep. Later work has revealed further nuances that can be discerned in the electrical record only with the fine-grained analyses that a computer can provide.

Computer analyses of records from one of the mid-line nuclei of this nonspecific sensory system in an unanesthetized animal have detected many unsuspected details. For example, when a light, flashing at a constant rate, is directed into the animal's eye, the ARC oscilloscope reveals that the averaged response is not at all simple but contains three distinct components and that, as time passes, one of these components gradually fades out. If the computer's mode of operation is then changed so as to produce amplitude histograms, the third component is found to have a greater dispersion than the other two and a skewed distribution.

A hypothesis suggests itself. One of the relatively constant components may pass on to the visual cortex, thereby signifying to the animal that the stimulus is visual and not, say, olfactory or auditory. Perhaps the second component indicates that the stimulus is a recurrent one. The third and waning component may be signaling "unexpectedness" and, by dropping out, may carry the message that the stimulus is simply repeating over and over without change. It may be saying, in effect, that the stimulus is devoid of novelty (or information) and can be safely ignored.

The experimenter, still watching the computer's oscilloscope, can then pro-



The averaged record from electrodes 6 and 8, which are not over the "hand area" of the brain, shows no response to the taps.

ceed to test this hypothesis by introducing novelty into the stimulus. For example, he can change the strength of the flash, its wavelength or its repetition rate, and watch for the reappearance of the third component. In this way the three-way interlocution between investigator, subject and machine proceeds.

The questions the investigator asks are not exhausted by those outlined above. He may want to know what the individual cells of the brain are doing. It has been known for many years that the frequency of action "spikes" in a nerve fiber is related to the intensity of the stimulus. As a rule the more intense the stimulus, the higher the firing rate. But how wasteful of "channel capacity" (to use the language of information theory) it would be if the only information conveyed by the action spikes were limited to stimulus intensity.

This has led investigators to consider the fluctuations in the groupings of these unit discharges. The unanalyzed record is bewildering, because different kinds of cell give different patterns of response to a given stimulus. Some that were busily active stop firing when the stimulus is given; others wake from idleness and burst into activity; still others signal their response by a change in the pattern of discharge.

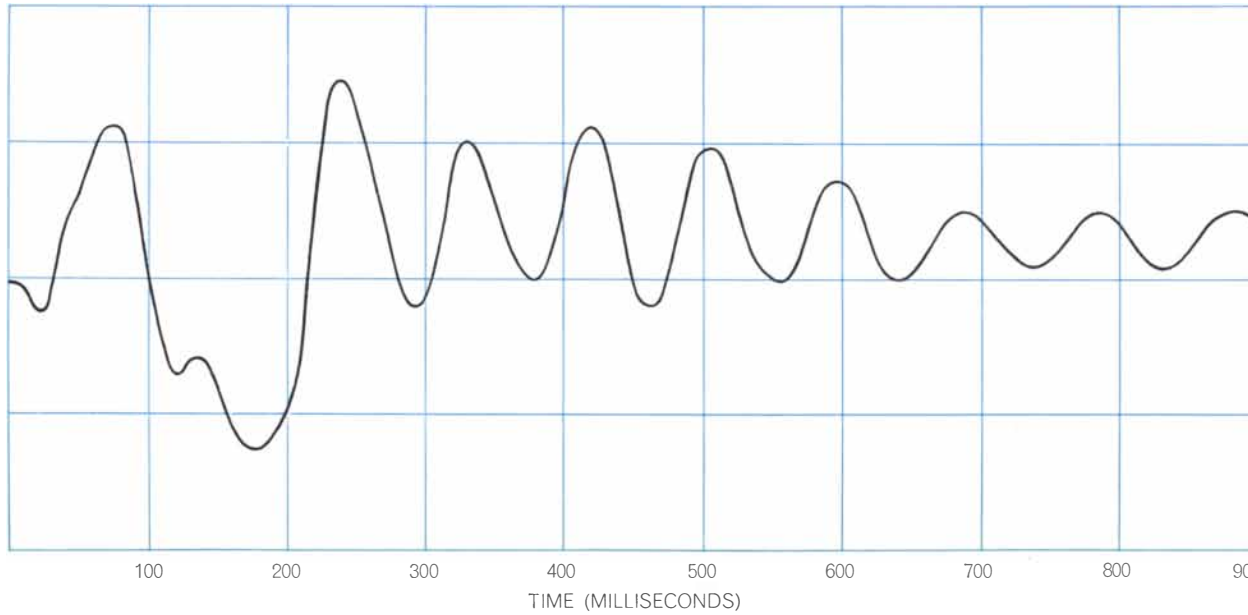
Computers are invaluable for this type of analysis. The Average Response Computer, as one example, has a special mode of operation that helps to clarify this patterning of activity in individual brain cells. It does this by giving a histogram of the time intervals between successive cell discharges. Each of its memory registers is allotted a different interspike interval. Whenever a cell fires, the interval since the last firing is established and a digit is added to the appropriate register. On command, the digits accumulated in the different registers are written out as a histogram [*see bottom illustration on page 152*]. Analyses of this kind, pioneered by George L. Gerstein with the TX-O computer at the Massachusetts Institute of Technology, have revealed a differentiation of response mechanisms among cortical cells that indicates a far greater degree of discriminatory capability than the old frequency-intensity rule would suggest.

Among other computer techniques under development are those for identification of temporal patterns in the EEG. These techniques should relieve the electroencephalographer of the tedium of searching many yards of records for meaningful changes. For example, Belmont Farley of the Lincoln Laboratory of M.I.T. has worked out programs for analyzing the trains of alpha rhythm that come and go in the EEG of man and provide clues to his level of consciousness and to the normality of his brain.

Farley's program specifies the range of amplitude, frequency and duration of the pattern known as an alpha burst. The program allows the investigator to make a statistical examination of the EEG of the same individual, as recorded under different experimental circumstances. The investigator may be interested in the effect of drugs or the changes brought about by conditioning of behavior. The degree of variation in the EEG can be accurately and objectively assessed, removing the hazards of subjective judgment. It is obvious that such objective methods of appraisal can be of great value in the clinical use of the EEG.

The rhythmicity of the EEG, as exemplified in the alpha rhythm, continues to be a mystery. It was first thought that brain waves were merely the envelopes of the spike discharges of the underlying neurons. But this view had to be abandoned when microelectrodes, reporting from inside the brain, showed the hypothesis untenable. It is now thought that the EEG waves reflect the waxing and waning of excitability in what are called the dendritic layers of the cortex. (Dendrites are hairlike processes that extend from the body of a nerve cell.) Quite unlike the explosive discharge of the nerve cell itself, the finely graded changes in dendritic activity seem to modulate cortical excitability.

In the common laboratory animals, with their comparatively small association cortexes, the simple, almost sinusoidal oscillation of the alpha rhythm is hard to find, if it exists at all. It is therefore tempting to relate rhythmic



LONG-LASTING TRAIN OF WAVES can be recorded from scalp following flash of light. This, of course, is an averaged record of many responses to many flashes. It emphasizes only the changes in electric potential time-locked to the flash and washes out the "noisy" background activity, which is actually of much higher amplitude. The flashes were all synchronized with beginning of trace.

waves to the large volume of association cortex possessed by man. These rhythmic waves usually signify that the brain is not under bombardment by stimuli, and their stability may reflect the homeostatic, or self-stabilizing, processes of the association cortex when undisturbed by the processing of transmitted messages.

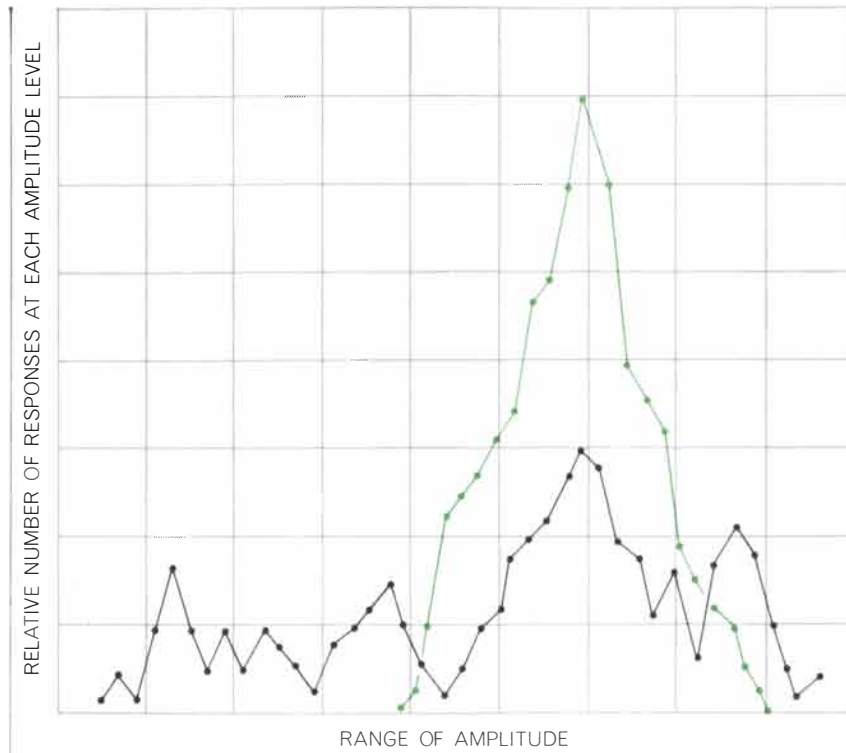
In the course of evolution homeostatic processes throughout the body, largely under the control of the brain stem, have provided the higher animals with a remarkably constant internal environment. The constancy of this *milieu intérieur*, as the French physiologist Claude Bernard pointed out, is "la condition de la vie libre." Conceivably it is the stabilizing effect of the brain stem that frees the cortex of man for its highest achievements.

Whatever the case, it has been discovered by the statistical method of autocorrelation analysis that EEG recordings from man often show a long-persisting phase constancy that has not been found in lower animals. There are also individual differences. In some people phase-locking of oscillations is, for long periods, nearly as predictable as a clock. In others (a minority) there is little, if any, stability of phase. Are the people who lack a stable phase-locked oscillation unable to clear their association cortex of interfering activity? Have they not yet attained the "free life" of Claude Bernard?

One of the earliest workers to encourage electroencephalographers to explore this approach was the M.I.T. mathematician Norbert Wiener. His strong influence lies behind much of the computer work in this area, and especially that which has come from the laboratory of Walter A. Rosenblith of M.I.T.'s Research Laboratory for Electronics.

No account of the electroencephalographer's use of computers should omit their recent use in seeking information about the correlations between deep and superficial activity in various parts of the brain. What is the correlation between the waves recorded from the outside of man's skull and activity in the depths? With what confidence can one say that an EEG is "normal" when only scalp recordings can be made?

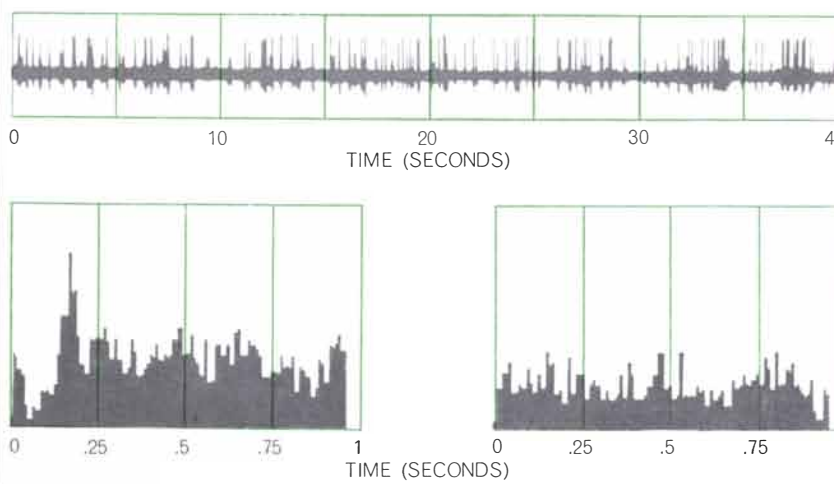
The first answers to these and many other questions are just emerging as computer analyses of electrical potentials from inside man's head are being correlated with those simultaneously recorded from his scalp. As more and more clinical investigators adopt computer techniques it should be possible to build up for the electroencephalographer, who



STEREOTYPED RESPONSE of brain of anesthetized animal to flash of light (*colored curve*) shows plainly when computer is programed to give information on amplitude variation. Unanesthetized animal gives widely fluctuating response (*black curve*). In each case the computer analyzed point in time at which response reached its maximum amplitude.

can record only from the surface of the unopened scalp, a reference library of correlations to use in assessing the probability of events in the hidden depths of the brain.

Nearly all the applications of the computer described here have involved averaging. This is not only because the average is an empirically useful statistic but also because many brain investigators suspect that the brain may work on a probabilistic basis rather than a deterministic one. To analyze the myriad complexities of the brain's function by nonstatistical description is too gigantic a task to be conceived, but exploration in terms of probability theory is both



HISTOGRAMS showing distribution of cell discharges relative to stimulus were made by George L. Gerstein at M.I.T. Upper line shows a short section of raw data consisting of cell discharges in the auditory part of a cat's brain in response to one-per-second clicks. The histogram at left shows number of cell discharges at fractional-second intervals after clicks. The histogram at right shows same analysis of cell discharges when no click occurred.

practical and rational. In characterizing nervous activity one would not therefore attempt the precise definition that arithmetic demands but would seek the statistical characteristics of the phenomena that appear to be relevant.

The margin of safety that the brain has for acting appropriately on a probabilistic basis would be much greater than that which would be imposed by a deterministic, arithmetically precise operation. Chaos would result from the least slip-up of the latter, whereas only a major divergence from the mean would disturb a system working on a probability basis. The rigidity of arithmetic is not for the brain, and a search for a deterministic code based on arithmetical precision is surely doomed to disappointment.

One can speculate how a brain might work on statistical principles. Incoming sensory messages would be compared with the statistical distribution of nerve cell characteristics that have developed as functions of the past activities of these cells. Significance of the message would then be evaluated and, according to the odds, its message could be appropriately acted on or ignored. The brain, with its wealth of interconnections, has an enormous capacity for storage, and one can observe the development of appropriate responses by watching the limited capacity of the child grow to the superior capacity of the man.

One might ask why it is the brain investigator, among biological scientists, who has reached out most eagerly to the computer for help. A likely answer is that within man's skull—a not very large, rigidly limited space—a greater number of transactions are taking place simultaneously than in any other known system of its size. The multiplicity of signals that these transactions emit and the truly formidable complexity of codes that they may use have proved beyond the capabilities of analysis by the methods of an earlier age.

The neurophysiologist cannot hope to study a single variable in isolation. The living brain will not still its busy activity so that the investigator can control whatever he wishes; neither will it forget its past. Every stimulus, however "constant" the experimenter may succeed in making it, enters a nervous system that is in an ever changing state. The "stimulus-response" experiment of an earlier day is no longer adequate. Experiment has to enter a phase of greater sophistication that may well prove out of reach without the help of the computer.

THIS GRINDING WHEEL COST $13,000

(IT PAID FOR ITSELF THE FIRST YEAR, AND HASN'T COST AN EXTRA CENT SINCE)

The Raytheon Company, Lexington, Mass., had a problem. They had to grind extremely tough aluminum oxide, titanium dioxide and barium titanate parts for microwave systems, radar, missiles. And they had strict tolerances: as little as 0.00025 inch in some cases.

Conventional abrasive wheels were found to be uneconomical. The tough ceramics wore down the wheels so quickly that dimensions could not be held on a production basis. Rejects were high because the wheels tended to glaze the ceramics and to leave black streaks.

In January, 1957, Raytheon installed a centerless grinder with a metal-bond natural-diamond grinding wheel, 24 inches in diameter. It cost $13,000. Results:

- Production was increased by 25 fold. Parts are now ground at the rate of 250 per hour.
- Average cost per workpiece was cut to a fraction of the former cost.
- Scrap was reduced by 30%.
- Surface finish was better and more consistent.
- Grinder settings were reduced because of the wheel's slow wear.

Now in its sixth year of continuous use, the wheel shows virtually no signs of wear. It has never required dressing since it was first installed.

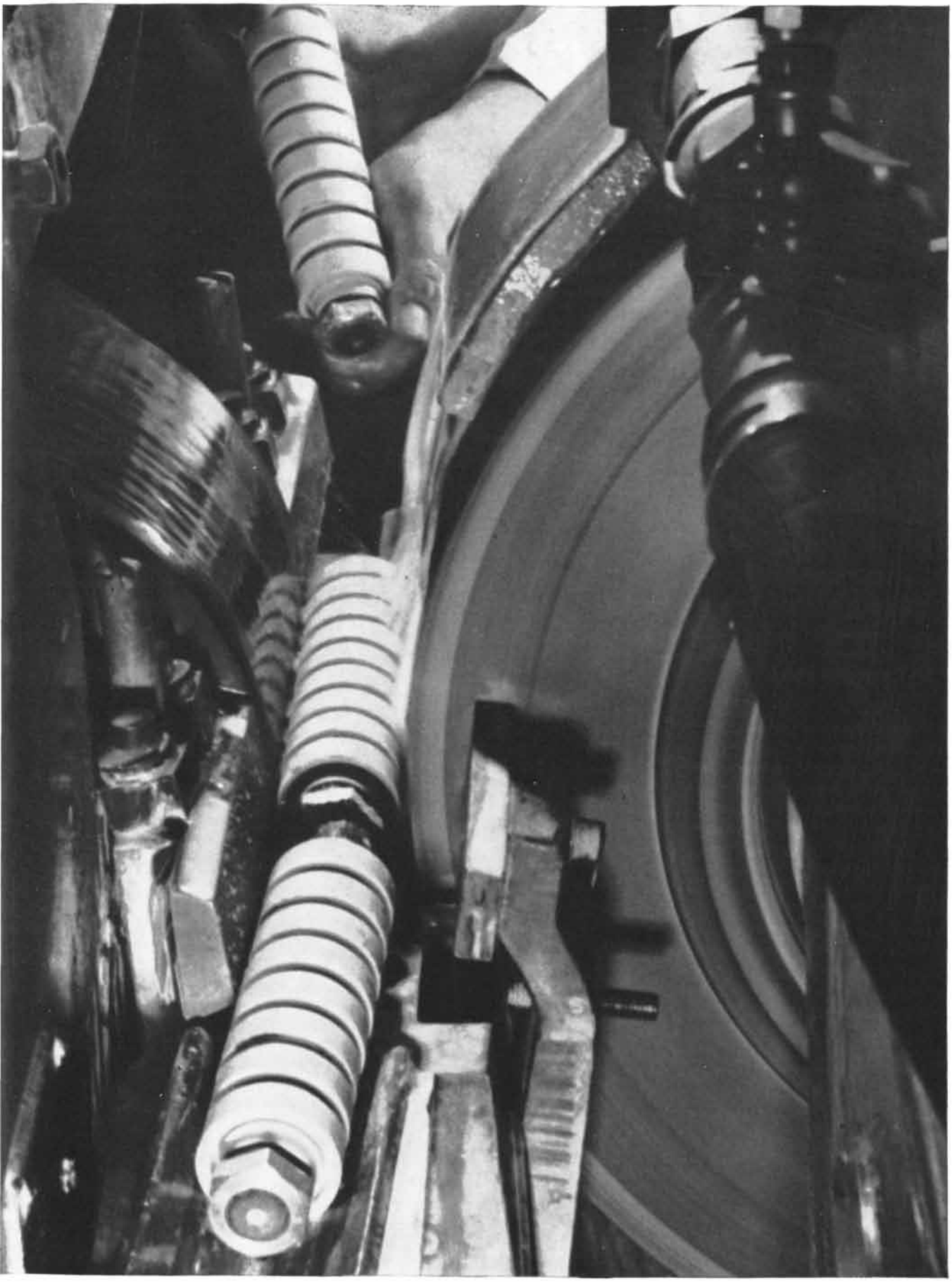
Thirteen thousand dollars for one wheel? Sounds extravagant—but it was actually a pretty shrewd economy, once you know the facts. Naturally, most diamond wheels are nowhere near this price. ***You can buy a natural-diamond grinding wheel for as little as $30—and get similar dramatic economies.***

So if you cut, sharpen, or smooth ***anything,*** natural diamonds can probably cut ***your*** costs, boost your production, cut down on rejects. Ask your tool and wheel manufacturer for further information.

Right—Metal-bond wheel embedded with natural diamonds (25 to 220 mesh) grinds ceramic parts at Raytheon Co. Wheel increased production 25 times, reduced scrap. After having ground nearly 11 million surfaces in over five years of continuous operation, the wheel has never required dressing.

Industrial Distributors (Sales), Ltd. World's leading supplier of diamonds for industry
JOHANNESBURG • LONDON

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



MATHEMATICAL GAMES

The game of solitaire and some variations and transformations

by Martin Gardner

"The game called solitaire pleases me much," the great German mathematician Gottfried von Leibniz wrote in a letter in 1716. "I take it in reverse order. That is to say, instead of making a figure according to the rules of the game, which is to jump to an empty place and remove the piece over which one has jumped, I thought it better to reconstruct what had been demolished, by filling an empty hole over which one has leaped. In this way one may set oneself the task of forming a given figure if that is possible, as it certainly is if it can be destroyed.

"But why all this? you ask. I reply: to perfect the art of invention. For we must have the means of constructing everything which is found by the exercise of reason."

Leibniz' last two sentences are a bit obscure. Perhaps they mean that it is worthwhile to analyze everything that has a logical or mathematical structure.

Worthwhile or not, no other puzzle game played on a board with counters has enjoyed such a long, uninterrupted run of popularity as solitaire. Its origin is unknown, although its invention is sometimes attributed to a prisoner in the Bastille. That it was widely played in France during the late 19th century is evident from the many French books and articles that were then written about the game. It is likely that almost every reader of this column has at one time or another racked his brain over the puzzle. At present several versions of solitaire are on sale in this country under various trade names, some with pegs that are moved from hole to hole and some with marbles that rest in circular depressions. The marble versions are easier to manipulate. One can also play by placing pennies, beans, small poker chips or any other type of counter on the board depicted on page 158.

This board, which has 33 cells, is the most popular form of solitaire in England, the U.S. and the U.S.S.R. In France the board has four additional cells at the positions indicated by the four dots. Both forms of the board are found throughout the rest of western Europe. The cells are labeled in traditional fashion, the first digit of each number giving the position of the column from left to right, the second digit giving the position of the row from bottom to top.

The basic problem—usually the only problem supplied by manufacturers of the puzzle—begins with counters placed on all cells except the center one. The object is to make a series of jumps that will remove every counter but one. For an elegant solution this last counter should be left on the central cell. A "jump" consists of moving a counter over any adjacent counter to land on the next empty cell. The jumped counter is taken off the board. This is the same as a jump in checkers except that each jump must be straight to the left or right, or straight up or down. No diagonal jumps are allowed.

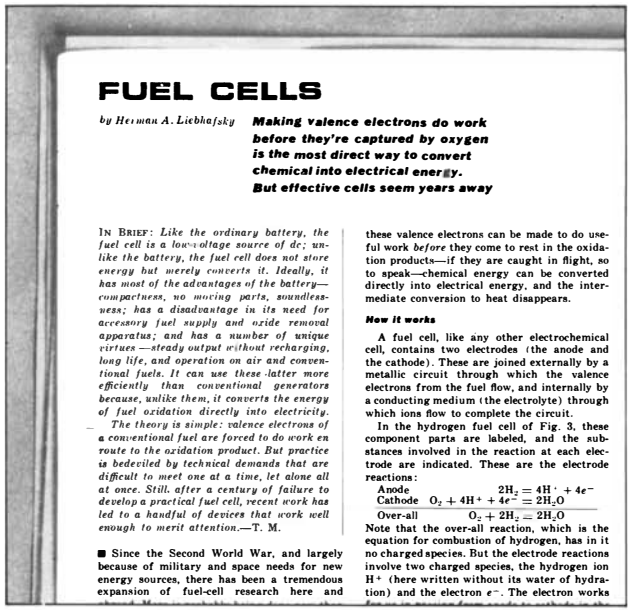
Each move must be a jump. If a point is reached at which no jumps are possible, the game ends in a stalemate. A single piece may continue in a chain of connected jumps as long as jumps are available, but it need not do so. A chain of jumps is counted as a single "move." To solve the puzzle 31 jumps obviously must be made, but if some are in chains, the number of moves can be fewer.

No one knows how many different ways there are to solve the puzzle leaving the last counter in the center. Scores of solutions have been published. Before discussing some of them, however, readers unfamiliar with solitaire are urged to try the six simpler figures shown in the illustration on page 160. In each case the last counter must be left on the center cell. For example, the Latin cross is easily solved in five moves: 45–25, 43–45, 55–35, 25–45, 46–44.

After mastering these traditional problems the reader may want to try the three puzzles shown on page 162. In

IBM® asks basic questions in information retrieval

What is known?



FUEL CELLS

by Herman A. Liebhafsky

Making valence electrons do work before they're captured by oxygen is the most direct way to convert chemical into electrical energy. But effective cells seem years away

IN BRIEF: *Like the ordinary battery, the fuel cell is a low-voltage source of dc; unlike the battery, the fuel cell does not store energy but merely converts it. Ideally, it has most of the advantages of the battery—compactness, no moving parts, soundlessness; has a disadvantage in its need for necessary fuel supply and oxide removal apparatus; and has a number of unique virtues—steady output without recharging, long life, and operation on air and conventional fuels. It can use these latter more efficiently than conventional generators because, unlike them, it converts the energy of fuel oxidation directly into electricity.*

The theory is simple: valence electrons of a conventional fuel are forced to do work en route to the oxidation product. But practice is bedeviled by technical demands that are difficult to meet one at a time, let alone all at once. Still, after a century of failure to develop a practical fuel cell, recent work has led to a handful of devices that work well enough to merit attention.—T. M.

■ Since the Second World War, and largely because of military and space needs for new energy sources, there has been a tremendous expansion of fuel-cell research here and

these valence electrons can be made to do useful work *before* they come to rest in the oxidation products—if they are caught in flight, so to speak—chemical energy can be converted directly into electrical energy, and the intermediate conversion to heat disappears.

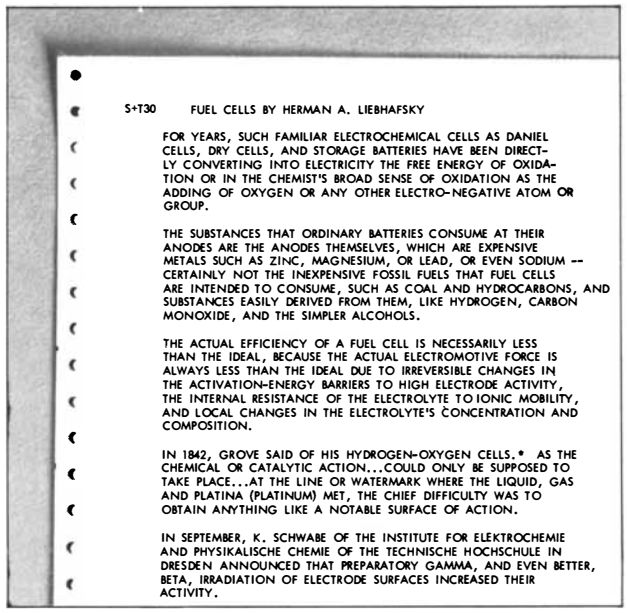
How it works

A fuel cell, like any other electrochemical cell, contains two electrodes (the anode and the cathode). These are joined externally by a metallic circuit through which the valence electrons from the fuel flow, and internally by a conducting medium (the electrolyte) through which ions flow to complete the circuit.

In the hydrogen fuel cell of Fig. 3, these component parts are labeled, and the substances involved in the reaction at each electrode are indicated. These are the electrode reactions:

Anode	$2H_2 = 4H^+ + 4e^-$
Cathode	$O_2 + 4H^+ + 4e^- = 2H_2O$
Over-all	$O_2 + 2H_2 = 2H_2O$

Note that the over-all reaction, which is the equation for combustion of hydrogen, has in it no charged species. But the electrode reactions involve two charged species, the hydrogen ion H^+ (here written without its water of hydration) and the electron e^-. The electron works



S+T30 FUEL CELLS BY HERMAN A. LIEBHAFSKY

FOR YEARS, SUCH FAMILIAR ELECTROCHEMICAL CELLS AS DANIEL CELLS, DRY CELLS, AND STORAGE BATTERIES HAVE BEEN DIRECTLY CONVERTING INTO ELECTRICITY THE FREE ENERGY OF OXIDATION OR IN THE CHEMIST'S BROAD SENSE OF OXIDATION AS THE ADDING OF OXYGEN OR ANY OTHER ELECTRO-NEGATIVE ATOM OR GROUP.

THE SUBSTANCES THAT ORDINARY BATTERIES CONSUME AT THEIR ANODES ARE THE ANODES THEMSELVES, WHICH ARE EXPENSIVE METALS SUCH AS ZINC, MAGNESIUM, OR LEAD, OR EVEN SODIUM -- CERTAINLY NOT THE INEXPENSIVE FOSSIL FUELS THAT FUEL CELLS ARE INTENDED TO CONSUME, SUCH AS COAL AND HYDROCARBONS, AND SUBSTANCES EASILY DERIVED FROM THEM, LIKE HYDROGEN, CARBON MONOXIDE, AND THE SIMPLER ALCOHOLS.

THE ACTUAL EFFICIENCY OF A FUEL CELL IS NECESSARILY LESS THAN THE IDEAL, BECAUSE THE ACTUAL ELECTROMOTIVE FORCE IS ALWAYS LESS THAN THE IDEAL DUE TO IRREVERSIBLE CHANGES IN THE ACTIVATION-ENERGY BARRIERS TO HIGH ELECTRODE ACTIVITY, THE INTERNAL RESISTANCE OF THE ELECTROLYTE TO IONIC MOBILITY, AND LOCAL CHANGES IN THE ELECTROLYTE'S CONCENTRATION AND COMPOSITION.

IN 1842, GROVE SAID OF HIS HYDROGEN-OXYGEN CELLS.* AS THE CHEMICAL OR CATALYTIC ACTION...COULD ONLY BE SUPPOSED TO TAKE PLACE...AT THE LINE OR WATERMARK WHERE THE LIQUID, GAS AND PLATINA (PLATINUM) MET, THE CHIEF DIFFICULTY WAS TO OBTAIN ANYTHING LIKE A NOTABLE SURFACE OF ACTION.

IN SEPTEMBER, K. SCHWABE OF THE INSTITUTE FOR ELEKTROCHEMIE AND PHYSIKALISCHE CHEMIE OF THE TECHNISCHE HOCHSCHULE IN DRESDEN ANNOUNCED THAT PREPARATORY GAMMA, AND EVEN BETTER, BETA, IRRADIATION OF ELECTRODE SURFACES INCREASED THEIR ACTIVITY.

This 4000-word article appeared in the January, 1962, issue of International Science and Technology. *To abstract the article, a document analyst would read it, define its purpose, and summarize its essential points.*

This abstract was prepared by an IBM computer. The text was first coded in machine language. The computer then counted key words, and printed out sentences having the greatest statistical significance.

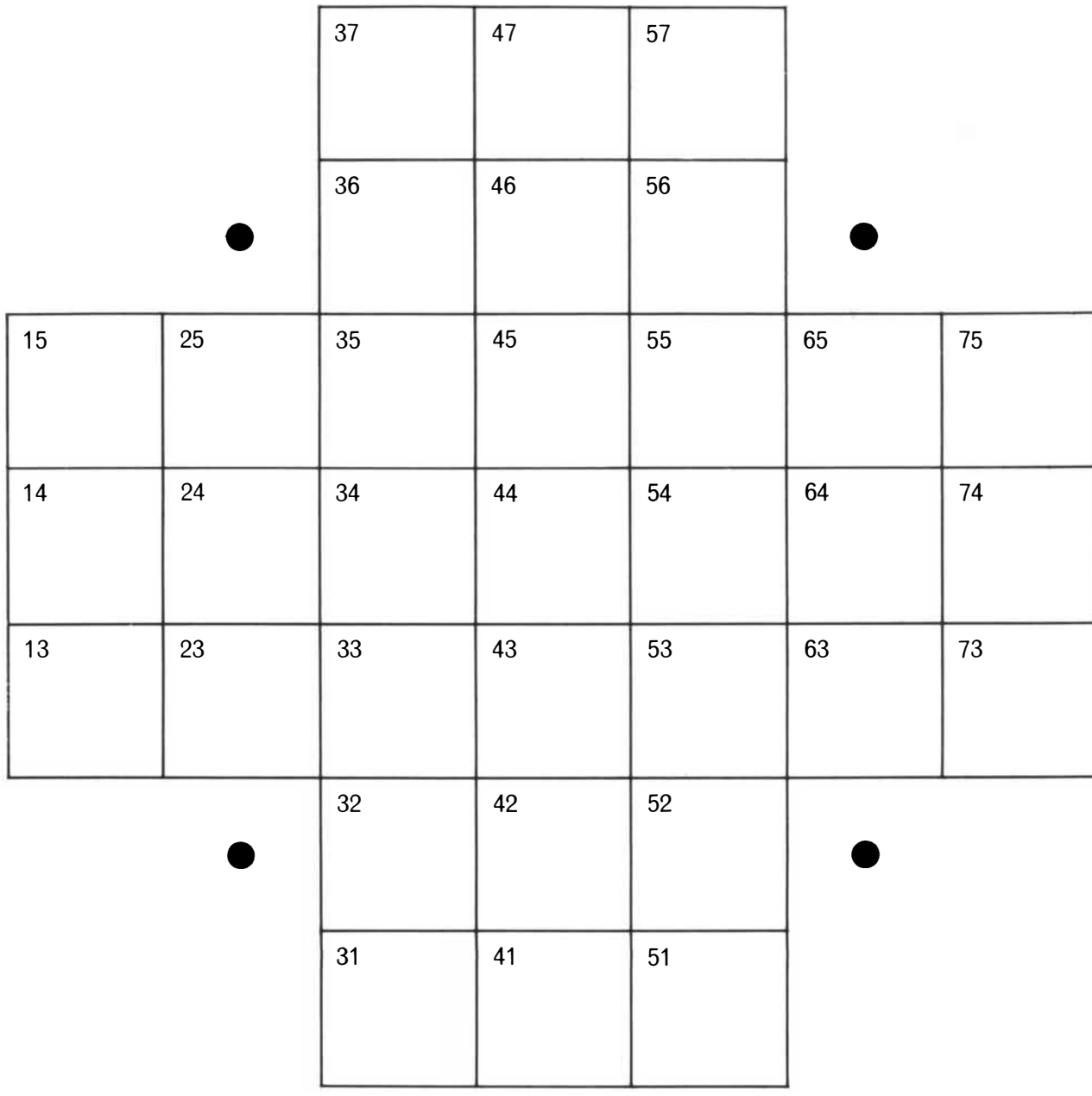
Each year in the physical and life sciences, some 50,000 technical journals will be published throughout the world. 100,000 research reports and 60,000 technical books will also be written. Somewhere in this mass of knowledge may be information you need. To tell what is known—and where to find it—IBM is investigating systems for the dissemination, storage, and retrieval of information.

To create an advanced information retrieval system, labels must be found for *all* useful information in documents. With conventional library indexing, it is difficult to make allowance for new kinds of knowledge. However, computers let us use more versatile methods of indexing. In one of these, the KWIC INDEX (Key Word In Context), a computer selects significant terms in the titles of documents, then prints them out as index entries.

Once indexed, characteristics of documents' contents can be used to notify people of their existence. The Selective Dissemination of Information system at IBM stores profiles describing individuals' interests. A new document's key words are matched against key words in a person's profile. If there is sufficient correlation, he is informed of the document. Profile matching can also be used to retrieve information by storing documents and feeding keyword queries through the system.

At present it is relatively difficult to get text into machine-readable form. However, the development of high-speed optical character readers, automatic language translators, and improved methods of capturing linguistic information at the source may make it possible to introduce information directly into retrieval systems. Once harvested, vast quantities of information will present storage problems. IBM is investigating random-access photostorage systems capable of storing millions of documents and retrieving them in seconds. Out of systems like these may come total information centers which will acquaint scientists and businessmen with all the information needed in their work.

If you have been searching for an opportunity to make important contributions in information retrieval, component engineering, optics, space systems, or any of the other fields in which IBM scientists and engineers are finding answers to basic questions, please contact us. IBM is an Equal Opportunity Employer. Write to: Manager of Professional Employment, IBM Corporation, Department 659S, 590 Madison Avenue, New York 22, New York.



The solitaire board

each of these one must begin with a full board, except for a vacant center cell, and play until the figure shown remains on the board. The first puzzle is easy; the other two are not. Note that the pinwheel is a stalemated position. (It is possible to reach a stalemate in as few as six moves. Can you discover how? The answer to this and the other problems will appear in "Mathematical Games" next month.)

Advanced students of solitaire have gone to fantastic lengths in setting themselves unusual tasks. For example, in his book *The Game of Solitaire* (1920) Ernest Bergholt introduces into his brilliant problems a variety of curious restrictions. (All the problems start with a full board, although the vacant cell need not be in the center.) His "ball on the watch" is a single counter—preferably a different color from the others—that must not be moved until the end of the game; then it captures one or more pieces to become the sole survivor. His "dead ball" is a counter that remains untouched throughout and is the last to be taken. A "sweep" is a long chain of jumps that closes a game. Bergholt gives many examples of games ending in eight-ball sweeps. It is possible, he maintains, to begin with the vacancy at 37 and end with a nine-ball sweep.

What is the smallest number of moves required to reduce a full board of 32 pieces to a single piece? If the initial vacancy is 13, 23 or 33 (or any of the other 17 cells that correspond to these three when the board is rotated or reflected), all counters but one can be removed in 16 moves. This is the shortest possible solution. If the vacancy is on any other cell, 17 is thought to be the minimum.

If the game opens with an empty cen-

ENGINEERS & SCIENTISTS FOR APPLIED RESEARCH & ADVANCED DEVELOPMENT

AEROTHERMODYNAMICS • APPLIED MECHANICS
ELECTRONICS • MATHEMATICAL ANALYSIS
MATERIALS SCIENCES • SPACE PROPULSION
SPACE ENVIRONMENTAL CONTROLS

YOUR OPPORTUNITY TO HELP STRUCTURE A NEW DIRECTION IN AEROSPACE TECHNOLOGY

Join Expanding R&D Staff at Republic on Wide-Ranging Programs for NASA and USAF

9 NEW CONTRACTS INCLUDING NASA's Project FIRE

Full resources of Paul Moore Research and Development Center at your disposal... the most sophisticated, complete and integrated aerospace facilities in the East.

INVESTIGATIONS RANGE OVER:

MEDICAL, PHYSIOLOGICAL, PSYCHOLOGICAL EFFECTS OF HUMAN EXPOSURE TO OUTER SPACE VOYAGES

GUIDANCE PROBLEMS OF ORBITAL RENDEZVOUS

DEVELOPMENT OF MATHEMATICAL EXPRESSIONS BASED ON SOLUTION OF TWO FIXED CENTER PROBLEMS (of trajectory determinations)

RELIABILITY OF HYDRAULIC & PNEUMATIC SYSTEMS IN EXTREME TEMPERATURE ENVIRONMENTS OF EXTENDED DURATION

EVALUATION OF NEW SPACE PROPULSION CONCEPTS

3-DIMENSIONAL TEMPERATURE DISTRIBUTIONS ON VARIOUS SPACE VEHICLES

PROCEDURES FOR REALISTIC PREDICTION OF OPTIMAL WEIGHT PARAMETERS OF RE-ENTRY VEHICLES AND OTHER COMPLEX INTERNAL & EXTERNAL STRUCTURAL FEATURES.

An Equal Opportunity Employer

LEADERSHIP POSITIONS OPEN:

STRUCTURAL RESEARCH PhD, MS, BS. Advanced theoretical structural analysis handling complex problems of thermal and mechanical stress in elastic and inelastic regimes.

HYPERSONIC GASDYNAMICS RESEARCH PhD, MS, BS. Formulation of theoretical and experimental investigations related to new re-entry projects.

RE-ENTRY & SATELLITE HEAT TRANSFER ANALYSIS PhD, MS, BS. Analysis and development of thermal design criteria.

ESTABLISH DESIGN CRITERIA PhD, MS, BS. For hypervelocity space vehicles, hypersonic re-entry vehicles.

PREDICT RE-ENTRY THERMAL PROTECTION PROBLEMS PhD, MS, BS. Predict and develop protective concepts for various superorbital, satellite and aerospace vehicles.

DIRECT HYPERSONIC WIND TUNNEL TEST PROGRAM PhD, MS, BS. Design, conduct and analyze experiments (36" diameter, pebble-bed heated tunnel).

ENVIRONMENTAL CONTROLS DEVELOPMENT MS, BS. For orbiting and lunar vehicles; space suits; advanced aerospace craft; closed ecological systems.

PROPULSION SYSTEMS — DESIGN STUDIES MS, BS. Conduct theoretical and experimental cycle investigations; develop advanced propulsion concepts integrated into vehicle design of rockets, hypersonic airbreathing vehicles.

CRYOGENIC RESEARCH MS, BS. Study problems of liquid hydrogen fuel tanks for hypervelocity space vehicles.

ALKALI METALS — CHEMICAL RESEARCH MS, BS. Investigate problems of compatibility at elevated temperatures of alkali metals with various materials.

ANTENNA DESIGN MS in Physics or EE. Design and development of antennas for re-entry vehicles. Knowledge of window effects and general re-entry radiation blackout problems.

ELECTRONIC INSTRUMENTATION BS, MS. Develop instrumentation for space vehicles. Knowledge of system integration and telemetry highly desirable.

LIFE SCIENCES PhD, MS, BS. Research and project support in manned and unmanned aerospace systems.

WEAPON SYSTEM ANALYSIS PhD, MS, BS. Evaluate, compare and establish requirements for a growing diversity of advanced aircraft, missile, and space weapon systems.

OTHER STIMULATING POSITIONS OPEN TO ENGINEERS with BS or better. Space environmental testing of vehicles; aerospace propulsion systems; aerospace applications of statistics to vehicle design; structural analysis; thermal protection analysis; gas dynamics; wind tunnel testing; aerospace hydraulic and pneumatic systems; advanced manned vehicle propulsion systems; aerothermodynamic evaluations of re-entry vehicles.

REPUBLIC
AVIATION CORPORATION

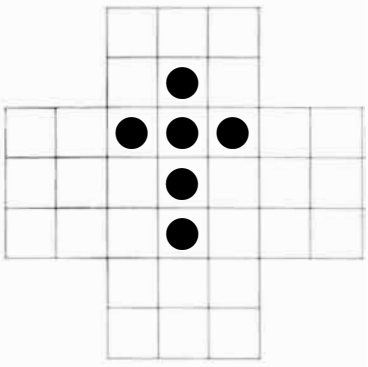
FARMINGDALE, LONG ISLAND, NEW YORK

Interested applicants are invited to write in confidence to Mr. George R. Hickman Technical Employment Manager Dept. 8-F.

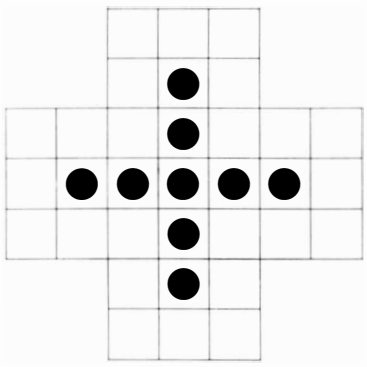
ter cell and ends with a counter on the same cell, 18 moves are required. Henry Ernest Dudeney, in his *Amusements in Mathematics* (Problem No. 227), gives a 19-move solution and adds: "I do not think the number of moves can be reduced." But Bergholt gives in his book the following 18-move solution: 46–44, 65–45, 57–55, 54–56, 52–54, 73–53, 43–63, 75–73–53, 35–55, 15–35, 23–43–63–65–45–25, 37–57–55–53, 31–33, 34–32, 51–31–33, 13–15–35, 36–34–32–52–54–34, 24–44.

"I will venture to assert," writes Bergholt, "that this record will never be beaten." Perhaps some reader can do to Bergholt what Bergholt did to Dudeney. Note that if the chain of jumps in Bergholt's next-to-last move is not interrupted, a 17-move solution is achieved, ending on cell 14, with the counter originally placed on cell 36 serving as a ball on the watch that closes the game with a six-ball sweep.

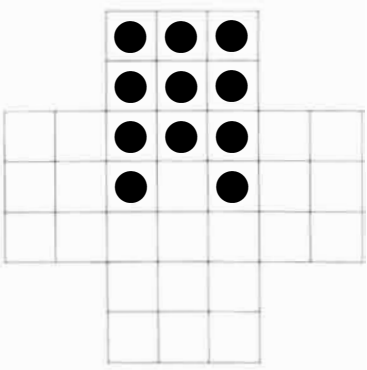
Other solutions of the classic center-to-center problem, although failing to



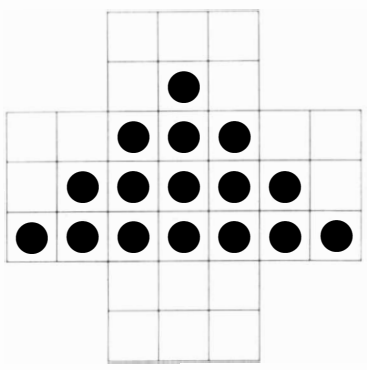
LATIN CROSS



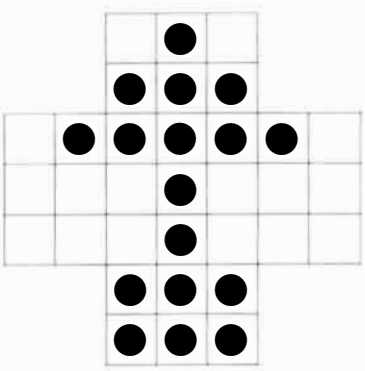
GREEK CROSS



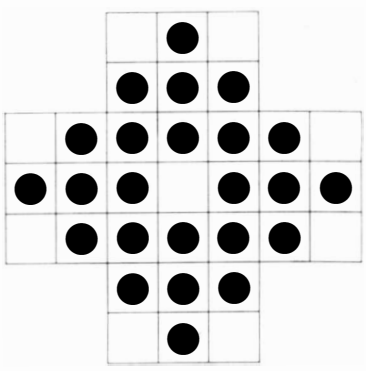
FIREPLACE



PYRAMID



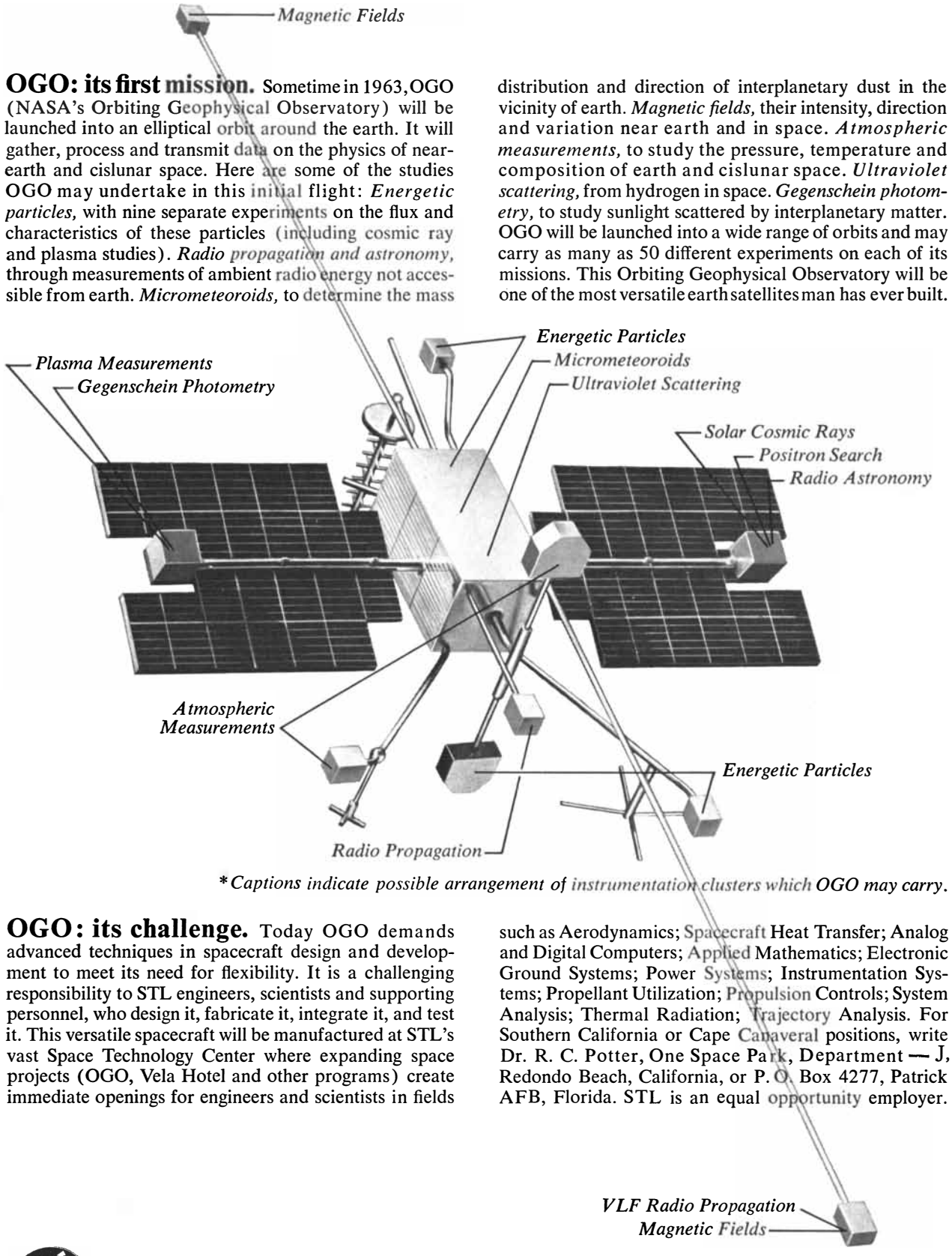
LAMP



INCLINED SQUARE

Traditional problems in which the last counter is to be left in the center

OGO: its first mission. Sometime in 1963, OGO (NASA's Orbiting Geophysical Observatory) will be launched into an elliptical orbit around the earth. It will gather, process and transmit data on the physics of near-earth and cislunar space. Here are some of the studies OGO may undertake in this initial flight: *Energetic particles,* with nine separate experiments on the flux and characteristics of these particles (including cosmic ray and plasma studies). *Radio propagation and astronomy,* through measurements of ambient radio energy not accessible from earth. *Micrometeoroids,* to determine the mass distribution and direction of interplanetary dust in the vicinity of earth. *Magnetic fields,* their intensity, direction and variation near earth and in space. *Atmospheric measurements,* to study the pressure, temperature and composition of earth and cislunar space. *Ultraviolet scattering,* from hydrogen in space. *Gegenschein photometry,* to study sunlight scattered by interplanetary matter. OGO will be launched into a wide range of orbits and may carry as many as 50 different experiments on each of its missions. This Orbiting Geophysical Observatory will be one of the most versatile earth satellites man has ever built.



**Captions indicate possible arrangement of instrumentation clusters which OGO may carry.*

OGO: its challenge. Today OGO demands advanced techniques in spacecraft design and development to meet its need for flexibility. It is a challenging responsibility to STL engineers, scientists and supporting personnel, who design it, fabricate it, integrate it, and test it. This versatile spacecraft will be manufactured at STL's vast Space Technology Center where expanding space projects (OGO, Vela Hotel and other programs) create immediate openings for engineers and scientists in fields such as Aerodynamics; Spacecraft Heat Transfer; Analog and Digital Computers; Applied Mathematics; Electronic Ground Systems; Power Systems; Instrumentation Systems; Propellant Utilization; Propulsion Controls; System Analysis; Thermal Radiation; Trajectory Analysis. For Southern California or Cape Canaveral positions, write Dr. R. C. Potter, One Space Park, Department — J, Redondo Beach, California, or P. O. Box 4277, Patrick AFB, Florida. STL is an equal opportunity employer.

SPACE TECHNOLOGY LABORATORIES, INC.
a subsidiary of Thompson Ramo Wooldridge Inc.

Los Angeles • Vandenberg AFB • Norton AFB, San Bernardino • Cape Canaveral • Washington, D.C. • Boston • Huntsville • Dayton,

achieve the minimum in moves, often have a remarkable symmetry. The following three are taken from *Puzzle Craft*, a booklet edited by Lynn Rohrbough and published in 1930 by the Co-operative Recreation Service of Delaware, Ohio.

"The Fireplace" (discovered by Josephine G. Richardson of Boston): 42–44, 63–43, 44–42, 51–53, 41–43–63, 73–53, 75–73, 65–63, 54–52, 73–53, 52–54, 23–43, 31–33, 43–23, 13–33, 15–13, 25–23, 34–32, 13–33, 32–34. The counters now form the fireplace shown in the illustration on page 160. The game is completed according to the solution of that puzzle.

"The Six-Ball Sweep": 46–44, 65–45, 57–55, 37–57, 54–56, 57–55, 52–54, 73–53, 75–73, 43–63, 73–53, 23–43, 31–33, 51–31, 34–32, 31–33, 36–34, 15–35, 13–15, 45–25, 15–35. The pattern now has vertical symmetry. A six-ball sweep (43–63–65–45–25–23–43) reduces the pattern to a T figure, easily solved with 44–64, 42–44, 34–54, 64–44.

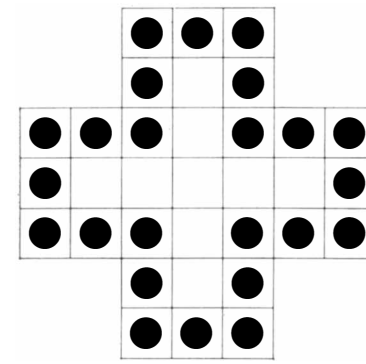
"The Jabberwocky": 46–44, 65–45, 57–55, 45–65, 25–45, 44–46, 47–45, 37–35, 45–25. The pattern is vertically symmetrical. The next 16 moves are mirror-image pairs that can be made simultaneously by the right and left hands, as follows:

Left hand	Right hand
15–35	75–55
34–36	54–56
14–34	74–54
33–35	53–55
36–34	56–54
31–33	51–53
34–32	54–52
13–33	73–53

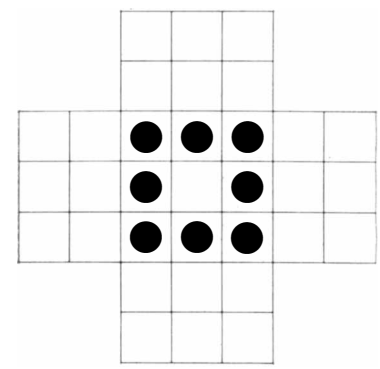
The solution concludes: 43–63, 33–31–51–53, 63–43, 42–44.

The mathematical theory behind solitaire is only partly known. In fact, one of the major unsolved problems of recreational mathematics is finding a way to analyze a given solitaire position to determine whether or not it is possible to reduce it to another given position. The man who has made the most progress in this direction is Mannis Charosh, a teacher of mathematics at New Utrecht High School in Brooklyn, N.Y. In *The Mathematics Student Journal* for March he proves a variety of unusual theorems that combine to provide an extremely useful technique for establishing the impossibility of certain solitaire problems. (Copies of this issue can be obtained by sending 15 cents to the National Council of Teachers of Mathematics, 1201 Sixteenth Street, NW, Washington 6, D.C.) Charosh's analysis simplifies and extends an earlier analysis by M. H. Hermary, to be found in the first volume of *Récréations Mathématiques*, edited by the French mathematician Édouard Lucas.

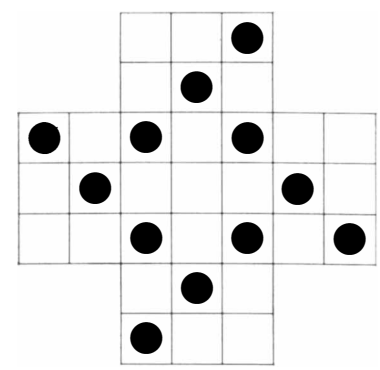
Charosh's method consists of applying a series of transformations to any starting position to see if it can be changed to the desired end position. If it can, the two positions are said to be



WALL



SQUARE



PINWHEEL

Play to leave these patterns on the board

An invitation to engineers and scientists interested in joining one of the most important developmental program areas of this generation—

RADIATION ELECTRONICS

is the unusually challenging area of NUDETS (477-L), a national network of nuclear detection and measuring devices now under development. Assignments for EE's include analysis, synthesis, integration, design, development of sensors, data processors and transfer equipment. Also damage assessment, hardening, equipment and component deterioration studies. BSEE or Physics; at least 2 years in solid state or experimental physics—instrumentation—circuit design. Also openings for ME's with electronic packaging experience. Write in confidence to Mr. P.W. Christos, Div. 59-MF.

DSD DEFENSE SYSTEMS DEPARTMENT
A Department of the Defense Electronics Division

GENERAL ELECTRIC

An Equal Opportunity Employer

NORTHERN LIGHTS OFFICE BUILDING, SYRACUSE, NEW YORK

"equivalent." If two positions are *not* equivalent, it is impossible to change one to the other by jumping pegs (or, alternatively, by working backward as Leibniz suggested). If two positions *are* equivalent, the problem may or may not be solvable by the rules of solitaire. In other words, the method gives to any solitaire problem, on any type of board, a necessary but not a sufficient condition of possibility.

Charosh's transformations involve any set of three adjacent cells that are in a straight horizontal or vertical line. Where there are counters on these three cells, remove them; where there are vacancies, put counters. Thus if all three cells are filled, all three counters can be removed. If all three are vacant, all three can be filled. If there are two counters, the two can be removed and a single counter can be placed on the previously empty cell. If there is only one counter, it can be removed and counters can be placed on the two previously empty cells.

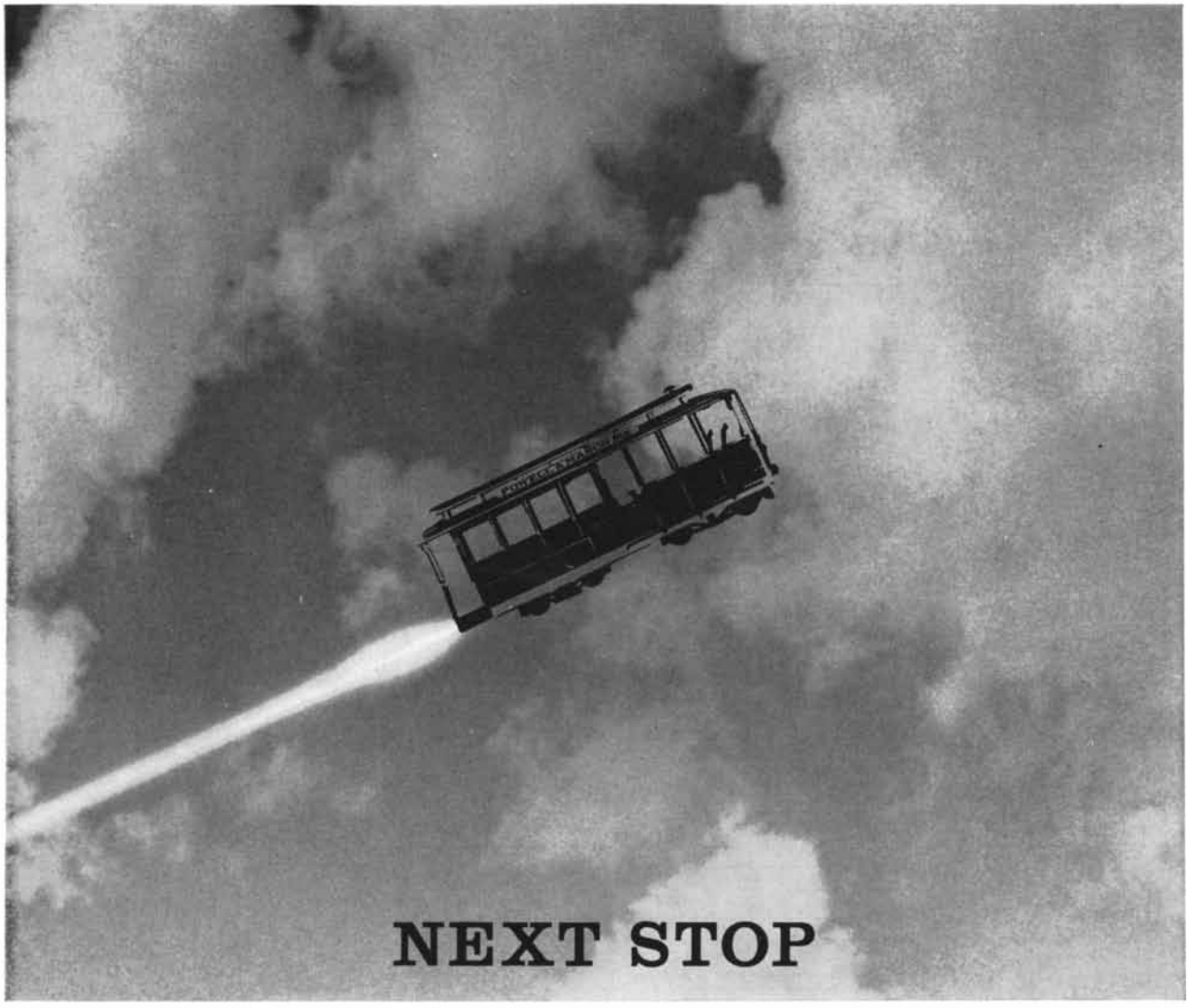
Let us apply this method to the classic problem that begins with a vacancy in the center. It can be seen at once that sets of three counters in a row can be removed until only two counters remain on, say, cells 45 and 43. Since these are the ends of the triplet 43, 44, 45, we can remove the two counters and substitute a counter on 44. We have thereby shown that the full board, with an empty cell at 44, is equivalent to an empty board with a single counter on 44; therefore the problem is not impossible. (We already know, of course, that it can be solved.) In similar fashion it is easy to see that if the game begins with a vacancy anywhere on the board, the position can be transformed by Charosh's method to a single counter on the same cell. Again, this can always be done in actual play.

Is it possible to begin with a center vacancy and end with the last counter on 45? No, it is not. There is no way that Charosh's method can be used to transform the board to a lone counter on 45. To prove this we do not have to start with a full board. We can begin with the single counter on 44 (which we know to be a possible ending) and determine how this position can be transformed to other positions with a lone counter. Thus: The counter on 44 can be removed and counters placed on 54 and 64 (because 44, 54, 64 form a triplet). The counters on 54 and 64 can in turn be taken away and replaced by a counter on 74. So a lone counter on 44 is "equivalent" to a lone counter on 74. We can put it this way: A single counter is equivalent to a single counter on any cell that can be reached by jumping over two cells in a straight line in any orthogonal direction. It is easy to see that 44 is equivalent only to cells 14, 47, 74, 41. These are the only cells on which it is possible to end a game that begins with a vacancy in the center. Practice bears this out. Any final jump that puts a counter in the center can be made in the opposite direction to put a counter in an equivalent cell. All five cells, therefore, can be reached in actual play—but no others.

Application of Charosh's method will reduce any position either to a single counter, two counters diagonally adjacent or no counters. The last cannot, of course, be reached in actual play; instead the game must end on a position equivalent to no pieces, such as three adjacent counters in a row, or two in a row with two spaces between them. It is not hard to show that any position is equivalent (transformable by Charosh's method) to its "inverse"; that is, to the same position with vacancies replaced by counters and counters by vacancies. For example, if counters are removed from two diagonally adjacent cells, say 37 and 46, the position is equivalent to an empty board with counters on those same two cells. Because there is no way to transform those two counters to a single counter, we know that it is not possible to start with vacancies at 37 and 46 and reduce the board to a single counter.

For anyone wishing to devise a new solitaire problem, Charosh's system can save endless hours of time spent in seeking solutions for impossible problems. Of course, once a problem is shown to be not impossible, the task of finding a solution remains. Sometimes a solution exists, sometimes it does not. In seeking a solution, Leibniz' method of working backward has one enormous advantage: using numbered counters and taking them in order makes it unnecessary to keep a record of each attempt. If the attempt succeeds, the numbers make it easy to reconstruct the sequence of the play.

In 1960 Noble D. Carlson, an engineer in Willoughby, Ohio, raised an interesting question: What is the smallest *square* solitaire board on which it is possible to start with a full board, except for a vacancy at one corner, and reduce the position to a single counter? Charosh's technique quickly shows that this is impossible on all squares except those with sides that are multiples of three. The



CAN ONLY BE UP

At Sylvania Electronic Systems the opportunities are nothing less than outstanding. The work is exciting and the advantages of living but thirty minutes from San Francisco speak for themselves. Challenging positions are now available for engineers who want to join us today and be with us at our next stop tomorrow.

SYSTEMS ENGINEERS for reconnaissance systems and subsystems, human factors engineering, operations research and system performance analyses. Five years' experience and background in communications or data processing systems.

DESIGN ENGINEERS for all levels with backgrounds in transmitting and receiving equipment, recording techniques, telemetry, antennas, DF and conversion equipment or computers. Opportunities are now available for both technical specialists and supervisors.

SENIOR RELIABILITY ANALYSIS ENGINEERS for test design, effectiveness studies and systems analysis. BS in EE or Physics with knowledge of calculus or probability. Four years' senior responsibility in associated programs.

SYLVANIA ELECTRONIC SYSTEMS
Government Systems Management
for GENERAL TELEPHONE & ELECTRONICS

Write in confidence to
Roger Harlan

SYLVANIA ELECTRONIC SYSTEMS · WEST
Dept. S-6, Box #188 • Mountain View, California
An Equal Opportunity Employer

7866

3×3 square, however, proves to be unsolvable. This leaves the 6×6 as the most likely candidate. The solution, if there is one, will end on the corner cell left open at the start or on one of the three cells "equivalent" to it. (Let the vacancy be at cell 1, in the upper left-hand corner, and number the cells left to right. The three equivalent cells are 4, 19 and 22.)

Can it be done? Yes. Carlson himself found a 29-move solution ending on cell 22. What is wanted now is a solution beginning with a vacancy at 1 and ending at 1. If readers will send in their best solutions (assuming there *is* a 1-to-1 solution), I will comment on the results three months from now in the September issue (although I will not undertake to acknowledge each letter). "Best" may be taken to mean two different things: (1) a minimum number of moves or (2) an elegant solution in terms of some type of symmetry play.

Last month's problems are answered as follows:

1. The number 337–31770 upside down spells "Ollie Lee."

2. Hold the sum to a mirror.

3. Turn the picture upside down, circle three 6's and three 1's to make a total of 21.

4. The basket has nine white eggs and nine brown eggs. When the sum, 18, is inverted, it becomes 81, the product. Had it not been specified that the basket contained more than six eggs, three white and three brown would have been another answer. Maxey Brooke, of Sweeny, Texas, has proved that no other answers are possible.

So many readers misunderstood the six-match problem given in February that I add here a clarification. Although matches are used to form patterns, the patterns are treated as line networks. Two networks are topologically identical if one can be changed to the other by twisting or stretching. A triangle is equivalent to a square or pentagon, a line of three matches is the same as a line of two matches, and so on. With this understanding, no more than 19 topologically distinct networks can be formed on the plane with six matches. In three dimensions, one more figure (the skeleton of a tetrahedron) can be added. Seven matches on the plane will form 39 different networks. No formula is known for the number of topologically distinct networks that can be formed on the plane or in space with n matches.

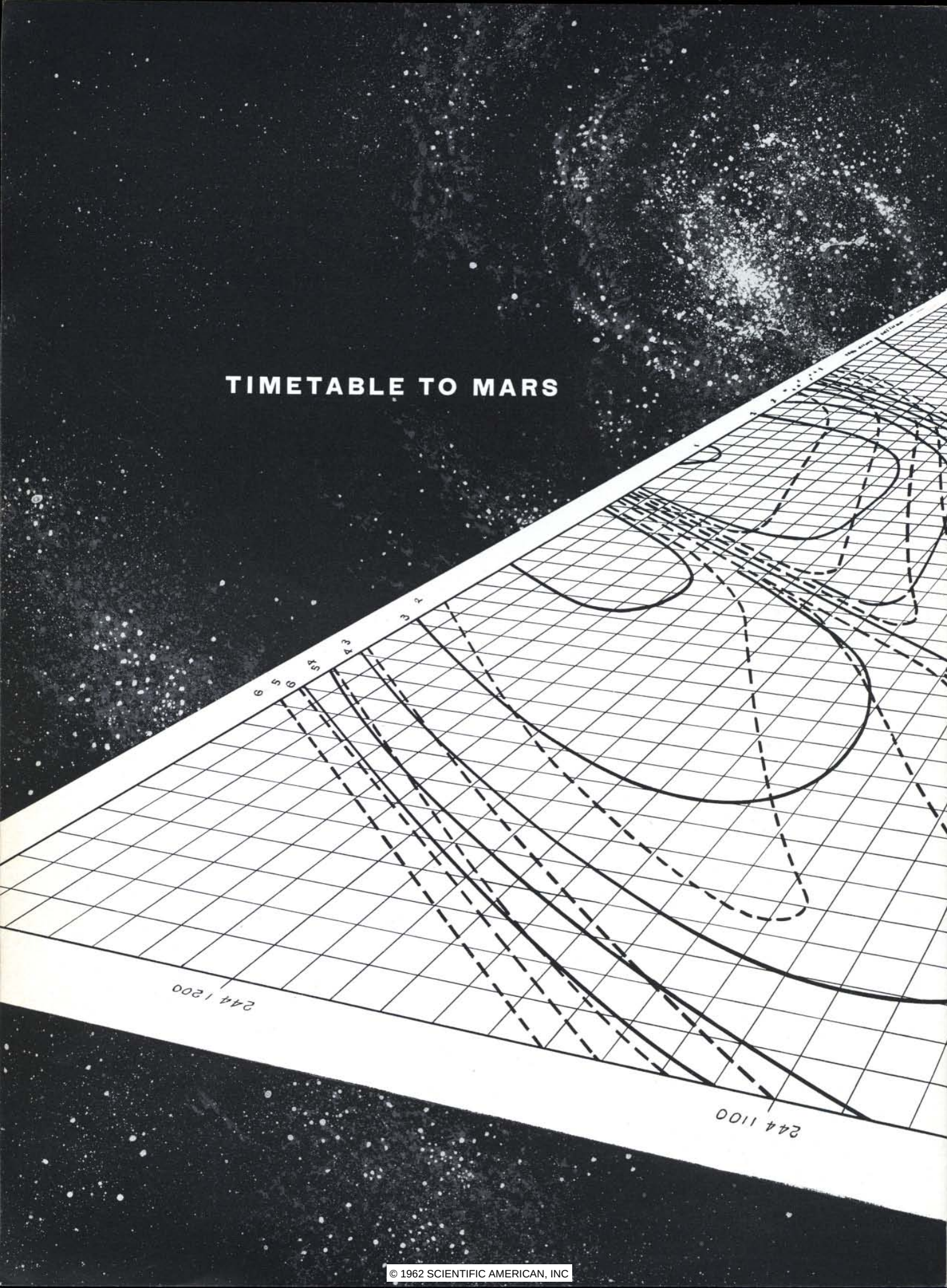
Information from countless sources, staggering amounts of it. New information that changes from moment to moment, old information that must be retrieved from storage in seconds. Information of world importance. This is what command decisions are based on: This is what a new science-technology must cope with to help make command decisions possible. The science-technology of which we speak involves the development of far-reaching man-machine systems to provide information processing assistance for military and government leaders. The needs of this field have created a number of new positions at System Development Corporation. Our scientists, engineers and computer programmers applied this science-technology to help develop SAGE. We now apply it to our work on the SAC Control System and other command and control systems being developed. At SDC, our staff participates in key phases of system development; analysis, synthesis, computer instruction, system training and evaluation. If you are a Computer Programmer seeking the work we describe, please contact Mr. A. C. Granville, Jr., SDC, 2430 Colorado Ave., Santa Monica, California. Positions are open at SDC facilities in Santa Monica; Washington, D.C.; Lexington, Massachusetts; and Paramus, New Jersey. "An equal opportunity employer."

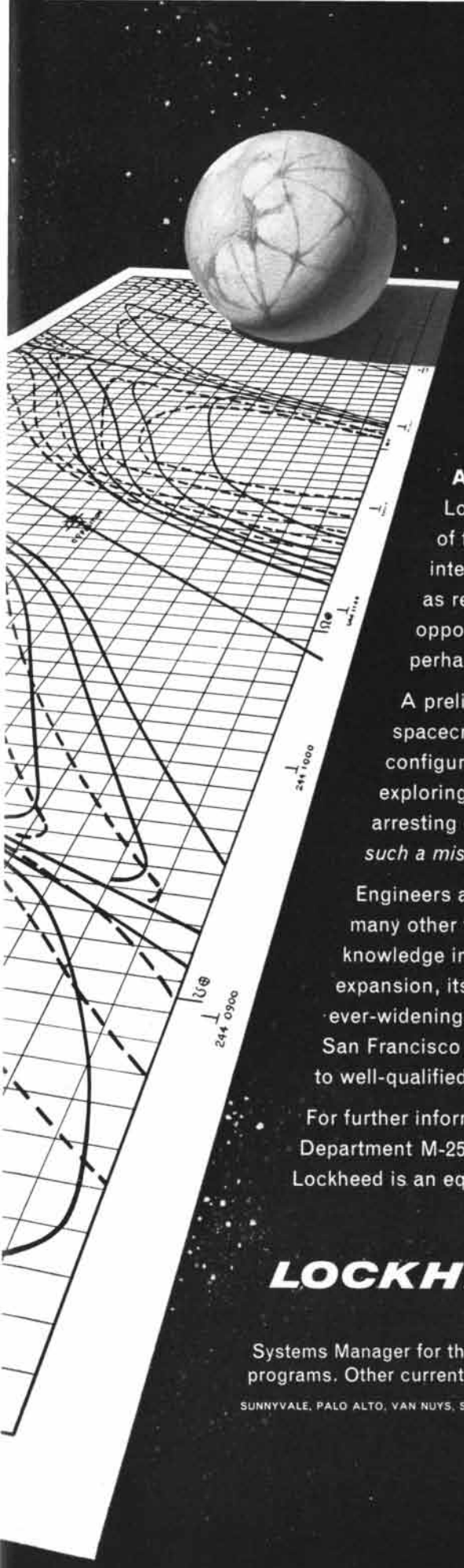
SDC

System Development Corporation

Systems that help men make decisions and exercise control

PHOTOGRAPHS BY USAF, NASA AND UPI





Arrive Mars: 10.3 August, 1971 Giant steps were taken recently at Lockheed Missiles & Space Company toward manned exploration of the planets Mars and Venus. For the first time, accurate interplanetary transfer orbits have been plotted to show velocities as related to departure and arrival dates for an entire cycle of planet oppositions. A "fast" round-trip would take a year, allowing perhaps ten days exploration time on Mars.

A preliminary but comprehensive study also was made on the spacecraft's design considerations. Many facets were explored—configuration, single versus multi-stages, weight, thrust, payload, exploring, landing, and return equipment; and many more. The arresting conclusion of Lockheed scientists: *A vehicle can perform such a mission within the present state-of-the-art.*

Engineers and scientists at Lockheed Missiles & Space Company conduct many other feasibility and research studies, probing for advanced knowledge in a wide diversity of disciplines. Lockheed's constant expansion, its growing leadership in missiles and space, its ever-widening scope of projects, its ideal location on the beautiful San Francisco Peninsula—all open new and unusual challenges to well-qualified people.

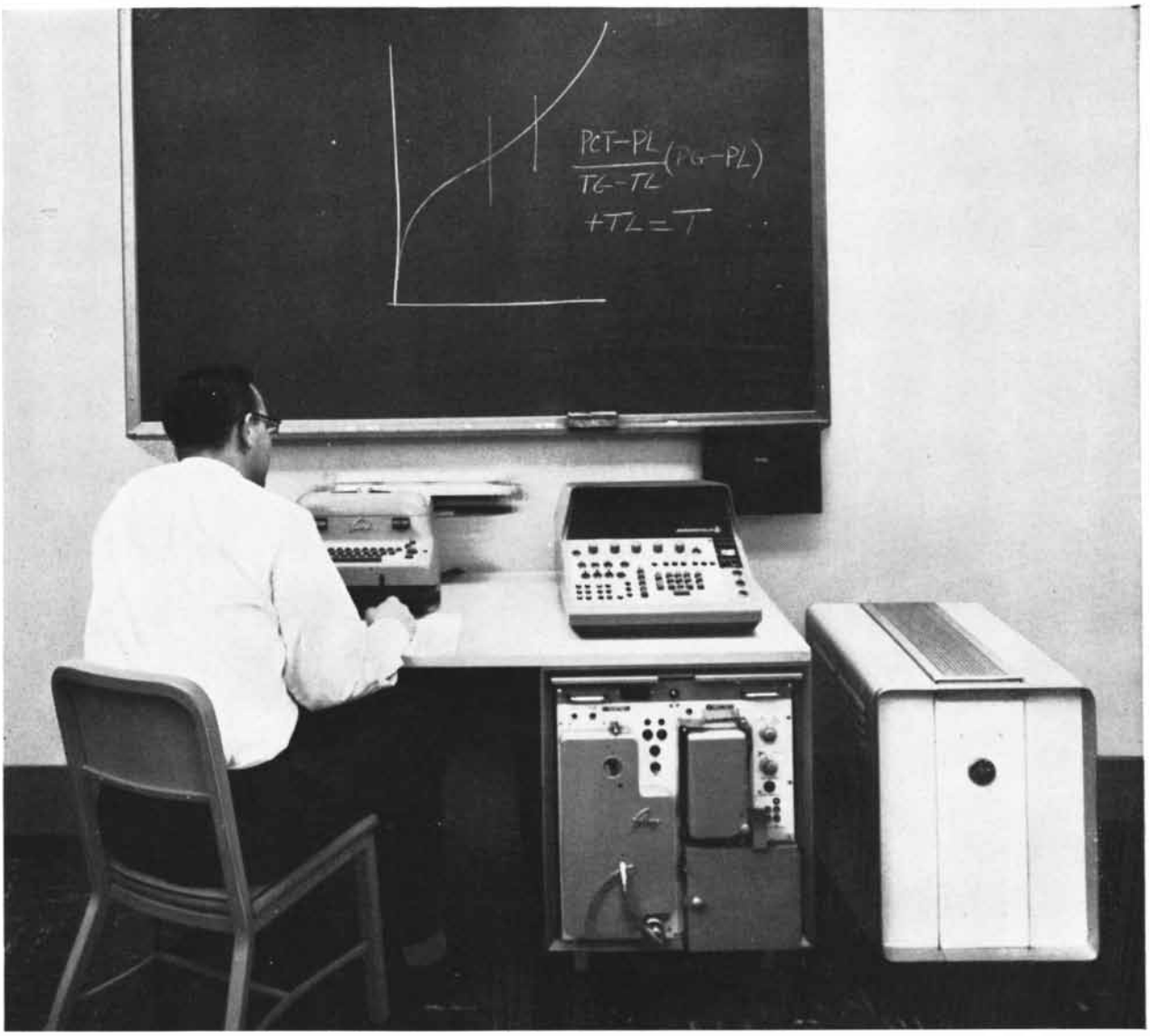
For further information, please write: Research and Development Staff, Department M-25A, 599 North Mathilda Avenue, Sunnyvale, California. Lockheed is an equal opportunity employer.

LOCKHEED MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

Systems Manager for the Navy POLARIS FBM and the AGENA vehicle in various Air Force Satellite programs. Other current projects include such NASA programs as OGO, ECHO and NIMBUS.

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA • CAPE CANAVERAL, FLORIDA • HAWAII



Standard Oil Company of California uses Recomp II in overall operations planning for its Richmond Refinery.

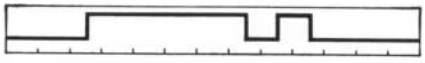
This computer speaks English.

Some computers act as though they're trying to hide the facts. Not Recomp.®

Recomp II has a built-in direct numerical display of any memory word. When it wants to show you a number like 1000., it shows just that: 1000. And it can carry it out to 12 digits. To show you 1000., other computers may display something like this:

● ○ ○ ○ ○ ○ ● ○ ● ● ●

or like this:



Recomp II automatically checks every program, bit by bit, against the original tape. And built-in echo checking of typewriter or punch output assures accuracy.

Recomp II abounds in other built-ins (floating-point, square root command, and conversion from decimal to binary, to name a few). It has two high speed memory loops (each containing 16 instructions). It has a large word length (40 bits). And a large memory (8160 instructions).

Recomp II is ideal for medium-scale needs; Recomp III is perfect for small-scale needs. You can lease a Recomp III for $1,495 (complete with no accessories required), or a Recomp II (with a complete line of peripheral equipment) for up to $4,500 a month.

There are many small and medium scale computers on the market today. Only a few are really outstanding. Recomp is one of them.* For the full Recomp story, write:

AUTONETICS Industrial Products
Department 106, 3400 E. 70th Street, Long Beach, California.
Autonetics is a Division of North American Aviation.

Recomp

*No computer feasibility study is complete without Recomp.

THE AMATEUR SCIENTIST

Analysis of blood-serum proteins by means of zone electrophoresis

Conducted by C. L. Stong

Give a novice a microscope and the chances are that within 24 hours he will prick his finger and examine a specimen of blood. Some amateurs have found the study of red and white blood cells so fascinating that they have made a hobby of hematology; a few have learned to identify the blood of animals as diverse as beetles, frogs, humans and birds from a single glance through the eyepiece. Apparently few beginners find equal interest in the straw-colored serum that oozes from a blood clot. Blood serum seems to be a homogeneous and dull liquid even when it is examined under the microscope. Yet each kind of protein molecule in the serum bears a characteristic electric charge and is subjected to a characteristic mechanical force when it is placed in an electric field. The electrophoresis apparatus utilizes this property to separate serum proteins and measure their relative concentration.

These proportions are at least as characteristic of each species as the structure and proportion of blood cells. Moreover, certain diseases cause marked changes in the serum proteins, so that the electrophoresis apparatus has become a useful aid in diagnosis. Graphs of protein concentration, known as phrenograms, have so far been drawn for only a few diseases of a few species, however, and phrenograms of even healthy animals vary somewhat depending on the design of the apparatus and the technique of the observer. As a result it is customary for each experimenter to construct a "normal" phrenogram by analyzing the serum of a number of healthy animals. Electrophoresis equipment is not readily available commercially but it can be devised by an amateur; blood can be obtained from veterinarians or slaughterhouses.

Two basic schemes have been devised for separating proteins by electrophoresis. In one an electric current is passed directly through the solution to be analyzed. The electrified molecules simply migrate toward one pole or the other depending on their size and the intensity of their charge. If the container is long in relation to its width and thickness—a glass tube, for example—the migrating substances concentrate in zones of differing refractive index and can be observed indirectly by measuring the optical refraction of each zone. This technique, known as free electrophoresis, was pioneered by the Swedish biochemist Arne Tiselius [see "Electrophoresis," by George W. Gray; SCIENTIFIC AMERICAN, December, 1951]. In the other scheme, known as zone electrophoresis, the electrified materials concentrate in zones along a strip of filter paper that carries an electric current of a few milliamperes. In the case of proteins the zones are dyed and subsequently evaluated by measuring the amount of light transmitted by each zone.

Richard LaFond of Monson, Mass., makes a hobby of zone electrophoresis. "Human blood serum," he writes, "is resolved into five zones of protein called albumin, alpha-1 globulin, alpha-2 globulin, beta globulin and gamma globulin. Similar proteins are found in the serum of other animals, but the proportions differ in each species. The analysis requires only a single drop of serum. The essential apparatus consists of (1) an electrophoresis cell that separates the proteins into zones on a strip of filter paper, (2) a bath of dye for staining the zones and (3) a photometer for measuring the opacity of the dyed proteins. All the essential materials are available from hardware stores and dealers in laboratory supplies.

"The electrophoresis cell consists of a pair of plastic containers fitted with plastic baffles, a pair of clamped glass plates for supporting the filter paper, a pair of electrodes, each surrounded by a test tube that has a hole in the bottom, and a supply of direct current at 500 volts [*see illustration on next page*]. I could not locate plastic containers of the desired size, so I made a pair from sheet Plexiglas an eighth of an inch thick. By collecting the sawdust manufactured when I cut the parts of the containers from the sheet and mixing it with acetone, I made an adhesive, of the consistency of light sirup, with which to cement the edges of the assembled containers. I also cemented a baffle in each container as shown in the illustration. The completed vessels were 16.5 centimeters long, 13 centimeters high and 12.5 centimeters wide; in operation they held 1,400 milliliters of solution. The two test tubes used to support the electrodes were 12.5 centimeters long and 1.5 centimeters in diameter. To make a hole in the bottom of each test tube I heated a small spot until the glass softened at the center and then I blew into the open end. The ragged film of glass around the blown-out hole was broken off and the edges were fire-polished by returning the glass to the flame. The electrodes were made by soldering a strip of platinum foil three millimeters wide and four centimeters long to each of two pieces of bare No. 10 copper wire about eight centimeters long. The wires were then pushed through rubber stoppers that fitted the test tubes. A groove cut in the side of each stopper equalized the air pressure within the tube. Electrodes made of carbon welding rod can be substituted for the foil, but platinum is preferred because it is more inert and can be cleaned easily by being heated to redness in a gas flame.

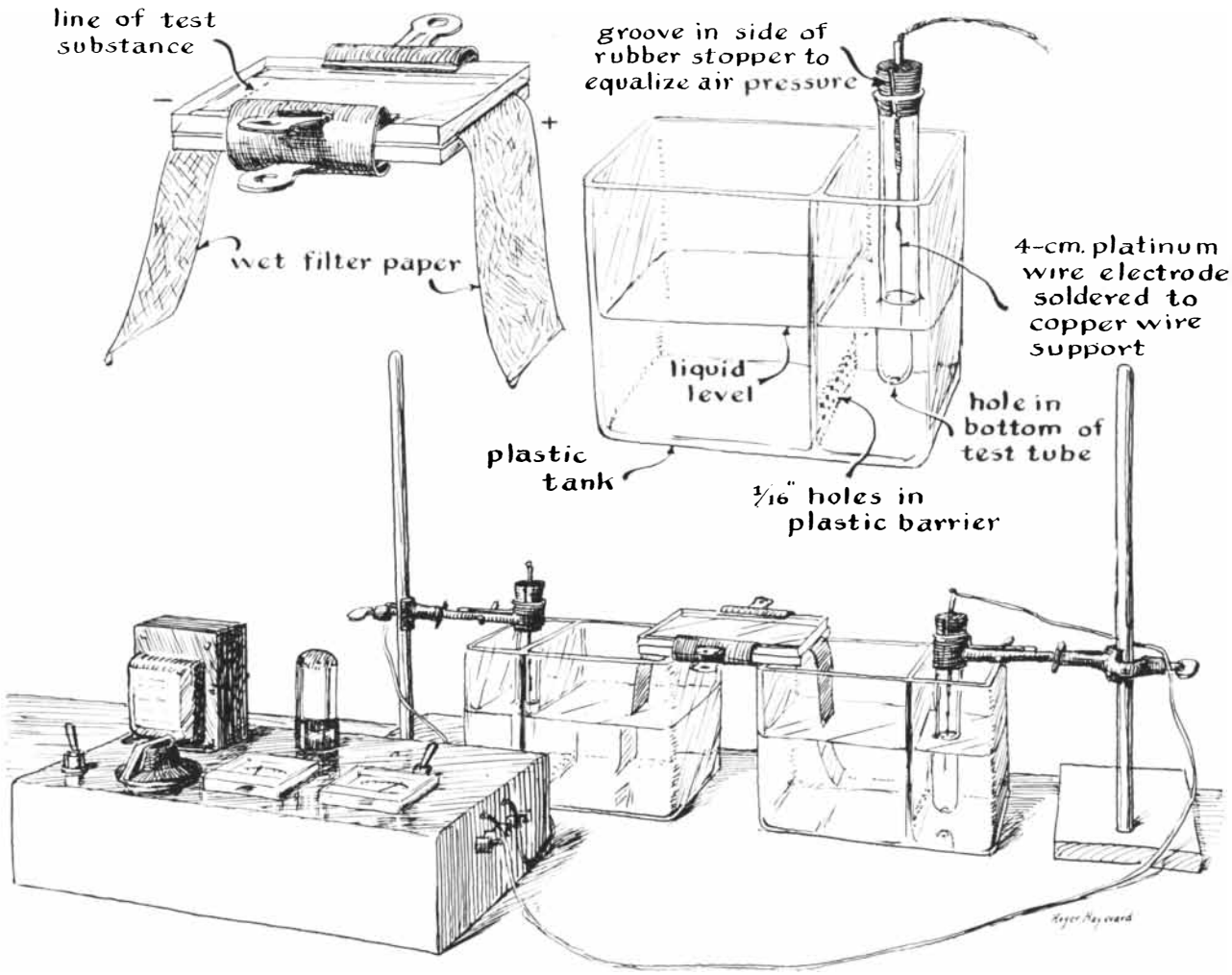
"The serum to be analyzed is applied in a thin line across a strip of filter paper that has been moistened with the solution in the containers and blotted almost dry. The paper is clamped between glass plates supported by the ends of the containers, as illustrated. The containers serve as chemically stable terminals through which the ends of the paper strip are connected to the power supply. The reason for this elaborate setup is that reactions always occur at the point where metal electrodes make contact with a solution that functions as an electrolyte. If the electrodes were

connected directly to the paper strip, the unwanted products of these reactions would migrate into the strip and interfere with the migration of the serum proteins. It is to prevent this contamination and the resulting interference with the protein separations that the platinum electrodes are placed in the test tubes, which act as baffles. As a further precaution the tubes are placed in the solution behind plastic baffles, which also help to confine the unwanted substances. Finally, because the ends of the paper strip dip into the compartment of the container that holds a large amount of electrolyte, such unwanted substances as may form there are highly diluted.

"The electrolyte is distilled water in which a chemical is dissolved that forms positive and negative ions. The ions act as carriers of current. The negatively charged ions migrate to the anode, where they give up electrons. The positively charged ions accept electrons from the cathode. The unwanted chemical products are the result of this exchange. Some of the products are liberated in the form of gases and bubble out of the solution harmlessly. Others, in the form of salts, are trapped in the system of baffles. A substance should be selected for the electrolyte that supplies ions to the solution at the rate at which they are removed by electrochemical reaction. The electrolyte should also be as dilute as possible so that the ionizing substance will not hamper the migration of the proteins. A .05 molar solution of sodium diethylbarbiturate works well. It is made by dissolving 62.2 grams of sodium diethylbarbiturate in 1,500 milliliters of distilled water. The electrolyte must be adjusted so that it is slightly alkaline—to a *p*H of 8.6. I borrowed a *p*H meter to adjust my electrolyte, but the alkalinity can also be tested with paper strips treated with phenolphthalein. Changes in the color of the moistened strips serve as an index of *p*H. The strips are inexpensive and come in a vial with a calibrated color chart. The *p*H of the electrolyte is altered by adding either dilute hydrochloric acid or sodium hydroxide (lye) as required.

"The completed cell is connected to a source of direct current capable of supplying about 20 milliamperes at a potential that can be varied from 50 to 500 volts as required. The power supply unit in many radio sets will serve adequately. Units from discarded radios can often be bought for a dollar or so from service shops. The output voltages from these units can be controlled by a continuously variable power transformer, such as a Variac. I built my unit from standard components and equipped it with a voltmeter and a milliammeter so that a record could be made of the current and voltage used during each experiment [*see illustration on page 174*].

"To prepare serum for analysis, pipette 10 milliliters of whole blood into a conical centrifuge tube and centrifuge it at 3,000 revolutions per minute for 10 minutes. The centrifuge consists of a horizontal arm about 20 centimeters long that supports a pair of hinged fix-



Details of the electrophoresis apparatus

The great paradox of our time, perhaps of all time, is that peace depends on our capacity to fight a war. Thus the person who contributes to our military strength, contributes to the cause of world peace.

MITRE's contribution is the design of command and control systems to give our military commanders the means to detect attack and retaliate.

The men who design these systems must think in terms of war and military operations — weapons, logistics, communications, intelligence, ability to destroy and ability to survive. They must be able to predict and solve the problems of future military command within the reality of existing or predictable electronic capability.

We call this "Military Command Technology."

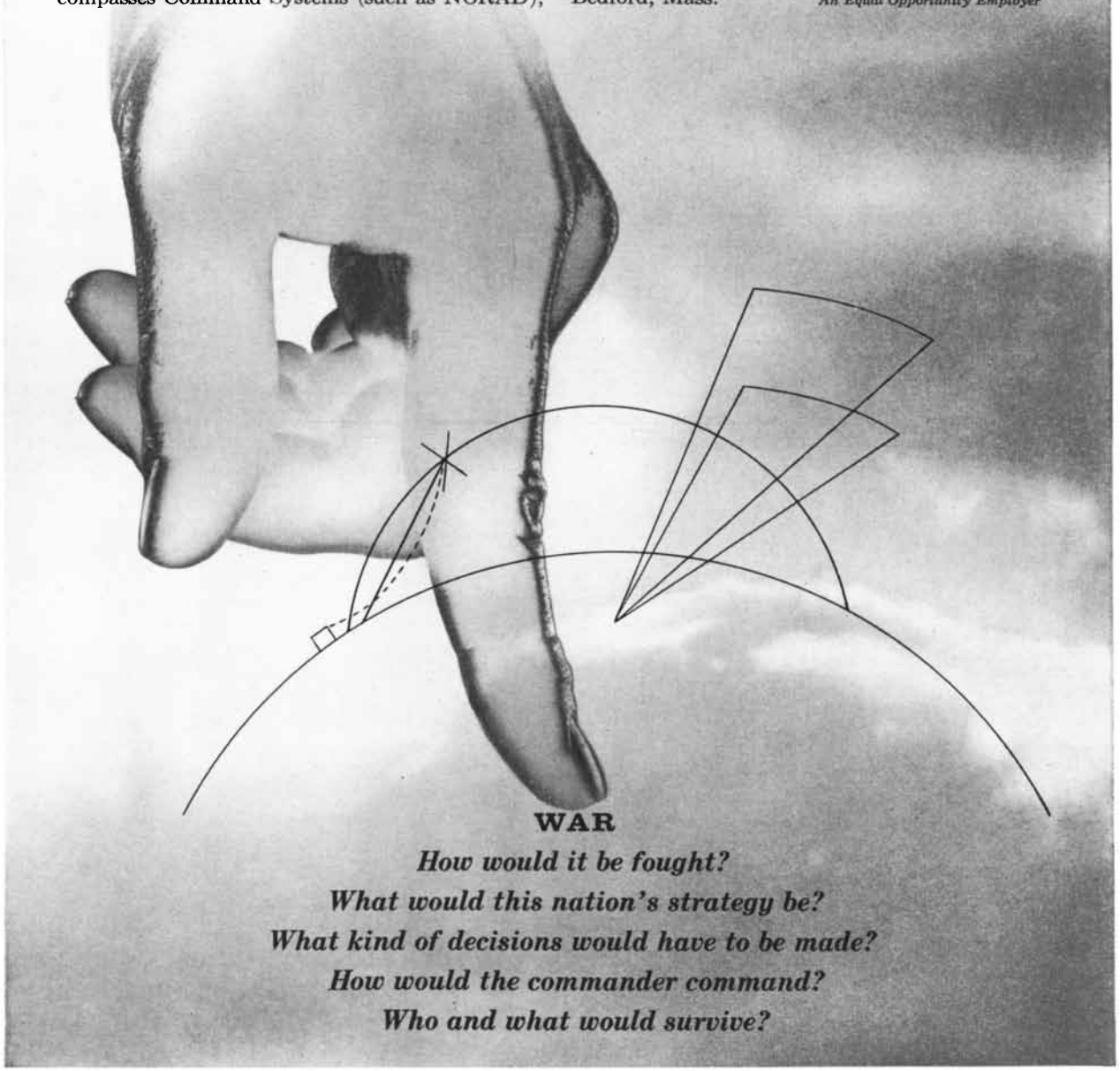
MITRE's specific assignment is the design, development, evaluation, and integration of several interrelated, constantly evolving systems. It encompasses Command Systems (such as NORAD); Control Systems (such as SAGE); Intelligence Systems (such as MIDAS); and Warning Systems (such as BMEWS).

The work involves important new areas of technology in such fields as communications, intelligence, space surveillance, survivability, computer applications, data processing and other electronic techniques.

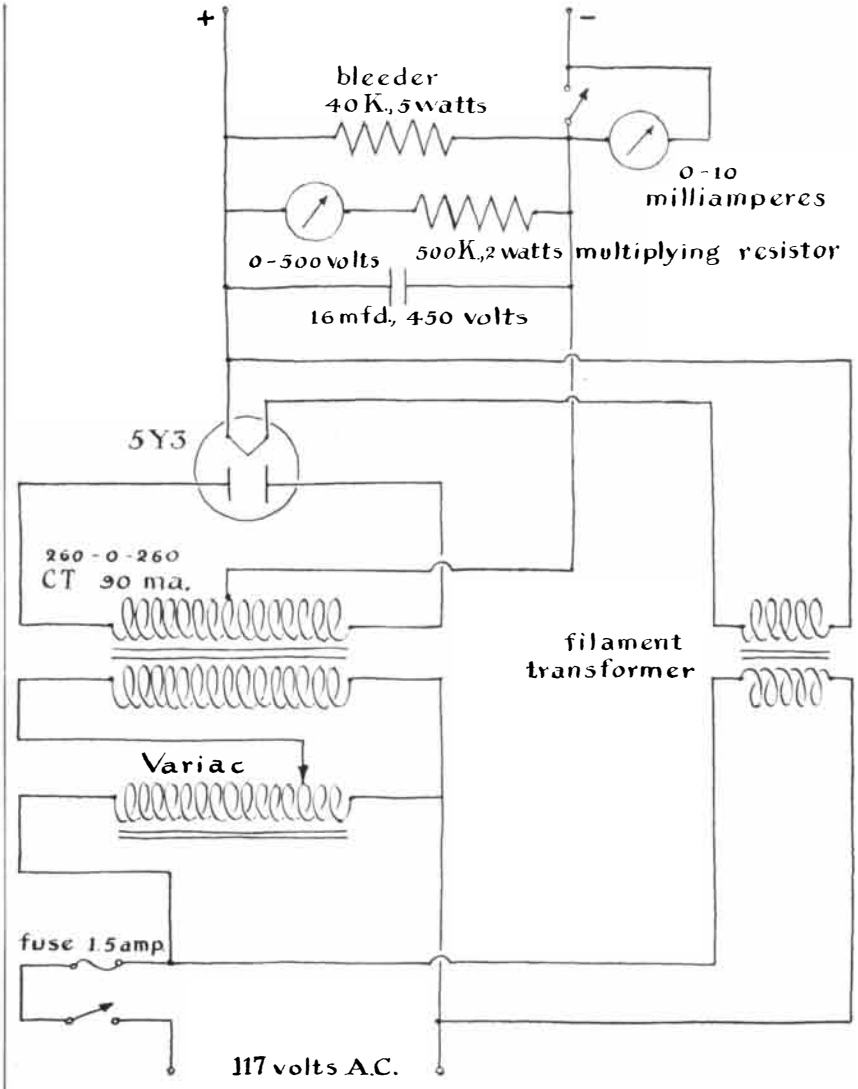
MITRE is located in pleasant, suburban Boston. Requirements: B.S., M.S., or Ph.D. in these disciplines — electronics, physics, and mathematics. Rewards are competitive. Openings also available in Washington, D.C. and Colorado Springs, Colo.

Write in confidence to Vice President — Technical Operations, The MITRE Corporation, Box 208, Dept. 9000, Bedford, Mass.

THE MITRE CORPORATION
An Equal Opportunity Employer



MITRE is an independent, nonprofit corporation working with — not in competition with — industry. Formed under the sponsorship of the Massachusetts Institute of Technology, MITRE serves as Technical Advisor to the Air Force Electronic Systems Division, and is chartered to work for such other Government agencies as FAA.



Schematic diagram of the power supply

tures at the ends into which the centrifuge tubes are inserted. The center of the horizontal arm is fixed to the upper end of a revolving shaft that is mounted in bearings at the bottom and driven through gears by either a hand crank or a motor. The hinged fixtures enable the bottoms of the test tubes to swing outward as the machine comes up to speed. The machine is balanced by partly filling the second tube with water. Centrifuge tubes can be bought at drugstores and the remainder of the apparatus can be improvised from scrap materials. After 10 minutes the solid part of the centrifuged blood will have largely collected in the pointed end of the centrifuge tube, leaving the straw-colored serum at the top. The serum is decanted into a clean tube and centrifuged an additional five minutes at 3,000 r.p.m. The upper half of the serum is then decanted into a vial and stored in a refrigerator at a temperature of 45 degrees Fahrenheit.

"The cell is prepared for an experimental run by first cutting a strip four centimeters wide and 10 centimeters long from a sheet of Whatman No. 3 filter paper and drawing a pencil line squarely across the strip .5 centimeter from one end. (Be careful not to scratch the paper with the pencil.) The strip is then saturated with electrolyte and blotted as dry as possible between two sheets of filter paper.

"A thin line of serum must now be applied along the pencil line. Fair results can be achieved by taking up a few drops of serum in a pipette and drawing the tip across the strip. But it is better to use a special applicator: a pair of fine, closely spaced parallel wires five centimeters long stretched between the tines of a short fork.

"To make the fork, bend a 25-centimeter length of heavy iron wire double

No two are the same

And the molecules in any two elements are never the same either. At Cal Tech's Jet Propulsion Laboratory, these molecular differences will soon add up to a better understanding of what the Moon is made of.

When the first Surveyor spacecraft soft-lands on the Moon in 1963, it will drill into and extract samples from the Moon's surface. After an electric oven decomposes these samples, their molecules in the form of burned-off gas will pass through a column to a detector. The detector response rate — and the amount of molecules — will be recorded and transmitted to earth.

Since JPL scientists and engineers know what molecules cause what kinds of responses (fingerprints), they will then know what elements are on the Moon. Most important, they may detect pre-life molecules on our satellite — a first clue to life in outer space.

At JPL it takes many good, curious, searching, dedicated minds to determine what instruments will measure what on the Moon and planets. Many many minds that work as one. Minds such as yours, perhaps. Will you write us today? If you have a mind to?

JET PROPULSION LABORATORY
4802 OAK GROVE DRIVE, PASADENA, CALIFORNIA
Operated by California Institute of Technology for the National Aeronautics & Space Administration

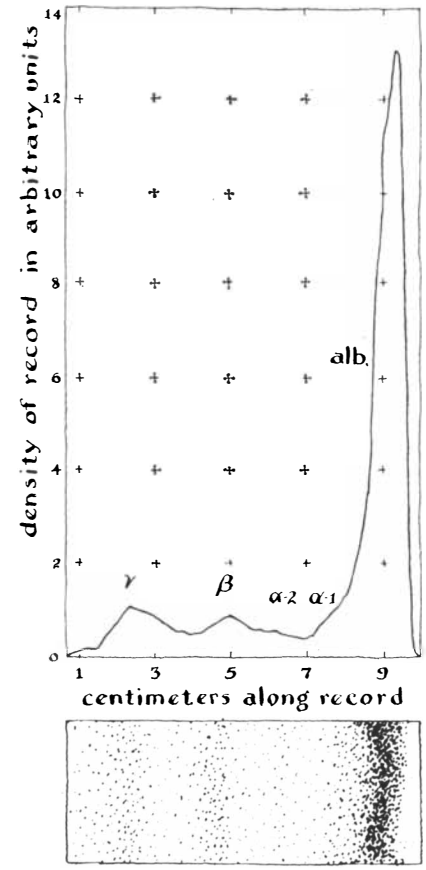
All qualified applicants will receive consideration for employment without regard to race, creed or national origin / U. S. citizenship or current security clearance required.

at the middle like a hairpin and clamp the free ends in a vise five centimeters below the loop. Insert a nail through the loop for a handle and twist the loop several times. Remove the wire from the vise and bend the free ends to form a pair of tines one centimeter long spaced five centimeters apart. The fine wires are made from the *E*-string of a violin. Fold an 11-centimeter length to make a double strand and solder the ends so that the wires stretch between the tines. Be sure not to solder the fine wires together except at the tines. When the solder cools, insert a razor blade between the strands at the ends where they are attached to the tines and spread them just enough to make a thin slit.

"Clean the completed applicator thoroughly. Then place a single drop of serum on the wires at the center. Capillary attraction will make the serum flow evenly across the slit. Transfer the serum to the filter paper by pressing the wires gently against the pencil mark. A straight, sharp line is wanted; getting it can be simplified if the serum is diluted with one part phenol red to two parts serum. The specimen will then appear as a pink line across the paper and any smudging will be evident. Phenol red does not react with proteins and migrates out of the paper when current is applied to the cell.

"The inner faces of the glass plates are coated lightly with silicone grease, which can be bought in tubes at radio supply stores. The paper is sandwiched between the two coated plates. The assembly is secured by clamps as shown, greased lightly along the sides to prevent evaporation and placed on the ends of the containers. Check to see that the level of the electrolyte in the two containers is the same, or it will flow from the higher to the lower container through the filter paper and interfere with the migration of the proteins.

"Connect the power supply to the cell, with the negative lead attached to the terminal at the specimen end of the paper strip. Switch the current on and adjust the potential to 300 volts. If the electrolyte is at the specified concentration and *p*H, the cell will draw about two milliamperes at this voltage. Switch off the current after two hours and tear off the dangling ends of the paper as close as possible to the glass plates. This prevents excess electrolyte in the discarded ends from flowing into the protected portion of the paper and smearing the zones. Release the clamps and remove the strip carefully. Place it on a sheet of dry filter paper and, keeping it horizontal, put it in an oven at about

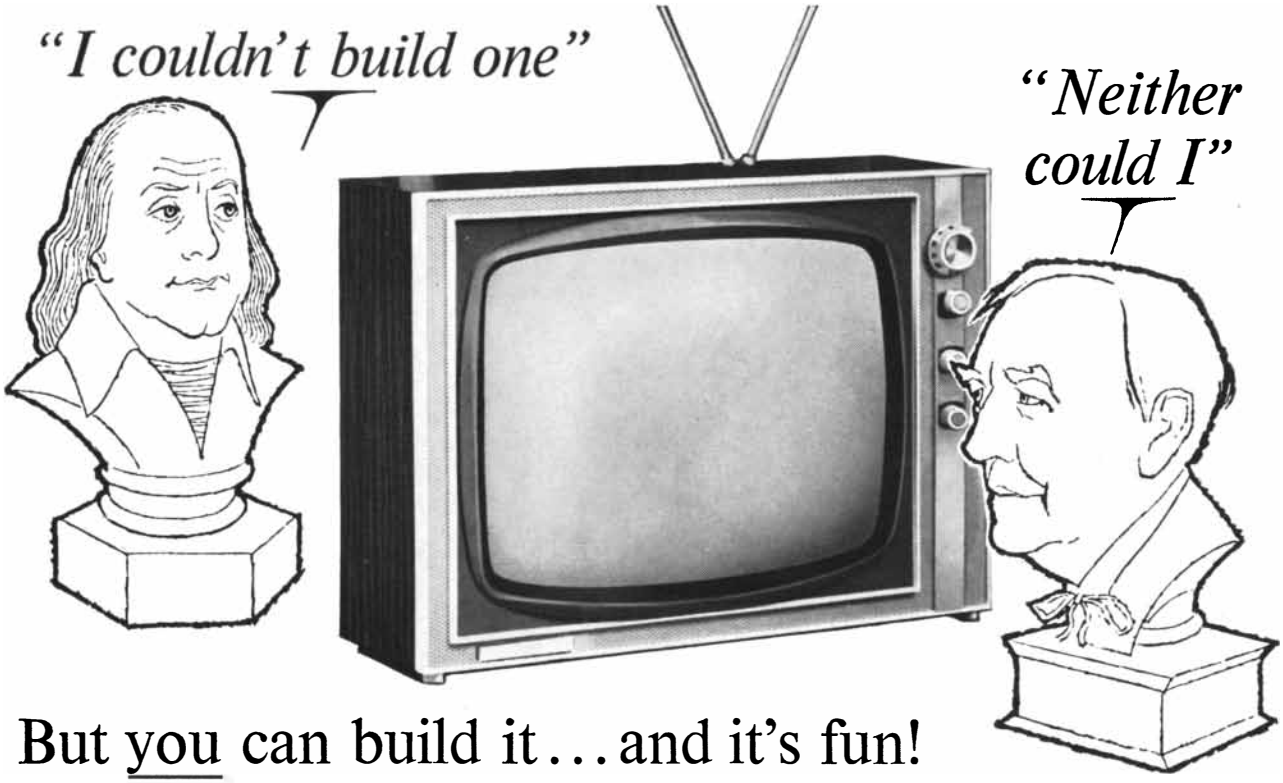


Serum-protein zones and density graph

250 degrees F. for 30 minutes. The heat binds the proteins to the paper and increases their affinity for dye.

"The proteins are then stained by immersing the strip for 16 hours in a solution of 50 milliliters of glacial acetic acid, 50 grams of zinc sulfate and .1 gram of bromophenol blue dissolved in distilled water to make one liter. This will color the whole strip deep blue. The paper is then rinsed twice for five minutes each time in a 4 per cent solution (by volume) of acetic acid, with fresh solution being used for each rinse. The protein zones should now appear as a series of blue transverse bands of varying density against a background of pure white. Next the strip is immersed for two minutes in a fixing solution made by dissolving 20 grams of sodium acetate and 100 milliliters of glacial acetic acid in distilled water to make one liter. Then the paper is blotted, dried in an oven for five minutes at 250 degrees, placed close to a tuft of cotton saturated with household ammonia and covered with a mixing bowl for 10 minutes.

"The significance of the electrophoresis technique becomes apparent when the density of the zones is measured and plotted as a graph. The measurement is



But you can build it... and it's fun!

Ben and Tom were born too soon. They had to be content with kites and light bulbs. But *you* can build your own TV set.

Don't shake your head . . . think positively. You *can* do it. The TV set you see above was built by an advertising copywriter with the mechanical ability of a two-toed sloth. And it works. Wonderfully! You, too, may be lucky.

This thinking man's toy is the Conar Custom 70: A do-it-yourself television receiver that is practically foolproof. (Conar is a division of the National Radio Institute—this nation's oldest, largest home study school teaching TV-Radio-Electronics. For almost 50 years, kits of home laboratory equipment developed by NRI have been effective features of NRI training methods.)

Why should you build a Conar Custom 70? Call it intellectual curiosity . . . the desire to know what makes TV tick (even if you detest TV). Call it tinkermanship . . . the love of creating something that lights up, talks and shows pictures. Call it one-upmanship . . . the urge to top that hi-fi bug down the street. We will say no more. Might get in bad with the Motivation Research Union. Besides—we really don't know why people do the things they enjoy doing.

Look at that set again. It's no rinky-dink, gutless wonder. Furthermore, here's an analysis to prove you may gain the distinction of owning *the most expensive* TV in your neighborhood:

(A) We sell you components and instructions for $135.
(B) It should take about 25 hours to put the kit together.
(C) Then figure that your overtime hourly rate is $40—

25 hours × $40 per hour + $135 = $1,135 (Q.E.D.)

We supply every last screw and widget, with directions and diagrams that lead you by the hand from the first connection to the final sigh of accomplishment. You need only a screwdriver, pliers and soldering iron.

Send the coupon today. Or if you are the cautious kind, think it over until tomorrow. But *do* get started on as rewarding a project as you ever tackled. It'll be fun . . . we guarantee it.

IF YOU MUST HAVE THEM—HERE ARE SPECIFICATIONS
(very dull reading)

- Extremely stable, trouble-free circuit with transformer power supply which isolates chassis and cabinet from the power line. (It's safe. No customers electrocuted yet.)
- Brilliant, glare-free, sharp picture; plenty of contrast and brightness. (No squint.)
- 19" aluminized, 114° self-focusing picture tube with 206 sq. in. of viewing area. (Funny thing—not every 19" tube is this big.)
- High gain, high signal-to-noise ratio front end tuner, factory assembled and pre-aligned. "Lock-set" feature lets you change channels without readjusting fine tuning. (No sweat.)
- Uses 3 stages of pre-aligned video IF, a separate pre-aligned 4.5 mc. sound IF amplifier and 2-stage video amplifier. It has keyed AGC and sync noise limiter. Audio power is enough to drive extra speakers, if desired. (Men who know appreciate those things.)
- Uses latest type multi-purpose tubes; has built-in rabbit-ear antenna and optional connections for outdoor antenna; attractively styled cabinet is only 8½" deep. (How can we do it for $135.00?)

GUARANTEE

If you don't think the "Custom 70" is all we say it is, just send it back and we'll refund every penny. We may bleed a little, but we won't quibble. NRI is an Associate Member of the Electronic Industries Association; an Accredited Member of the National Home Study Council.

CHECK APPROPRIATE PLAN:

☐ You've sold me. Send me the whole kit and caboodle. $135.00 is enclosed.

☐ I'm 25% sold. Enclosed is $36 for package # 1. I'll order the other 3, at $36 each, as I am ready.

☐ I'll spring for two bucks to get the Assembly Manual. Credit the $2 to my future order.

I understand prices include 10% Fed. Tax. I will pay shipping costs upon arrival.

CONAR *instruments*
3939 Wisconsin Avenue, Washington 16, D. C. FN 2 C

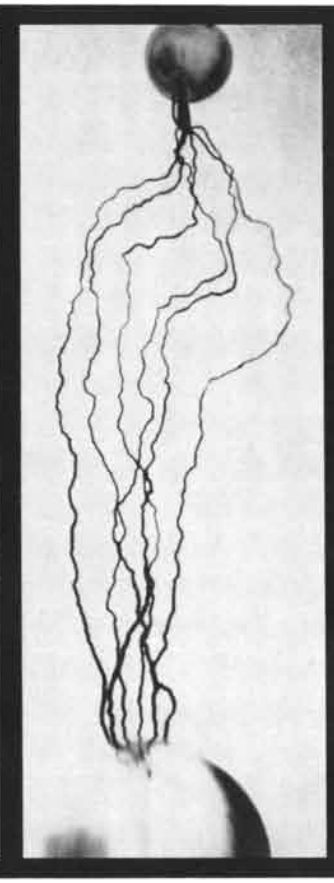
I have checked the plan I want.

NAME_____

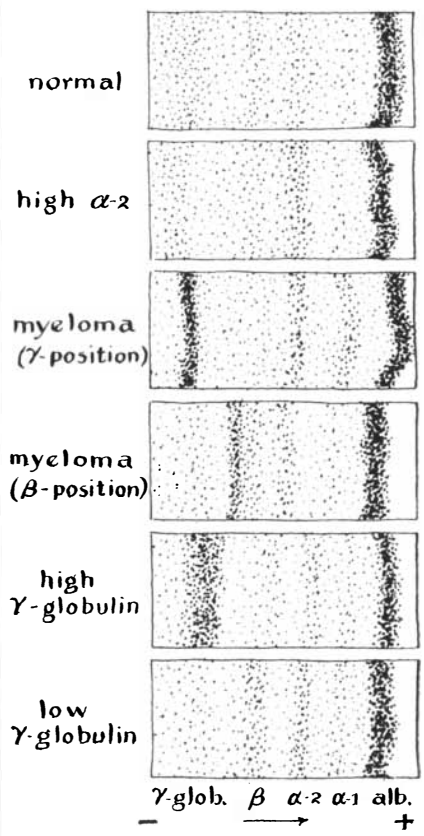
ADDRESS_____

CITY_____ ZONE____ STATE_____

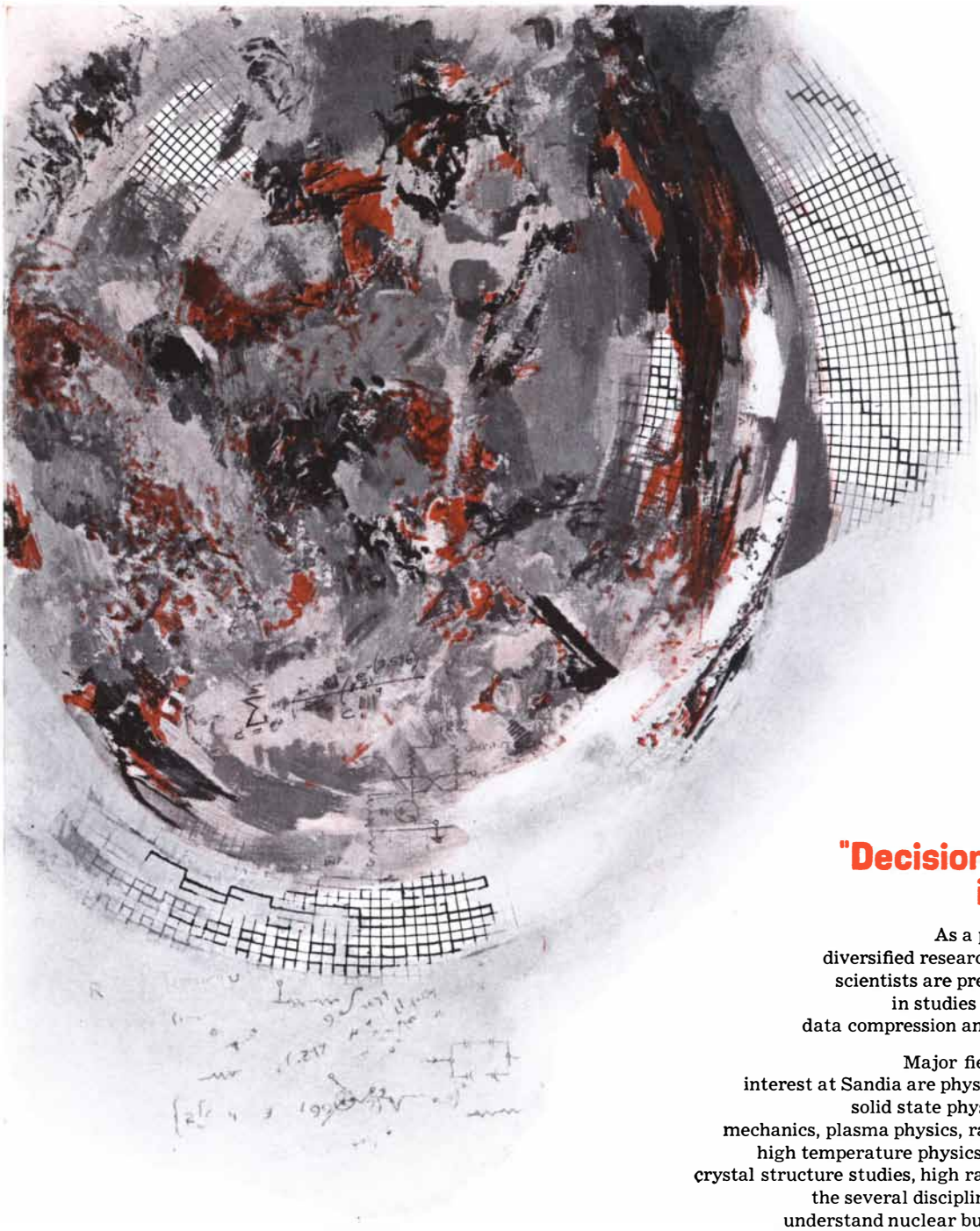
Division of National Radio Institute



made by means of a densitometer, a photocell that indicates the intensity of light transmitted by the stained proteins through a slit moved along the strip. A densitometer can be improvised from an ordinary exposure meter of the type used by photographers, a sheet of glass set in a frame and some cardboard. Cut a piece of cardboard large enough to mask the photocell aperture, and with a razor blade cut a straight slit in the center of the mask about two centimeters long and one millimeter wide. Fasten the mask over the photocell with adhesive tape. Then, with a pencil, draw a series of index marks precisely one millimeter apart along the full length of the prepared electrophoresis strip at one edge. Center the indexed strip on the framed glass, with the bottom face of the strip in contact with the glass, and attach the ends to the glass with adhesive tape. Clamp one edge of the frame to the edge of a desk or table so that the glass extends out from the support, with the paper on top. Place the slit of the exposure meter squarely over the most intensely dyed zone and position a 100-watt incandescent lamp below the glass at a distance such that the pointer of the exposure meter is deflected slightly by the



Variations in zones of stained proteins



"Decision-Maker" in Space

As a part of Sandia's diversified research program, our scientists are presently engaged in studies involving space data compression and transmission.

Major fields of research interest at Sandia are physical electronics, solid state physics, theoretical mechanics, plasma physics, radiation effects, high temperature physics, molecular and crystal structure studies, high rate kinetics, and the several disciplines necessary to understand nuclear burst phenomena.

Sandia has openings at the Ph.D. level in the following fields: Materials Science, Engineering, Mathematics, Physics, Chemistry, and Aerodynamics.

Qualified scientists interested in careers at Sandia are invited to send resumes to Professional Employment, Section 569.

SANDIA CORPORATION

ALBUQUERQUE, NEW MEXICO
LIVERMORE, CALIFORNIA

An equal opportunity employer.

RESEARCH LABORATORIES AND INDUSTRIAL USERS

Cal. Tech.—Jet Propulsion Lab.
Naval Research Laboratory
M.I.T.—Lincoln Laboratory
Royal Inst. of Tech., Sweden
Aerospace Corporation
Arma Corporation
Aura, Incorporated
Avco—Everett Research Lab.
Bell Telephone Laboratories
Bolt, Beranek & Newman
Celanese Corporation
Chase Manhattan Bank
Comision Federal de Electicidad, Mexico
Convair
Cornell Aeronautical Laboratory
E. I. duPont de Nemours Co.
East Africa Agri. & Forestry Research Organ., Kenya
Duval Industries
Edgerton, Germeshausen & Grier
Electronics Corporation
Engelhard Industries, Inc.
Fisher's Television Co.
Ford Motor Company
Frankford Arsenal
General Electric, Schenectady and Philadelphia
G.M.—AC Spark Plug Div.
Hammarby Bakelit Industri Aktiebolag, Sweden
IGY Program, Germany
Los Alamos Scientific Lab.
Minneapolis-Honeywell, Minn. and St. Petersburg
North Am. Aviation—Autonetics
Northrup Aviation—Nortronics
Patapsco Engineering Co.
Photogrammetry, Inc.
Raytheon Manufacturing Co.
RCA Laboratories
Michael Reese Hospital
Servomechanisms, Inc.
Shell Development Company
Sperry Gyroscope Company
Sports Network, Inc.
The Standard Oil Company
Tell Manufacturing Company
Texas Instruments, Inc.
United Aircraft Corp.—Norden
U.S. Naval Electronics Lab.
Univox Corp.
Westinghouse Electric Co.
WHDH-TV, Boston
Woods Hole Oceanographic Inst.

UNIVERSITIES AND COLLEGES

Univ. of Aberdeen, Scotland
University of Arizona
University of California
University of Chicago
University of Colorado
University of Hawaii
University of Illinois
University of London
University of New Hampshire
University of Pa., Sch. Med.
University of Poona, India
University of Rochester
University of Toledo
University of Toronto
University of Utah
Baylor Univ., Coll. Med.
Christian-Albrecht U., Ger.
Columbia University
Memphis University School
Stanford University
Washington University
Adams State College
Adrian College
Arizona State College
Beloit College
California Inst. of Technology
California St. Teachers Coll.
Carnegie Institute
Christian College
Clemson College
Cooper Union
Dickinson College
Fraunhofer Inst., Germany
Georgia Inst. of Technology
Glendale College
Harbor College
Indiana State College
Lawrence College
Long Beach State College
Los Angeles State College
Mt. San Antonio College
Mundelein College
Newark State College
Oklahoma A & M College
Parsons College
Pierce College
Principia College
Randolph-Macon College
Rollins College
St. Mary's College
San Diego State College
Southern Conn. State College
Sul Ross State College
Whitman College
William and Mary College

GOVERNMENT AGENCIES

Atomic Energy Commission
NASA, Edwards, California
NASA, Langley Field, Va.
NASA, Titusville, Florida
NASA, Goddard Space Flight Center, Greenbelt, Md.
National Institutes of Health
Aberdeen Proving Ground
U.S. Army, Ft. Monmouth, N.J.
Redstone Arsenal
U.S. Army Intell. Center
White Sands Proving Ground
Griffiss AFB, New York
Holloman, AFB, New Mexico
Wright-Patterson, AFB, Ohio
Naval Air Develop. Center
Naval Air Station, Norfolk, Va.
U.S. Nav. Ord. Sta., China Lake
CARDE, Def. Res. Bd., Can.
CIA
Department of State
FBI
French Government—Army
National Bureau of Standards

OBSERVATORIES AND MUSEUMS

Dominion Observatory, Canada
Hayden Planetarium
High Altitude Observatory
U.S. Naval Observatory, Wash.
Osservatorio Astronomico di Capodimonte, Italy
Valley View Observatory
Columbia Museum of Art
Grand Rapids Public Museum
Kingsman Museum Nat. Hist.
Mount Stromlo Ob., Australia
Museum of New Mexico
Saskatchewan Mus. Nat. Hist.
National Observatory

SECONDARY SCHOOLS

Elmira Free Academy
Flint Junior College
Friends Academy
Greenwich, Conn. H.S.
Kent School
Millbrook School for Boys
Newton Public Schools
Oklahoma High Schools
Paris Junior College
Pomfret School
Riverdale Country School
St. Louis Prep. Seminary
San Diego Unified Sch. Dist.
Wamogo Regional High School
Waseca Public Schools
Waterford High School
Village of Wayland Pub. Sch.
Westminster School
Yuba City Union High School

light that comes up through the zone. Then shift the slit along the strip, one millimeter at a time, and tabulate the deflections for each interval. The accuracy of the measurement can be improved by taping a ruler to the glass so that the slit can be kept at right angles to the edge of the strip and shifted parallel to it. A densitometer that is of higher sensitivity and more convenient to use can be assembled by connecting a silicon solar cell, such as the International Rectifier Type S1020E8-PL, to a milliammeter calibrated to read 30 milliamperes at full scale.

"A graph of protein density in rectangular co-ordinates is made by plotting the tabulated meter readings against the length of the strip (in millimeters). The concentration of proteins in human blood from a healthy person should resemble the accompanying graph [*page 176*]. To compute the relative proportions of the proteins, measure the area under each of the five humps in the curve and calculate the percentage of the total accounted for by each.

"Departures from this normal graph have been identified with a variety of diseases. Prolonged malnutrition and diseases of the liver are associated with abnormally low albumin. Abnormally high levels of alpha-2 globulin, such as that indicated in the second strip from the top in the accompanying illustration [*page 178*], can indicate inflammation or tissue destruction. Antibodies are included in the gamma globulin zone; low values may indicate poor natural resistance to disease. Zone electrophoresis is particularly helpful in diagnosing agammaglobulinemia, a condition characterized by the absence of gamma globulin.

"Interesting differences in the proportions of serum proteins have been tabulated for a few animals. In the case of human blood, the level of albumin normally ranges from 47 to 71 per cent of the total serum proteins, with a mean value of 59.2 per cent, whereas in mature horses it ranges from 50 to 55 per cent, with a mean value of 51.8 per cent. The corresponding mean values of alpha globulin reported in human serum and horse serum are 12.5 per cent and 17.1 per cent, for beta globulin, 11.4 and 16 per cent, and for gamma globulin, 15.1 per cent and 16.6 per cent.

"Normal values have been tentatively established for cows, pigs, dogs, rats, mice and alligators. In general the graphs appear to differ increasingly from those of human serum as animals at progressively lower levels of evolution are analyzed."

Research Scientists • Systems Analysts • Physicists • Economists • Mathematicians
Social Scientists • Life Scientists • **Career Appointments**

CREATIVE THINKING TODAY FOR 1965, 1970, 1975

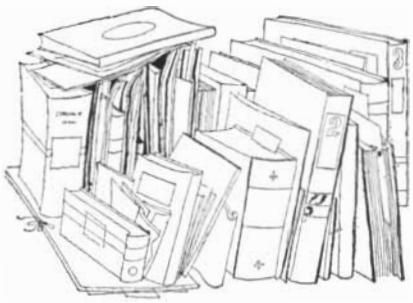
The Research Analysis Corporation applies the techniques of operations research to the timely solution of tomorrow's emerging problems—military, political, economic, social. In this critical mission, RAC utilizes the knowledge and skills of mathematicians, physicists, economists, psychologists, political scientists and others.

RAC, a private, nonprofit organization now staffed with more than 400 people, is expanding dynamically. We offer professional men and women an uncommon opportunity for challenging, exciting, and rewarding work within an intellectual atmosphere.

Career positions are now available at all experience levels. Financial remuneration reflects the importance of the work you will be doing. Your inquiries are invited; send resume to: Mr. John G. Burke, Research Personnel Officer.

RESEARCH ANALYSIS CORPORATION RAC

6935 Arlington Road, Bethesda 14, Maryland • An equal opportunity employer



BOOKS

Concerning the forces that have shaped the architecture of the affluent society

by Serge Chermayeff

ARCHITECTURE AND THE ESTHETICS OF PLENTY, by James Marston Fitch. Columbia University Press ($7.50).

In his book *The Affluent Society,* John Kenneth Galbraith says that the U.S. has an "abundance" of building. Unfortunately very little of this abundance deserves to be called architecture. Why this is so is the question to which James Marston Fitch applies himself with erudition and wit in *Architecture and the Esthetics of Plenty.* Fitch is especially concerned with the peculiarly American ingredients of the architecture of the affluent society.

The frustrations and delays of World War II repressed so many individual talents longing to find expression in architecture that when the war ended, the pent-up urge to build reached an explosive force matching the explosion in technology and the expansion of the national economy. Structures of every kind and new transportation and communication facilities sprang up almost overnight. Everything moved so quickly and the appetite for new things was so ravenous that few producers or consumers could, or even wanted to, take the time to weigh the consequences of the great upsurge.

As was to be expected, the architectural profession itself went through a period of profound change, not only in the opportunities afforded by the biggest building boom of all time but also in the popularity of architecture as a career. Within a few years the profession became, to anyone who could draw a little and was vaguely "artistic," a desirable (and easier) alternative to a career in science, engineering, medicine or law. For the individual consumer architecture became a fashionable and dignified advertisement: a modern house, modern furniture and in particular modern art became more impressive status symbols than the latest automobile—more enduring, more patrician and even a better investment.

But if this period of feverish activity brought forth mountains of trash, it also produced some of the greatest designs of our time. A number of architectural masters, hospitably received before the war as refugees from Nazism, were practicing in the U.S. Their philosophy and talent complemented in diverse ways the philosophy and talents of native American architectural genius. Their lifework was much in the American vein of pragmatism, willingness to try anything and, above all, industrialization of production.

Fitch recounts the events and pressures that gave rise to contemporary architecture and tells of its prophets and pioneers. Instead of the aesthetic and elegant, if somewhat obscure, phrasing one usually finds in architectural criticism, Fitch's essays present a clear, reasoned theme of the development of architecture from the beginning of the 19th century to the present. He begins with the democratic functionalism of Thomas Jefferson, who designed for the University of Virginia buildings well suited to the purposes of democratic education, and for his own home at Monticello a house thoughtfully adapted to meet the service problems of a large establishment. Fitch then describes the work of such stanch U.S. nonconformists as Horatio Greenough in the 1840's, Catharine Beecher in the 1860's, Louis Sullivan and Frank Lloyd Wright at the turn of the century, the *émigrés* from Europe in the late 1930's and finally the amalgam of talents that is turning out today's architecture.

Greenough, a sculptor who ruthlessly criticized the excesses of neoclassicism, formulated the principle "form follows function." He gets from Fitch the attention he deserves and proper credit for first defining the principle of fitness for purpose in nature as well as in the man-made. This conceptual innovation is often mistakenly attributed to Louis Sullivan, who revived and followed the principle much later.

The discussion of the roots of Frank Lloyd Wright's architectural advances emphasizes the thread of pragmatism, usually not recognized by his many biographers and disciples. Wright respected laborsaving devices and new conveniences generally for their ability to reduce household drudgery and make a house a delight as well as a dwelling. His work echoed Catharine Beecher's "ideal" houses, which transformed the farm kitchen into a laborsaving unit of essential elements and conveniently disposed facilities. Miss Beecher's boldly reformed kitchen, supplemented by sensible rearrangements of the furnace and ovens and by the introduction of the Franklin stove instead of the fireplace (which she considered dirty and inefficient), constituted the first mechanical "core," which became a commonplace 100 years later in the modern house.

An excellent essay on Wright's "beloved master" Sullivan reinforces this central theme in discussing the rural bank building designed by Sullivan for a man named Bennett in Owatonna, Minn. Bennett wrote Sullivan that he sought a design "to express the thought or use underlying a building." Sullivan, says Fitch, saw the general implications of current developments and insisted not only on pointing them out but also on giving expression to them in his work.

When he considers the contribution of European-born architects to the American style, Fitch centers his discussion on two great figures: Walter Gropius, founder of the Bauhaus, and Miës van der Rohe. In many ways the chapter on Gropius best illustrates the theme underlying most of Fitch's writings: a search for an aesthetic basis for architecture, freed from formalist preconceptions. Increasingly Gropius' work has fallen under the attack of younger men. Fitch takes an entirely different view. He compares Gropius to Einstein, Shaw, Matisse and Wright—"shakers and makers of the modern world [who] spent their lives under a very special set of historical conditions [and] lived to be very old men in a period of fantastically accelerated social change. Unlike the great prophets of past times, they survived not merely to see their predictions come

true [but] lived on into a world in which their work had become commonplace, the very warp and woof of everyday life.... This situation, so novel in human affairs, creates a dilemma both for them and for us, who have so hugely profited from their efforts."

"In its short and crisis-ridden life," Fitch continues, "the Bauhaus trained more than 500 men and women in various fields. Its publications, exhibitions and lectures so precisely filled a vacuum that its influence was out of all proportion to its size. It irradiated all of Western Europe and (after Gropius' arrival at Harvard in 1937) America. Although the Bauhaus curriculum could not be applied at the Graduate School of Design, the Gropius philosophy of design could. It made Harvard a leading world center of architectural studies and produced a whole generation of designers who have now emerged as leaders of the profession. The durability of the Bauhaus concept is proved by the fact that designers have been coasting for decades upon the momentum generated by those first historic years at Weimar and Dessau. Yet education for design has not followed the precedent set by the Bauhaus; it seems instead to have taken the opposite path. Art schools and trade schools have proliferated; but where in the world today is there an institution that faces the problem as squarely, as profoundly as did the Bauhaus in its time?... The designer is more and more removed from any control over, or any real understanding of, science and technology. And the process of design deteriorates into mere cosmetics: robbed of any firm base in function, it has become the prisoner of fad and fashion. In such a context it should be clear that, far from having 'outgrown' the need for a Bauhaus type of education, we need it more than ever."

The antagonism to the Bauhaus, it might be added, is now being consciously cultivated by the single-minded disciples of Le Corbusier, to whom any idea of competition with their idol has become abhorrent. They have forgotten the earlier programmatic Le Corbusier and worship exclusively the later personal, sculptural vigor of raw concrete, regardless of place and purpose.

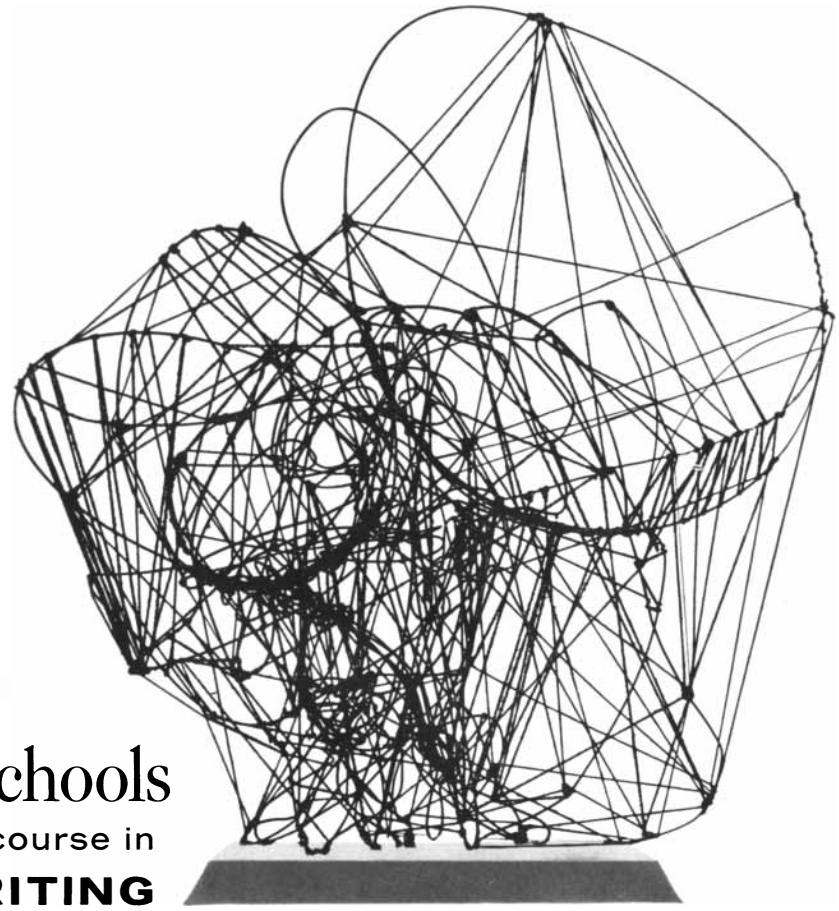
It should also be noted that the Le Corbusier idiom, aesthetically derived from the historic architecture of the "golden crescent" of the Mediterranean Sea and Near East, is technically based on steel-hungry and industrially underprivileged economies. It is not in the American vein and transplants as unhappily from the blazing light of the Near East or India to New England as do sunbreak grilles.

Turning from Gropius to Miës van der Rohe, Fitch recognizes a quite different genius. He speaks of Miës and the climate of Plato. "The German Pavilion at the Barcelona International Exposition of 1929 and the Tugendhat residence of 1930 in Brno, Czechoslovakia, proved to be two shots that would be heard around the world. Although both buildings played important roles in the battle for world-wide acceptance of the modern style, the Pavilion was perhaps the more influential.... Fortunately it was photographed before it was dismantled, and through this medium it survived to engrave its dazzling image on the modern retina. No other single building of the 20th century was to do more in shaping the taste of the era." How was this possible? "It was not due to any single innovation in plan; both Wright and Le Corbusier had already employed the hovering roof, the nonstructural screen wall, the floor-to-ceiling glass. Nor was the building especially advanced technically.... No, the greatness of the Pavilion lay in something more subtle: the fact that it managed to express, in the most exquisitely polished and exact terms, the highest aspirations of a Europe racked by war and inflation. Here were the clarity, order, peace it longed for; here were the noble spaces, unpolluted by any connotation of a discredited feudal past; here were fine materials, freed of decadent motifs and moldy symbols, glowing with their own intrinsic beauties. Here was a catalytic image that was to clarify problems of design for whole generations of men."

Skyscrapers, a particularly American aspect of the architecture of plenty, are discussed by Fitch with emphasis on the enclosing skins: "They become, ultimately, mere textural manipulations of the surface, like the weave of a fabric." He casts doubt on the ability of architects to remain in command of the skyscraper's plasticity unless the rectangularity derived from the grid pattern of streets in which they have been built is abandoned, together with the office occupancy as its single function. This seems a flawed argument. Standardized, anonymous space is surely inherent in the skyscraper, which has to provide accommodation for unknown tenants, for unknown periods of time and for changing purposes. But immediately thereafter Fitch defines the true basis for architectural control and formal variety. It is this section of the book that I find the most fascinating and rewarding.

The man-made mountains rise into a

learn to
translate your
specialized knowledge
into
common
understanding



Sculpture, "Space Capture" by Martinez

Britannica Schools
announces a new course in
TECHNICAL WRITING

Must you translate technical and specialized knowledge for non-technical management (or employees) . . . for other technicians who require clear and concise information . . . for customers who understand function but not construction or operation?

Obviously, your ability to communicate, to translate your specialized knowledge and ideas into commonly understood terms, may well be the most important skill you can develop.

Recognizing this critical need, Britannica Schools, the newest member of the Encyclopaedia Britannica family, sponsored the development of a fresh and excitingly effective case approach to the teaching of technical writing.

Now, after a thorough testing in the college and industry classroom, this dynamic, modern course, *Technical Writing,* is available to you, for study in your own home under the guidance of trained technical-writing tutors.

You will learn how to sift, select and organize factual data and information . . . how to think and write logically, with precision and clarity . . . how to define scientific terms and use them with integrity . . . how to work in concert with designers, engineers and top management.

You must see the course materials to appreciate the sophisticated presentation. You will be pleasantly surprised with the mature blending of wit and wisdom, of good humor and good teaching.

Working at your own pace, in the privacy of your own home, you will waste no time in fanciful discussions of writing theory. Rather, utilizing the effective "case approach" technique, you will learn how to write by writing under the personal tutelage and individualized guidance of your own instructor.

Fill out and return the coupon in this ad. You will receive detailed information about *Technical Writing* and an opportunity to study the valuable new course material, at your leisure, during a 10 day free examination.

Britannica Schools

division of Encyclopaedia Britannica Films Inc.
14 East Jackson Blvd. • Chicago 4, Illinois

Dept. SAJ
Gentlemen:
Please send me further information about your course, **Technical Writing.** I understand that no salesman will call on me, nor will this request obligate me in any way.

Name _____ Age _____

Occupation _____

Address _____

City _____ Zone _____ State _____

hostile climate. The lower buildings that preceded skyscrapers enabled the enclosure to act as a relatively uncomplicated boundary between the natural conditions outside and the interior. Today the sheltering wall, the windows that could be opened for ventilation, that were clear for view and light, have been discarded. Increase in size and height and improvements in mechanical controls have given the great containers of our period immunity from the vagaries of climate and diurnal cycle.

A standardized artificial environment 24 hours a day is now possible. The trend is to make it undesirable even to look out. We are only beginning to understand the inevitable conflict between the objectives of comfort and convenience and that of not being cabined, cribbed and confined. Structural as well as mechanical devices must be conceived in the resolution of this conflict.

"It becomes increasingly hard," says Fitch, "to defend [the present standardized approach] from the points of view of human comfort and mechanical efficiency. Air-conditioning equipment is expected to meet undeviating physiological criteria (e.g., 72° F. air temperature, 50 per cent relative humidity) throughout the enclosed volume of the building. Yet around the periphery of this volume conditions would vary immensely. Thus on a cold, bright, windy day in December the north wall—chilled by the wind and untouched by the sun —would have the climate of Canada. At the same time the south wall of the same building, protected from the wind and exposed to the sun, would have a climate like that of South Carolina. On a hot July afternoon the west wall would have the climate of the Arizona desert, while at the same time the east wall would have the climate of Massachusetts."

The best possible combination of technical features conducing to comfort and convenience must inevitably produce new forms. We continue, however, to do rather foolish things; for example, making transparencies that have to be filled and translucencies that are blinding. There is more glare through a diffusing sheet than is created by the sky itself; a greater intensity of artificial illumination is required to reduce contrast glare in the latest glass-curtain-walled skyscrapers during the day than at night, when the lights are actually dimmed. Fitch speculates: "A technology that can achieve the thermonuclear bomb and the moon rocket should give us a wall that behaves like the epidermis of the animal body—i.e., that responds actively and automatically to changes in its external environment. It is not too difficult to imagine such a wall. In the first place, it should have a capillary heating and cooling system built into it, much like the skin of a warm-blooded mammal. The function of these capillaries would not be actually to heat and cool the interior volumes of the building so much as to provide a thermal symmetry inside that the air conditioning could more effectively operate." As things are, the ubiquitous and not particularly efficient Venetian blinds remain down 24 hours a day and constitute the single greatest acreage in any cityscape.

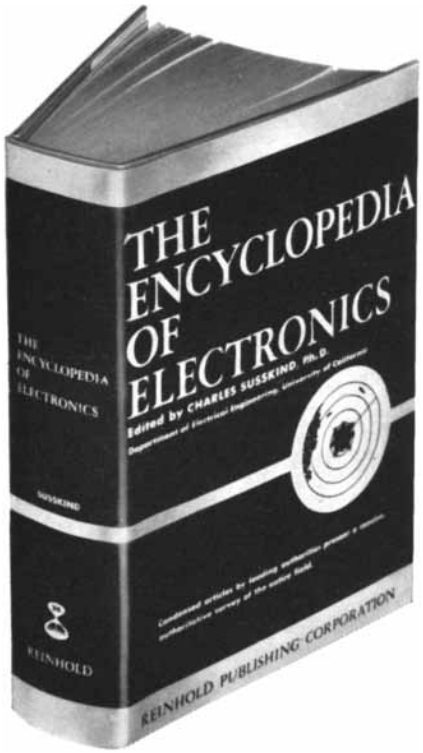
Whatever we do to change this architectural desert will not come easily, and it certainly will not come from the whimsical and willful redesigning of façades. "Façadism," the prevailing millinery of today's architecture, is no adequate substitute for the "drapes" of yesterday. Wherever the architecture of plenty may be going, it will not get there by superficial and facile adventures. Hunting for mere style is obsolete. The art and science of architecture, which Fitch discusses in the last chapters of his book, demand hard work and concentrated thought. Neither the "artist" nor the "master builder" image of the architect of the new era of abundance rings quite true. One can no longer perform by ear or intuitively in any profession, any more than the pilot of a modern aircraft can fly by the seat of his pants. The technology is too complex, the pace is too rapid, the scale is too large, the purposes are too diversified. Even the "practical man" of generalized, pragmatic experience becomes less and less practical, more limited and, in an age of rapid obsolescence, himself obsolete.

The word "architect," as used in the affluent society, is the name for many men engaged in different activities of designing, planning and construction. Today's master builder is an organization for the financing and building process. Architect and master builder: each differs as markedly from his immediate predecessor as a young American does from his parents.

The spectrum of design has become suddenly enlarged, and arbitrary distinctions between all sorts of functionaries are disappearing. At one end of the range is industrialized production, with its precision and repetition, embracing almost numberless components but often limited choice; at the other end are the social and natural complexities, of infinite variety and little precision. The problems to be resolved require not only intuitive grasp of principle but also computer techniques, and the solutions must

Today's world of electronics at your fingertips—a pre-publication offer!

COVERS ALL ASPECTS OF A FAST-DEVELOPING SCIENCE, INCLUDING PRACTICAL APPLICATIONS



Over 500 authoritative articles range from standard technology to latest discoveries. Whole volumes compressed by author-experts into useful, well-written articles.

Just Published!

THE ENCYCLOPEDIA OF ELECTRONICS

edited by Charles Susskind

Associate Professor of Electrical Engineering,
University of California

1962, 7″ x 10″, approximately 1,000 pages, fully illustrated

Pre-publication price $19.50
List price after Sept. 30 ..... $22.50

Packed with useful information on all phases of electronics, this one-volume reference work covers the science itself, as well as its significant ramifications and applications. There are articles on basic principles and physical effects underlying electronics, articles on materials, components, systems, applications, manufacturing processes, and the newest analytical techniques used in electronics. All entries are arranged alphabetically, *indexed and cross-indexed for easy reference.* In addition to covering all aspects of the science of electronics itself, the articles describe practical applications in air traffic control, cybernetics, geophysical prospecting, heating, machinery, operations research, refining, and many others. Numerous entries describe the overlapping of electronics with astrophysics, mathematics, chemistry, geophysics, and physics. *Included also are articles on topics barely known or totally non-existent only a few short years ago,* such as atomic clocks, lasers, the Mössbauer Effect, digital instrumentation, translation by machine, and stereophonics. Nor is the *Encyclopedia* restricted to technical topics: there are articles on patents, electronic music, economics of the electronics industry, historical background, and interesting biographies of well-known electronics engineers and scientists. Contributors were drawn from several countries and represent universities, government and industrial laboratories, and private concerns. Authors were selected not only for technical expertness, but for demonstrated skill in published writings. *Wherever possible, the original discoverer or inventor of a new phenomenon or device was engaged to write the corresponding article.*

The Encyclopedia of Electronics is directed primarily to the professional worker, and will prove invaluable also for the non-specialist who needs to become acquainted with electronics principles and applications, or who wants to find out more about a specific topic. Send coupon below to Reinhold Publishing Corporation, 430 Park Avenue, New York 22, N. Y.

The Information You Need

Antennas, Propagation, Radiation—Bioelectronics—Circuits and Networks—Communication Theory and Math. Techniques—Components—Computers—Control and System Theory—Electroacoustics—Biographies—Industry and Manufacturing—Instrumentation and Measurement—Materials and Chemistry—Modulation and Noise—Navigation—Physical Electronics—Physics—Semiconductor Devices—Television—Transmission—Tubes

Written by Experts

H. R. Aaron: Pulse Code Modulation
H. A. Haus: Noise in Electron Beams
E. I. Jury: Sampled Data Systems
R. N. Bracewell: Extraterrestrial Radio Sources
W. W. Mumford: Radiation Hazards
L. B. Lusted: Medical Electronics
O. Klemperer: Electron Optics
V. H. Grinich: Semiconductor Manufacture
J. R. Whinnery: Noise in Vacuum Tubes
W. K. Linrill: System Identification
A. T. Waterman, Jr.: Atmospheric Propagation
E. J. Nalos: Microwave
Hans Motz: Undulator
G. D. O'Neill: Electron Tubes (conventional)

Over 500 full-scale articles, hundreds of internationally-known contributors!

GET YOUR COPY NOW
At Special Pre-Publication Price—SAVE $3.00!

REINHOLD PUBLISHING CORPORATION, DEPT. M-990
430 Park Avenue, New York 22, N. Y.

Send me *The Encyclopedia of Electronics* at the special pre-publication price of $19.50 for 30 days' examination (in U.S.A. only) under the following terms:

☐ Total purchase price enclosed (Reinhold pays regular shipping costs). Please add sales tax on Ohio, Pa., and New York City orders.

☐ Bill me (plus postage)

NAME (please print) .....

ADDRESS .....

CITY ..... ZONE ..... STATE .....

SAVE MONEY! You save postage and delivery charges by sending payment with order. Same return privilege guaranteed. Send check or money-order only. DO NOT ENCLOSE CASH!

reflect the commitment of many interests. As we reshape our environment, remaking it rather than adapting ourselves to it, we must consider carefully the implications and consequences of our tampering. The astronaut who goes to the moon must bring some of his environment with him to meet his biological needs; he must also consider a large range of technical problems relating to landing, moving about, returning to earth. Many skills and specialized branches of knowledge have to be tapped successfully to complete such a mission. Similarly, the redesigning of the architectural landscape to modify the environment and to meet old and new requirements demands the resources and knowledge of many skills and disciplines.

To this immensely complex task the superficially educated pseudo artist-designers can make little contribution. The handwriting is on the wall. Other agencies, under other titles, are in fact producing more architecture than the architects. All too frequently we read an account of a very large urban, industrial or commercial development in which the financier, the developer, the administrator, the engineer and, worse, the decorator and industrial designer are named as the creators, with never a mention of the architect, who has slipped almost imperceptibly, as a professional, into a lower status in our society. At a moment when so-called new frontiers are being broken, it is strange that architecture should be uniquely identified with an age already past of personal, artistic expression.

Fitch, in spite of the diversity of subject matter in the essays that form this book, is quite consistent in his message: the problems of an expanding population, science and technology, transportation and communication require a re-evaluation of the purpose of design and the redeployment of the functionaries engaged in this already gigantic and expanding enterprise. Anyone who believes that so important an activity as environment building should be seriously studied is urged to read Fitch's penetrating and prophetic analysis. The architecture of plenty is groping its way toward an aesthetic comprehensive enough to unify technology and art for the comfort and pleasure of man. Nothing less will suffice.

Short Reviews

CIVIL DEFENSE IN THE SOVIET UNION, by Leon Gouré. University of California Press ($2.45). Current controversies about the need for and adequacy of

the U.S. civil defense program have been intensified by vigorous assertions and equally vigorous denials that the U.S.S.R. has for some years been engaged in an expanding program of the same kind. Until now the assertions have been made by officials who were apparently unqualified on the basis of knowledge or experience to tell us anything whatever about the U.S.S.R.; and the denials have come from U.S. foreign correspondents and others who have spent long periods in the U.S.S.R. yet were unable to gather any real evidence that civil defense was being seriously pushed. The present volume, by a member of the staff of the Rand Corporation, purports to resolve the question. As part of Rand's "continuing program of research for the United States Air Force," Gouré has studied the available printed material, which consists of copies of Soviet civil defense manuals and instructions, published speeches of military and civil defense officials, and fragmentary "reports, descriptions or criticisms of local civil defense efforts" published in Soviet newspapers and magazines.

This is pretty lean fare on which to nourish a set of healthy conclusions about what the Russians are actually *doing* about civil defense as against what they are *saying* should be done; and the fare looks even leaner in light of Gouré's concession that no information is available "pointing to the actual scope and preparedness of the [civil defense] organization," and "nothing has been published on the civil defense budget, the total number of persons engaged in civil defense organizations and those in training, the rate of shelter construction, the quantity and capacity of the various kinds of shelter already in existence, the size of stockpiles or the availability of essential equipment. Even the whereabouts of existing shelters are veiled in secrecy, since under normal conditions no signs are posted showing their location."

Such gaps in knowledge, however, do not hobble, much less dampen, the ardor of intelligence specialists; like cosmologists, they are most venturesome in their extrapolations when the available information is exiguous. And so with Gouré. In this 207-page paperback he presents a detailed picture of civil defense in the U.S.S.R. There are chapters on background and concepts, scope and organization, training the population, dispersal and city planning, individual means of protection, shelters, evacuation and so on. The material has been put together ingeniously. The great bulk of it, of course, has been taken from the manuals

and other printed sources, and consists of everything from instructions on how to decontaminate yourself and where to put your cow in the ultimate emergency to excerpts from speeches by Premier Khrushchev.

This in itself does not make the most exciting story since Ben-Hur, let alone reveal very much about Soviet civil defense. The book therefore supplies quantitative estimates, inferences and conjectures for each type of activity. These are couched in such language as "All indications are that the MPVO [the Soviet civil defense agency] disposes over a large and far-flung organization"; "Although the exact civil defense budget is not known," an estimate by Frank B. Ellis, director of the Office of Civil and Defense Mobilization, given in testimony to a Congressional committee, states that " 'a secret report... showed Russia was spending from $500,000,000 to $1,500,000,000 a year' on civil defense"; "A plausible estimate of the number of people who attended the latest [civil defense] training courses might be at least 50 million"; "If we assume that the Soviet authorities so far have distributed between 20 and 30 million masks, five to 10 million suits, and possibly as many as 100 million decontamination packets, they will have spent, on the basis of U.S. prices, between 390 and 635 million dollars [although] how much the Government is actually spending on this kind of equipment, or has spent in the past, is difficult to ascertain"; "The total Soviet shelter capacity certainly cannot be assessed from public sources. In Moscow it probably exceeds 20 per cent of the residents...." Again, the reader is referred to Ellis' "secret report," which " 'indicated that the Soviet Union was building enough shelters to protect the great majority of its population from fallout in the event of nuclear war.' "

It is in the discussion of shelters that Gouré exhibits most clearly his tendency to support conjecture with adventitious and circumstantial data. For instance, much is made of the fact that the Moscow subways, built over a 23-year period, from 1931 through 1953, can be used as effective shelters for a large number of people. Since it is obvious that they were not built for this purpose, and since there is no dependable evidence that they have been adapted for such use, the author introduces two photographs of subway stations, each purporting to show what he calls a "concealed door," which, he implies, have something to do with civil defense. It is hard to understand why the doors, which are plainly

visible, are called "concealed"; and whether what lies behind them is a washroom, a porter's closet or Ali Baba's cave remains an enigma. That the Soviet authorities have thought about the problems of civil defense, that manuals have been issued and organizations set up, that there are various kinds of shelter, old and new, that other civil defense measures have been taken, that civil defense has been discussed by politicians and generals and newspapers, partly for domestic reassurance, partly for foreign propaganda—all this seems clear enough, but one is little wiser about the qualitative dimensions of the Soviet civil defense program after reading this book than one was before.

ROGER JOSEPH BOSCOVICH, edited by Lancelot Law Whyte. Allen & Unwin, Ltd. (32 shillings). Studies of the life and work of Boscovich on the 250th anniversary of his birth (1711). Roger Boscovich, a Jesuit born in Ragusa in Dalmatia (now Dubrovnik in Yugoslavia), is not so well known as he deserves to be. He is remembered, if at all, for his model of the dimensionless point-atom, the source, in his view, of all the forces between the particles of the universe. This theory, in which the point-atoms correspond rather closely to the nucleons of contemporary physics (but are permanent), and in which the universe is supposed to be constituted of nothing but these points set in space (as the frame of their spatial relations), and in time (as the succession of their changing patterns), had a significant influence on 19th-century physical science, especially on the work of Faraday. But although the theory can be regarded as Boscovich's major contribution, he was a prolific and many-sided man whose work also added to the sciences of astronomy and geodesy, to mathematics, to optics and the design of instruments, and to the theory of observations. In addition to finding time for these varied scientific labors, he was a traveling representative of the Jesuit order and a diplomatic emissary from Ragusa to Italy, France, Austria and other Western countries. In Britain, where he spent considerable time, he was friendly with some of the leaders of scientific thought in the 18th century and was elected a Fellow of the Royal Society. This collection of studies, based on a large quantity of source materials, which have not yet been fully explored, includes a biographical essay by Elizabeth Hill, professor of Slavonic Studies at the University of Cambridge, and pieces by Whyte, Zdeněk Kopal, J. F. Scott, Churchill

Eisenhart and others on Boscovich's contributions to science. There is also a long and careful bibliography.

THE PENGUIN DICTIONARY OF QUOTATIONS, by J. M. and M. J. Cohen. Penguin Books Inc. (paper-backed, $2.95). Atheneum Publishers ($7.95). It will be quickly apparent to any reader, whether he is hunting a reference or dipping in casually for entertainment, that this is a fresh, handy, up-to-date compendium, the best thing of its kind to appear in years. The Cohens, father and son, have compiled more than 12,000 quotations from English writings of every period, from foreign languages such as French, German and Spanish (always followed by a prose translation), and from Greek and Latin authors. Quotations are taken from the most readily available sources; the arrangement is by alphabetical order of authors; there is an excellent index of 25,000 entries listed by key words. One cannot fail to appreciate the compilers' imagination and nice sense of balance: in addition to including all the staple items, they have picked up material from modern authors, familiar lines from present-day politicians, current catchwords, slogans, witticisms, wisecracks and the like. The more topical stuff may not be truly memorable, but to have it accessible is both convenient and agreeable. This Penguin will not supplant Burton Stevenson's immense hamper, the old faithful by Bartlett, the superb *Oxford Dictionary of Quotations* or H. L. Mencken's characteristically personal collection, but it is a useful supplement to those and other standard works, and if shelf space or purse or both are limited, it will serve admirably all by itself.

KARAKORAM, by Fosco Maraini. The Viking Press ($10). An account of the Italian Alpine Club's successful expedition in 1958 to climb Mount Gasherbrum IV (also known as K3), a hitherto unclimbed peak in the Baltoro-Karakoram, the famous range north of the western Himalayas. Most mountain climbing books are written in a rather spare style and tend to confine themselves to the day-to-day account of the ascent. Mountaineering buffs, however, never tire of such chronicles; indeed, they are not tiresome because the excitement pours from the event itself and the vicarious pleasure of participating in it. Maraini, a professional writer, known for his popular book *Meeting with Japan,* is disinclined to an austere report. His book gives more information about the people and places of the area explored, about religion and customs, the history of the mountain ranges, the personalities of the expedition members, interpreters, porters and others than about the climb. This makes for a somewhat leisurely story, which is apt to leave the reader a little impatient to get on with the ascent, but nevertheless it is colorful and always interesting. Splendid photographs, some in color.

ON KNOWING: ESSAYS FOR THE LEFT HAND, by Jerome S. Bruner. Harvard University Press ($3.75). A collection of essays by a Harvard psychologist, concerned with the powers of "intuition, feeling and spontaneity" and the part they play in the process of knowing, in constructing what we consider to be reality, in teaching, in influencing "action and commitment." The range of topics is broad, from art, literature and myth to the learning of mathematics and the control of human behavior, but the presentation is self-consciously literary and diluted by discursiveness, and it is often hard to know what, if anything, Bruner is driving at—as if he were thinking as well as writing with his left hand.

THE GREAT PHILOSOPHERS, by Karl Jaspers. Harcourt, Brace & World, Inc. ($8.50). The first volume in a history of philosophy by the noted German existentialist. Seven philosophers are discussed: the "paradigmatic individuals," Socrates, Buddha, Confucius and Jesus; and the "seminal founders" of philosophical thought, Plato, Augustine and Kant. The organization and presentation of the work are unorthodox and reflect an intensely personal approach. Jaspers has a brief section on the life and work of each philosopher and then devotes the bulk of the essay to an exposition and critical examination of the individual's main philosophical ideas and their consequences. The purpose is to show that the ideas still live, have played their part in the development of civilization and are relevant to the thought and problems of contemporary man, either in helping him to ward off the possibility of a world catastrophe or at least in enabling him "to suffer lucidly and stand up to events in the dignity of freedom." The book is marked by Jaspers' own spirit and fervor and is more of an exhortation to rationality and decency than it is a history of philosophy.

THE STRUCTURE AND BIOSYNTHESIS OF MACROMOLECULES, edited by D. J. Bell and J. K. Grant. Cambridge University Press ($5.50). Papers given at a symposium held at the University of

Do you share his organized impatience?

Tomorrow isn't soon enough to suit him. He wants new answers and new applications now. By constantly challenging the state of the art he keeps it advancing.

If you share his itch for action, come to Northrop where action is a way of life. Work on projects ranging from space guidance and navigation to automatic checkout equipment, from computer design and world-wide communications to laminar flow control.

On the following pages you'll find some specific positions available now at Northrop Space Laboratories and the Norair Division. Look them over. One may be just the spot for you.

But even if you don't find your specialty listed—don't go away. We simply don't have room to mention all the opportunities to be found throughout Northrop's several divisions. If you're the kind of man who gets things done, there's bound to be a place for you at Northrop. Write to Dr. Alexander Weir at Northrop Corporation, Beverly Hills, California, and tell us about yourself. You will receive a prompt reply.

NORTHROP

AN EQUAL OPPORTUNITY EMPLOYER

London in 1961 to commemorate the 50th anniversary of the Biochemical Society. Included are papers by Paul Doty on nucleic acids, J. N. Davidson on the biochemical aspects of polynucleotide biosynthesis, E. L. Hirst on the structure of polysaccharides, M. F. Perutz on the exploration of the structure of proteins by crystallographic methods, E. L. Smith and his colleagues on the relation of protein structure to enzymic activity in the body. An informative report on a most active branch of scientific research. Illustrations.

ESSAYS IN PRE-COLUMBIAN ART AND ARCHAEOLOGY, by Samuel K. Lothrop and others. Harvard University Press ($12.50). A collection of essays on various aspects of the arts and crafts of pre-Columbian Indians in the Americas. The subjects include metalwork, portraiture, figurines, vases, ball-game handstones and gloves, ball courts, ceramics and other artifacts. Particularly interesting are some of the conjectures by archaeologists on the way Indians played their ball games and the implements they used, among which were heavy stone rings worn around the waist as "collars"; the player, apparently by subtle movements of the hips, would strike the hard rubber ball with the collar. Many good illustrations.

VISTAS IN ASTRONOMY: VOL. IV, edited by Arthur Beer. Pergamon Press ($12). This volume continues an excellent series, already reviewed in these columns, that consists of monographic articles on various aspects of astronomy. Included are essays on artificial satellites (Sir Harrie Massey), dynamical effects in the motion of earth sputniks (L. I. Sedov), photographic observations of artificial earth satellites (A. G. Massevitch and A. M. Lozinsky), dispersion in the period-luminosity relation (C. Payne-Gaposchkin) and archaeomagnetism (J. C. Belshé). The last-mentioned article, which deals with techniques for sampling and measuring the weak permanent magnetism in earth materials (in particular ancient kilns), thereby shedding light on secular variation of the geomagnetic field in Europe, is of particular interest.

MR. PULLMAN'S ELEGANT PALACE CAR, by Lucius Beebe. Doubleday & Company, Inc. ($17.50). A remarkably comprehensive, well-organized survey of this particular branch of the choo-choo-train business, which Beebe has made a lifework. The photographs are fine, although after a while one sleeping

How Mel Herrmann met the Emperor on a Navy Ice Runway

Mel Herrmann—Structural and Environmental Research Engineer with the Navy's Bureau of Yards and Docks—has met the Emperor Penguin on its own ground, at the U.S. Naval Air Facility, McMurdo Station, Antarctica. Mel came down—*and the Penguins apparently came up*—to inspect the year-round ice runway the Seabees were building to supply this remote operation.

Mel's job takes him to distant parts of the world. Last winter he was in Antarctica making snow drift control studies to help the Navy's Antarctic support forces. Before that, on a total of ten different occasions, he landed north of the Arctic Circle to work with other Naval scientists at the Arctic Research Laboratory who are studying geology, marine biology and ocean bottom characteristics and amassing vital weather data that will help BuDocks perfect construction and maintenance techniques in that region.

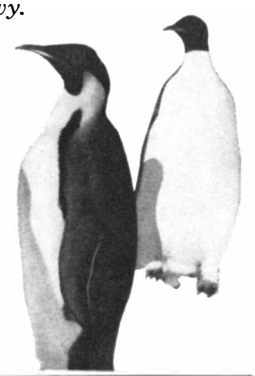
All is not penguins, polar bears, and parkas for this graduate engineer from Duke University, however. BuDocks is likely to become responsible for enlarging Naval facilities at some tropical island, in which case Mel Herrmann will trade his parka for an aloha shirt . . . *and take off again.*

Adventure in the Navy is not confined to the men who go down to the sea in ships. Many professional people with imagination and initiative, tiring of uncertainties and restrictions elsewhere, are finding wide-ranging, "far out" adventures of the mind as well as the body as civilian engineers with the Navy.

Whatever your field, the Navy may hold the key to your future. Write Thomas McKenna, Code 600, Department of the Navy, Main Navy Building, Room 1006, Washington 25, D.C.

The U.S. Department of the Navy

One of the Foremost Research Sponsors in the World



car or diner is indistinguishable from another, and the author, both in spite of and because of his rapturous prose, manages to convey a true feeling of the American artistic instincts, lavish vulgarity, snobbishness and surrealistic fancy represented by the evolution of the Pullman car.

THE EXACT SCIENCES IN ANTIQUITY, by O. Neugebauer. Harper Torchbooks ($1.60). The second edition, in inexpensive form, of a distinguished work in its field, a group of essays based on lectures given at Cornell in 1949 by a foremost student of ancient science. The topics include Babylonian and Egyptian mathematics and astronomy, the origin and transmission of Hellenistic science, certain problems of Greek mathematics —in trigonometry and geometry—that were stimulated by astronomy. Diagrams and plates.

GALEN: ON ANATOMICAL PROCEDURES, translated by W. L. H. Duckworth and edited by M. C. Lyons and B. Towers. Cambridge University Press ($7.50). A translation of the final six and a half books of Galen's *Anatomical Procedures*, published in its final form only a few years before his death (about A.D. 200) and embodying the results of a lifetime of practical research in dissection. The earlier books, which survived in the original Greek, were translated into English by the historian of science Charles Singer. The books offered here are based on an Arabic translation of the complete work.

TIME AND THE PHYSICAL WORLD, by Richard Schlegel. Michigan State University Press ($7.50). A discussion of the time concept as it is used in our understanding of the physical world, this book includes such topics as origins and measurements of time, clock and cyclical processes, the direction of time, entropy, reversible and irreversible processes, the theory of relativity, time and quantum theory. The book uses mathematics, but a good deal of the text can be followed by nonmathematicians interested in physics and the philosophy of science.

RECENT ADVANCES IN SCIENCE, edited by Morris H. Shamos and George M. Murphy. Science Editions, Inc. ($1.95). A reissue of a collection of papers that discuss recent advances in applied physics and mathematics. The authors include Richard Courant, I. I. Rabi, Hans Bethe, Victor Weisskopf, William Shockley, Edward Condon. These

California Institute of Technology : Case Institute of Technology : University of Chicago : Columbia University
Massachusetts Institute of Technology : University of Michigan : Pennsylvania State University : Stanford University : Tulane University

Interchange

The devices that engineers compound for the interchange of traffic sometimes seem, to a casual observer, hopelessly complex. Yet, to a man who knows where he is going, they are not complex at all. * Interchange, whether it be of concrete objects or abstract ideas, requires design. The man who knows where he is going moves freely in a complex world when properly designed interchanges are there to serve him. * IDA is an interchange, a link between the mutually interdependent worlds of science and strategy. It is an association of nine great universities formed to help to bring the technical talents residing in the academic and professional scientific community to bear on real and pressing problems of the National Security, as viewed at the highest military and technical levels in the Department of Defense. * IDA's staff members come from many sources and many disciplines: from industry, research laboratories, university faculty and graduates. They come to grips with tough and momentous problems, which when resolved become bases for decisions that affect the immediate, and determine the future, defense posture of the country. * IDA seeks highly qualified scientific and engineering talent. Scientists and engineers who know where they are going, and can qualify in the IDA climate are invited to discuss an interchange of mutual advantages. A permanent career in IDA has many advantages and many satisfactions. In addition, due to its unique design and structure, IDA can employ qualified people for comparatively short, two- or three-year periods, of service.

INSTITUTE FOR DEFENSE ANALYSES *Department A, 1710 H Street, NW, Washington 6, DC An equal opportunity employer*

IDA

are not popular lectures, the level of presentation being described as intermediate. A paperback.

THE SELECTED LETTERS OF WILLIAM JAMES, edited by Elizabeth Hardwick. Farrar, Straus and Cudahy, Inc. ($4.75). William James was a superb letter writer, warm, self-revealing, marvelously observant, always in key with the person to whom he was writing. Even those who are not interested in his views as a psychologist and philosopher will find this volume, with a first-rate introduction by the editor, a delight.

A CONCISE ANGLO-SAXON DICTIONARY, by John R. Clark Hall. Cambridge University Press ($6.50). The fourth edition of a standard work that deals with all the words that occur in Anglo-Saxon poetry and prose. The preceding edition has been out of print for some years but is in continuing demand. The present edition, edited by Herbert D. Meritt, adds 1,700 words not previously listed.

Notes

GENERAL RELATIVITY AND COSMOLOGY, by G. C. McVittie. University of Illinois Press ($6.95). This volume in the "International Astrophysics Series" explores the possibilities of general relativity as a method in mathematics and astronomy and as a means of interpreting the data supplied by observation.

EMOTIONS AND MEMORY, by David Rapaport. Science Editions, Inc. ($1.95). A reissue of the second edition of the late David Rapaport's study of the part emotions play in helping us to remember, in distorting our recollections or making us forget, in shaping dreams, in repressing thoughts, and so on. A paperback.

BIOGRAPHICAL MEMOIRS OF FELLOWS OF THE ROYAL SOCIETY: Vol. VII. The Royal Society ($4.50). The subjects of the obituaries include Maurice de Broglie, Harold Spencer Jones, C. E. K. Mees, Erwin Schrödinger, Sir Henry Tizard, Ross Harrison. Portraits and bibliographies.

GREEK SCIENCE, by Benjamin Farrington. Penguin Books Inc. ($1.45). A sound, readable history by a noted classicist of Greek science from its dawn, around 600 B.C., to its evening and final brilliance with the appearance of Ptolemy and Galen. A paperback.

INDEX OF ADVERTISERS

JUNE 1962

BIBLIOGRAPHY

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

THE DETECTION OF UNDERGROUND EXPLOSIONS

EARTH MOTION FROM THE ATOMIC BOMB TEST. L. Don Leet in *American Scientist*, Vol. 34, Spring, pages 198–211; April, 1946.

RESULTS OF SEISMIC OBSERVATIONS OF UNDERGROUND NUCLEAR AND TNT EXPLOSIONS. I. P. Pasechnik, S. D. Kogan, D. D. Sultanov and V. I. Tsibul'skii in *Seismic Effects of Underground Explosions*, pages 1–42. Consultants Bureau Enterprises, Inc., 1962.

SEISMIC WAVE TRAVEL TIMES FROM NUCLEAR EXPLOSIONS. Dean S. Carder and Leslie F. Bailey in *Bulletin of the Seismological Society of America*, Vol. 48, No. 4, pages 377–398; October, 1958.

SEISMIC WAVES FROM ATOMIC BOMB TESTS. B. Gutenberg and C. F. Richter in *Transactions of the American Geophysical Union*, Vol. 27, No. 6, page 776; December, 1946.

SEISMOLOGY. Perry Byerly. Prentice-Hall, Inc., 1942.

SUPERCONDUCTING MAGNETS

PROGRESS IN LOW TEMPERATURE PHYSICS, VOL. II. Edited by C. J. Gorter. Interscience Publishers, Inc., 1957.

SUPERCONDUCTING MATERIALS AND HIGH MAGNETIC FIELDS. J. E. Kunzler in *Journal of Applied Physics*, supplement to Vol. 33, No. 3, pages 1042–1048; March, 1962.

SUPERCONDUCTIVITY. D. Shoenberg. Cambridge University Press, 1952.

SUPERCONDUCTIVITY. B. T. Matthias in *Scientific American*, Vol. 197, No. 5, pages 92–103; November, 1957.

SUPERCONDUCTIVITY IN HIGH MAGNETIC FIELDS AT HIGH CURRENT DENSITIES. J. E. Kunzler in *Reviews of Modern Physics*, Vol. 33, No. 4, pages 501–509; October, 1961.

COMPUTER PROGRAMS FOR TRANSLATION

THE DEPTH HYPOTHESIS. Victor H. Yngve in *Structure of Language and Its Mathematical Aspects*, pages 130–138. The American Mathematical Society, 1961.

LANGUAGE. Leonard Bloomfield. Henry Holt & Company, Inc., 1933.

MACHINE TRANSLATION OF LANGUAGES. Edited by William N. Locke and A. Donald Booth. John Wiley & Sons, Inc., and The M.I.T. Press, 1955.

A MODEL AND AN HYPOTHESIS FOR LANGUAGE STRUCTURE. Victor H. Yngve in *Proceedings of the American Philosophical Society*, Vol. 104, No. 5, pages 444–466; October, 1960.

A SYNOPSIS OF ENGLISH SYNTAX. Eugene A. Nida. Oklahoma University Summer Institute of Linguistics, 1960.

THE PATH OF CARBON IN PHOTOSYNTHESIS

NEW ASPECTS OF PHOTOSYNTHESIS. J. A. Bassham in *Journal of Chemical Education*, Vol. 38, No. 3, pages 151–155; March, 1961.

THE NURTURE OF CREATIVE SCIENCE AND THE MEN WHO MAKE IT. THE PHOTOSYNTHESIS STORY: A CASE HISTORY. Melvin Calvin in *Journal of Chemical Education*, Vol. 35, No. 9, pages 428–432; September, 1958.

THE PATH OF CARBON IN PHOTOSYNTHESIS. Melvin Calvin and James A. Bassham. Prentice-Hall, Inc., 1957.

THE PATH OF CARBON IN PHOTOSYNTHESIS. XXI: THE CYCLIC REGENERATION OF CARBON DIOXIDE ACCEPTOR. J. A. Bassham, A. A. Benson, Lorel D. Kay, Anne Z. Harris, A. T. Wilson and M. Calvin in *Journal of the American Chemical Society*, Vol. 76, No. 7, pages 1760–1770; April 5, 1954.

PHOTOSYNTHESIS. J. A. Bassham in *Journal of Chemical Education*, Vol. 36, No. 11, pages 548–554; November, 1959.

THE PHOTOSYNTHESIS OF CARBON COMPOUNDS. Melvin Calvin and James A. Bassham. W. A. Benjamin, Inc., 1962.

ISHANGO

MISSION J. DE HEINZELIN DE BRAUCOURT. Institut des Parcs Nationaux du Congo (Belge) et du Ruanda-Urundi, 1950.

"FLOATERS" IN THE EYE

EYE AND CAMERA. George Wald in *Scientific American*, Vol. 183, No. 2, pages 32–41; August, 1950.

FUNDAMENTALS OF OPTICS. F. A. Jenkins and H. E. White. McGraw-Hill Book Company, Inc., 1957.

IMPORTANCE OF THE VITREOUS BODY IN RETINA SURGERY. Edited by C. L. Schepens. The C. V. Mosby Co., 1960.

ANNOUNCING AN ISSUE OF **SCIENTIFIC AMERICAN** DEVOTED TO THE TOPIC OF

THE ANTARCTIC

TO BE PUBLISHED IN SEPTEMBER, 1962

THE VERTEBRATE VISUAL SYSTEM. S. Polyak. The University of Chicago Press, 1957.

THE SCHOOLING OF FISHES

THE DEVELOPMENT OF SCHOOLING BEHAVIOR IN FISHES. Evelyn Shaw in *Physiological Zoology*, Vol. 33, No. 2, pages 79–86; 1960.

THE DEVELOPMENT OF SCHOOLING IN FISHES II. Evelyn Shaw in *Physiological Zoology*, Vol. 34, No. 4, pages 263–272; 1961.

STUDIES ON SOCIAL GROUPINGS IN FISHES. C. M. Breder, Jr., in *Bulletin of the American Museum of Natural History*, Vol. 117, Art. 6, pages 393–481; 1959.

STUDIES ON THE STRUCTURE OF THE FISH SCHOOL. C. M. Breder, Jr., in *Bulletin of the American Museum of Natural History*, Vol. 98, Art. 1, pages 1–27; 1951.

THE ANALYSIS OF BRAIN WAVES

COMPUTER TECHNIQUES IN EEG ANALYSIS. Edited by Mary A. B. Brazier. *Electroencephalography and Clinical Neurophysiology*, Suppl. 20; 1961.

THE ELECTRICAL ACTIVITY OF THE NERVOUS SYSTEM. Mary A. B. Brazier. The Macmillan Co., 1960.

PROCESSING NEUROELECTRIC DATA. Communications Biophysics Group of Research Laboratory of Electronics and William M. Siebert. The Technology Press of the Massachusetts Institute of Technology, 1959.

SOME USES OF COMPUTERS IN EXPERIMENTAL NEUROLOGY. Mary A. B. Brazier in *Experimental Neurology*, Vol. 2, No. 2, pages 123–143; April, 1960.

THE WAKING BRAIN. H. W. Magoun. Charles C Thomas, Publisher, 1958.

MATHEMATICAL GAMES

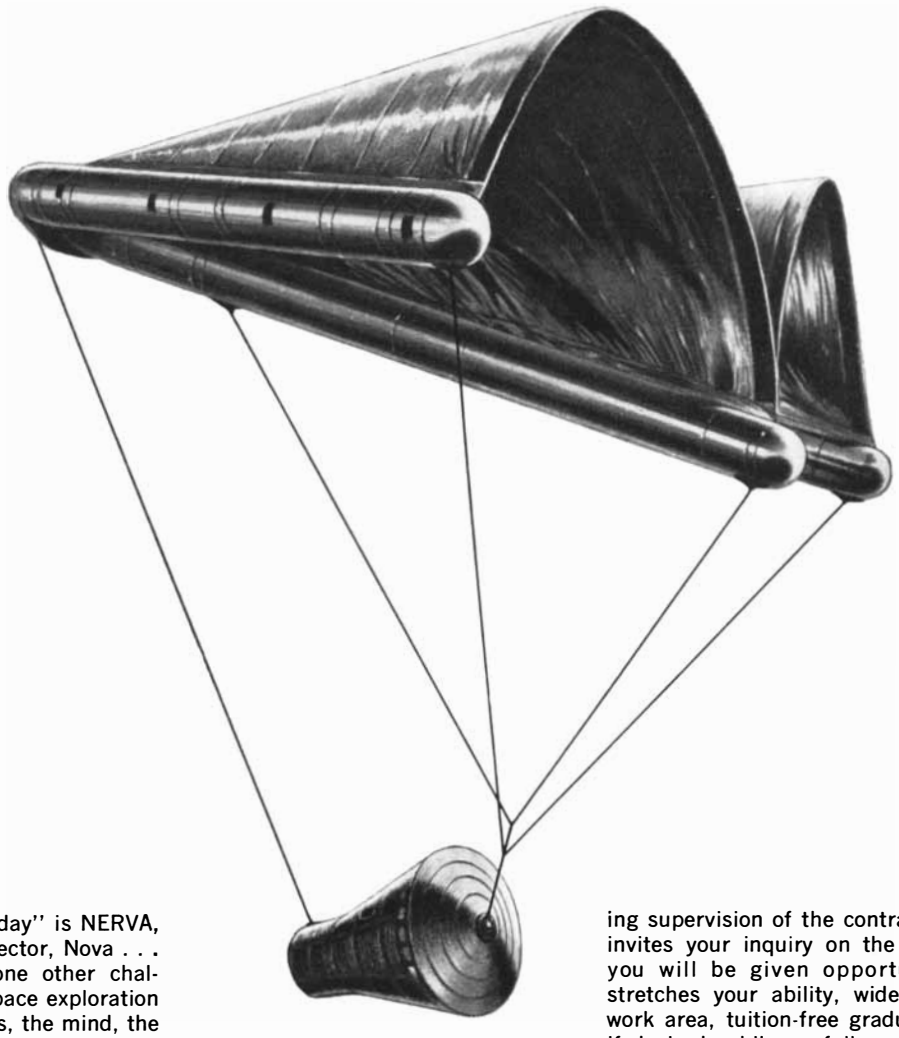
COMPLETE HANDBOOK TO THE GAME OF SOLITAIRE. Ernest Bergholt. E. P. Dutton & Co., 1921.

DOMINOES AND SOLITAIRE. "Berkeley" (W. H. Peel). G. Bell & Sons, 1890.

THE AMATEUR SCIENTIST

A MANUAL OF PAPER CHROMATOGRAPHY AND PAPER ELECTROPHORESIS. Richard J. Block, Emmett L. Durrum and Gunter Zweig. Academic Press Inc., 1958.

THE SCIENTIFIC AMERICAN BOOK OF PROJECTS FOR THE AMATEUR SCIENTIST. C. L. Stong. Simon and Schuster, Inc., 1960.



For the NASA man, "today" is NERVA, Apollo, Surveyor, Prospector, Nova . . . and a thousand and one other challenges. The future of space exploration is primarily in the hands, the mind, the ingenuity of NASA men and women.

NASA is the focal point for the assault on space. Here are unmatched facilities —the tools, the associates, the atmosphere a man needs for unfettered creativity. NASA is downstage center, and the scientist or engineer who works under this exacting spotlight finds the opportunity, the fulfillment, the security and respect that so many of us so eagerly pursue.

NASA is for the man who wants to be "in at the beginning."

NASA scientists and engineers work in many diversified fields. Included are: Fluid and Flight Mechanics, Energy and Power Systems, Materials and Structures, Space Sciences, Measurement and Control Systems, Data Systems, Experimental Facilities and Techniques, Life Sciences and Systems, and Program and Project Management, including supervision of the contracts. NASA invites your inquiry on the basis that you will be given opportunity that stretches your ability, wide choice of work area, tuition-free graduate study, if desired, while on full pay. You may direct your inquiry to any of the following NASA centers:

AT NASA, YOU'LL WORK ON THE PROJECTS OF 1970 . . . TODAY

NASA Launch Operations Center, Cocoa Beach, Florida; NASA Manned Spacecraft Center, Houston, Texas; NASA Goddard Space Flight Center, Greenbelt, Maryland; NASA Marshall Space Flight Center, Huntsville, Alabama; NASA Ames Research Center, Mountain View, California; NASA Flight Research Center, Edwards, California; NASA Langley Research Center, Hampton, Virginia; NASA Wallops Station, Wallops Island, Virginia; NASA Lewis Research Center, Cleveland, Ohio, or NASA Headquarters, Washington 25, D. C.

All qualified applicants will receive consideration for employment without regard to race, creed or color, or national origin. Positions are filled in accordance with Aero-Space Technology Announcement 252-B.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GET READY FOR THE SPACE and SCIENCE ERA! SEE SATELLITES, MOON ROCKETS CLOSE-UP

AMAZING SCIENCE BUYS for FUN, STUDY or PROFIT

Photographers! This is an actual photograph of the moon taken through our Astronomical Telescope by a 17-year-old student.

See the Stars, Moon, Planets Close Up!

3" Astronomical Reflecting Telescope 60 to 180 Power

An Unusual Buy! Famous Mt. Palomar Type

You'll see the Rings of Saturn, the fascinating planet Mars, huge craters on the Moon, Star Clusters, Moons of Jupiter in detail, Galaxies! Equatorial mount with lock on both axes. Aluminized and overcoated 3" diameter high-speed f/10 mirror. Telescope comes equipped with a 60X eyepiece and a mounted Barlow Lens, giving you 60 to 180 power. An Optical Finder Telescope, always so essential, is also included. Sturdy, hardwood, portable tripod.

FREE with Scope:—Valuable **STAR CHART** plus 272 page **"HANDBOOK OF HEAVENS"** plus **"HOW TO USE YOUR TELESCOPE"** BOOK

Stock No. 85,050-S.....$29.95 Postpaid

4¼" REFLECTING TELESCOPE! Up to 255X

New vibration-free metal pedestal mount. With this scope you can see everything with greater power plus will split finer stars. Mirror has twice the light gathering power. Mirror guaranteed to give theoretical limit of resolution. Rack and pinion focusing, real equatorial mounting—only one adjustment follows stars! Aluminum tube. 6 power finder telescope. 2 standard size eyepieces and mounted Barlow lens give you powers of 45X—90X—135X—180X and 255X. Low-cost accessory eyepiece available for higher powers. FREE with Scope:—Valuable **STAR CHART** plus 272 page **"HANDBOOK OF HEAVENS"** plus **"HOW TO USE YOUR TELESCOPE"** Book. Shipping weight 25 lbs.

Stock No. 85,105-S.....$79.50 f.o.b.

Same Telescope as above but equipped with Electric Clock Drive—
Stock No. 85,107-S **$109.00 F.O.B. Barrington, N. J.**

THE PLANETARIUM PORTRAYS THE FASCINATING STORY OF EARTH IN ACTION

Here is the story of cosmic motions—how the moon revolves around the earth, and the earth around the sun, with our planet rotating simultaneously. With this instrument, the observer sees a three-dimensional moving demonstration of how seasons, day and night, and moon phases occur. This handsome gear-and-chain-driven unit is supported by a smartly finished wood base. The sun is 6" in diameter, and the earth is 4". Planetarium stands 12" high, is 8" wide; arm is 18" long. A completely illustrated, delightfully informative handbook included.

Stock #70,415-S.....$29.95 ppd.

NEW ZOOM MICROSCOPE EYEPIECE ZOOMS POWERS FROM 30X TO 2000X

Greatest microscope accessory yet! Priced amazingly low. Combines all eyepiece powers from 10X to 20X in one assembly. Twist of dial . . . without more focusing . . . without extra eyepiece changing . . . and you command powers up to 2000X. Professional all-metal quality construction, heavily plated, anodized. Fits any standard .917" dia. microscope tube. Built-in, adjustable clamping ring insures tight, mar-free attachment. Stops eyepiece changing. Coated elements, 2¾" lg., 1½" max. dia., 5 oz. wt.

Stock No. 60,270-S.....$25.00 Pstpd.

NEW! STATIC ELECTRICITY GENERATOR

Sturdy, Improved Model!

See a thrilling spark display as you set off a miniature bolt of lightning. Absolutely safe and harmless. Sturdily made—it stands 14" high. Turn the handle and two 9" plastic discs rotate in opposite directions. Metal collector brushes pick up the static electricity, store it in the Leyden jar type condenser until discharged by the jumping spark. Countless tricks and experiments. 24 page instruction booklet included.

Stock No. 70,070-S.....$12.95 Postpaid

WOODEN SOLID PUZZLES

Here is a fascinating assortment of wood puzzles that will provide hours of pleasure. Twelve different puzzles, animals and geometric forms to take apart and reassemble, give a chance for all the family, young or old, to test skill, patience, and, best of all to stimulate ability to think and reason while having lots of fun.

Stock No. 70,205-S...$3.00 Postpaid

"FISH" WITH A GIANT MAGNET

Bring Up Under-Water Treasures

Real fun! Profitable, too! Simply trail this powerful 5 lb. Magnet out the stern of your boat—retrieve outboard motors, fishing tackle, anchors, other metal valuables. Alnico V-Type Magnet has terrific lifting power—2000 Gauss rating—lifts over 125 lbs. on land—more under water. Many industrial uses, too; recover tools and parts from inaccessible spots, hold work in place, rid shop floors of metal fragments, pins, etc.

Stock No. 70,183-S 5-lb. size.....$9.95 Pstpd.
Stock No. 70,416-S 3½ lb. size.....$7.95 Pstpd.

HIGH-SPEED AERIAL CAMERA LENS COST GOVT. $2,000—YOURS FOR $495

Perkin-Elmer make, designed by Dr. J. G. Baker. Suited to spectral ballistic camera for missile re-entry, satellite and asteroid photography, lab collimater for large field of view. 36" F/4. Covers 20" dia. field (14" x 14"). Color-corrected for TRI-X with a dichroic filter coated on element #4, peaking at approx. 5100-6900 Angstroms. Well corrected even at full aperture. Angle of view 31°. Aperture: relative f/4, front opening 12". Focusing range: fixed at infinity with provision for fine focusing. Back f/1 20¾". Transmittance (through orange filter) 62%. Flange f/1 10" ± .003". 33⅜" total lgth. Total dia. 22⅝". 7 elements. Wt. 257 lbs. Shipping wt. 713 lbs.

Stock No. 85,149-S.....$495.00 F.O.B. Barrington, N. J.

VISIT & SEE THE FAMOUS EDMUND RAINBOW SHOWPLACE SEATTLE WORLD'S FAIR APRIL 21 to OCTOBER 21

American Made—Over 50% Saving

STEREO MICROSCOPE

Years in development. Equals $300 to $400 instrument. Precision American made. Used for checking, inspecting, small assembly work. Up to 3" working distance. Clear, sharp, erect image. Wide, 3 dimensional field. 2 sets of objectives on rotating turret. 23X and 40X. 10 Day Free Trial.

Stock No. 85,056-S.....$99.50
f.o.b. Barrington, N.J.

MAKE YOUR OWN POWERFUL ASTRONOMICAL TELESCOPE

GRIND YOUR OWN ASTRONOMICAL MIRROR

Kits contain mirror blank, tool, abrasives, diagonal mirror and eyepiece lenses. You build instruments ranging in value from $75.00 to hundreds of dollars.

Stock No.	Dia. Mirror	Thickness	Price
70,003-S	4¼"	¾"	$ 7.50 postpaid
70,004-S	6"	1"	11.95 postpaid
70,005-S	8"	1⅜"	19.50 postpaid
70,006-S	10"	1¾"	30.75 F.O.B.
70,007-S	12½"	2⅛"	59.95 Barrington

SCIENCE TREASURE CHESTS

For Boys—Girls—Adults!

Science Treasure Chest—Extra-powerful magnets, polarizing filters, compass, one-way-mirror film, prism, diffraction grating, and lots of other items for hundreds of thrilling experiments, plus a Ten Lens Kit for making telescopes, microscopes, etc. Full instructions included.

Stock No. 70,342-S.....$5.00 Postpaid

Special Reduced Price for '62!

LIFE SIZE VISIBLE HUMAN HEAD

Precise, Full Color, Take-apart Model

Study the most complex organ easily, inexpensively. Ideal for student, hobbyist, professional. You will be amazed at the detail. Molded from actual human skull. Eyes, ears, and teeth easily removed and disassembled for complete study. Entire brain, spinal cord and organs of mouth and throat presented in vivid detail. Amazingly low price—conforms to rigid laboratory standards. 16-page fully illustrated medical handbook included.

Stock No. 70,447-S.....$8.95 Postpaid

OTHER VISIBLE TAKE-APART MODELS

Stock No. 70,470-S Heart .....$3.00 Pstpd.
Stock No. 70,228-S Man .....$4.98 Pstpd.
Stock No. 70,283-S Woman .....$4.98 Pstpd.

OFFSPRING OF SCIENCE . . . REALLY BEAUTIFUL CIRCULAR DIFFRACTION GRATING JEWELRY 1" DIAMETER

A Dazzling Rainbow of Color!

As a scientific phenomenon, this new kind of jewelry is capturing attention everywhere. Shimmering rainbows of gem-like color in jewelry of exquisite beauty—made with CIRCULAR DIFFRACTION GRATING REPLICA. Just as a prism breaks up light into its full range of individual colors, so does the Diffraction Grating.

Stock No. 1704-S Earrings .....$2.20 Pstpd.
Stock No. 1714-S Cuff Links .....$2.20 Pstpd.
Stock No. 1729-S Pendant .....$2.20 Pstpd.
Stock No. 1727-S Tie-Clasp .....$1.65 Pstpd.
Stock No. 1735-S Bracelet (Six ¾" Gratings)....$7.70 Pstpd.

Remove Your Retaining Rings—Disassemble Lenses, Cameras, etc.

ADJUSTABLE SPANNER WRENCH

Made for U.S. Air Force—available at a fraction of Government cost. A top grade, versatile tool that every instrument and camera repair man or just plain tinkerer should own. Adjustable for ⅛" to 12" diameter retaining rings. Complete with six different pairs of points to fit all types of slots and holes. 3", 6", and 12" main bars. All steel and nicely plated. The finest tool we have ever come across for this type of retaining ring work AND a real bargain at our low price.

Stock No. 70,355-S.....$12.50 Postpaid

7x50 BINOCULARS—TREMENDOUS BUY!
War Surplus American-Made

Big savings! Brand new! Crystal clear viewing—7 power. Every optical element is coated. An excellent night glass—the size recommended for satellite viewing. Individual eye focus. Exit pupil 7mm. Approx. field at 1,000 yds. is 376 ft. Carrying case included. American 7 x 50's normally cost $274.50. Our war surplus price saves you real money.

Stock No. 1544-S.....only $74.80 Pstpd.
(Tax included)

6 x 30 Binoculars—similar to above and a terrific bargain.

Stock No. 963-S.....$33.00 Pstpd.
(Tax included)

INTRIGUING LOW-COST MOON MODEL

Exciting outer space display and conversation piece. Exact replica. 30,000 formations—peaks, craters, Ocean of Storms, etc.—all in relief. Scaled to size. Accurate distance relationships. Proper lighting shows moon phases; "black light" produces startling effects. Tough, washable plastic. Three colors. Far side blank—can be used for space data. Excellent gift item. 12" dia., wt. ¾ lb.

Stock No. 70,515-S.....$12.50 Postpaid

BUILD A SOLAR ENERGY FURNACE

Easy! Inexpensive! We furnish instructions. This sun powered furnace will generate terrific heat—2000° to 3000°. Build with your scrap wood and our Fresnel Lens—14" diameter, f/1.14".

Stock No. 70,130-S, Fresnel Lens .....$6.00 pstpd.
11" Sq. Fresnel Lens F.L. 19", **Stock No. 70,533-S $4.75 Ppd.**

WRITE FOR

FREE CATALOG!

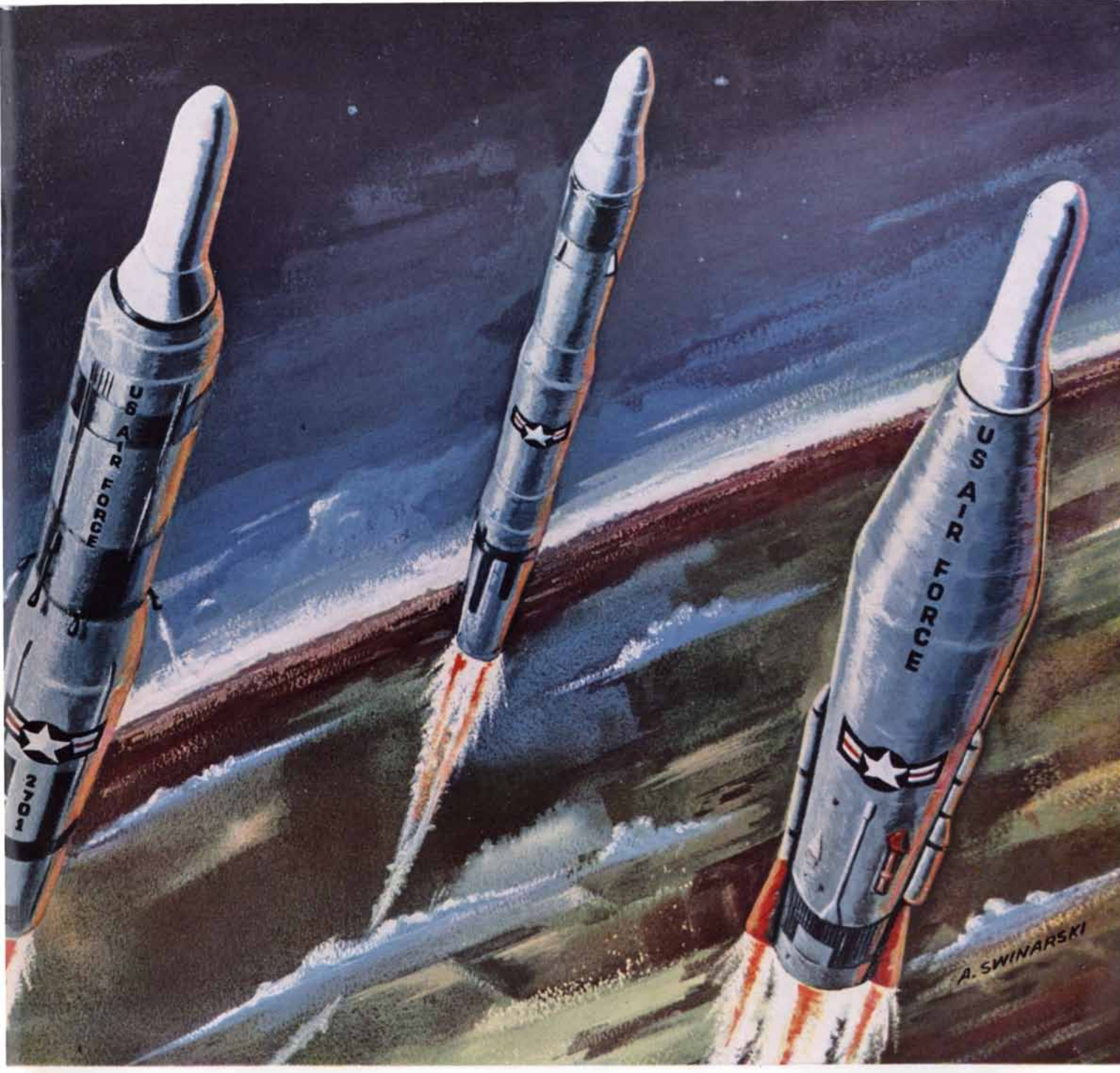
EDMUND SCIENTIFIC CO.
Barrington, N. J.

160 Pages! Over 1000 Bargains! Huge selection of lenses, prisms, war surplus optical instruments, parts and accessories. Telescopes, Microscopes, Binoculars, Sniperscopes, science experiment items, math learning and teaching aids. Request Catalog-S.

Name .....
Address .....
City ..... State .....

ORDER BY STOCK NUMBER . SEND CHECK OR MONEY ORDER . SATISFACTION GUARANTEED!

EDMUND SCIENTIFIC CO., BARRINGTON, N. J.



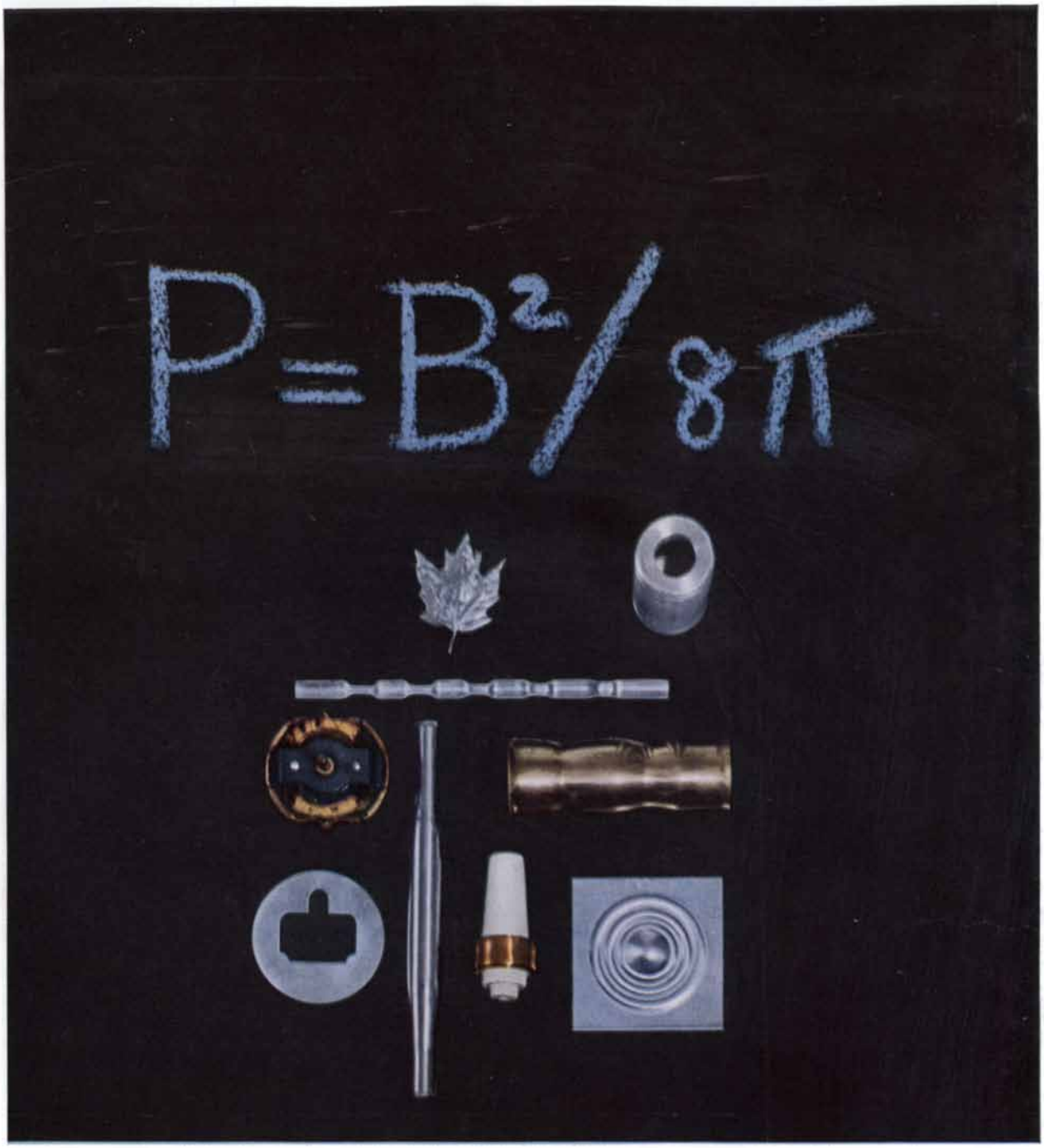
For free reprints of this illustration, suitable for framing, write to Avco Public Relations, Stratford, Connecticut.

Avco is at the head of each class

Avco designs and produces re-entry vehicles for the Titan, Minuteman, and Atlas intercontinental ballistic missiles. Avco has developed ablative materials to protect these vehicles from the superheat of re-entry. Avco is also responsible for arming and fuzing, and contributing related electronic gear, on several major missile programs. Avco has successfully combined outstanding research facilities, unique technological experience, and unusual production techniques. The result is total re-entry systems capability —tried and tested in flight.

Avco

UNUSUAL CAREER OPPORTUNITIES FOR QUALIFIED SCIENTISTS AND ENGINEERS . . . REGARDLESS OF RACE, CREED, COLOR, OR NATIONAL ORIGIN . . . WRITE AVCO TODAY. **AVCO CORPORATION, 750 THIRD AVENUE, NEW YORK 17, NEW YORK**



A PRACTICAL PROGENY OF FUSION RESEARCH: MAGNETIC-PULSE FORMING...

Fusion research in the joint program of the General Atomic Division of General Dynamics and the Texas Atomic Energy Research Foundation* has as its objective the ultimate production of electric power from nuclear fusion. ∞ Out of this extensive theoretical and experimental work have also come some immediate non-fusion applications. One such has been Magneform**, the first commercially available magnetic-pulse metal-forming machine. ∞ In research directed toward a controlled fusion reaction, confining magnetic fields are used to surround and attempt to contain the intensely hot gas required. ∞ This magnetic field principle is applied in Magneform. Capacitor-stored energy is converted into high density magnetic energy, to produce uniform and controlled pressures up to 50,000 p.s.i. ∞ Magneform has no moving parts. It can swage, expand, compress and assemble metals of light to medium gauges with no mechanical contact, as well as shear and coin. Its inherent simplicity marks a departure from all traditional metal-forming equipment.

*Composed of eleven investor-owned utilities **Trademark

GENERAL DYNAMICS GD