

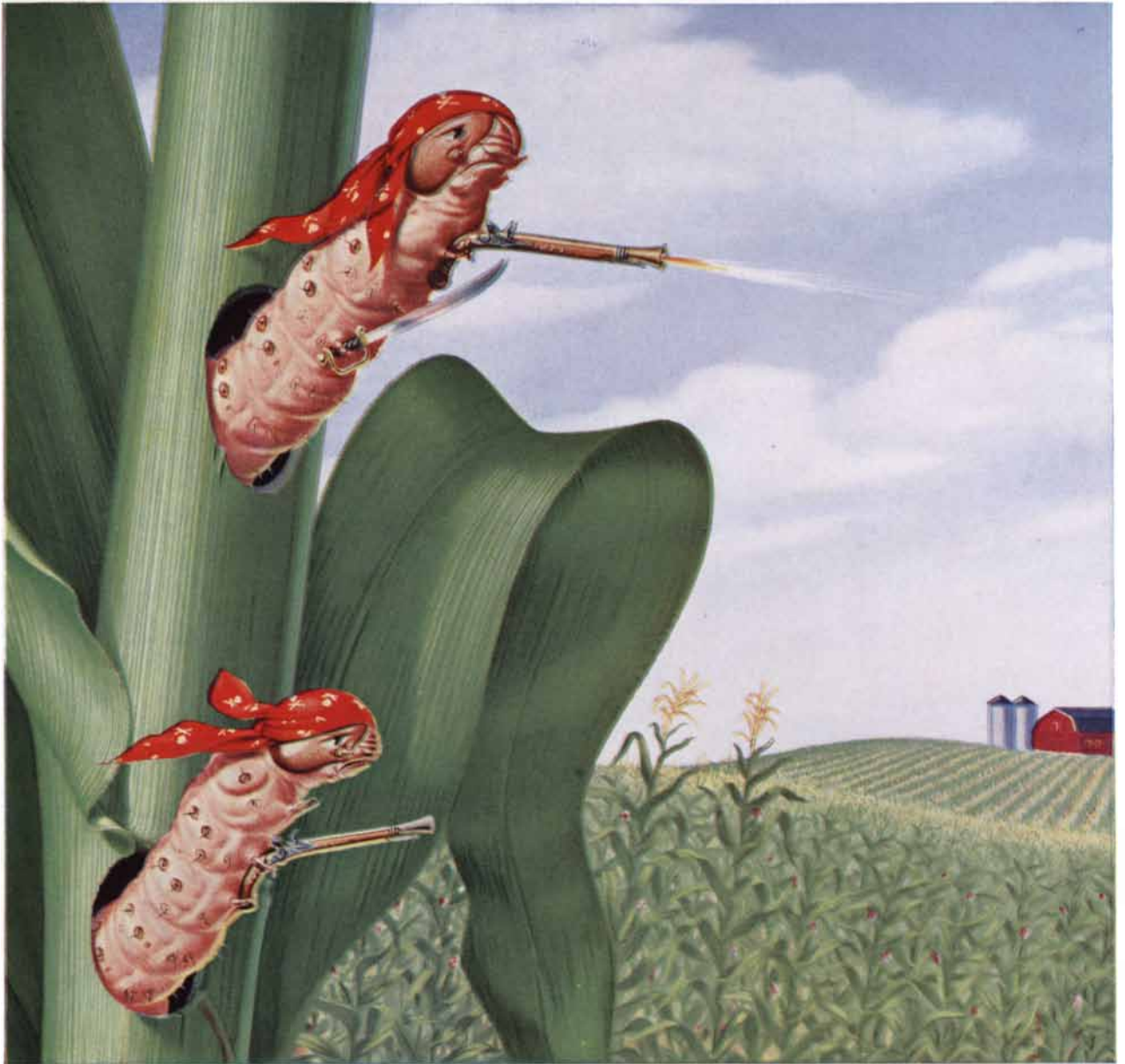
SCIENTIFIC AMERICAN



ANCIENT GREEK COMPUTER

FIFTY CENTS

June 1959



PIRATES! in the sea of corn

ANY BUCCANEER who ever sailed under the Jolly Roger would be happy with a tiny cut of the plunder *corn borers* take from cornfields every year. But now, with Shell Chemical's insecticide *endrin*, the sailing is rough for insect freebooters.

Corn borers burrow into cornstalks, eating them hollow while hidden from view and protected from attack. Stalks sag and bend, ears are small and poorly formed because nourishment is cut off.

Now endrin kills hungry corn borers *before* they have a chance to do their disappearing act. The result: cornstalks perk up their ears . . . farmers build up their profits.

The development of more powerful insecticides to fight caterpillars like corn borer, sugar cane borer and armyworm is still another way Shell Chemical helps guard an abundant land.

Shell Chemical Corporation
Chemical Partner of Industry and Agriculture
NEW YORK





TR-10 with EAI 1100 E XY Plotter as read-out.

THE *FIRST* ALL TRANSISTORIZED ANALOG COMPUTER

— basic model less than \$4000

PACE TR-10 Eliminates Drudgery— Gives New Insight Into Engineering Problems

This compact unit, 15" x 16" by 24" high, is powered by 115 volts AC and can provide day-in day-out instant solution of your most vexing engineering problems. Even if you have never seen a computer before, you can learn to operate the TR-10 as easily as you learned to use a slide rule.

Simply turn a dial to feed in design parameters, and the computer provides an instant by instant, dynamic picture of the effect of each change. You can study the inter-related effects of heat, pressure, flow, vibration, torque or any variable, and visually compare one with the other. Engineering data comes alive—insight into how new designs will work is obtained easier, faster.

Because of its minimum size and low price, the TR-10 can become your own personal analog computer. You gain first-hand experience with the power of analog techniques, and convert more of your time to *creative engineering*. New ideas that were too costly to try before are now practical.

You can design virtually to perfection and have a permanent, visual record of performance before building pilot models or prototypes. As a result, "cut and try" expense is reduced.

The same quality workmanship and design that has made Electronic Associates the world's leading producer of precision general purpose analog computers will be found in this new unit. Accuracy to ± 1 per cent. Modular construction allows you to select varying quantities of the following computing functions: summation, integration, multiplication or division, function generation, parameter adjustment, logical comparison.

For complete engineering data, write for Bulletin TR-10

EAI

ELECTRONIC ASSOCIATES, INC.
Long Branch, New Jersey



Sir Michael Foster...on the heritage of science

“For indeed it is one of the lessons of the history of science that each age steps on the shoulders of the ages which have gone before. The value of each age is not its own, but is in part, in large part, a

debt to its forerunners. And this age of ours if, like its predecessors, it can boast of something of which it is proud, would, could it read the future, doubtless find also much of which it would be ashamed.”

—*History of Physiology, 1901*

THE RAND CORPORATION, SANTA MONICA, CALIFORNIA

A nonprofit organization engaged in research on problems related to national security and the public interest

ARTICLES

- 52 **ROCKET ASTRONOMY**, by **Herbert Friedman**
Rocket-borne instruments begin to show how the universe appears in ultraviolet.
- 60 **AN ANCIENT GREEK COMPUTER**, by **Derek J. de Solla Price**
A device dating from the first century B.C. calculated astronomical phenomena.
- 68 **LOVE IN INFANT MONKEYS**, by **Harry F. Harlow**
Experiments with dummy mothers suggest that infants learn to love by contact.
- 90 **BEER**, by **Anthony H. Rose**
Its making from grain is now understood in terms of enzymes and microorganisms.
- 105 **SELF-REPRODUCING MACHINES**, by **L. S. Penrose**
Units that assemble replicas of themselves shed light on molecular reproduction.
- 118 **JUNCTION-DIODE AMPLIFIERS**, by **Arthur Uhlir, Jr.**
These devices are "quieter" than transistors and work in a wider frequency range.
- 132 **WORM AUTOBIOGRAPHIES**, by **G. P. Wells**
The simple rhythms of marine worms are recorded to elucidate biological "clocks."
- 146 **PRIMITIVE KINSHIP**, by **Meyer Fortes**
The kinship system of a society is a reflection of the society's basic organization.

DEPARTMENTS

- 14 **LETTERS**
- 28 **50 AND 100 YEARS AGO**
- 40 **THE AUTHORS**
- 76 **SCIENCE AND THE CITIZEN**
- 160 **MATHEMATICAL GAMES**
- 173 **THE AMATEUR SCIENTIST**
- 187 **BOOKS**
- 200 **BIBLIOGRAPHY**

BOARD OF EDITORS Gerard Piel (Publisher), Dennis Flanagan (Editor), James R. Newman, E. P. Rosenbaum, C. L. Stong, Esther A. Weiss

ART DIRECTOR James Grunbaum

GENERAL MANAGER Donald H. Miller, Jr.

ADVERTISING MANAGER Martin M. Davidson

Janitrol Reports

on aircraft and missile components

Too thick and too heavy

You'd hardly consider the foil that wraps smoking tobacco a structural material. It is perhaps only .010" thick. Yet sheet metal of this thinness is still not light enough to meet some of the almost incredible demands for lightweight heat exchangers. Combinations of plate, extended surface, and tubular structures are built of paper-thin stainless or aluminum, and still meet tough



design and reliability requirements. Improved efficiency, ease of manifolding, ability to crowd more performance into small odd-shaped spaces—these are some of the objectives which Janitrol is uniquely qualified to tackle.

Bracelets for bleed air lines

The Janitrol couplings which tie together the vital lines for high pressure air in aircraft and missiles are far from decorative. Yet they must possess jewel-like perfection.

They must stay tight under pressures up to 600 psi, temperatures up to 750°F. In addition to withstanding heavy vibration and bending loads, they must permit disconnects and pressure-tight reassembly repeatedly, reliably.

In Janitrol Dubl-lock couplings, an extra measure of safety is included: a tang lock will hold even if the bolt should fail under overloads or over torquing. You can get Janitrol standard or Dubl-lock couplings in stainless steel or titan-

ium, in sizes up to 7" diameter, and specials up to 36" diameter.

Janitrol's unique experience in welding and fabricating high temperature alloys to extremely tight physical and dimensional specifications has contributed much to the reliability of pneumatic systems in aircraft.

Minus nothing—Plus very little

The tolerances specified in Janitrol pneumatic control valves and regulators are so tight as to call for considerable artistry in their manufacture. To provide high reliability, the valve must not deliver less than specified performance; yet the designer must observe all weight restrictions and safety factors. And because air is such a versatile servant in advanced aircraft—for canopy seal, fuel transfer, blowers, coolers, actuators, and what have you—Janitrol valves and regulators are finding new and exciting applications every day.



If you need help in the design of a valve, duct support, or coupling—or the development of a subsystem involving air handling, you'll find Janitrol people talk your language.

We invite you to write for a "Janitrol Resources" brochure giving a clear picture of our capabilities. Janitrol Aircraft Division, Surface Combustion Corporation, 4200 Surface Road, Columbus 4, Ohio, BRoadway 6-3561.



**pneumatic controls • duct couplings and supports • heat exchangers
combustion equipment for aircraft, missiles, ground support**



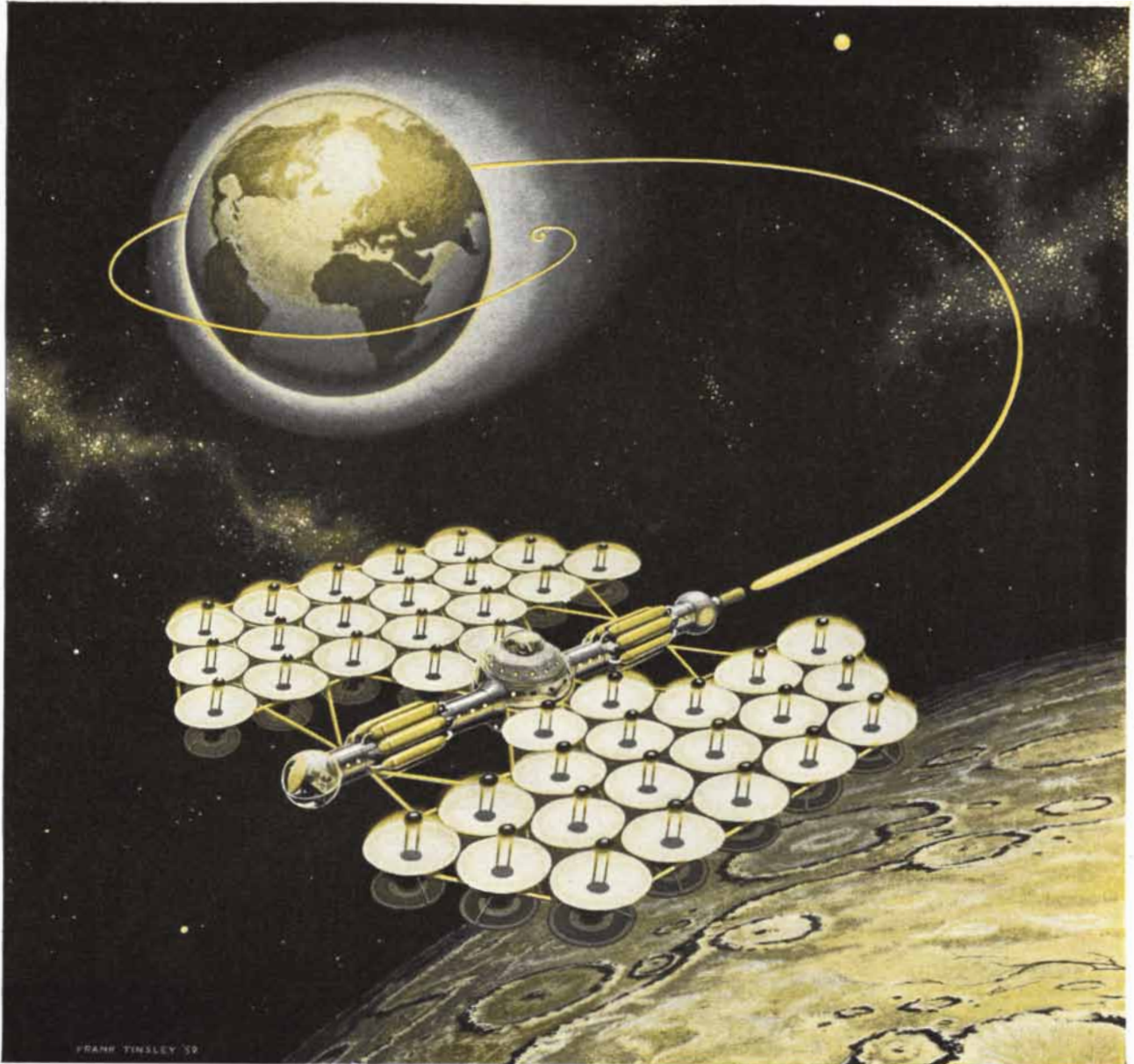
THE COVER

The photograph on the cover shows a fragment of an ancient mechanism that has recently been identified as a device for calculating, among other astronomical phenomena, the motions of the stars and planets (*see page 60*). Dated from the first century B. C., the mechanism was discovered in 1901 by sponge divers exploring a shipwreck close to the small Greek island of Antikythera.

THE ILLUSTRATIONS

Cover photograph
by Derek J. de Solla Price

Page	Source
53	Naval Research Laboratory
54	Bunji Tagawa (<i>top</i>), Naval Research Laboratory (<i>bottom</i>)
56-57	Bunji Tagawa
58-59	Naval Research Laboratory
61	Derek J. de Solla Price
62-67	Bunji Tagawa
69	Gordon Coster
70	Emi Kasai
71-73	Gordon Coster
74	Emi Kasai
91-92	David Linton
93-95	Eric Mose
96-97	Evelyn Urbanowich
98	Emi Kasai
100	Rijksmuseum van Oudheden, Leiden
105-114	Alex Semenoick
118	David Linton
119-124	James Egleson
126	Bell Telephone Laboratories (<i>top</i>), James Egleson (<i>bottom</i>)
129	General Electric Company
132	John Langley Howard
133	D. P. Wilson
134-135	John Langley Howard
136-138	G. P. Wells
140-141	John Langley Howard
146-147	Eric Mose
148-153	Emi Kasai
154-155	Meyer Fortes (<i>top</i>), Emi Kasai (<i>bottom</i>)
160-166	James Egleson
174-182	Roger Hayward



STEPS IN THE RACE TO OUTER SPACE

Cosmic Butterfly

Spreading its wings to absorb the eternal flow of solar energy is the Cosmic Butterfly, a space vehicle of a type first conceived by Dr. Ernst Stuhlinger of Redstone Arsenal.

Each of the fifty-foot parabolic mirrors in the wings concentrates the Sun's rays on a boiler at its focal point. Steam is developed, which drives a 200-kw turbo-generator in the base. Cooled by frigid outer space in heat diffusers, the steam reverts to water and is pumped back to the boiler to be used over and over again.

The current thus generated drives the main propulsion unit, an ion rocket in which powerful electric fields accelerate charged particles, shooting them from the rear of the rocket exactly as the elec-

tron gun in your TV set bombards the screen. Sunlight, then, is the power source, whereas cesium is the propellant.

While the recoil thrust is relatively small, the weightless vehicle is operating in a vacuum and the push is enough to enable the Butterfly to reach interplanetary speeds. Unlike conventional rockets, the Butterfly is under power the entire trip. Half way to its destination it turns around, and the ion thrust is used to slow the craft down to arrival speeds.

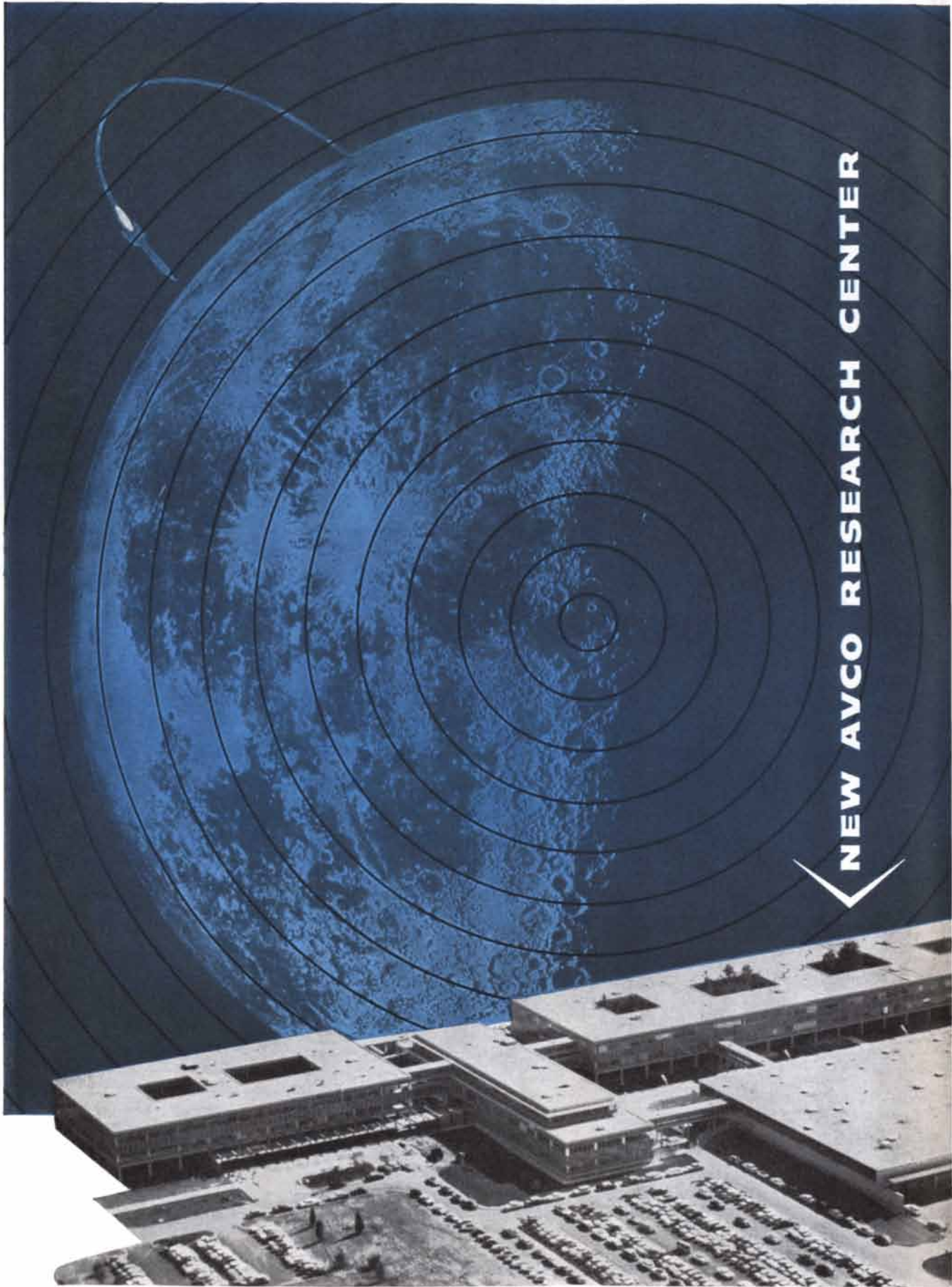
Since its thrust is entirely inadequate to cope with the gravity of major planets, the Cosmic Butterfly never lands. It is

assembled in space and shuttles between artificial satellites.

The Cosmic Butterfly could carry ten passengers and 50 tons of cargo from an Earth satellite to a comparable one orbiting around Mars in about one year of continuous travel.

Inertial navigation systems will play an increasing role in the exploration of outer space. **ARMA** is actively supporting the Air Force's program in long range missiles and is in the vanguard of the race to outer space. **ARMA** . . . Garden City, New York. A Division of American Bosch Arma Corporation.

AMERICAN BOSCH ARMA CORPORATION



NEW AVCO RESEARCH CENTER





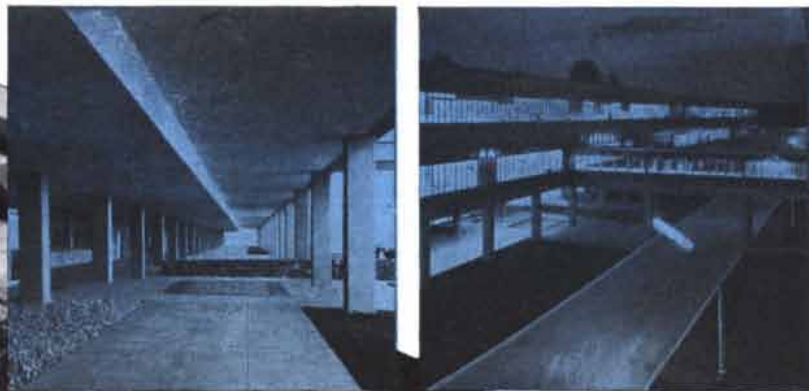
Space age research gets a new headquarters

One of the largest and best-equipped research facilities in the nation is the new 16-million-dollar Avco Research Center at Wilmington, Massachusetts. Here, research and development in space age technology is already being conducted in areas ranging from missile re-entry to satellite design. From work such as this—and equally important work at the nearby Avco Research Laboratory—will come further contributions to national security and the conquest of space!

UNUSUAL CAREER OPPORTUNITIES FOR QUALIFIED SCIENTISTS AND ENGINEERS... WRITE AVCO TODAY

Avco

AVCO MAKES THINGS BETTER FOR AMERICA / AVCO CORPORATION / 750 THIRD AVENUE, NEW YORK 17, N.Y.





ASBESTOS FIBRE RETAINS
91.6% OF ITS TENSILE
 STRENGTH AT **600F** FOR
 THREE MINUTES

Products made with asbestos fibre have endured brief exposures to extremely high temperatures.

The **heat resistance** of J-M Asbestos Fibre can put your product in the high-temperature zone

THE HIGH HEAT RESISTANCE of asbestos fibre combined with its many other unique properties make it a mineral filler of wide and diverse applications—many yet to be discovered. A standard ingredient in many high-temperature applications, asbestos fibre is sure to play an important role in missile and aircraft developments and other areas where temperatures are higher than ever before encountered.

Other important properties of asbestos fibre include its high tensile strength—*greater than ingot or wrought iron*; its extreme fineness—*1500 asbestos fibres are finer than one human hair*; its tremendous

surface area—*50 times greater than nylon*; its high pH of 10+; its high bulking action; its feltability; its reactivity with phosphates, soaps and mineral acids and its resistance to grinding.

Asbestos fibre is familiar as an ingredient in textiles, building materials, insulations, pipe, brake linings, friction materials and packings and gaskets. Other successful applications include plastics paints, auto underbody coatings, adhe-

sives, cements, putties and calking compounds. Chances are it can do a job in your product, too. To find out write Asbestos Fibre Division, Canadian Johns-Manville, Box 1500, Asbestos, P.Q. Can.

Approximate Chemical Analysis of Asbestos			
SiO ₂	38-42	Fe ₂ O ₃	Tr-6
MgO	40-42	Al ₂ O ₃	Tr-3
H ₂ O	12-15	CaO	0.3
FeO	Tr-6		

JOHNS-MANVILLE



NEW DESIGNS IN MARLEX

New floating "Pooltex"® mesh pool cover woven of Reeveon yarn made from Marlex resin and ultra-violet stabilized by Reeves Bros., Inc., N.Y.C., is so light one person can carry it—so tough three people can stand on it! This new cover keeps pools clean . . . lets rain pass through, but keeps out leaves, insects, etc.—helps protect pool owner from danger of children falling in!

Get in the swim—with water sports products made of **MARLEX*** . . . the tough, rot-proof, floating plastic!

Cash in on profitable water sports markets with new idea products made of MARLEX, the linear polyethylene that is so strong and tough it can be used for tugboat hawsers, yet so light it actually floats.

You can soak products molded from MARLEX in salt water for long periods, and they won't absorb a drop of

water or show the least sign of corrosion or discoloration. And they won't crack or break at temperatures from -180° to $+250^{\circ}$ F!

In fact, no other type of material can serve so well and so economically in so many different applications. How can MARLEX serve you?

*MARLEX is a trademark for Phillips family of olefin polymers.



Sinko Mfg. & Tool Co., Chicago, Ill., offers this new "Sea Guard" battery case that is impervious to acids, salt air and water. This new unbreakable case made of MARLEX withstands both high and low temperatures . . . holds all standard 6 and 12-volt marine batteries.



Fishing tackle boxes injection-molded from MARLEX by Plano Molding Co., Plano, Ill., are lightweight, rugged and corrosion-proof. These unbreakable tackle boxes will not crack or dent, and are completely weather-proof. Their attractive finish is durable and scratch-resistant.



Many leading manufacturers offer rope made of MARLEX to the marine market for ski tow ropes, hawsers, shrouds, life lines, heaving lines and general usage. Unbreakable, unsinkable rot-proof handles for ski tow ropes are molded from MARLEX by Lock-Hauer Co., Portland, Ore.

PHILLIPS CHEMICAL COMPANY, Bartlesville, Oklahoma

A subsidiary of Phillips Petroleum Company

PLASTICS SALES OFFICES

NEW ENGLAND

322 Waterman Avenue
East Providence 14, R. I.
Geneva 4-7600

NEW YORK

80 Broadway, Suite 4300
New York 5, N. Y.
Digby 4-3480

AKRON

318 Water Street
Akron 8, Ohio
Franklin 6-4126

CHICAGO

111 S. York Street
Elmhurst, Ill.
TERRace 4-6600

WESTERN

317 N. Lake Ave.
Pasadena, Calif.
RYan 1-6997

SOUTHERN

6010 Sherry Lane
Dallas, Texas
EMerson 8-1358

EXPORT

80 Broadway, Suite 4300,
New York 5, N. Y.
Digby 4-3480



ALPHA



A NEW NAME IN WORLD-WIDE SYSTEMS PROJECTS

To broaden and extend its systems projects services in keeping with the space age . . . Collins Radio Company has created Alpha Corporation . . . a wholly-owned subsidiary to be staffed initially with Collins specialists and executives.

For a number of years, Collins has been engaged in a concentrated program of design, engineering and installation of complex communication systems for both military and commercial uses. This program has resulted in the development of technical skills, management techniques and know-how representing a significant addition to the company's primary activity of developing and manufacturing individual units of electronic equipment. Alpha has

been formed to expand upon Collins activities in this field. Alpha, with its highly specialized systems management organization of designers, engineers, scientists and constructors, will produce complete, packaged commercial and government installations in this country and abroad . . . using the best available equipment from industry to deliver to its clients turn-key installations meeting the highest standards of dependability and quality . . . ready for operation.

Alpha will provide "on-the-job training" for customer engineers and technicians assigned to the installations . . . or furnish complete crews of skilled specialists to staff the finished projects.

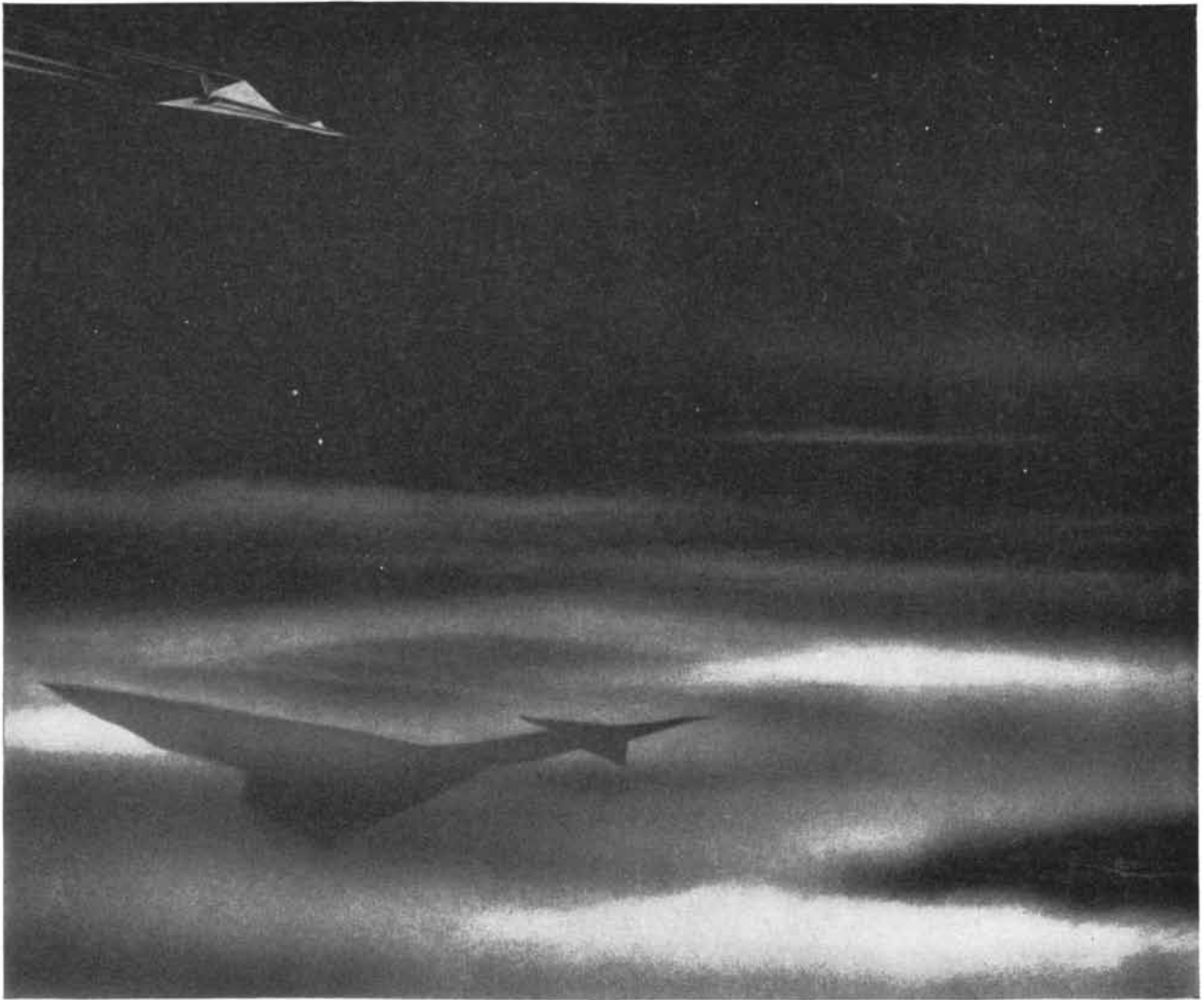


DESIGNERS, ENGINEERS, CONSTRUCTORS, WORLD-WIDE • RICHARDSON, TEXAS • TELEPHONE DALLAS ADams 5-2323 • CABLE ADDRESS: ALPHA DALLAS

Alpha capabilities include technical systems management in all fields, with special emphasis on: • Space vehicle tracking and communication

Test range instrumentation and communications • Voice, teletype and data transmission • Aircraft modification and overhaul

Integrated shipborne, airborne, and ground communications • High capability remote control and switching



8497-AC

SPECIFICATION: AERONCA BRAZED HONEYCOMB STRUCTURES

DESTINATION: *MACH 3!*

To meet the critical demands of Mach 3 performance, new concepts in air vehicle structures have been evolved. Stainless steel honeycomb sandwiches, for example, are specified as major structural components in current weapons systems designed to operate in high mach environments.

Aeronca, a pioneer in the application of stainless honeycomb to air weapons, has developed advanced production methods and facilities under a proprietary research and development program. As a result, Aeronca is one of the few companies actually producing these high-temperature structures in quantity.

Aeronca is proud that its capabilities have been selected to support the North American B-70 and F-108 Weapons Systems.

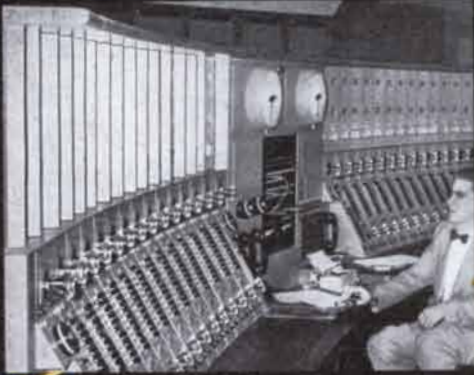


AERONCA manufacturing corporation

1722 GERMANTOWN ROAD • MIDDLETOWN, OHIO

Expansion of our operations has created openings for additional senior engineers. Write to L. C. Wolfe, Chief Engineer.

Electronic Communications



Electronic Defense

Electronic Guidance



Electronic Navigation



**wherever
there's
electronics...**

there's Transiron

Electronic Computers



Electronic Auto-Pilots



Manufacturers of TRANSISTORS • DIODES • RECTIFIERS • REGULATORS • VOLTAGE REFERENCES



Transiron

electronic corporation • wakefield, massachusetts



SALES OFFICES IN PRINCIPAL CITIES THROUGHOUT THE U. S. A. • CABLE ADDRESS: TRELCO

...NEWS IS HAPPENING AT NORTHROP

Demonstrating the platform of LINS – new, Lightweight Inertial Navigation System – is Dr. William F. Ballhaus, Vice President and General Manager of Nortronic.



NORTRONICS REVEALS LINS... COMPLETE PRECISION INERTIAL NAVIGATION SYSTEM!

A recent demonstration at Nortronic's Guidance Symposium revealed the most advanced precision inertial guidance system ever assembled. LINS—Lightweight Inertial Navigation System—includes platform, platform electronics, environmental control and computer. Total system weight: slightly in excess of 100 pounds. Equipment volume: less than three cubic feet.

Actual working hardware, LINS is a complete, precision system for automatic navigation applications to advanced aircraft, drones,

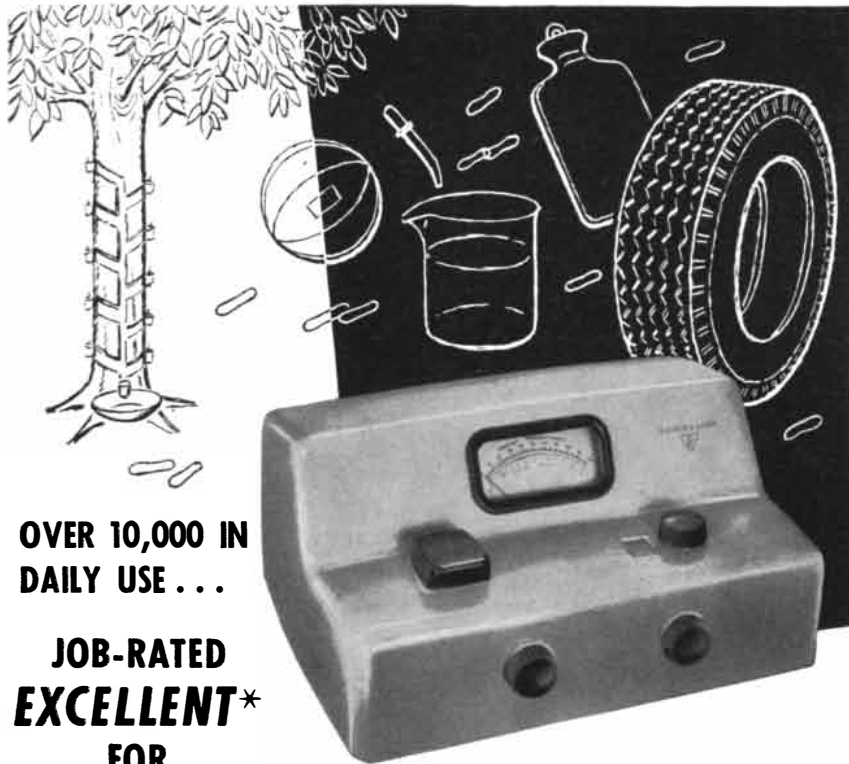
missiles, and space vehicles. It is ready now—the latest result of Nortronic's more than twelve years of creative research and production in the field of automatic guidance and navigation systems.

If you have the need to know more—contact Nortronic today, regarding LINS for your own system requirement. Nortronic's experience offers unique and proven capabilities in tailoring the design, development and production of complete and integrated guidance systems to your requirements.



NORTRONICS

HAWTHORNE, CALIFORNIA
A Division of Northrop Corporation



OVER 10,000 IN
DAILY USE . . .

**JOB-RATED
EXCELLENT***
FOR

ACID DETERMINATIONS

* "We use it to test for nitric acid in sulfuric acid, iron in sulfuric acid, TNT and TNT complexes in waste water. Performance is excellent. Instrument is easy and simple to operate and gives dependable results."

*Leading Rubber
Manufacturer
—name on request.*



This low-cost "production tool" gives you quick, dependable photometric readings . . . easy as tuning your radio! In many industries it's basic equipment for quality control testing, inspection . . . even research! Here's why:

- **DEPENDABLE ACCURACY!** Narrow band pass (only 20m μ !) assures highest spectral purity.
- **EASIEST TO USE!** Dial instantly sets Certified-Precision diffraction grating to desired wavelength; no color filters to fuss with.
- **FASTEST READINGS!** Instant-acting meter gives exact percent transmission, or optical density.
- **LOW PRICE, DOUBLE VALUE!** Colorimeter plus spectrophotometer, 375m μ -950m μ range in one long-life, trouble-free instrument. (Extended range, 340m μ -950m μ at slight extra cost.)

Used in these and many other industries to maintain quality and boost output:

METALS	PLATING
RUBBER	LEATHER
PETROLEUM	DYES
FOODS	PAPER
PLASTICS	BEVERAGES
PAINTS	TEXTILES
	PHARMACEUTICALS
	SYNTHETIC FIBERS

MAIL COUPON FOR IMPORTANT DATA

BAUSCH & LOMB OPTICAL CO.
69442 St. Paul St., Rochester 2, N. Y.

- Send me B&L Spectronic 20 Catalog D-266.
- I would like an obligation-free demonstration of the B&L Spectronic 20 Colorimeter at my convenience.

Name Title

Company

Address

City Zone State

LETTERS

Sirs:

In a letter in your April issue Mr. Merrill Eisenbud, Manager of the New York Operations Office of the United States Atomic Energy Commission, New York, criticizes the review by James R. Newman of my book *No More War!*

It is my opinion that Mr. Eisenbud's criticism is unjustified and seriously misleading.

Mr. Eisenbud says "James R. Newman reviewed Linus Pauling's book *No More War!* in your February issue and referred to a statement which I am said to have made. Mr. Newman writes: 'Merrill Eisenbud, an Atomic Energy Commission official, wrote an article in 1955 which stated that "the total fallout to date from all tests would have to be multiplied by a million to produce visible, deleterious effects except in areas close to the explosion itself."' . . . Newman's information, which comes in part from Professor Pauling's monograph, is incorrect. This statement did not come from an article I wrote. . . . I have admired Mr. Newman's writing for many years. . . . However, when even as reliable a writer as Mr. Newman will take confused fourth-hand information, and further confuse it in creating a fifth-hand version, one begins to wonder when to trust the 'facts' he reads."

The quoted statement attributed to Mr. Eisenbud appeared in an article in

Scientific American, June, 1959; Vol. 200, 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 S. W. 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.



AT RAYTHEON

Scientific imagination focuses on SONICS

Sound waves generated by electro- and hydro-acoustic transducers are used in a wide variety of applications. Flow metering, medical therapy and diagnosis, and degreasing of small parts are a few. Covering about 25 octaves, the sonic spectrum ranges from audible to ultrasonic frequencies as high as 10^9 cycles.

Raytheon scientists have made noteworthy contributions to transducer technology and acoustic propagation techniques. Examples: the development of the first low-cost depth sounder, the practical application of ultra-

sonics in machining refractory materials, and the use of electromechanical filters for spectrum analysis. Currently, Raytheon is producing for the Navy the AN/BQQ-1 sonar—the most comprehensive underwater sound system yet devised for detecting, tracking and attacking enemy submarines.

Among the distinguished scientists at Raytheon who are expanding basic knowledge of sonics is Dr. Theodor F. Hueter of the Government Equipment Division's Sonar Department.

RAYTHEON COMPANY, Waltham, Mass.



*Excellence
in Electronics*

ARE YOU READY FOR THE 60's?

Tomorrow's technology demands cryogenic devices of small size and high reliability . . .

The ADL MinIRcooler, designed for use with devices that detect very long wave-length infrared or extremely small temperature differentials, provides closed-cycle refrigeration in a miniaturized, low-pressure (300 psia), lightweight system of high reliability. *The only moving part below ambient temperature is a tiny plastic piston.* The MinIRcooler can maintain IR detectors down to 60°K.

ADL is currently developing similar devices for spot cooling at temperatures down to 20°K.*

*Hamilton Standard Division, United Aircraft Corp. has been licensed for manufacture and sale of the MinIRcooler for IR applications above 30°K.

Arthur D. Little, Inc.

CAMBRIDGE • CHICAGO • SAN FRANCISCO
NEW YORK • WASHINGTON • SAN JUAN • EDINBURGH

You may be interested in some articles and papers by ADL staff members. Please indicate below those you desire and attach to your letterhead.

SPECIFICATION SHEET
— ADL MinIRcooler

"YOUR DOLLAR RETURNS FROM RESEARCH," I. Telling & W. S. Berg, *Industrial Research*

"A NEW TECHNIQUE FOR MEASURING THE SPECTRAL EMISSIVITY OF SOLIDS AT HIGH TEMPERATURES," P. E. Glaser & H. H. Blau, Jr., *Journal of Heat Transfer*

"AUTOMATION — YES OR NO"

"FUNCTIONAL FEATURES IN PRODUCT

STRATEGY," J. B. Stewart, *Harvard Business Review*

"CRYOPUMPING FOR HIGH VACUUM WITH LOW POWER," B. M. Bailey & R. L. Chuan, Fifth National Vacuum Symposium

"SUPERCONDUCTIVE SWITCHING CIRCUITS," A. E. Slade & H. O. McMahon, *Proceedings of the National Electronics Conference*

"RADIATION, A TOOL FOR INDUSTRY," S. E. Eaton & M. Michaelis, presented before 7th Annual Conference, Atomic Energy for Industry

Your request will receive the prompt attention of:

Director of Public Relations,

Arthur D. Little, Inc., 21 Acorn Park, Cambridge 40, Mass.

the *New York Sunday News* of March 20, 1955. It is reproduced on page 1,279 of *The Nature of Radioactive Fallout and Its Effects on Man*, the report of hearings before the Special Subcommittee on Radiation of the Joint Congressional Committee on Atomic Energy.

Mr. Eisenbud's letter to you suggests strongly that the quotation attributed to him was not made by him. But he does not deny that he made the statement. In his testimony before the Special Congressional Subcommittee (page 1,274) Senator Anderson had said to him: "Mr. Eisenbud, this statement was made on 20 March 1955. I understand you do not question the accuracy of the quotation." Eisenbud replied "I do not question the accuracy of the quotation nor will I certify it."

On February 24, 1959, I wrote to Mr. Eisenbud, pointing out that in his testimony he had not questioned the accuracy of the quotation. In my letter I stated that "I note that you do not question the accuracy of the statement attributed to you by the writer of the article in the *Sunday News* either in your letters to *Scientific American* or to me or in your testimony before the Special Subcommittee on Radiation." I have received no answer, and I conclude that there is no reason to doubt that the statement is properly attributed to Mr. Eisenbud.

In view of these facts, I believe that Mr. Eisenbud's letter to you is seriously misleading.

LINUS PAULING

Gates and Crellin Laboratories
California Institute of Technology
Pasadena, California

Sirs:

Perhaps it should be stated even more definitely than Robert A. Hall did in his excellent and thought-provoking piece ["Pidgin Languages"; *SCIENTIFIC AMERICAN*, February] that pidginization and creolizing are not the result of the impact of well-developed languages of the Western world on underdeveloped idioms of more primitive cultures but rather the normal way languages split up and develop daughter languages. The fact that no such thing has happened in Europe for hundreds of years should not blind us to the fact that our own mother tongues are nothing but the result of creolization at an earlier stage. As a romancist, Dr. Hall will undoubtedly agree that French, Italian, Spanish, Portuguese, Catalan, Provençal, Romansch and Rumanian are, in their origin, noth-

SERVING SAFETY THROUGH SCIENCE



THE priceless ingredient of civilization...its most valuable "raw material"...is the life of the human being. Second only to the safety of the individual is the preservation and protection of those things which contribute to his life...food, places to live and work, and ways of getting there.

Serving this principle through the application of science is the *raison d'être* of every division of Servo Corporation of America. A case in point:

Infrared systems represent a field in which Servo Corporation enjoys technological leadership based on many years' experience. Out of its Infrared Research Laboratories came the **SERVOSAFE® Hot Box Detective***, a device supplied by the Railroad Products Division and now in use on 17 leading U. S. railroads.

The **SERVOSAFE** system spots overheated journal boxes—"hot boxes" which can lead to derailments and loss of time, goods, lives. It automatically examines each and every journal box as a train passes. When a hot box is detected, a stop signal is tripped, the tower operator is alerted, and a graph points out *which* journal box on *which* side of *which* truck on *which* car is dangerously overheated.

All this happens in seconds. By the time the train rolls to a halt, the one dangerous journal box out of harmless hundreds

is located immediately; and the danger is corrected. The train then proceeds in safety.

The value of such split-second detection can be added in terms of the number of cars which need *not* be sidetracked for costly repairs—or the tons of perishable goods which need *not* perish—or the consignments which need *not* be delayed.

The value may also be measured in terms of *people*...of ourselves, our wives, and our children.

This becomes more evident in air traffic control. Servo's Air Traffic and Navigation Systems Division provides AID (Automatic Instantaneous Direction-finding) with its **SERVOFLIGHT® Doppler DF Systems**. These provide accuracy, stability, and speed never before attained.

Air safety depends on knowledge of weather conditions. The **SERVOFLIGHT** Radio Theodolite tracks weather balloons for this purpose, passing on information about temperature, humidity, pressure, wind directions, and speeds.

And so it goes with other divisions and products...infrared systems for industry to provide safe control of industrial processes...and, of course, military systems which guard against surprise enemy attack. Thus, in every respect, Servo Corporation products serve safety through science.



*Protected by U.S. Patent No. 2,880,309. Other U.S. & Foreign Patents Applied For

SERVO CORPORATION OF AMERICA 20-20 Jericho Turnpike, New Hyde Park, L. I., N.Y.

©1959 SERVO CORPORATION OF AMERICA

THE WESTINGHOUSE "TRINISTOR"



... a high-power, high-speed silicon switch for applications now employing thyratrons, relays, and conventional rectifiers.

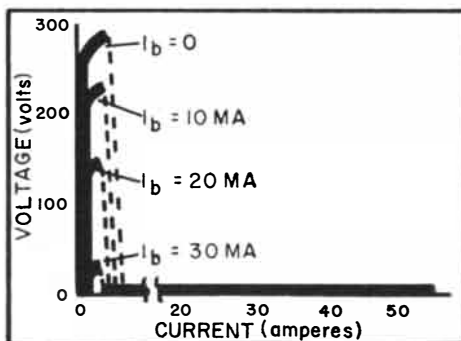
The "Trinistor," semiconductor successor to the thyatron, is a highly efficient three-terminal switching device which overcomes the thyatron's limited power handling capacity, low switching speed, and relatively high forward drop. With recent developments at Westinghouse, Trinistors of various high-power capacities will soon be commercial realities.

The Silicon Trinistor will find a host of new applications. It can be used wherever today's thyratrons, relays, magnetic amplifiers, power trans-

sistors and standard rectifiers find use. Applications include the high-speed switching of AC and DC, full-wave phase controlled DC power supplies, circuit breakers, inverters, motor control, and many others.

The switching characteristic of the Silicon Trinistor from the "OFF" to the "ON" condition, and the control function of the base current I_b , are illustrated below.

Watch for the announcement of commercial availability of the new Westinghouse Silicon Trinistor.



YOU CAN BE SURE...IF IT'S **Westinghouse**
Westinghouse Electric Corp., Semiconductor Department, Youngwood, Pa.

ing but different forms of creolized Latin. It can also be stated that medieval English was, at different periods, first creolized Old Norse and then creolized Norman French. . . .

GUNNAR LEISTIKOW

New York, N. Y.

Sirs:

It is tempting to think that the Romance languages may be of creolized origin. However, we must distinguish two main types of linguistic change: (1) the "normal" kind, slow and gradual, extending over centuries and millennia; and (2) the sudden, drastic reduction and brusque, extensive re-structuring involved in the formation of a pidgin. The historical evidence shows clearly that the differentiation of the Romance languages and of the other group mentioned by Mr. Leistikow was of the first, not the second, kind. Furthermore, there is no evidence that there was ever a time when the ancestral forms of these languages were never spoken by anyone as his or her native language, as would be required by the other part of our definition of a pidgin.

ROBERT A. HALL, JR.

Cornell University
Ithaca, N. Y.

Sirs:

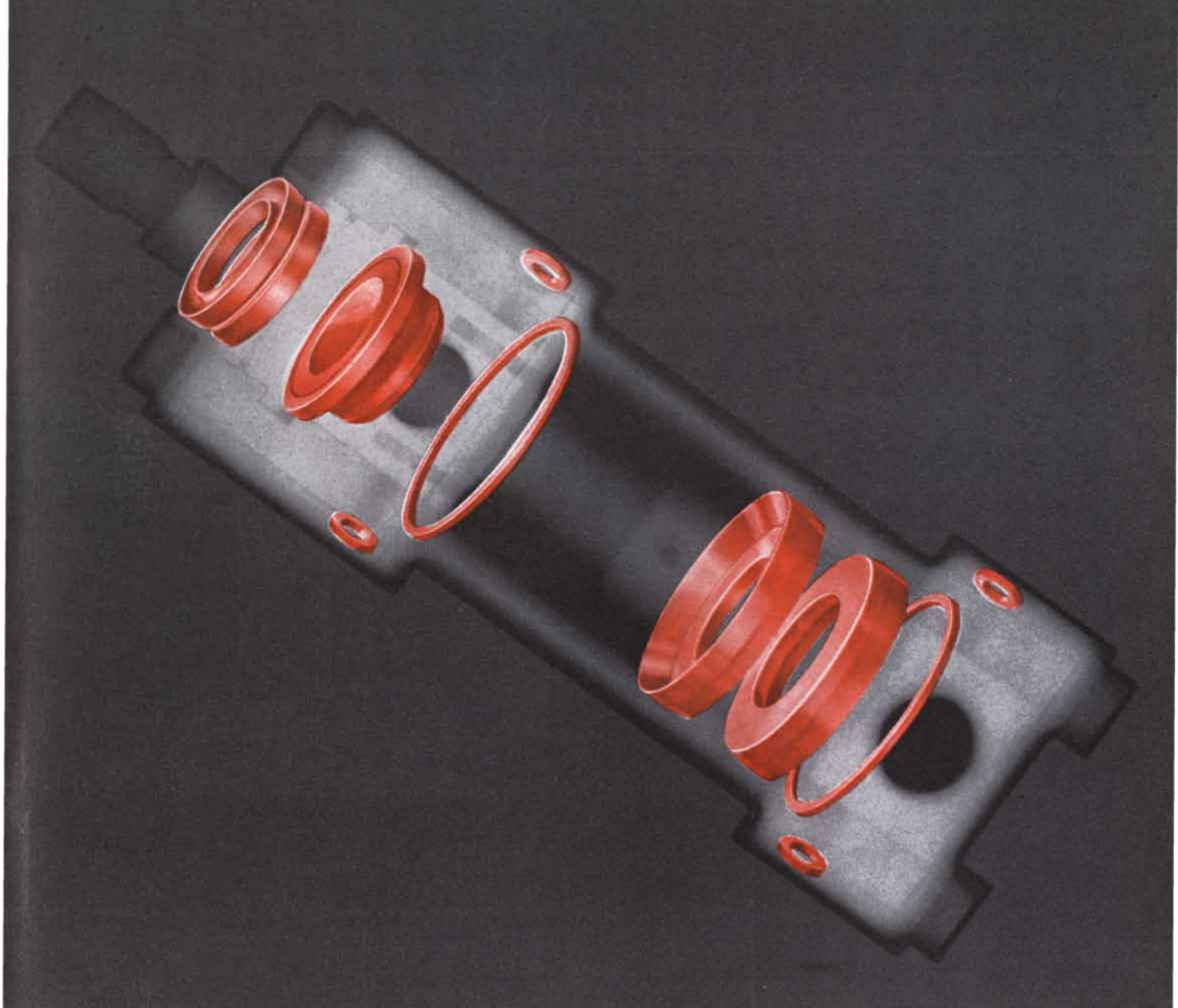
"Reactor Fuel Elements" by James F. Schumar [*SCIENTIFIC AMERICAN*, February] is not only a clear and interesting article, but it is a sturdy blow in the long battle for good grammar and diction. Only once does he use the bastard word "cladding" and then in quotes to show its questionable nature.

Use of "clad" as a root verb with all normal verbal inflections is gaining ground, largely because engineering ears used to "metal-clad" don't accept the other tenses, "clothe" and "clothing," in association with metal.

The English language is rich with bastard forms already. Not legitimacy, but usefulness, should be the criterion for accepting new words. Mr. Schumar's prose clearly demonstrates that the language doesn't need these illogical and ear-grating forms.

VAN V. TRUMBULL

General Electric Company
Schenectady, N. Y.



Seals of Du Pont TEFLON TFE resins boost performance of hydraulic power cylinder. (By Miller Fluid Power Div. of Flick-Reedy Corp., Bensenville, Ill.)

THE INSIDE STORY: Seals that help put the muscle in machines

Tons of traction and thrust are applied by hydraulic power cylinders to the mighty mechanisms of industry. For maximum reliability and efficiency the hydraulic seals are often made of TEFLON TFE-fluorocarbon resins. Because TEFLON resins have the lowest coefficient of friction of any known solid materials, these seals require no lubrication, reduce torque and will not stick or freeze. TFE resins are unaffected by even the most corrosive synthetic hydraulic fluids and retain their unique properties from temperatures of minus 320°F. to 500°F.

Throughout industry and in advanced military applications, TFE resins are raising the performance of equipment and processes to new, high levels. For an interesting and informative booklet on the properties and uses of Du Pont TEFLON TFE-fluorocarbon resins just write to: **E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room T-396, Du Pont Building, Wilmington 98, Delaware.**

In Canada: Du Pont Company of Canada Limited, P. O. Box 660, Montreal, Quebec.



TEFLON[®]
TFE-FLUOROCARBON RESINS

TEFLON is Du Pont's registered trademark for its fluorocarbon resins, including the TFE (tetrafluoroethylene) resins discussed herein.

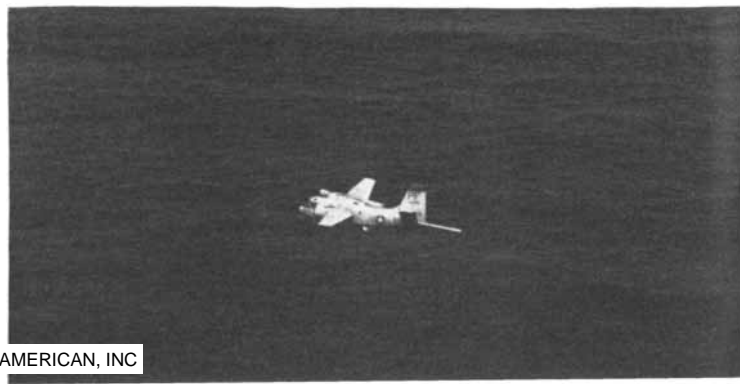
BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY



Here are Grumman S2F Trackers on board aircraft carrier, mainstay of United States Navy HUK Group on Anti-Submarine Warfare maneuvers.



S2F starts search with electronic gear that can detect snorkel, periscope, or sub radar, even the submerged sub's disturbance of the earth's magnetic field.



Cities are Sitting Ducks



Coastal cities—of course. Midland cities, too. In fact, any city anywhere in the U. S. is a sitting duck target for missiles launched from subs.

One of the free world's greatest menaces is the submarine.

Best protection against this danger is the U. S. Navy—and its long-range anti-submarine task forces. Fixed-wing long-range aircraft, launched from task force carriers, patrol the high seas, probe their depths, screen their contents. They detect, identify and track. And, upon provocation, destroy. They help make the Navy our strongest defense against the threat of the submarine.

These anti-submarine warfare (ASW) aircraft are operational with the Navy throughout the world. Many are Grumman S2F Trackers. They carry the most advanced electronic detection gear plus the weapons that enable them to perform the complete search-attack assignment.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
Bethpage • Long Island • New York

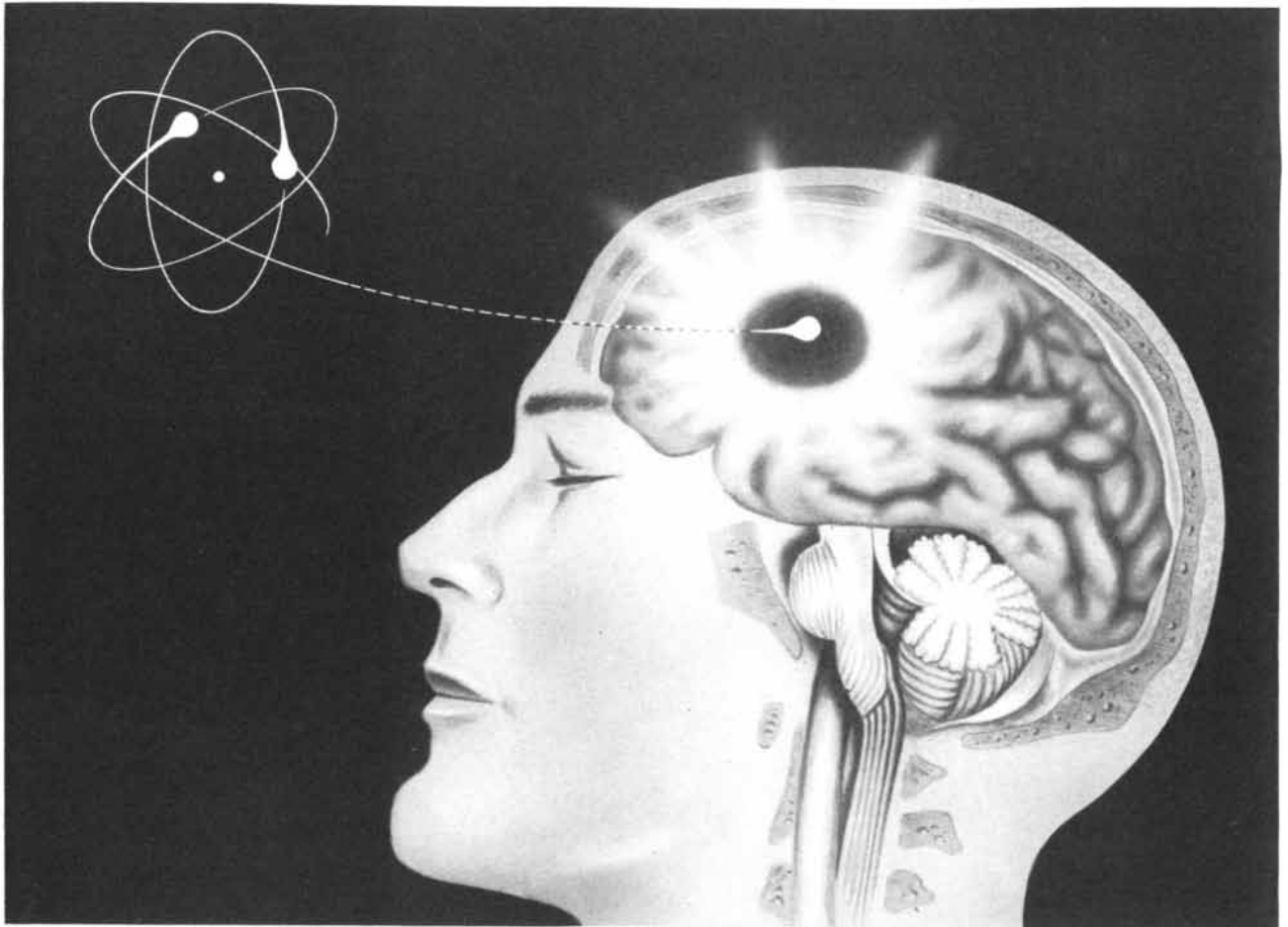


Personnel of Combat Intelligence Center are receiving S2F Tracker report of contact and the dropping of detection devices to pinpoint submarine.



Grumman S2F Tracker is returning to aircraft carrier after "sinking" submarine in war games with depth charges and an ingenious homing torpedo.





Neutron-sensitive isotope made in Monel fractionator

Boron-10 vs. brain tumors

Physicians and scientists working in cancer research at Brookhaven National Laboratory, Upton, N. Y., are probing the use of Boron-10 isotope in treating a common type of brain tumor (*glioblastoma multiforme*).

Results of this therapy are so encouraging that Brookhaven and at least two other institutions are constructing additional nuclear reactors used in this therapeutic venture.

The method. In a technique known as Neutron Capture Therapy, the patient receives an injection of a Boron-10 compound. Cancerous tissue absorbs Boron-10 more rapidly than healthy tissue. While the isotope is concentrated in the tumor, neutrons from a nuclear reactor are beamed at it. The Boron-10 in the

cancer absorbs most of the neutrons.

In the split second that the Boron-10 becomes radioactive, it produces short-ranged alpha particles which destroy cancerous tissue with a minimum of damage to healthy tissue.

Producing the isotope. The plant furnishing Boron-10 to Brookhaven ordinarily turns out about three pounds during a 24-hour work day. Separation of the isotope takes place in what is described as "the world's most efficient fractionating system." In 350 feet of total height, six series-connected Monel* nickel-copper alloy columns enrich a complex containing 18.8% Boron-10 isotope to one containing 92% Boron-10.

Corrosive action foiled. Throughout subsequent manufacturing proc-

esses, where equipment is constantly subject to fluoride attack, only pure Nickel or Monel alloy is used. These metals hold corrosion at arm's length in columns, reboilers, condensers, vessels, pumps, and piping.

Is there a metal problem facing you? One that involves corrosion... high temperatures... low temperatures... stress... fatigue? Monel alloy or another of the many Inco Nickel alloys may be just the metal you're searching for. Write for our helpful booklet, "Corrosion: Processes - Factors - Testing."

*Registered trademark

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

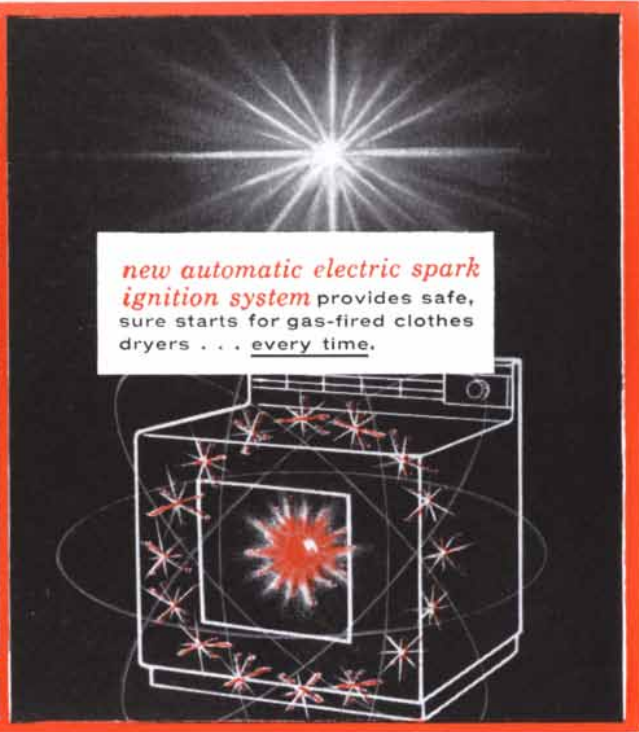


INCO NICKEL ALLOYS

NICKEL ALLOYS PERFORM BETTER LONGER

Controls Company of America

(what's new in laundromation?)

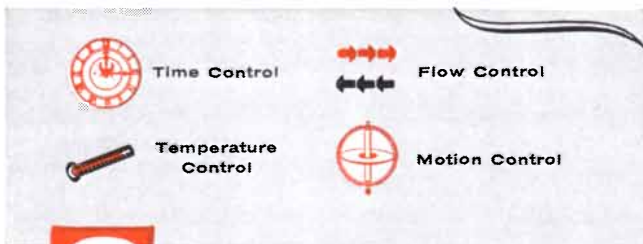


how can we work for you?

Modern laundry equipment has taken much of the back-work out of the family wash. Now Controls Company of America has removed the brain-work through laundromation — thanks to CC integrated control systems. Both *Cycle-Set* power timer and automatic electric spark ignition systems are controlling factors on leading manufacturers' top-of-line laundry appliances this season — another example of how CC creative engineering continues to serve home and industry.

CC's control system approach is the result of many years' experience in the appliance and heating fields. We have developed hundreds of standard control components — valves, switches, solenoids, motors in almost every type and size. CC's unique combination of creative engineering assistance and a complete control line means a fast solution to *your* control problems. Write today for full details on our comprehensive service.

This is our line



If you're looking for a better way to control time, flow, temperature or motion, our creative engineering service may help you find it. We can supply single controls or complete, integrated systems.



Creative Controls for Industry CONTROLS COMPANY OF AMERICA

EXECUTIVE OFFICES: SCHILLER PARK, ILLINOIS



MILWAUKEE VALVE CO., MILWAUKEE, WIS. • LAKE CITY, INC., CRYSTAL LAKE, ILL.
CONTROLS COMPANY OF AMERICA (CANADA) LTD., COOKSVILLE, ONTARIO;
CANADA • INTERNATIONAL DIVISION, SCHILLER PARK, ILL., U.S.A. • CONTROLS
AG, ZUG, SWITZERLAND • CONTROLS MAATSCHAPPIJ EUROPA N.V., NIMEGEN,
HOLLAND • CONTROLS COMPANY OF AMERICA (ARGENTINA) SRL, BUENOS AIRES.

CHOOSE FROM 100 RARE EARTH SALTS

One of them may offer you unexpected and profitable advantages

a report by LINDSAY

The unique properties, intriguing characteristics and amazing versatility of the rare earths suggest the possibility of their usefulness to you. It's not unlikely when you consider that rare earth salts are being used today in production processes involving glass, metals, ceramics, chemicals, fabrics, paint and pharmaceuticals, just to name a few.

Even today, some manufacturers have not investigated the rare earths because they still think they are *rare*. That is not so. Only a few years ago, the rare earths were little more than laboratory oddities, except of course for a few well-known basic and critically important applications.

It will interest you to know that we are producing more than 100 rare earth, yttrium and thorium salts. We can make prompt shipments in commercial quantities. And at extremely favorable prices.

If you are concerned with research, product development or production processes, it will be significant to you that there has been a vast change in rare earth production during the past ten years . . . in volume, in varieties, in purities of materials commercially available, and in prices.

This is the result primarily of two factors. The curiosity and imagination of research workers who have developed many practical applications. And our own enormously expanded production, particularly of rare earths in high purities up to 99.99%.

Look with us for a moment at some of the interesting developments.



Glass polishing with cerium oxide is one of the most extensive rare earth applications. Lindsay, nearly 20 years ago, revolutionized glass polishing practices in this country when it introduced cerium oxide. Today it is used for polishing millions of spectacles, lenses for cameras and other high precision optical instruments, TV picture tubes, fine quality mirrors, automobile windshields and many glass specialties.

We are operating a fully equipped and capably staffed polishing laboratory continually working on quality control and evaluation of new formulas. If you have a polishing problem, you may find it fruitful to talk with us.

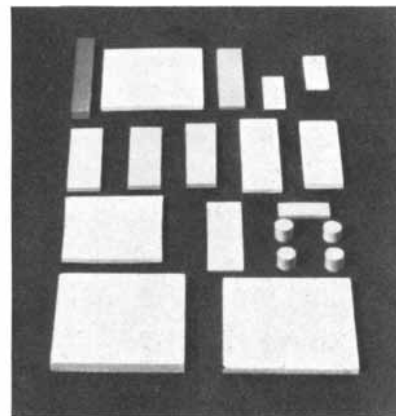
Rare earth garnets for electronic equipment are structurally somewhat similar to the garnet variety grossularite (formula $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$). The most interesting ones are the rare earth-iron garnets such as $\text{Y}_3\text{Fe}_2(\text{FeO}_4)_3$. This mouthful of formula has been abbreviated by researchers to "YIG" for obvious reasons. Other names stem from other rare-earth symbols. These garnets, particularly those of yttrium, gadolinium, erbium, and some others have interesting ferrimagnetic properties, making them useful as ferrite materials in electronic equipment.

We don't make the garnets but we can supply the correct material for this particular application, and, of course, helpful technical service.

Neutron absorbing rare earths are now available in ample quantities and at reasonable costs for use as poisons in nuclear reactors. Europium is the most effective control rod material but is relatively scarce and expensive. Control rod designers are making progress in demonstrating the desirable performance characteristics of gadolinium, dysprosium, samarium and erbium.

We would be happy to supply to qualified persons information about significant developments in this field.

Sintered shapes. Through our laboratory research, we have developed a process for producing rare earth oxides in sintered shapes. This information is



now available to you if your experimental work indicates this a desirable form of the rare earth oxides.

Rare earth and yttrium metals are now available from Lindsay. Many users of rare earths prefer them in this form. Our high purity rare earth metals are furnished primarily in the form of ingots or lumps. They are available for prompt shipment from our inventory in experimental quantities.

You will find costs reasonable and advantageous for your research or product development and production operations. Want more information?

This report indicates a wide range of commercial interest in the rare earths. Certainly they have a quite remarkable flexibility and versatility in their application to many uses.

We can't tell you how to use the rare earths in your processes. But we can offer you technical data which may be of interest to your research people.

Please tell us your area of potential interest and we'll try to supply information which is most helpful to you.

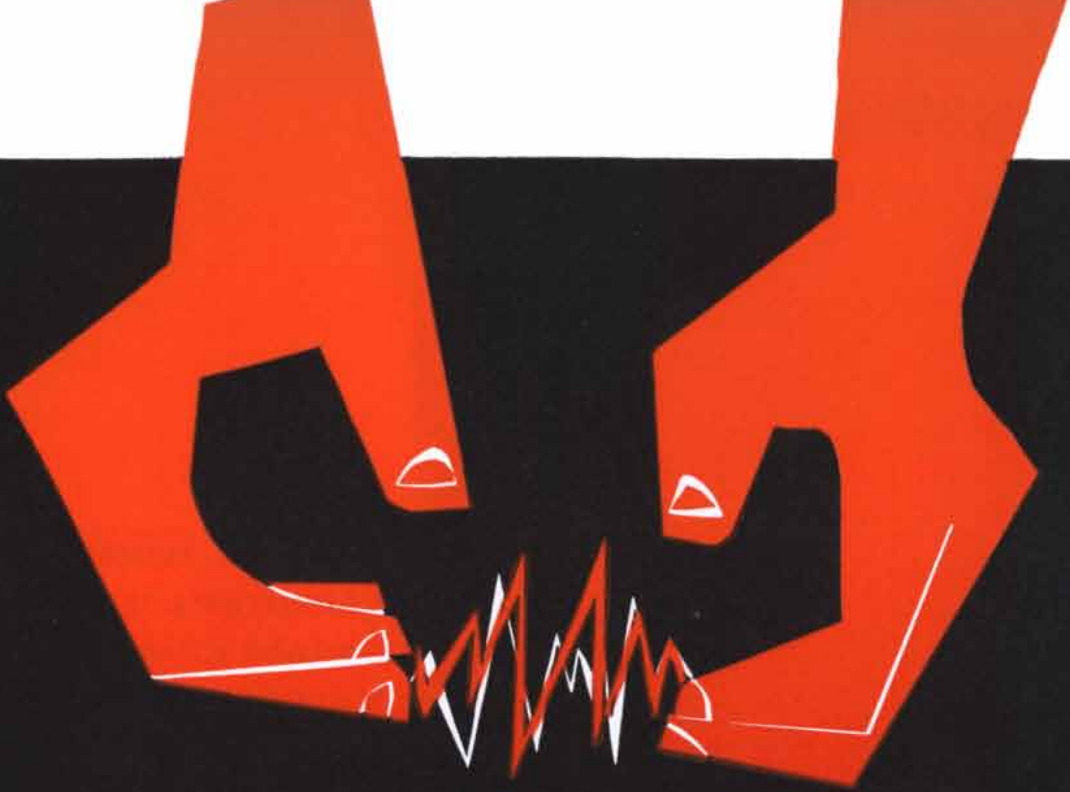


PLEASE ADDRESS INQUIRIES TO
LINDSAY CHEMICAL DIVISION

American Potash & Chemical Corporation

264 ANN STREET • WEST CHICAGO, ILLINOIS

OFFICES: CHICAGO • LOS ANGELES • SAN FRANCISCO • NEW YORK • PORTLAND (ORE.) • ATLANTA • COLUMBUS (O.) • SHREVEPORT



FRANKLIN "ONE FLUID" and the IONOSPHERE

Creative Imagination enabled Benjamin Franklin to orient all the observed electrical phenomena to his own "one fluid" theory—the basis of all our comprehension of electricity today.

At National Co. creative imagination is continuing to broaden our comprehension of the physical universe and apply it to the realization of such new means of communication as Ionospheric scatter systems.

The implications and applications of such new means of communication are vast.

National Co. is a community of minds and talents that enjoys the challenge and the prestige of success in such advanced fields as multipath transmission, noise re-

duction, correlation techniques for signal processing, Tropospheric scatter systems, Ionospheric scatter systems, molecular beam techniques, long range microwave transmission, and missile check-out equipment using microwave and digital techniques.

National Co. has grown with the Tradition of New England electronics. Your needs and problems receive exceptional attention at National Co. because, here, *creativity is required, recognized and rewarded.*

Write or phone

tuned to tomorrow **National** 

National Company, Inc., Malden, Mass.

MANUFACTURERS OF MATERIEL AND EQUIPMENT FOR U. S. DEFENSE

REG. U.S. PAT. OFF.
SCOTCH BRAND MAGNETIC TAPE
 FOR INSTRUMENTATION USE



**MAGNETIC MEMORY OF A
 COMPUTER'S "FAST TALK"
 —90,000 CHARACTERS
 A SECOND,
 CAUGHT UNBLURRED**

Done in days — the calculations that might take the human brain months! To speed its work, the computer draws on a perfect memory — data translated to the pure language of mathematics — recorded as signal "bits" on "SCOTCH" BRAND Magnetic Tape.

Where a mote of dust can mean an error, "SCOTCH" BRAND Magnetic Tape is a clear, unclouded memory—supplying data for calculation at the unimaginable speed of over 500,000 signal bits or 90,000 characters a second.

The first practical magnetic tape ever devised, "SCOTCH" BRAND Magnetic Tape remains the leader as newer, more sensitive instrumentation tapes are developed for science, business and industry. It helps explore sea and space, directs automated industry, balances the accounts of business—and it will serve you, too. For information on tape constructions for your specific needs, write Magnetic Products Division, 3M Company, 900 Bush Ave., St. Paul 6, Minnesota.

© 1959 3M Co.

*"SCOTCH" BRAND Magnetic Tape
 —the memory of tomorrow*

The term "SCOTCH" is a registered trademark of 3M Company, St. Paul 6, Minnesota. Export: 99 Park Avenue, N.Y. Canada: London, Ont.

MINNESOTA MINING AND MANUFACTURING COMPANY

...WHERE RESEARCH IS THE KEY TO TOMORROW



Here are the "basic ingredients" in some of today's most advanced design concepts . . . Norton Ceramic Materials. Exceptionally versatile, these exciting materials are meeting operating requirements of products and processes across industry.

Norton Ceramic Materials offer design engineers a wide range of outstanding physical, chemical, thermal, and electrical properties. What's more, they provide interesting *combinations* of these properties. For example: CRYSTOLON* silicon carbide provides high thermal conductivity as well as exceptional thermal strength; ALUNDUM* aluminum oxide has excellent chemical stability in addition to good abrasion resistance; MAGNORITE* magnesium oxide offers high purity, thermal and electrical resistance; fused

Dynamic Ideas in Engineering . . .

thrive on Norton ceramic materials

zirconium oxide is today's highest melting point material available in tonnage quantities and it's immune to both reducing and oxidizing atmospheres. And each product has *many* other invaluable properties.

Think of Norton Ceramic Compositions as essential components in equipment for metal and chemical processing, electrical, electronic, ceramic and nuclear applications . . . as "the answer" to literally hundreds of design problems. They're manufactured to meet highly exacting standards of purity, density, shape, size and wear resistance . . . available in granular and in fabricated form to meet *your* requirements efficiently and economically. For complete details, write for "Norton REFRACTORY GRAIN". NORTON COMPANY, Refractories Division, 545 New Bond Street, Worcester 6, Mass.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries



REFRACTERIES

Engineered... **R**... Prescribed

Making better products . . . to make your products better

NORTON PRODUCTS Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electrochemicals — BEHR-MANNING DIVISION Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes



A HIGH POLISH FOR HIGH FLYING

KENNAMETAL* meets many critical requirements

This unretouched photograph shows the high reflective finish of a Librascope† integrator disc, 1 3/8" diameter, made from Kennametal. Little discs like this one are of big importance in the operation of guidance systems, automatic pilots, and gyrostabilizers. In addition to a high polish, the discs must have high YME, hardness, and compressive strength . . . all qualities of Kennametal. Need for these properties, or a combination of other exceptional characteristics, is often met by a specific grade in the Kennametal family of tungsten carbide alloys.

In highly specialized types of photographic equipment, for example, Kennametal optical flats substitute for fragile glass mirrors to overcome distortion due to centrifugal or other forces. Many other vital parts subject to abrasion or corrosion are now being made of Kennametal . . . such parts as high pressure compressor cylinder liners, seal rings for rotary pumps, valve parts, plungers, and bushings.

JUST HOW IS KENNAMETAL SUPERIOR?

- Kennametal has an extremely high YME . . . up to 94 million psi compared to steel's 30 million . . . ranges up to 94.7 Rockwell A.
- Some grades of Kennametal have a density as high as 15.5 gms/cc . . . twice that of heat treated steel . . . while other grades will stand up for days in boiling 5% HNO₃ and 5% H₂SO₄.
- Kentanium,* a series of hard titanium carbide alloys, retains sufficient strength for many applications at temperatures of 2200°F. and above.

Chances are some vital components for *your* equipment could be made of Kennametal to provide greater reliability, over a wide range of operating conditions, than that provided by conventional materials. A Kennametal Carbide Engineer will gladly discuss your problem with you. Or write us for one or both of these booklets: B-111A—"Characteristics of Kennametal," and B-444A—"Kentanium." KENNAMETAL INC., Dept. SA, Latrobe, Pennsylvania.

*Trademark †Trademark of Librascope, Inc.

INDUSTRY AND
KENNAMETAL
... Partners in Progress

50 AND 100 YEARS AGO



JUNE, 1909: "The *Zeppelin II*, the large dirigible balloon built by Count Ferdinand von Zeppelin, left its floating shed on Lake Constance late on Saturday night, May 29th, with the supposed object of sailing to Berlin. At Bitterfeld, 465 miles from its starting point, the Count decided to return, as he had lost some gas. At Goppingen a descent was made to replenish the supply of fuel. The motors had already stopped, and the airship was nearing the ground in an open field, when a gust of wind carried it against a tree with considerable force. The prow of the balloon was crushed in. Later dispatches report great skill, promptitude and spirit on the part of Count Zeppelin in making repairs, congratulatory telegrams from the German Emperor and—six weeks required to restore the balloon. It is a very great feat so to construct an immense gas bag so as to navigate it continuously for 36 hours, traversing 850 miles. Yet if such damage can be caused by a puff of wind the moment the controlling motors are stopped, we maintain that nothing lighter than air is going to give us the ultimate solution of the problem of mechanical flight, any more than we are limited to materials lighter than water for the navigation of the sea."

"The Council of the Röntgen Society has decided that the gamma-ray ionization from one milligram of pure radium shall be regarded as a standard, and called a unit of radioactivity. Three standards of radium bromide are to be prepared, and comparison will be made in the specimen of the purest radium bromide at the Victoria University in Manchester."

"Mr. Marconi denies the statement which has recently been made that wireless telegraph waves are injurious to operators, and that they produce various diseases such as conjunctivitis and corneal ulcers. To use his own words: 'During the 12 years or so of our operations we have had to deal with no single case

“No man can improve an original invention...”

—*William Blake*

THERE are many scientists today who would argue this point with Blake.

At Bell Telephone Laboratories, for example, we have seen original inventions improved and re-improved countless times, the better to serve mankind.

But William Blake went on to say “. . . nor can an original invention exist without execution organized, delineated and articulated.” Here Blake expressed ideas that apply with striking emphasis today. At Bell Laboratories organized effort is constantly aimed at fostering an environment in which inventions can exist and prosper, where they can be expressed either as ideas or in physical form, and where clear understanding of their principles can be achieved.

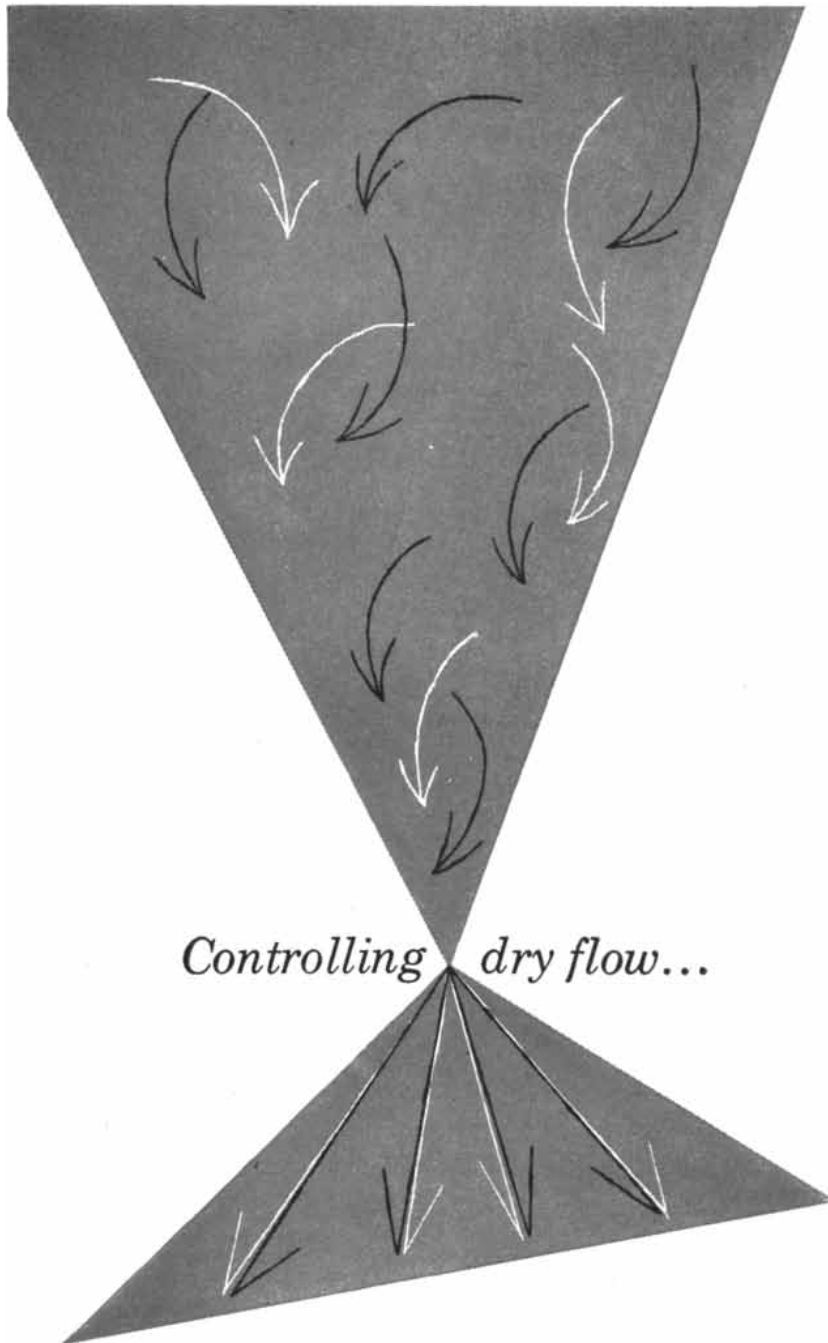
By helping scientists and engineers to reach for the things they seek, by organizing and coordinating their efforts, Bell Laboratories has made important contributions to the art of communications: proof of the wave nature of the electron, first research in radio astronomy, discovery of the transistor principle, invention of the feedback amplifier. Such ventures into the unknown have twice brought the Nobel Prize to Bell Laboratories scientists, and at the same time have helped create the most efficient and versatile telephone system ever known.



William Blake (1757-1827), a versatile genius, was famous for brilliant, sometimes prophetic, insights which he expressed with provocative beauty in drawing, painting, poetry and prose.

BELL TELEPHONE LABORATORIES
WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT





Controlling dry flow...

No two dry materials move exactly alike. Carbon black doesn't flow in the same way as cement; plastic resin fluidity is different than powdered metals'.

That's why a group at W&T specializes in dry fluid mechanics. And from this specialization comes the complete line of W&T metering and feeding equipment for any kind of dry flowing material.

If you have batch processes, W&T Feeders can control batching more accurately . . . possibly even help create continuous processing. Or perhaps you want to increase the efficiency of an existing continuous process through higher accuracy—wider range. Then, too, there's inventory and accounting. W&T Meters can measure and record the movement of dry materials into, through or out of your plant.

May we send you more information?
Just address Department M-46.83.



WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

of compensation for any injury of this origin.'"

"Wilbur and Orville Wright are extremely careful in making their experiments, and both have a great amount of patience. They always delve to the bottom of any problem they have to solve. As their only sister, Miss Katherine, so aptly puts it: 'To hear them argue around and knock the bottom out of each other's ideas till, at the end of three hours, you find Orv where Wil started off and Wil where Orv began, is just the killingest thing imaginable, and makes them both burst out laughing—but it saves them no end of useless experiment.'"

"When the great Cunard turbine boats *Lusitania* and *Mauretania* made their appearance, it was predicted that they would never be surpassed in size or speed. In speed they probably never will be surpassed, but in size they are destined to be greatly surpassed by the *Olympic*, which is now under construction at Belfast for the White Star Company. These truly enormous vessels (the sister ship will be named *Titanic*) will be 890 feet in length, 92 feet in beam and 64 feet in molded depth."

"Prince Henry, brother of the German Emperor, is the inventor of an automatic window washer. It is intended for the purpose of wiping off moisture from the glass wind-break of an automobile, so that the rider's vision may be clear at all times."



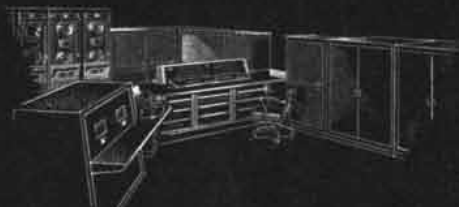
JUNE, 1859: "Alexander von Humboldt, the great philosopher, traveler and author, expired on June 6 in Berlin, Prussia, at the advanced age of 91 years. Von Humboldt received a high education in the University of Göttingen. His fame as a mineralogist was early established, and at 23 years of age he was appointed to the important government post of Superintendent of Mines in Franconia. He visited the New World under the patronage of the Spanish Government, and in 1799 commenced to explore the great valley of the Orinoco. During the five years he was a traveler in our hemisphere, he visited the sources of the Amazon, climbed the snow-capped peaks of the Andes, and under a burning sun traversed vast plains, pesti-

For men who
decide the future...
the world of
tomorrow is now

Forward-looking management finds Philco Transac S-2000
all-transistor data processing equipment the ultimate in accuracy and speed.
Conceived and perfected by the top technical skills in the industry,
Transac is first in completely transistorized data processing...insuring
incomparable quality and long, dependable service. If you decide
the future for your company...look to Philco to solve
your data processing problems...today.

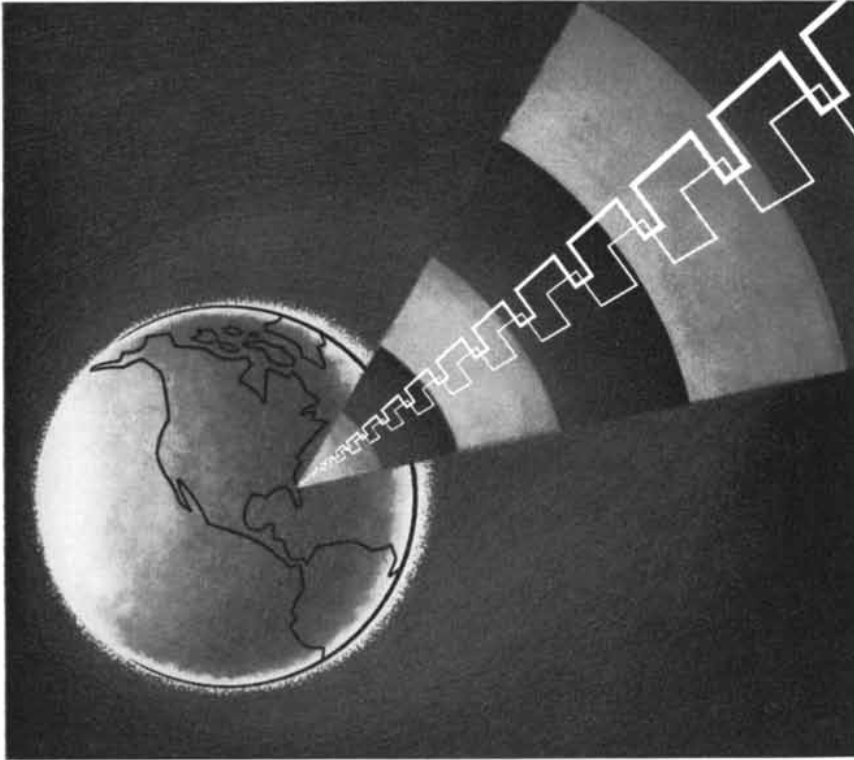


transac s-2000 by PHILCO
First in Transistorized Data Processing



GOVERNMENT AND INDUSTRIAL DIVISION • 4700 WISSAHICKON AVENUE, PHILADELPHIA 44, PENNSYLVANIA

SYLVANIA SYSTEMS... **IN COMMUNICATIONS**



Plasma, Ionization, Breakdown Effects, Deionization and Propagation studies are adding new strength to space communication systems.

Forging new electronic links to outer space

Sylvania Electronic Systems is now applying important new knowledge and experience to the formidable problems of space communications.

NEW TECHNIQUES have been developed as a result of depth studies in plasma energy transfer, electro-magnetic breakdown, and ionization and deionization phenomena. Greater understanding of these phenomena is producing vital links essential to stronger communication chains.

This applies equally whether information exchange is between satel-

lite and earth, control center and drone, or any air to air, ground to air, or ground to ground system; from ship or land, UHF or VHF, voice or data.

In space communications, as in every major area of communications and electronic systems, Sylvania can assume full responsibility for program management from system analysis to research and engineering, product design, and through production.

Sylvania welcomes the opportunity to outline its special talents and capabilities to you or your organization personally. Simply address your inquiry to the address below.

Sylvania Electronic Systems
A Division of Sylvania Electric Products Inc.
63 Second Ave., Waltham, Mass.



lential swamps, and barren deserts where the foot of white man had never trod before. His published accounts of these travels attracted the attention of the whole civilized world. They were printed in 17 large volumes, richly illustrated with figures of the subjects described. They embraced geography, zoology, botany, mineralogy, the natural history of animals, astronomy, geology, climatology, in short, every branch of science. So varied and profound were his attainments that it was at once felt that he stood out in bold relief as the most accomplished traveler that ever lived. For the past 50 years he has been the Nestor of science, and has gone down to the grave bearing the esteem of all men, and 'laden with wealth and honors nobly won.'"

"SCIENTIFIC AMERICAN is no new enterprise. Its character and influence have been acknowledged and felt for nearly 14 years past. It is the only journal of its kind in the U. S. which has met with success; since its commencement no less than 15 similar journals have been started, and have expired after a brief and unhealthy career. The publishers of SCIENTIFIC AMERICAN respectfully announce to their readers and the public generally, that, on the first day of July next (1859), their journal will be enlarged and otherwise greatly improved. Instead of eight pages in each number as now, there will be *sixteen*."

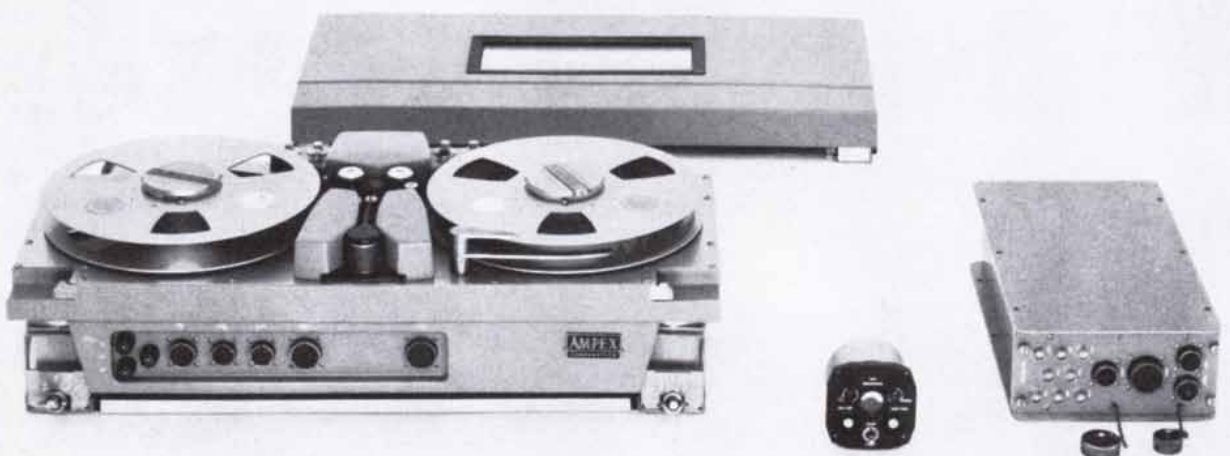
"There are now six lines of street railroads in New York City, which, taken all together are about 45 miles in length. They are great corporations in every sense of the term, for they carried during the past year no less than 27,057,000 passengers, and earned \$1,352,000. These roads employ about 2,000 horses and mules to draw the cars."

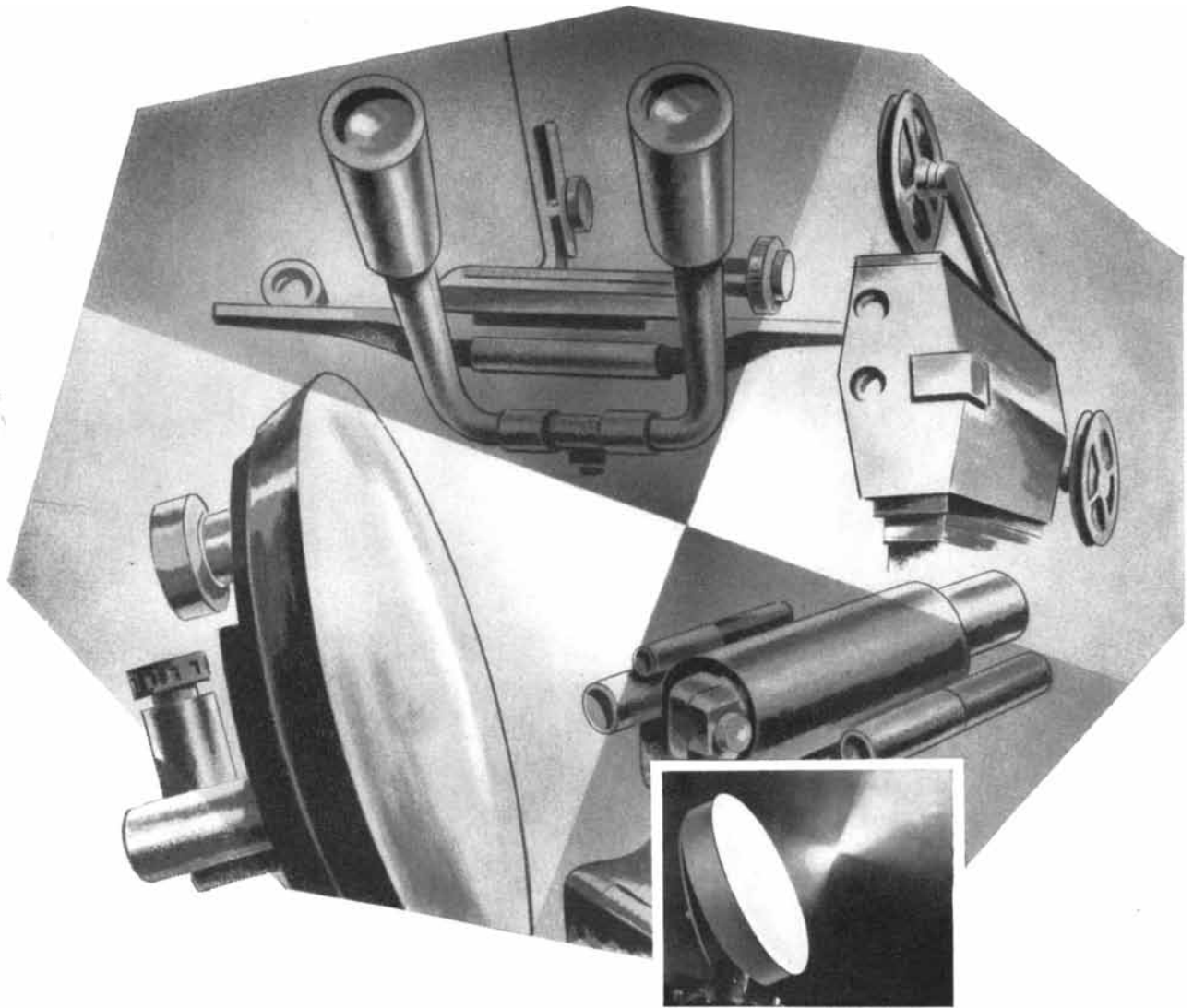
"The inventor of friction matches was John Walker, a chemist of Stockton, England, who died on May 5 at the advanced age of 79 years. He made the discovery nearly half a century ago while experimenting with various chemical substances, and for a number of years he realized a handsome income from the sale of matches at the price of about 36 cents a box."

"Ozone, according to Professor Faraday in a late lecture, is oxygen gas under electrical excitement. It can be formed by passing the electric spark directly through the gas or by making the electric current pass over the exterior of a tube containing oxygen."



A new mark in the sky... **AMPEX AR-200**
... an **all solid-state** airborne and mobile
magnetic tape recorder... for reliability
in extreme environments... less than 90 pounds
of rugged precision in only 1½ cubic feet
of space... all power supplies in transport...
complete 7-track system below operates
from aircraft 28-volt DC... 14-track analog or up
to 32-track digital systems also available.
Your further inquiry is invited.
AMPEX INSTRUMENTATION DIVISION,
934 Charter Street, Redwood City, California





Unbreakable Repli-Kote Mirrors out-perform glass, slash costs

These new lightweight, low distortion Repli-Kote Mirrors of cast epoxy resin offer design engineers optical reflectors with a matchless combination of properties, impossible with glass. A single master mirror is all that's necessary for mass producing precision Repli-Kote Mirrors—at significant cost savings.

Optical Precision — 6" — 5¼" Focal Length Repli-Kote paraboloid mirrors have been produced in quantity with an accuracy permitting 90% of incident collimated light to be concentrated within a disc of 0.1 mm diameter. Higher rate of thermal diffusion through epoxy also lowers distortion caused by temperature transients.

Permanent Reflective Surface — High

vacuum applied, silicon monoxide protected aluminum reflective surface is *permanently* bonded to epoxy backing, will resist flaking or peeling for extended periods.

High Mechanical and Thermal Shock Resistance — Repli-Kote Mirrors have withstood impacts as severe as 22,000 g, undergone rapid temperature cycling from -55°C to +125°C with no measurable physical change.

Light Weight—Repli-Kote Mirrors cast of epoxy are much lighter than glass. Suitable fillers can be added if desirable.

Any Shape—Paraboloids, hyperboloids, ellipsoids and more complex aspheric surfaces not previously reproducible in

glass by mass production methods can now be quickly fabricated.

Ease of Mounting—Fixtures, threaded inserts, electrical components can be molded directly into the mirror backing, opening an almost limitless field of design possibilities. Repli-Kote Mirrors are also easily machined.

If you are working on tracking and guidance systems—or any system employing reflective optics—durable, lightweight, precision Repli-Kote Mirrors offer you greater design and production freedom. Let us help you make the most of Repli-Kote Mirrors in building a better product at lower cost.

Address Inquiries to Repli-Kote, Singer-Bridgeport, 915 Pembroke Street, Bridgeport 8, Conn.



THE SINGER MANUFACTURING COMPANY

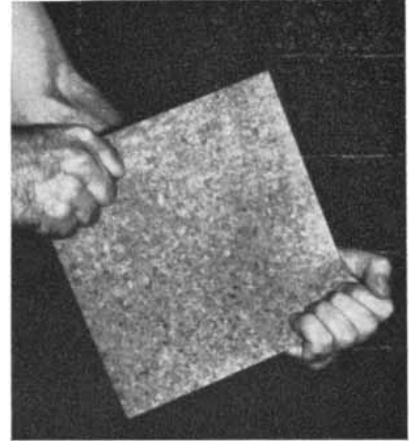
Military Products Division • 149 Broadway, New York 6, N. Y.

HRB • DIEHL • BRIDGEPORT

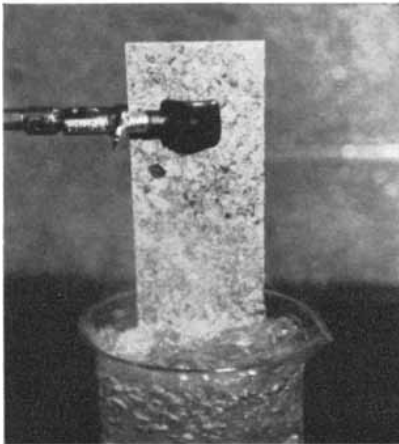
Look what happens when you add a pinch of permanence



1. WANT DURABILITY IN YOUR PRODUCT? Who doesn't! Here's how one manufacturer gets it. Floors take a beating—but *this* floor can stand the gaff for years. It's cork tile by Kentile, Inc. The permanence is *built in* with phenolic resins by Durez.



2. CORK GRANULES are locked together to stay. You can bond many materials this way—with Durez resins that soften under heat, then set hard.



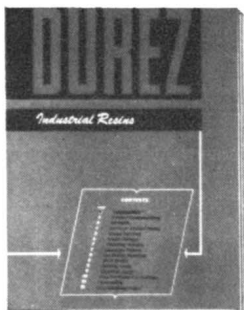
3. NOT EVEN BOILING WATER can weaken the good, strong bond Durez resins provide. These resins resist heat, moisture, abrasion—for keeps.



4. WHERE can you use them? Here are examples. Rubber, paper, sand, asbestos, ground wood—Durez resins bond them all into strong, useful products.



5. IT DOESN'T TAKE MUCH. Often, one part in ten gives you the properties you want. And phenolic is one of the cheapest bonding agents you can buy!



GET THIS IDEA-BOOK on how, where to use phenolic resins for more durable products. Tells how 12 different industries use Durez resins to add strength, hardness, heat and moisture resistance at low cost. Write today for your copy—free.

DUREZ PLASTICS DIVISION

HOOKER CHEMICAL CORPORATION

9406 WALCK ROAD, NORTH TONAWANDA, N.Y.





Little Boy Not Lost

A tragic accident took this little boy's parents when he was only five. Nothing will ever make up for their loss. But he is not alone.

His father had the ability and foresight to provide adequately and to plan wisely for all contingencies. Under the terms of his Will, the family property and investments will be managed in trust by experienced Trust Company executives. And, in the Trust Company, his young son has a dependable advisor who, in understanding cooperation with certain relatives, will guide and care for him until he becomes a man. Through occasional visits and meetings he will come to realize that First National City Trust is a friend he can *always* rely on.

So here he is with his banker pal, on a surprise Saturday afternoon at the Zoo, looking the big cats straight in the eye.

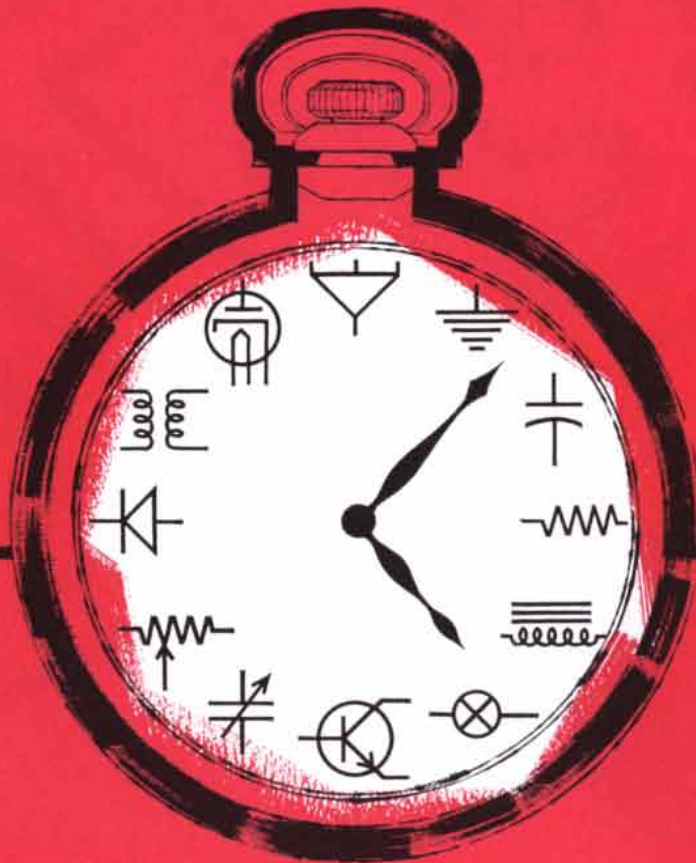
Our booklet, called "WHAT YOU SHOULD KNOW ABOUT PERSONAL TRUSTS" might be a good thing for you to look straight in the eye. A free copy is yours for the asking.

**FIRST
NATIONAL CITY TRUST
COMPANY**

Dept. M, 22 William Street, New York 5, N. Y.

Affiliate of
The FIRST NATIONAL CITY BANK of New York
MEMBERS FEDERAL DEPOSIT INSURANCE CORPORATION

Electronic Creativity is a timeless quest



- ✓ Original Conception
- ✓ Design
- ✓ Expedited Production

Melpar's deep reservoir of technological electrocraft is solving problems of almost incredible complexity—with the utmost scientific precision.

Electronic elements of the nation's space exploration and defense fall within our scope. This advanced equipment is created and produced for the U.S. government and its major prime contractors.



MELPAR INC

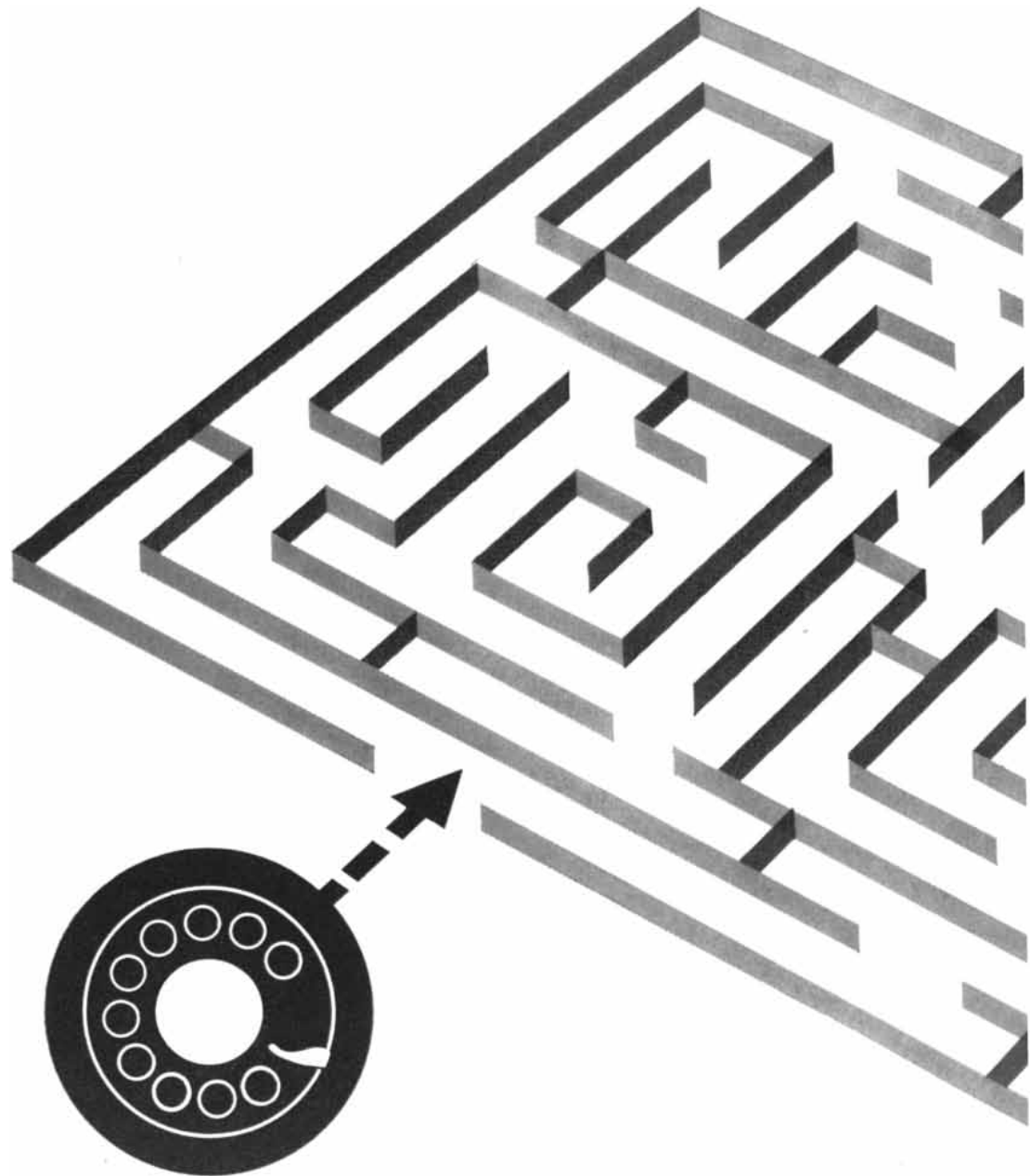
A SUBSIDIARY OF WESTINGHOUSE AIR BRAKE COMPANY

For details on provocative job openings in advanced scientific-engineering areas, write to: Professional Employment Supervisor

3607 Arlington Boulevard, Falls Church, Virginia

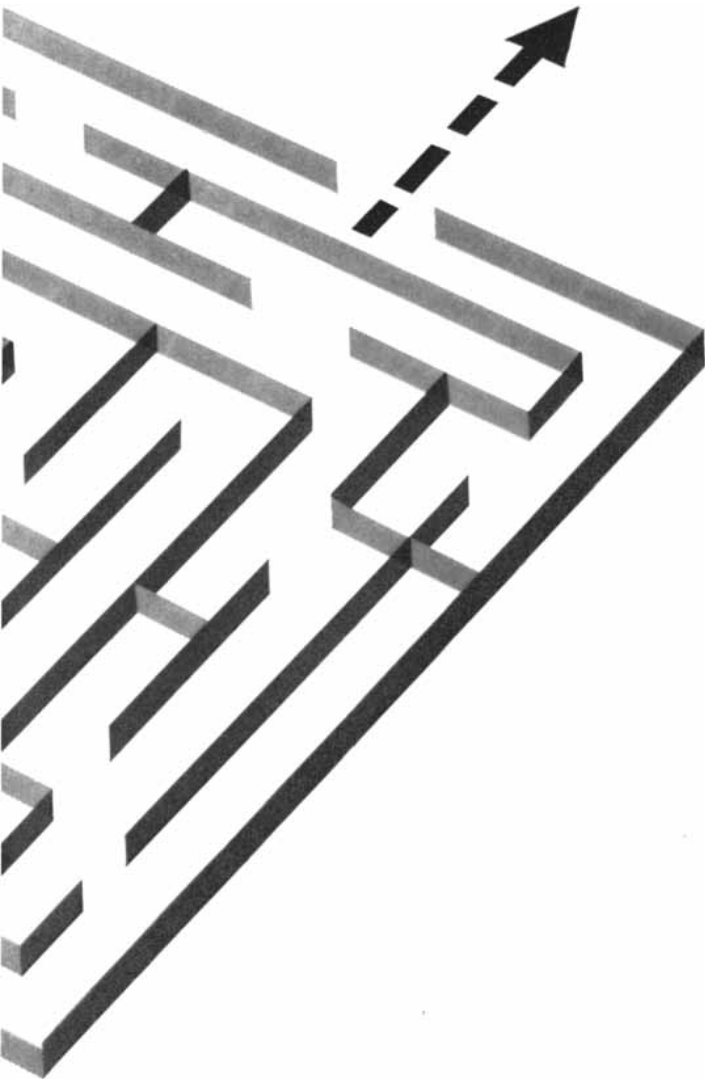
Automation cut its teeth on the

...how ITT's early work in telephony advanced



telephone

the art of automation



The dial telephone exchange was one of the first examples! Today, automatic switching and new electronic techniques for automation are altering the operations of virtually every business and industry.

It was natural that ITT System companies, pioneers in the first, should be leaders in the second.

Customers have ranged from mail-order houses, railroads, libraries and oil companies to the air forces of several NATO governments.

There have been dramatic results.

One example is the automatic check-processing system developed by ITT System companies for one of the nation's largest banks. It codes, sorts and verifies checks. It performs all normal bookkeeping and accounting operations for demand deposits.

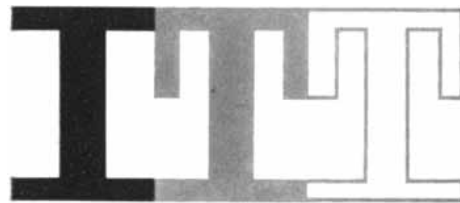
Another is the automation system for a large steel mill which records the program of requirements for every job, then feeds back information to production control centers as each phase is completed.

Still another: the first automatic U. S. post office, now under construction in Providence, Rhode Island.

Hundreds of others could be cited. Each required a complete understanding of automation from the design of a simple switch to the functioning of a fully-integrated electronic complex.

The ITT System has many specialists in this field. Among them: Intelex Systems Incorporated in retained-document automation; Kellogg Switchboard and Supply Company in automatic switching; Airmatic Systems Corporation in automatic-switch pneumatic tube and document-conveyor systems; ITT Federal Division in automatic test equipment, both military and industrial. ITT's European subsidiaries add to this experience.

To learn more about ITT's abilities in the area of automation, write for further information.



. . . the largest American-owned world-wide electronic and telecommunication enterprise, with 101 research and manufacturing units, 14 operating companies and 130,000 employees.

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION 67 Broad Street, New York 4, N. Y.

ITT COMPONENTS DIVISION • ITT FEDERAL DIVISION • ITT INDUSTRIAL PRODUCTS DIVISION • ITT LABORATORIES • INTELEX SYSTEMS INCORPORATED
AIRMATIC SYSTEMS CORPORATION • KELLOGG SWITCHBOARD AND SUPPLY COMPANY • ROYAL ELECTRIC CORPORATION • AMERICAN CABLE & RADIO
CORPORATION • FEDERAL ELECTRIC CORPORATION • ITT COMMUNICATION SYSTEMS, INC. • INTERNATIONAL ELECTRIC CORPORATION • INTERNATIONAL
STANDARD ELECTRIC CORPORATION • LABORATORIES AND MANUFACTURING PLANTS IN 20 FREE-WORLD COUNTRIES

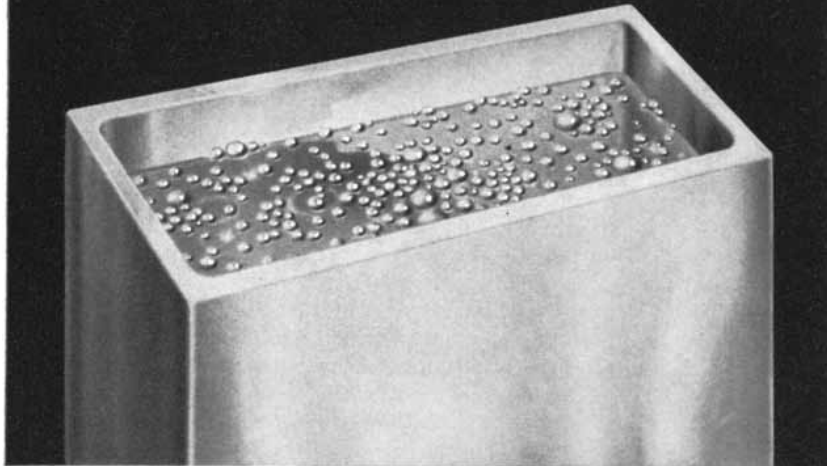
THE AUTHORS

HERBERT FRIEDMAN ("Rocket Astronomy") is superintendent of the Atmosphere and Astrophysics Division of the Naval Research Laboratory. He graduated from Brooklyn College and in 1940 received a doctoral degree in physics from Johns Hopkins University. After a year as a physics instructor at Johns Hopkins he joined the Naval Research Laboratory, where he became head of the Electron Optics Branch. For the past 10 years he has been engaged in research by means of rockets. At present his primary concern is the instrumentation of earth satellites.

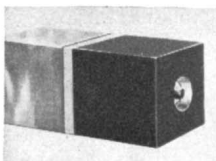
DEREK J. DE SOLLA PRICE ("An Ancient Greek Computer") is a fellow of the Institute for Advanced Study in Princeton, N. J., where he studies ancient astronomy and the history of scientific instruments. He acquired an interest in the latter subject while working as laboratory assistant in a British technical college. Price is a Londoner by birth and a graduate of the University of London, from which he received a Ph.D. degree for his World War II research in experimental physics. "After holding a Commonwealth Fund Fellowship in mathematical physics at Princeton University and a lectureship in mathematics at the University of Malaya in Singapore I returned to England in 1950," he says. "Out of chagrin at not being able to cover all parts of physics and mathematics at the research front, I contrived to deal with 'science in the large' in the humanistic tradition, and proceeded to a second Ph.D. (from the University of Cambridge) in the history of science." For his second doctoral dissertation Price edited a medieval English text on astronomy. This work drew considerable attention because of two claims made by Price: that the work was by Geoffrey Chaucer and that it was the only extant manuscript in Chaucer's own handwriting. Price returned to the U. S. two years ago to help plan the Smithsonian Institution's new National Museum of History and Technology.

HARRY F. HARLOW ("Love in Infant Monkeys") is George Cary Comstock Professor of Psychology and head of the Primate Laboratory at the University of Wisconsin. He received his A.B. from Stanford University in 1927 and his Ph.D. from the same institution in 1930, the year in which he joined the

ONLY ACOUSTICA ULTRASONIC CLEANERS HAVE MULTIPOWER!



MAJOR BREAKTHROUGH IN ULTRASONIC TECHNOLOGY!



In determining which ultrasonic cleaner to buy, remember that all ultrasonic cleaners are not alike. There is variation in uniformity of cavitation. There is variation in the transducer — and the transducer is the heart of an ultrasonic cleaner. The Multipower transducer developed by

Acoustica research, multiplies the power and efficiency of ultrasonic action. Cleaning is faster, labor costs are lower.

Acoustica ultrasonic cleaners are engineered and produced to the finest standards, unequalled in quality and value. Off-the-shelf in capacities from 1 to 75 gal. or custom built to 5000 gal. Expert Acoustica engineers can help you with your cleaning problems.

Send for further information.

NEW YORK
LOS ANGELES

acoustica

LEADER IN ULTRASONIC RESEARCH AND DEVELOPMENT

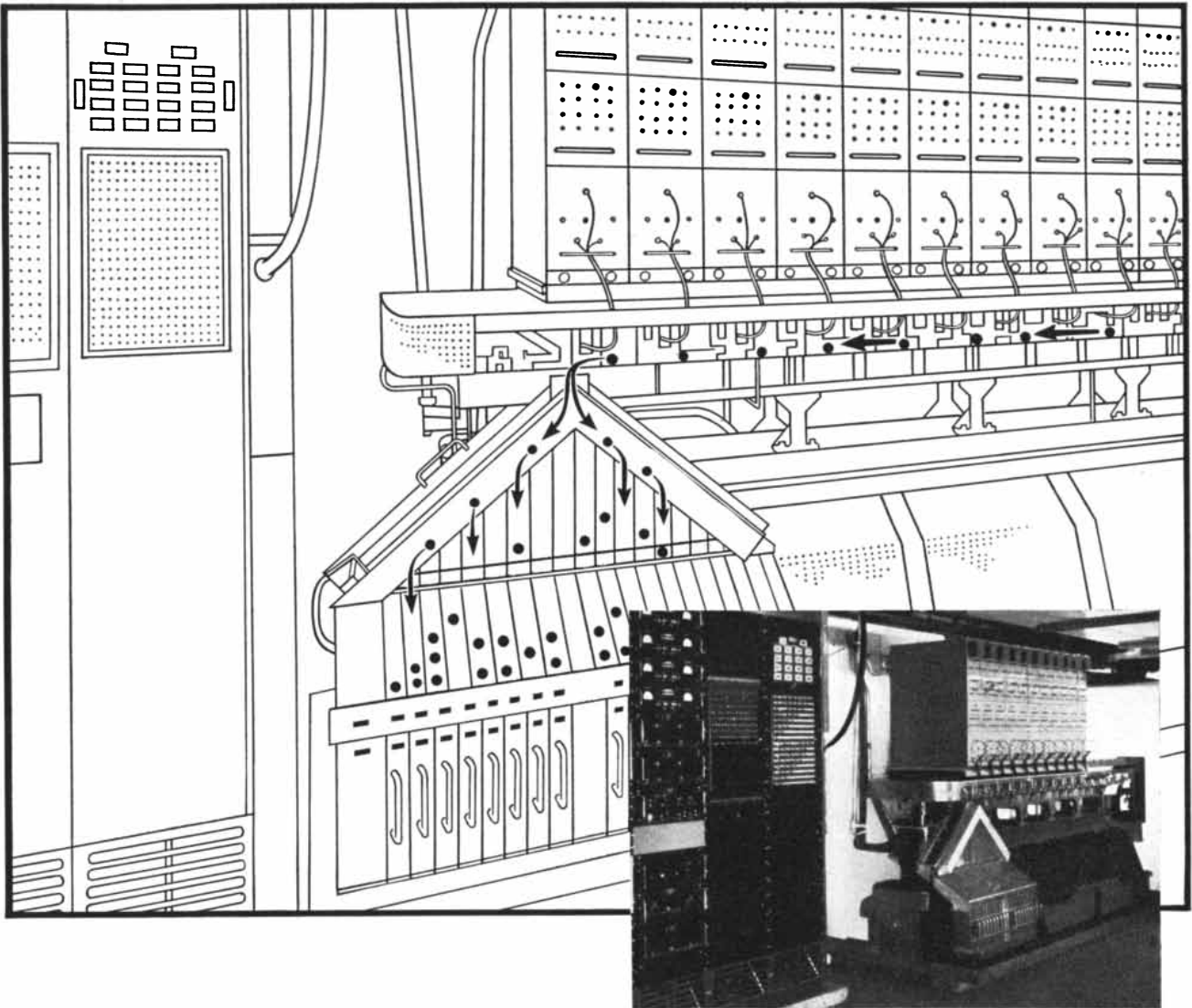
©1959 By Acoustica Associates, Inc.

Acoustica Associates, Inc.
Dept. SA, Fairchild Court, Plainview, N. Y.

Send information describing advantages of Acoustica ultrasonic cleaners:

Name _____
Company _____
Address _____
City _____ Zone _____ State _____

TECHNOLOGICAL LEADERSHIP IN SEMICONDUCTORS



How DATAC rates semiconductors

Now in operation at Sylvania's Semiconductor Division is DATAC, Digital Automatic Tester and Classifier. Designed and developed by engineers of the Division, it automatically subjects semiconductors to 16 separate tests and classifies them into as many as 256 different categories at a speed of 1500 per hour. DATAC rates each semiconductor on each test. It compares the final test results with predetermined standards and then places each unit in its proper category. Replaceable plug-in test modules enable Sylvania's DATAC to test for an almost infinite variety of electrical and mechanical characteristics and parameters.

For the circuit designer... DATAC means new uniformity and higher quality in semiconductors. It eliminates damage due to excessive handling and reduces human error to a minimum, assuring duplicate performance from unit to unit. Continuous operation has proved test accuracy within a tight 0.5 percent limit for all parameters. The end result is a new standard of excellence in semiconductor devices.

At Sylvania, technological achievements like DATAC are in progress every day. Always, the objective is to produce the best possible semiconductor at the lowest possible cost.

 **SYLVANIA**
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS



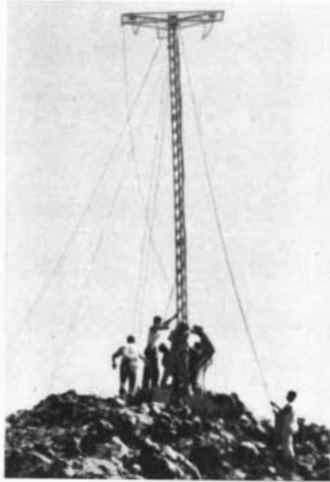
SYLVANIA ELECTRIC PRODUCTS INC.
Semiconductor Division
100 Sylvan Rd., Woburn, Mass.

WHO DO YOU HIRE

to do what's never been done before?

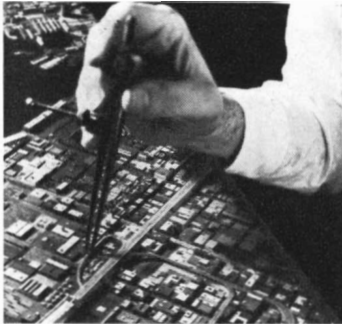
Could your research and development program move faster if you had expert aid in scaled simulators . . . photo interpretation . . . field tests of instrumentation? In evaluation of guidance and positioning systems? Or technical aid in the fields of geodesy, airborne geophysics, topographic mapping or related activities?

Aero Service Corporation is the largest company in the world engaged in this range of activities. Its many skills and 40 years' experience may greatly advance your special project. Two examples of Aero's work . . .



MAPPING A NATION

Problem: photograph and trilaterate an entire 500,000 sq. mi. nation. From rugged mountain tops accessible only by mule train or air drop, Aero crews provided a Shoran trilateration network. Air photos were made from 30,000 ft. in Shoran-guided B-17. Electronic data processing furnished positional control for whole area.



SCALED SIMULATORS

Problem: simulate a target area for photo intelligence studies. Aero constructed a model, exactly to scale, showing an industrial area with refining and factory complexes; rural areas; harbors and bridges; military installations. By photographing at various scales, different altitudes are simulated. Lighting simulates time and season. Similar mock-ups, precisely to scale, can be made of any military, industrial or other areas for briefing . . . intelligence studies . . . other uses.

Aero is ready to engage in assignments ranging from a pilot study to large-scale operations in remote areas. Our engineers will be glad to detail our capabilities. Or write for special facilities report.

AERO SERVICE CORPORATION, Philadelphia 20, Pa.

Oldest flying Corporation in the world



Wisconsin faculty. Harlow is currently president of the American Psychological Association.

ANTHONY H. ROSE ("Beer") is a lecturer in microbiology at Heriot-Watt College in Edinburgh, Scotland. He studied industrial fermentation at the University of Birmingham, from which he graduated in 1950. In 1954 he acquired a Birmingham Ph.D. in applied biochemistry and, in addition, one of the first King George VI Fellowships of the English-Speaking Union, which brought him to the Institute of Microbiology at Rutgers University. Later he was drafted into the Royal Air Force as an education officer and held a fellowship in fermentation in the National Research Council of Canada.

LIONEL S. PENROSE ("Self-Reproducing Machines") is Galton Professor of Eugenics at University College London. He pursued his undergraduate studies at St. John's College in the University of Cambridge, then studied medicine at St. Thomas's Hospital in London. In 1928 he became a member of the Royal College of Surgeons and a licentiate of the Royal College of Physicians (the licensing bodies for physicians for England and for London, respectively). Two years later he obtained at Cambridge the degree of M.D. (in British practice an advanced research degree). During the 1930s Penrose was research medical officer of the Royal Eastern Counties' Institution of Colchester. From 1939 to 1945 he directed psychiatric research for the Canadian province of Ontario.

ARTHUR UHLIR, JR. ("Junction-Diode Amplifiers") is director of semiconductor research and development at Microwave Associates, Inc. He studied chemical engineering at the Illinois Institute of Technology, where he was class valedictorian at his graduation in 1945. For several years he was an engineer in the employ of the Armour Research Foundation working on fluid mechanics and thermodynamics. He then studied physics at the University of Chicago under an Atomic Energy Commission predoctoral fellowship, acquiring his Ph.D. in 1952.

G. P. WELLS ("Worm Autobiographies") is professor of zoology at University College London. He is the elder son of H. G. Wells (G. P., H. G. and Sir Julian Huxley were the three co-authors of a well-known popular work on biology: *The Science of Life*). Wells gradu-



HUNTER-KILLER

T E A M T R A I N I N G

NTDC'S* ANTI-SUB TACTICS TRAINERS BY ERCO;

AD-5N, P5M-1, S2F-1, ZSG-4,

P2V-5, P2V-7... AND NOW THE S2F-3,
 PROVIDE INTEGRATED CREW TRAINING
 FOR THE MEN SAFEGUARDING OUR
 SHORE-LINES. THIS LATEST ERCO
 7-MAN TEAM TRAINER SIMULATES ALL
 ASPECTS OF ANTI-SUBMARINE

WARFARE FROM SEARCH, TO TRACK, TO KILL.

*NAVAL TRAINING DEVICE CENTER



ERCO TRAINING—TO FILL THE SUITS... TO MAN THE PLANE.

- Man-machine task analysis (instructor and crew) — maximum learning transfer.
- Automatic self-checking system—maximum utilization through minimum maintenance.
- Complete environmental realism.
- Completely activated tactical equipment.
- Largest magnitude simulator for team training.

ERCO

NUCLEAR PRODUCTS—ERCO, DIVISION OF
 QCF INDUSTRIES, INC., RIVERDALE, MARYLAND

AMERICAN CAR AND FOUNDRY



AVION



CARTER CARBURETOR



SHIPPERS CAR LINE



W-K-M





MISSILE DESIGN WITH HITCO IN MIND

HITCO is one of the world's leading developers and manufacturers of ultra-performance thermal materials capable of resisting extremely high temperatures, even up to 15,000°F. for short duration! Call or write us for Capabilities Brochure and complete Technical Data.



- REFÉRASIL Materials
- HITCO Metal Blankets
- THERMO-COUSTI Materials
- THOMPSONSoglas Materials
- ASTROLITE Reinforced Plastics
- HITCORE Structural Core Materials

H. I. THOMPSON FIBER GLASS CO.

1733 Cordova Street • Los Angeles 7, Calif. • REpublic 3-9161

WRITE FOR INFORMATION • WRITE FOR INFORMATION



check, clip and mail to:
W. & L. E. GURLEY
562 Fulton Street
Troy, N. Y.

PRODUCTS and SERVICES

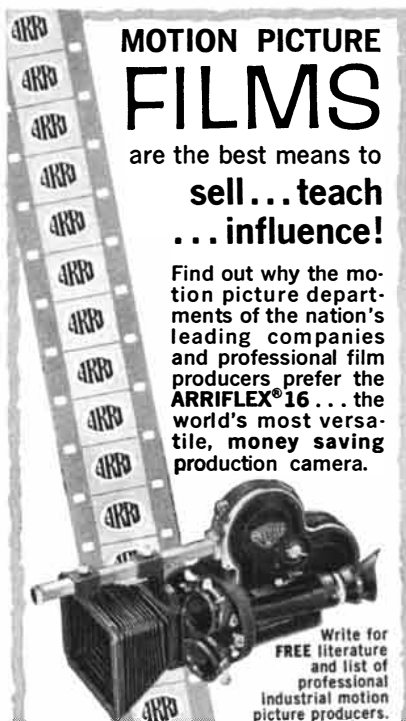
- CUSTOM SERVICES**
Reticles for Optical and Photoelectric Instruments • Precise Photography • Precision Patterns on Glass & Metal • Electroforming and Electroetching • Circular, Linear and Cylindrical Dividing
- PHOTOELECTRIC DEVICES**
Shaft Position Encoder • Pulse Generators Readout Devices for Angular and Linear Position
- OPTICAL INSTRUMENTS**
Optical Coincidence Reading Systems • Collimators • Special Optical Instruments
- SURVEYING INSTRUMENTS**
Transits • Theodolites • Levels • Alidades Rods • Plane Tables • Field Equipment
- HYDROLOGICAL INSTRUMENTS**
Current Meters • Water Level Recorders Hook Gages
- METEOROLOGICAL INSTRUMENTS**
Wind Direction and Velocity • Pilot Balloon Theodolites
- TESTING INSTRUMENTS**
Smoothness, Stiffness, Porosity, Sizing Testers for Paper & Textiles
- SCIENTIFIC INSTRUMENTS**
Standards of Mass, Length and Volume

WRITE FOR INFORMATION • WRITE FOR INFORMATION

MOTION PICTURE FILMS

are the best means to
sell... teach
... influence!

Find out why the motion picture departments of the nation's leading companies and professional film producers prefer the **ARRIFLEX® 16**... the world's most versatile, money saving production camera.



Write for
FREE literature
and list of
professional
industrial motion
picture producers.

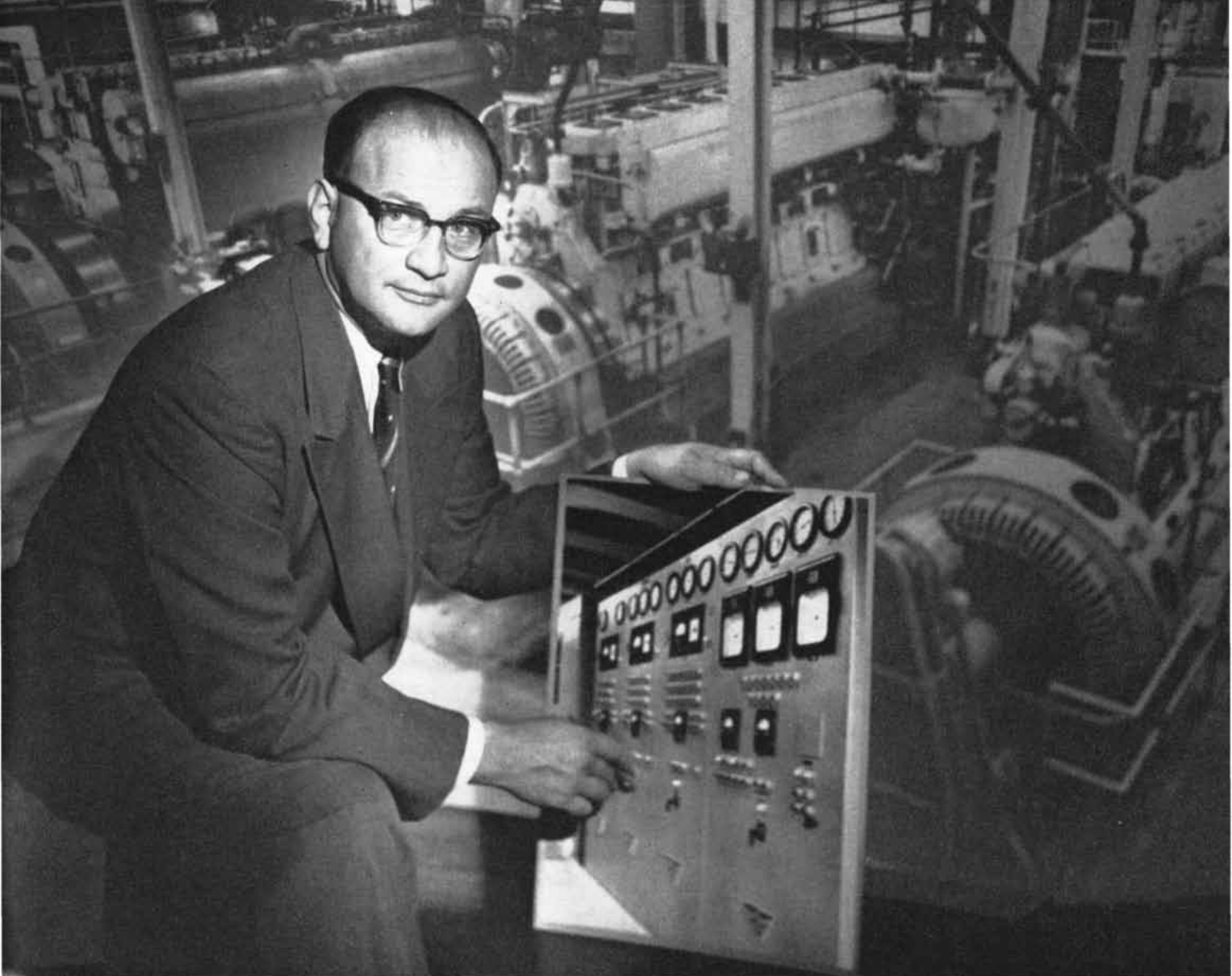
ARRIFLEX division of
KLING PHOTO CORPORATION
2575 Fourth Ave., New York 10, N. Y.

name _____
address _____
city _____ zone _____ state _____

ated from the University of Cambridge, then spent a year at Harvard University and another year at the Marine Biological Laboratory in Plymouth, England, before his appointment as a lecturer at University College London in 1931.

MEYER FORTES ("Primitive Kinship") is currently in residence at the Center for Advanced Study in the Behavioral Sciences in Palo Alto, Calif. He is on leave of absence from the University of Cambridge, where he is William Wyse Professor of Social Anthropology and a fellow of King's College. Fortes received his undergraduate training at the University of Capetown in his native South Africa, where, he says, "It was almost inevitable that I should become concerned with the race question." As a student of race psychology at the London School of Economics and University College London, he attempted for three years to design a nonverbal cross-cultural intelligence test. The techniques he worked out have since been developed into the widely used Progressive Matrices Test. Fortes, however, ceased to believe in the possibility of a truly culture-free assessment of intelligence. As a sideline he had worked in a London child-guidance clinic, and he observes: "I could not help discovering that economic and other social disabilities produced some kinds of personality disability and some degree of intellectual retardation." To sharpen his understanding of these social factors, Fortes abandoned laboratory psychology for a year's study of juvenile delinquency in London's East End. At the same time he came under the influence of two psychoanalytically oriented anthropologists: C. G. Seligman and Bronislaw Malinowski. For 18 months he studied anthropology at the University of London under Seligman and Malinowski. Then he went to the Gold Coast (now Ghana), where for most of four years he lived with the Tallensi tribe, studying their patterns of family life. In 1939 he was appointed lecturer at the University of Oxford, where he studied family and kinship with the leading authority on these subjects, A. R. Radcliffe-Brown. Later, while on wartime service in the Gold Coast, Fortes studied an important matrilineal tribe, the Ashanti.

I. BERNARD COHEN, who reviews Arthur Koestler's *The Sleepwalkers* in this issue, is associate professor of the history of science and of general education at Harvard University. He has contributed a number of articles to this magazine.



Frank L. Friedli, *Manager En-Tronics Sales, The Cooper-Bessemer Corporation, reports on...*

How automation pays off at Nantucket

Nantucket Gas and Electric Company had a costly power plant problem caused by Nantucket's population variation from a normal 3500 to a summertime 15,000. Now, everything is under control with a *fully automatic* Cooper-Bessemer En-Tronics system.

Peak load on this resort island requires three Cooper-Bessemer engines driving generators totaling 2950 kw capacity. The background photo shows this installation.

The En-Tronics control system, shown in the other photo, makes possible unattended operation. It starts engines, puts them on the line when the load builds up, takes them off when not needed, maintains correct frequency at all times, and increases plant efficiency over manual control. It also improves plant reliability, sensing irregularities and taking corrective action quickly.

Mr. C. G. Snow, Vice President of the Nantucket utility says, "It is expected that cost of the En-Tronics installation will be paid off rapidly from savings."

Find out how this new automatic control can be applied to *your* advantage. Write for free copy of new Bulletin E-88.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester
Chicago • Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans
Shreveport • Houston • Greggton • Dallas • Odessa • Pampa • Casper
Seattle • San Francisco • Los Angeles

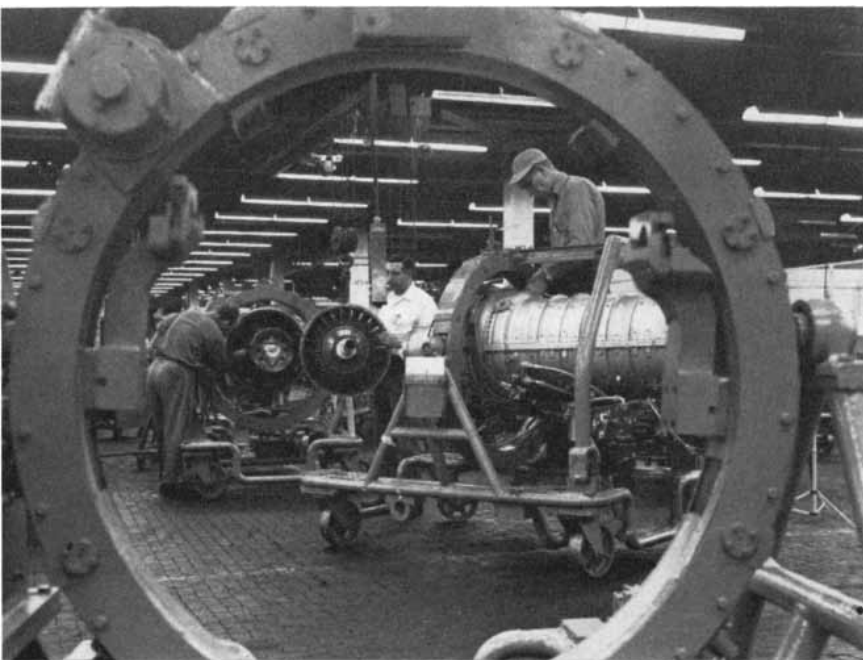
SUBSIDIARIES: Cooper-Bessemer of Canada, Ltd. . . . Edmonton
Calgary • Toronto • Halifax
C-B Southern, Inc. . . . Houston
Cooper-Bessemer International Corporation . . . New York • Caracas
Mexico City
Cooper-Bessemer, S.A. . . . Chur, Switzerland • The Hague, Netherlands

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS - DIESEL - GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL
ENGINE OR MOTOR DRIVEN

Why Westinghouse designs advanced propulsion systems more rapidly, meets all requirements on time



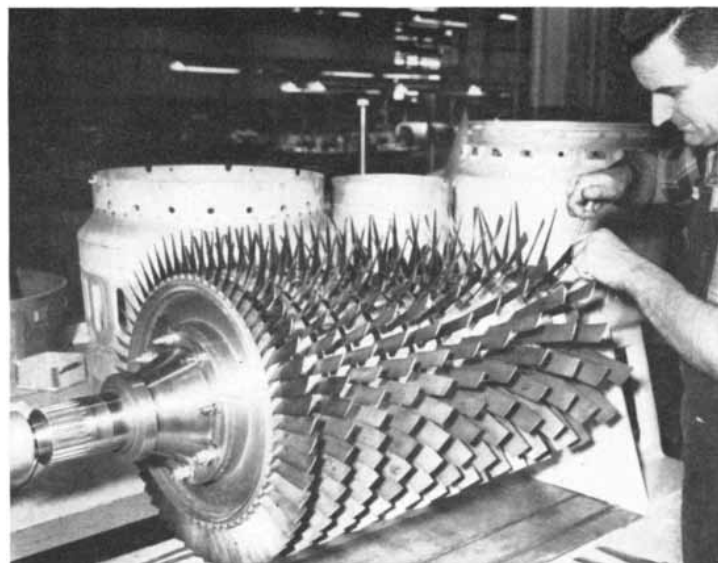
PRODUCTION POTENTIAL. The Aviation Gas Turbine Division at Kansas City has built more than 6,000 engines and associated spare parts. Engineering and Production experience with conventional gas turbine propulsion systems continues to be characterized by high-quality, on-schedule performance.



AUTOMATIC PRODUCTION TESTING, developed by Westinghouse, improves and speeds final pre-shipment testing. Test cell controls put engine through required tests automatically and record test results on the form prescribed for the engine log book.



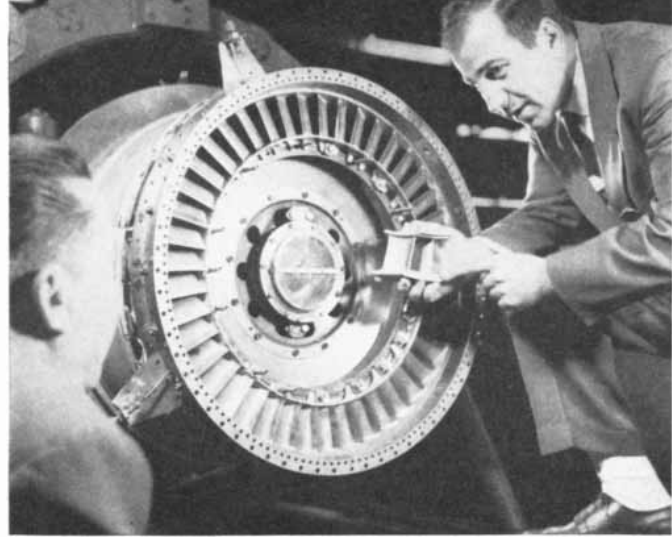
FLIGHT TEST OPERATIONS. Following thorough component testing under simulated operating conditions in the Low and High Power Laboratories, Westinghouse engineers at the AGT Division's Flight Test Center at NAS Olathe, Kansas, test all propulsion systems under actual flight conditions.



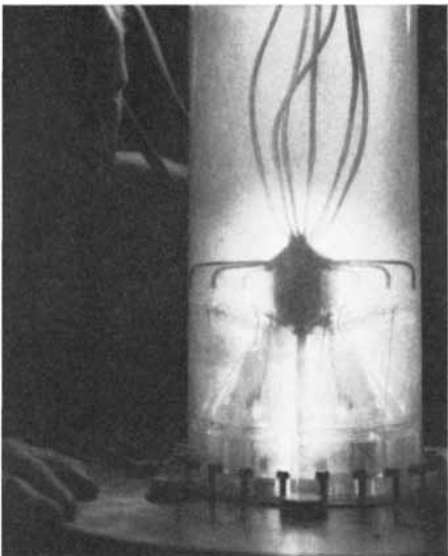
EXPERIMENTAL DEPARTMENT. This specialized factory-within-a-factory converts ideas into working prototypes. Independent engineering, tool design, progress and material control, permit self-sufficiency. Above, blades of a test cell bound compressor rotor are checked for proper balance.



ROLLS-ROYCE INFORMATION INTERCHANGE. A Rolls-Royce representative, resident at the AGT Division, here discusses new design concept with Westinghouse technical management. The Rolls-Royce-Westinghouse ten-year agreement permits faster jet engine design and production cycles.



AIR-COOLED TURBINE NOZZLES permit more efficient operations at higher temperatures. Design permits air to enter through wide slots on one side, pass through interior, and leave through smaller slots along blade's trailing edge. This cools the vane and lets turbine operate at higher temperatures.



NEW FUEL INJECTOR DESIGN—fashioned from inexpensive plastic—is tested with colored water and air bubble mixture in this flow analogy test rig to predetermine its performance characteristics. Test minimizes time-consuming and costly testing previously required with expensive handmade metal prototypes.



VIBRATION AND STRESS ANALYSIS data are obtained in hours instead of days with this special Westinghouse-developed Strain Gage Analyzer. From signals recorded on 14 channel magnetic tape, the analyzer plots multiple continuous curves visualizing vibration frequency and strain at varying engine speeds.



LINE-FLOW PRODUCTION. The 85-acre Kansas City plant of AGT is well adapted to line-flow production techniques. This system permits smoother and more efficient engine production . . . a characteristic of quality performance.

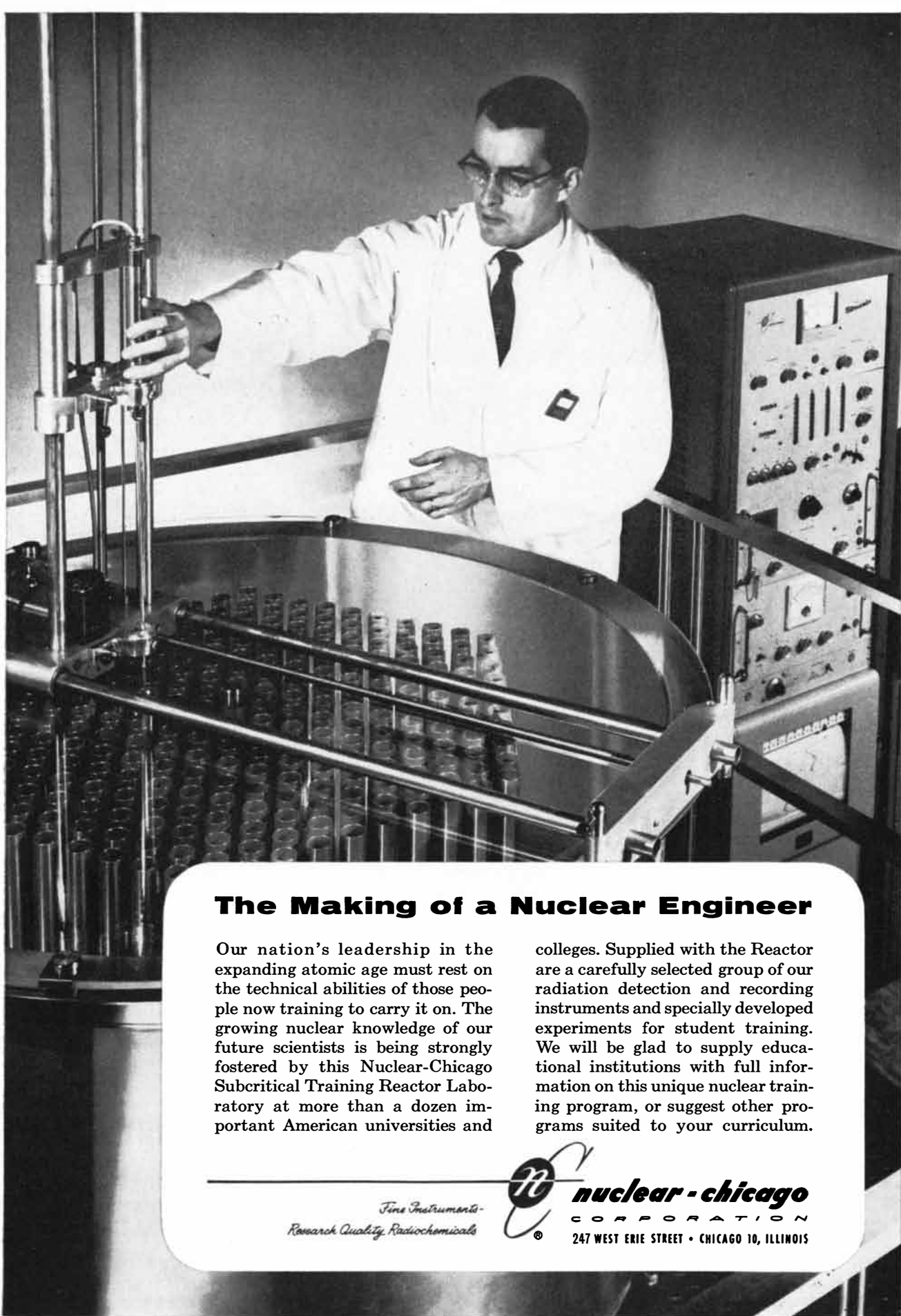
Westinghouse

DEFENSE PRODUCTS

1000 CONNECTICUT AVENUE, N. W., WASHINGTON 6, D. C.

AIR ARM DIVISION
 AVIATION GAS TURBINE DIVISION
 ELECTRONICS DIVISION
 AIRCRAFT EQUIPMENT DEPARTMENT
 ORDNANCE DEPARTMENT

YOU CAN BE SURE... IF IT'S Westinghouse



The Making of a Nuclear Engineer

Our nation's leadership in the expanding atomic age must rest on the technical abilities of those people now training to carry it on. The growing nuclear knowledge of our future scientists is being strongly fostered by this Nuclear-Chicago Subcritical Training Reactor Laboratory at more than a dozen important American universities and

colleges. Supplied with the Reactor are a carefully selected group of our radiation detection and recording instruments and specially developed experiments for student training. We will be glad to supply educational institutions with full information on this unique nuclear training program, or suggest other programs suited to your curriculum.

*Fine Instruments -
Research Quality Radiochemicals*



nuclear - chicago

CORPORATION

247 WEST ERIE STREET • CHICAGO 10, ILLINOIS

It's legibility
at first sight

...with **BUTYRATE**



There's no mistaking the message of the Edco Tel-A-Flasher sign... and the panels, vacuum formed from sheet of Tenite Butyrate plastic, play a big part in getting that message across—immediately.

Because of Butyrate's brilliant luster, these panels present an eye-catching, eye-pleasing appearance in daytime; and when the sign is internally lighted at night, the sharp contrast of colorful letters with white background gives long-distance legibility.

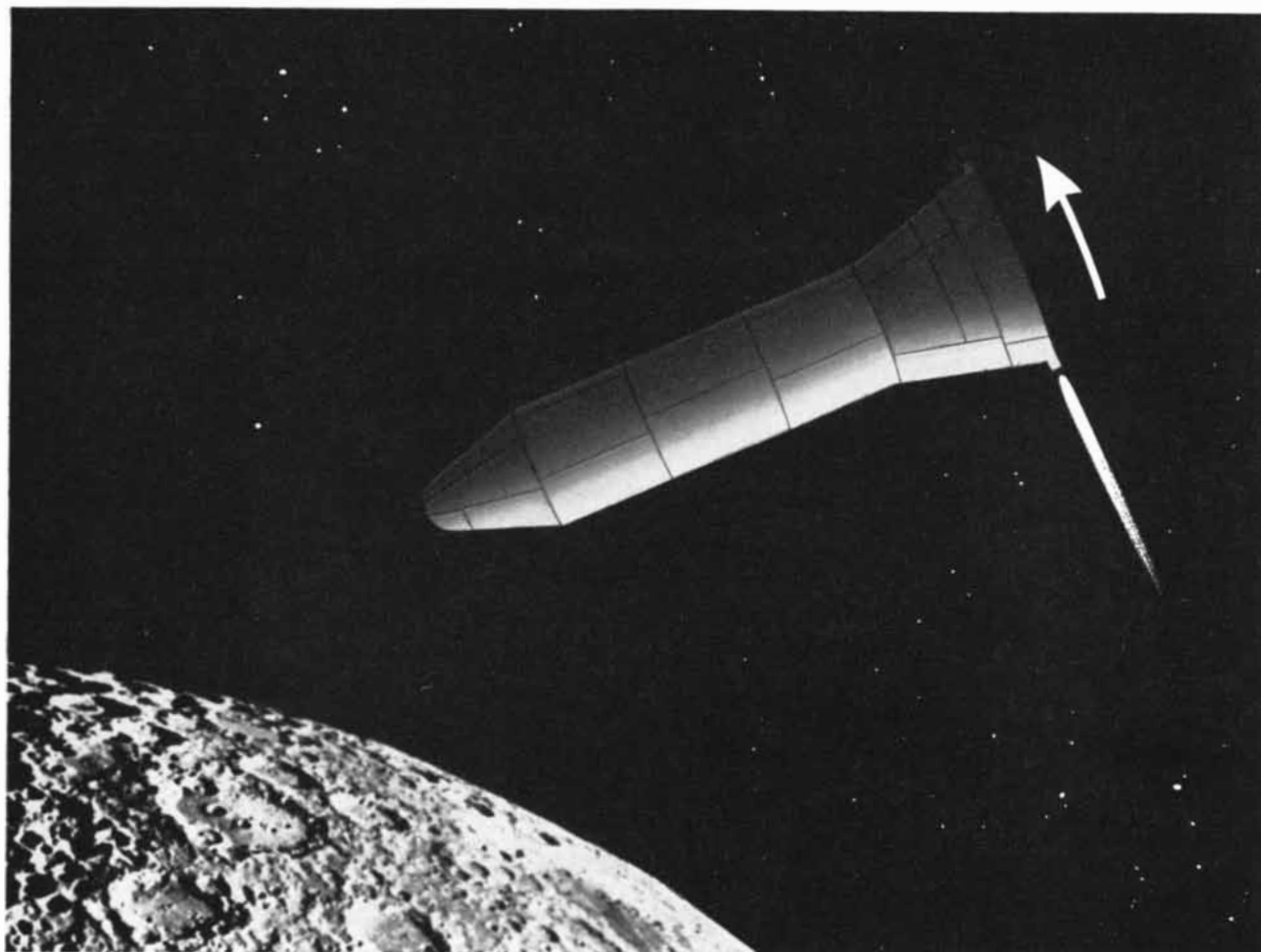
The low specific heat of Tenite Butyrate makes it an ideal material for sheet thermoforming. With Butyrate there is no need for special preheating oven equipment. Vacuum, air pressure, and mechanical methods are used with inexpensive molds on fast-cycle machines. Available in special weather-resistant formulations and popular sign colors, sheet of Butyrate can also be decorated with lacquers before or after forming.

The outdoor sign industry is but one of many to take advantage of the design and production flexibility of Tenite Butyrate. In addition to its possibilities in sheet forming, this tough thermoplastic material can be rapidly injection molded or continuously extruded to serve a wide range of uses—from steering wheels to skin packaging; from tool handles to telephone housings.

When your product needs call for a material that has superior impact and weather resistance, yet is light in weight, lustrous, easy and economical to form or fabricate—consider Tenite Butyrate. For additional information concerning its physical properties and uses, write to EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

TENITE
BUTYRATE
an Eastman plastic

EDCO Tel-A-Flasher signs consist of individual letter panels which can be rotated within their frames to any desired angle. Panels are 15"-diameter or 20"-diameter discs of Tenite Butyrate plastic with raised letters (11" or 15" respectively) vacuum formed into their surface. Manufactured and marketed by Electrical Development Company, 719 E. Madison, P. O. Box 3472, Phoenix, Arizona. Butyrate sheet extruded by Jet Specialties Co., Inc., Los Angeles 63, California.



HOW TO MAKE A "LEFT TURN" IN OUTER SPACE

Bendix®, which makes controls for almost everything that rolls, flies or floats, has developed a practical, precision method for steering and controlling the attitude of space vehicles.

It was a tremendous feat to place a satellite in orbit. But when out in space there was no means for changing its direction. Nor was there any provision to keep it in a desired attitude or to prevent it from tumbling over and over. To put a man on the moon it will be necessary to steer the space ship to a selected lunar location, to prevent it from tumbling crazily, and to land it right side up.

The Bendix devices which represent a major step toward the ultimate control of man-made objects in space are a series of gas reaction controllers

(actually miniature rockets). A number of these are mounted around the satellite. Individually controlled by a built-in intelligence system within the satellite, they emit metered jets of gas on signal whenever it is necessary to change the position of the satellite. Since there is no air resistance in space, a small amount of thrust from the tiny rocket is enough to do the job.

This is but one of the space contracts which we have secured. Others include the development of control rod drive mechanisms for an AEC nuclear-powered rocket and mass spectrometers which can make thousands of analyses per second of the upper atmosphere in which rockets or satellites are traveling. In addition,

we are making nuclear radiation investigations to definitely determine how various products and materials stand up under varying degrees of radiation—knowledge important to the operation of nuclear power plants for aircraft and space vehicles.

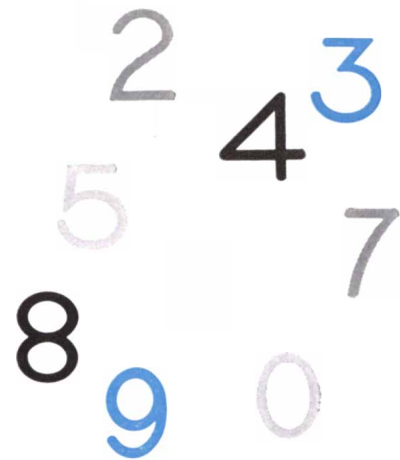
So that missiles and space vehicles may report their in-flight progress we build telemetering systems which transmit back to earth as many as 500 channels of information.

Because both space and missile projects have much in common, it is important to mention that in addition to building the Talos missile for the Navy we are also responsible for developing the Navy's newest missile, the "Eagle." We also furnish major systems for missiles of all types.

A thousand products



a million ideas



Presenting **hp** 524D Electronic Counter

New 8-decade numerical readout! **New $5/10^8$ per week stability!**

SPECIFICATIONS

(Basic 524D without plug-ins)

Frequency:

Range: 10 cps to 10.1 MC
Gate Time: 0.001, 0.01, 0.1, 1, 10 secs or manual
Accuracy: ± 1 count $\pm 0.000005\%$
Reads in: KC. Automatic decimal

Period:

Range: 0 cps to 10 KC
Gate Time: 1 or 10 cycles of unknown
Accuracy: $\pm 0.3\%$ (1 period)
 $\pm 0.03\%$ (10 period average)
Stan. Freq. Counted: 10 cps, 1 KC, 100 KC, or 10 MC, or external
Reads in: Secs, msec, μ sec

General:

Registration: 8 places (99,999,999 max.)
Stability: 5/100,000,000. May be standardized with WWV or external 100 KC or 1 MC primary standard.
Display Time: Variable 0.1 to 10 secs; or "Hold"
Input Voltage: 1 v min, 1.5 v peak. Rise time 0.2 seconds max.
Input Impedance: Approx. 1 megohm; 40 μ f shunt.
Price: \$2,150.00 f.o.b. factory.
Data subject to change without notice

plus all these frequency and time measuring advantages!

- Direct, instantaneous, automatic readings**
- Frequency coverage 10 cps to 220 MC***
- Time interval 1 μ sec to 100 days**
- Resolution 0.1 μ sec**
- High sensitivity, high impedance**
- No calculation or interpolation**

New convenience of uniform 8-decade numerical readout without meters — new 5 parts in 10^8 stability simplifying standards and other microwave measurements — this is the capsule story of the new *hp*- 524D Electronic Counter.

Electrically similar to the widely used *hp*- 524B Counter, the new 524D provides for full frequency measurements from 10 cps to 10 MC and period measurements from 0 cps to 10 MC. Low cost plug-in units extend frequency measuring range to 220 MC, permit period measurements of over 10,000 periods, and increase sensitivity for precise measurement of weak signals. Still another plug-in provides for time measurements from 1 μ sec to 100 days with 0.1 μ sec resolution. When used with *hp*- 540A Transfer Oscillator, the 524D will measure accurately to 12 KMC. For complete details, write or call your *hp*- representative; or write direct.

HEWLETT-PACKARD COMPANY

50225 PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
 CABLE "HEWPACK" • DAVENPORT 5-4451

*with plug-ins

FIELD REPRESENTATIVES IN ALL PRINCIPAL AREAS



world's most complete line of electronic counters

Rocket Astronomy

Rockets which briefly soar above the greater part of the earth's atmosphere, where short wavelengths such as the ultraviolet are filtered out, have gathered new information about the universe

by Herbert Friedman

W e perceive only a few octaves of the radiance of the cosmos when we look out through the sky. The sun and the other stars, the great clouds of interstellar dust and gas and the moon and the planets together flood the universe with radiant energy on all wavelengths of the electromagnetic spectrum, from the shortest gamma rays out to the longest radio waves. On earth, however, all we can see is the radiation admitted through two "windows" in our atmosphere: one open to visible light; the other, to the band of radio waves from one centimeter out to 40 meters. The atmosphere absorbs or reflects back into space all other wavelengths. No radiation of wavelength shorter than 2,850 angstrom units reaches the ground; the harsh ultraviolet rays, X-rays and gamma rays are absorbed by interaction with the atoms and atomic particles in the thin upper reaches of the atmosphere, at 16 miles and above. Life could of course not exist without this shelter; if such energetic radiations could penetrate the atmosphere, they would prevent the formation of the large molecules of living matter. But these same radiations bear so much information about the processes of the universe that astronomers have dreamed of the day when they could set up their instruments in outer space.

That day is now at hand. During the past 10 years rockets have been giving us our first glimpses of how the universe looks at wavelengths shorter than those

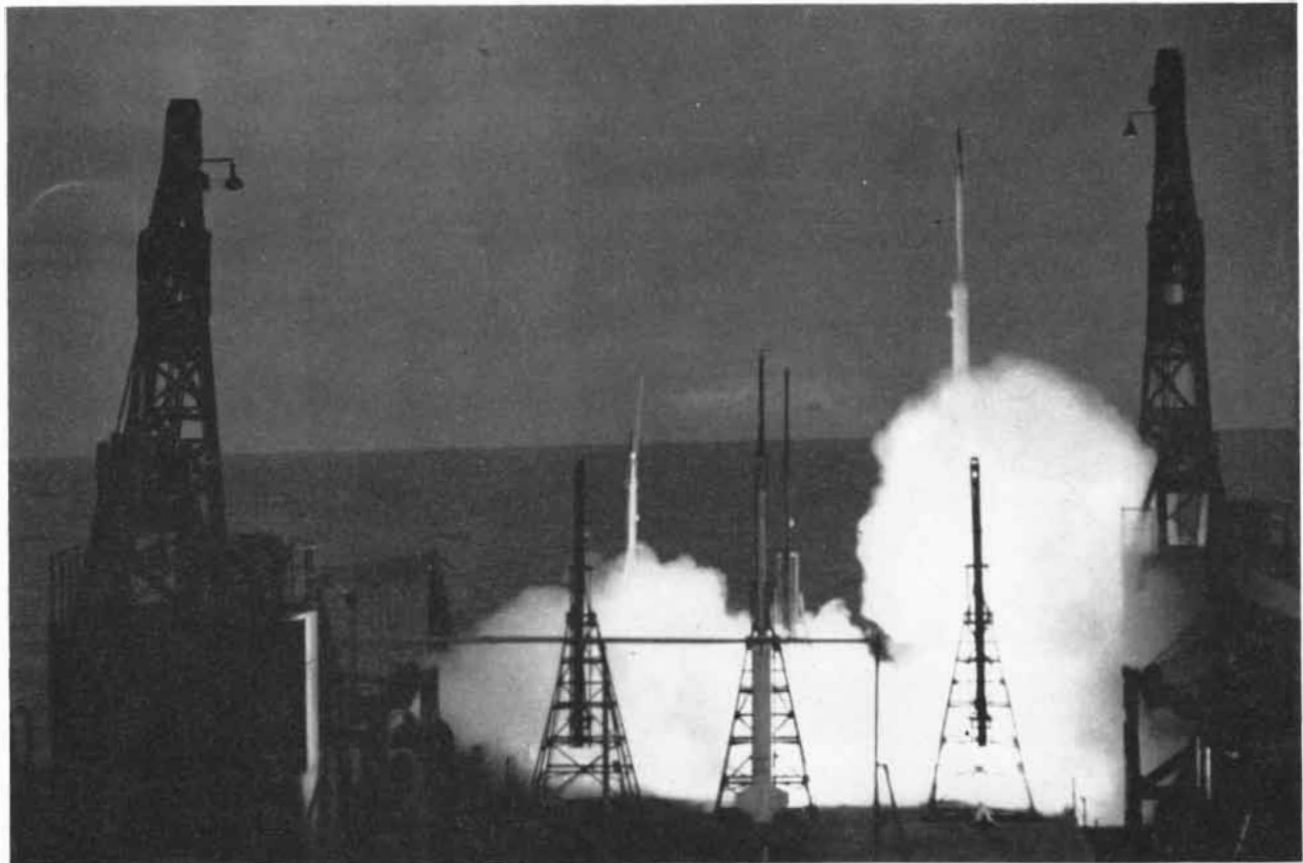
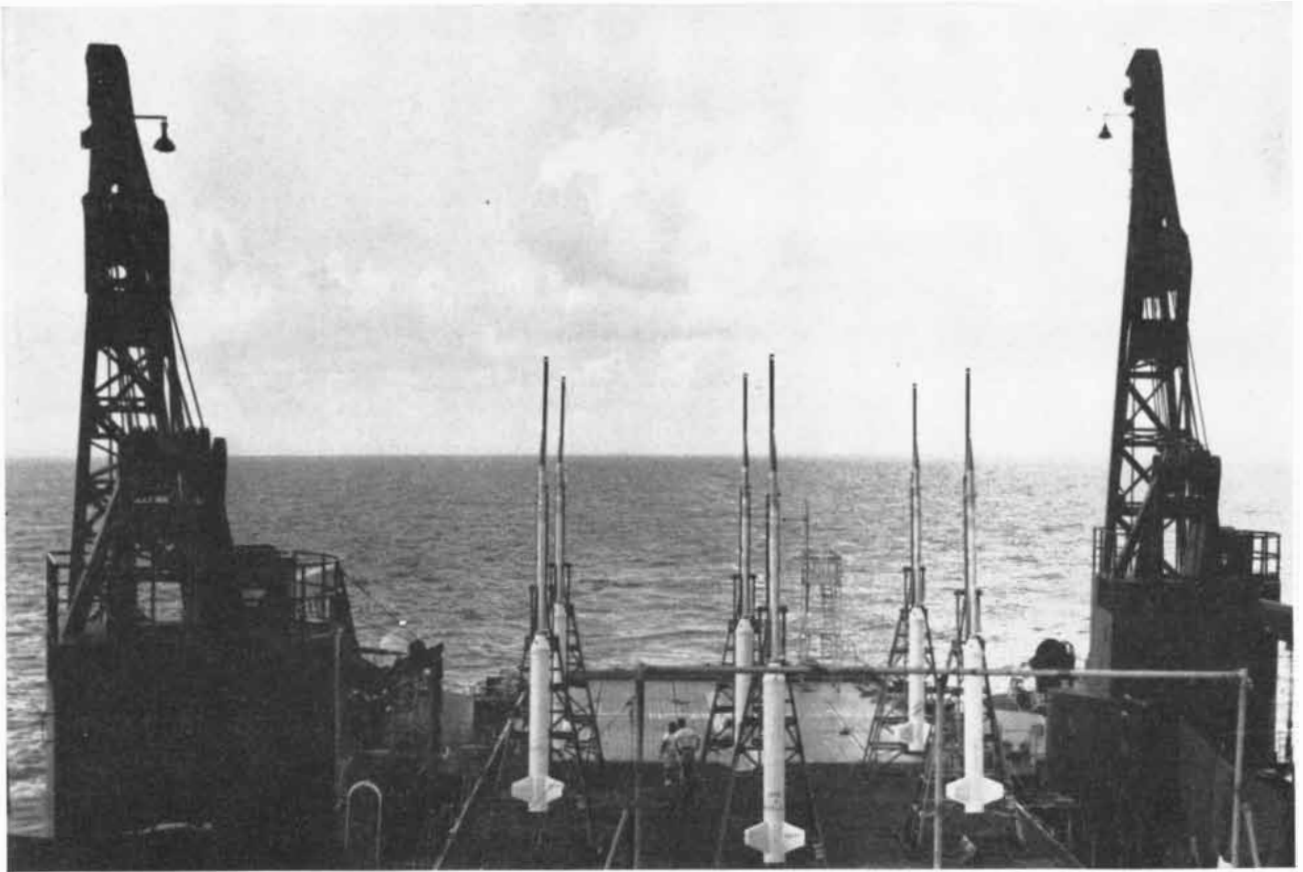
of visible light. The glimpses last only two to five minutes, as the rocket coasts around the top of its trajectory, and rockets provide highly unstable platforms for our instruments. But we have made some unexpected discoveries and have beheld some marvelous sights. The dominant color of the nearby universe appears to be a far ultraviolet, at the wavelength of 1,216.7 angstroms, almost two octaves higher in frequency than the violet edge of the visible spectrum. The sun shines more brightly at this so-called Lyman-alpha line than at any other; if our eyes could perceive the Lyman-alpha radiation in the night sky, its diffuse glow would overwhelm the other radiations of the stars. Elsewhere in the universe vast clouds of dust and gas shine so brightly with ultraviolet light that they hide the hot stars that generate this energy in their interiors. Since the sun is the nearest star, we have the most to report about it. We have now explored the major features of the solar spectrum down to one-angstrom X-rays, and we have deepened our understanding of how the sun interacts with the earth's atmosphere. The abundant yield of these first ventures into space makes it plain that a major fraction of all future astronomical investigation will be carried on from stations above the atmosphere.

The rocket astronomer relies on the same two instruments—the telescope and the spectroscope—that are employed by his earth-bound colleagues. But a rocket

is mostly fuel and engine and allows little space and weight for the observatory payload. A small solid-propellant system such as the Nike-Asp can carry about two cubic feet of instruments weighing about 50 pounds to an altitude of 150 miles; the larger Aerobee-Hi rocket accommodates about 10 cubic feet and 200 pounds of payload on a trip to the same altitude. The firing of a larger liquid-fueled rocket involves lengthy preflight preparations, and firing time is frequently dictated by considerations other than the best moment for the experiment. But even though the solid-propellant rocket offers greater freedom of operation, its explosive start may subject its instrumentation to the shock of transient accelerations amounting to several hundred times that of gravity.

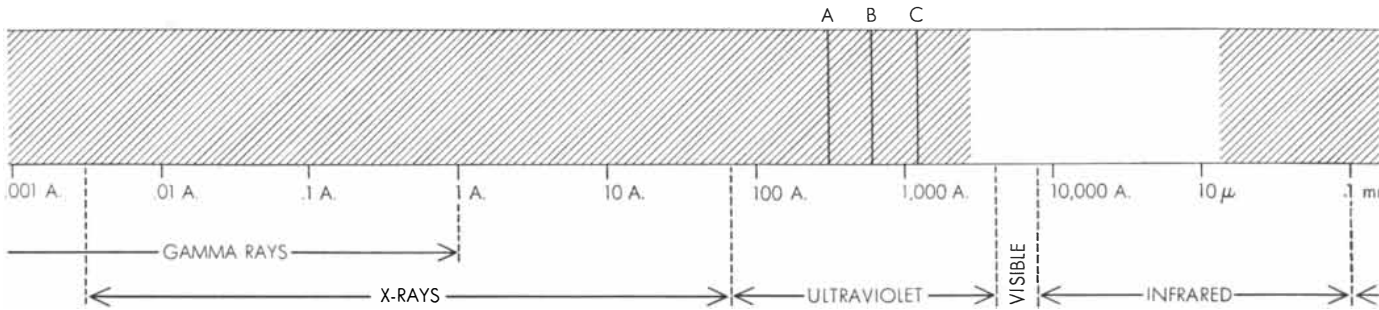
The instruments must be designed to function with the vehicle in erratic motion. It has been the practice to stabilize the rockets in flight merely by causing them to spin, like a rifle bullet, on their long axes; the rocket may nonetheless wobble about its spin axis, enter a flat spin or tumble. When the sun is to be observed, such behavior reduces the available exposure time to a small percentage of total flight time; this can be offset to a certain degree by the use of sun-following devices and biaxial pointing-controls.

The recovery of exposed film introduces the final set of design problems. The film-holder must be strong enough



SIX ROCKETS WERE FIRED from the *U.S.S. Point Defiance* to make observations of the sun's radiation during the Pacific eclipse

of October 12, 1958. At top the rockets are ready for firing. At bottom the fourth rocket is fired in the darkness of the eclipse.



“WINDOWS” in the earth’s atmosphere which admit electromagnetic radiation are indicated by the unhatched areas in this chart of

the electromagnetic spectrum. The shorter wavelengths are measured in angstrom units (A.) or microns (μ). To the left of the win-

to withstand the impact of coming to earth; if it is to be recovered at sea, it must float. In the latter case a radio transmitter must be included to broadcast its position. Telemetering the measurements while the rocket is aloft eliminates some of these problems but introduces limitations of its own. Whether the precious instrumentation succeeds or fails in its mission, it is almost invariably destroyed upon falling to earth.

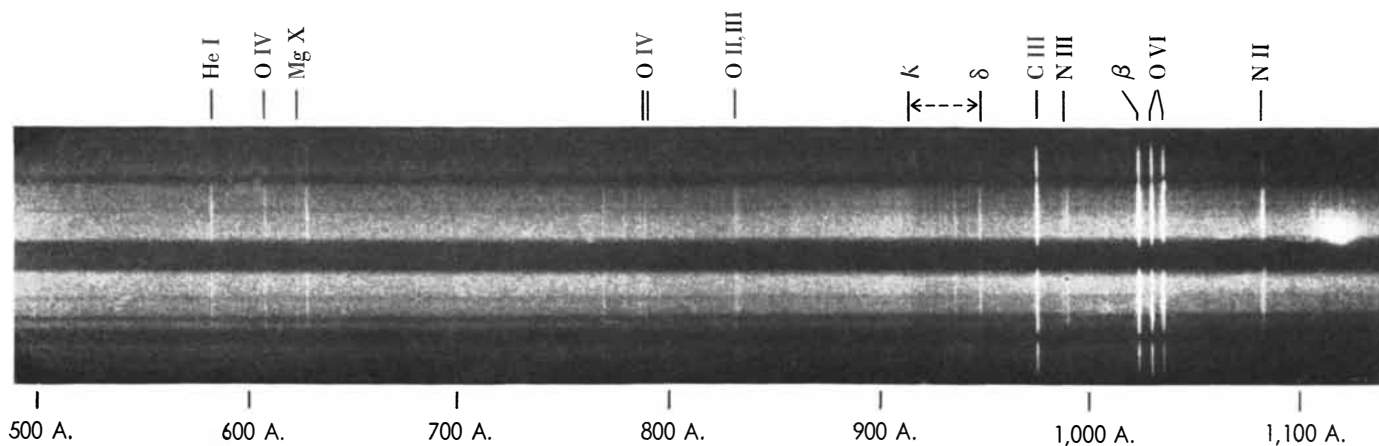
The sun was the first object to be studied by rocket astronomy. The initial objective was to get pictures of the solar spectrum in the ultraviolet, where spectral emission and absorption lines hold clues to so many aspects of the sun’s constitution and behavior. But early efforts to obtain spectrograms of this biggest and brightest of all targets met with so many misfortunes that the spectrograph was supplemented by simple photon-counters and ion chambers tuned to narrow bands of wavelengths. For example, a chamber filled with nitric-oxide gas (which is ionized by wavelengths below 1,350 angstroms) and with a window of lithium fluoride (which is transparent to wavelengths above 1,060

angstroms) gives us a detector that responds only to wavelengths from 1,060 to 1,350 angstroms. This band of course includes the Lyman-alpha line at 1,216.7 angstroms. More recently Richard Tousey and his associates at the Naval Research Laboratory have secured spectrograms of high resolution down to 584 angstroms, using a spectrograph with a concave diffraction grating. Improvements in coatings that reflect ultraviolet radiation will soon make it possible to record the Lyman-alpha region with fine resolution in hundredths of a second.

From the spectrograms and photon-counter readings made to date we have been able to plot an approximate map of the solar spectrum over the entire short-wavelength region. The sun’s visible spectrum (from 4,000 to 7,000 angstroms) tells us that the photosphere (the surface of the sun as seen in white light) has a temperature of 6,000 degrees Kelvin (degrees centigrade above absolute zero). In this region of the spectrum thousands of dark absorption lines indicate the presence of cooler gases, with temperatures as low as 4,000 degrees K., in the upper layers of the photosphere. The first rocket spectro-

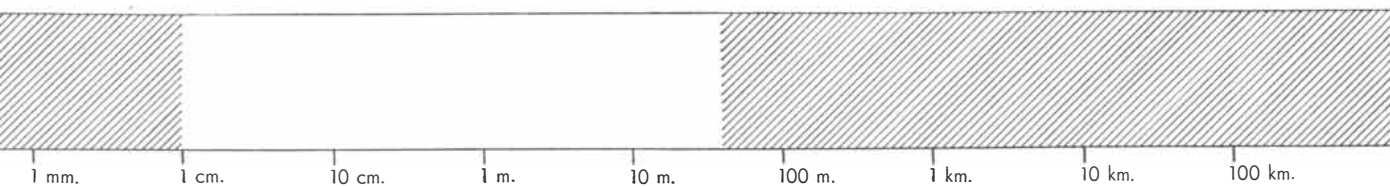
grams reaching to 2,000 angstroms in the ultraviolet indicated a brightness and apparent temperature of 5,000 degrees, and measurements with photon counters out to 1,200 angstroms extended this trend of decreasing brightness down to 4,000 degrees. Apparently the decrease in solar emission in this spectral region is due to the crowding together of the absorption lines of the cooler gases in the upper photosphere. Spectrograms of higher resolution will reveal the abundance of the many rare constituents of the solar atmosphere (e.g., the halogens, arsenic, selenium, tellurium and radon) which give rise to these lines. At 2,100 angstroms the absorption lines are so crowded that they become almost continuous; they finally disappear at about 1,700 angstroms.

Below 1,600 angstroms the rocket spectrograms begin to provide information about the sun’s chromosphere. This transition region, about 10,000 miles deep, between the comparatively cool photosphere and the million-degree solar corona is visible during eclipses as a thin red ring. It derives its red color from the hydrogen-alpha emission line



ULTRAVIOLET SPECTRUM of the sun was made on March 13 from a Naval Research Laboratory Aerobee rocket which rose to a height of 123 miles. The spectrum shows about 100 ultraviolet

emission lines: 60 more than had been observed previously. Of the lines labeled here, the brightest is the Lyman-alpha line of hydrogen (α). The additional Greek letters indicate other lines of



RADIO

dow at left are three important spectral lines to which the atmosphere is opaque: the 304-angstrom line emitted by singly ionized

helium (A), the 584-angstrom line emitted by un-ionized helium (B) and Lyman-alpha line emitted by un-ionized hydrogen (C).

at 6,563 angstroms in the visible spectrum. In the ultraviolet region the chromosphere radiates strong emission lines, many of them associated with highly ionized atoms of oxygen, nitrogen, carbon, silicon and helium.

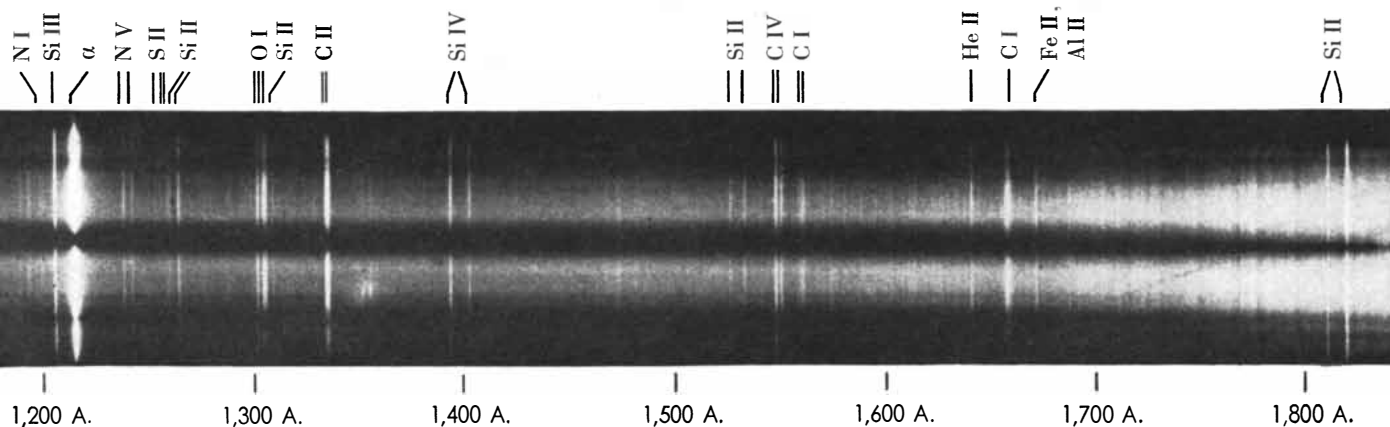
The chromosphere is also the source of the sun's powerful Lyman-alpha radiation at 1,216.7 angstroms. This is the primary resonance wavelength of hydrogen; it is associated with the jumping of the atom's single electron between its first and second energy levels or shells, a photon being absorbed when the electron jumps to the second shell and emitted when it falls back to the first shell. Since hydrogen is by all odds the most abundant constituent of the sun and of the universe as a whole, it is no surprise that Lyman-alpha radiation is so prominent in the solar spectrum and in the universe.

From the solar X-ray spectrum (below 100 angstroms) we have gained new insight into the nature of the corona and its interaction with the earth's atmosphere. The hot, tenuous gas of the corona, reaching millions of miles out into space, is visible only during solar eclipses; it is so thin that faint stars can

be seen through it, and comets traverse it without detectable drag. Since rocket investigations of the X-ray spectrum have so far been conducted only with narrow-band photodetectors, the distribution of energy in this region is not yet fully plotted. The peak of emission at about 60 angstroms, observed when the sun is quiet, indicates that the corona has a steady temperature of 500,000 degrees. When the sun is disturbed by the passage of sunspots and other manifestations visible in the photosphere, it is believed that the corona develops local condensations in which temperatures rise to millions of degrees [see "Hot Spots in the Atmosphere of the Sun," by Harold Zirin; SCIENTIFIC AMERICAN, August, 1958]. Although rocket measurements are still scanty, they support this belief; they show X-ray emission in the extremely short wavelengths of five or six angstroms, which indicate extremely high temperatures and are well correlated with other symptoms of solar disturbance.

Before the advent of rocket astronomy our understanding of solar ultraviolet and X-ray emission was predicated upon the indirect evidence of the behavior of

the ionized layers of the earth's upper atmosphere. The daily cycle of growth and decay in the density of electrons at altitudes between 50 and 200 miles is a plain indication of the ionizing action of these high-energy radiations. Now, with the direct records of the sun's emission in this region of the spectrum, we have acquired a clearer understanding of what goes on in our ionosphere. We can see that the Lyman-alpha radiation induces the formation of the lowest, or "D," region of the ionosphere (45 to 55 miles) by ionizing nitric oxide, even though this compound is present only in a concentration of one part per million. The "E" region (60 to 80 miles) can be attributed principally to X-rays from the quiet corona, which ionize any of the atmospheric gases. It has been known that the electron density of the E region varies in perfect harmony with sunspot number; now rocket observations reveal a similar correlation with solar X-ray emission. When the sun is active, the increased intensity of X-rays arriving in the E region increases the over-all electron density, and the output of harder and more penetrating X-rays in the five-to 20-angstrom band spreads the E re-



hydrogen. The other symbols denote lines emitted by the variously ionized atoms of helium (He), oxygen (O), magnesium (Mg), carbon (C), nitrogen (N), silicon (Si), sulfur (S), iron (Fe) and

aluminum (Al). The Roman numerals refer to the number of electrons removed from the atom. The experiment was designed by J. D. Purcell, D. M. Packer, W. D. Hunter and Richard Tousey.

gion to lower altitudes. In the top, or "F," layer of the ionosphere, most of the ionization is apparently caused by the far-ultraviolet emission of the principal resonance line of singly ionized helium, at 304 angstroms.

The most impressive disturbances of the ionosphere, associated in human affairs with the blackout of radio communications, have been found to coincide with the most spectacular event observed on the face of the sun: the solar flare. A flare begins as a local brightening in the vicinity of a sunspot group, visible in the red hydrogen-alpha line. In a few minutes it may flash to 10 times the brightness of the surrounding photosphere and spread over hundreds of millions of square miles. Almost simultaneously a burst of ionizing radiation announces the event in the terrestrial atmosphere by a sudden short-wave radio fade-out. This effect was traced some time ago to increased ionization in the D region. A principal objective of rocket astronomy during the sunspot maximum of the International Geophysical Year was to get a direct measurement of the ionizing radiation which causes these effects in association with solar flares.

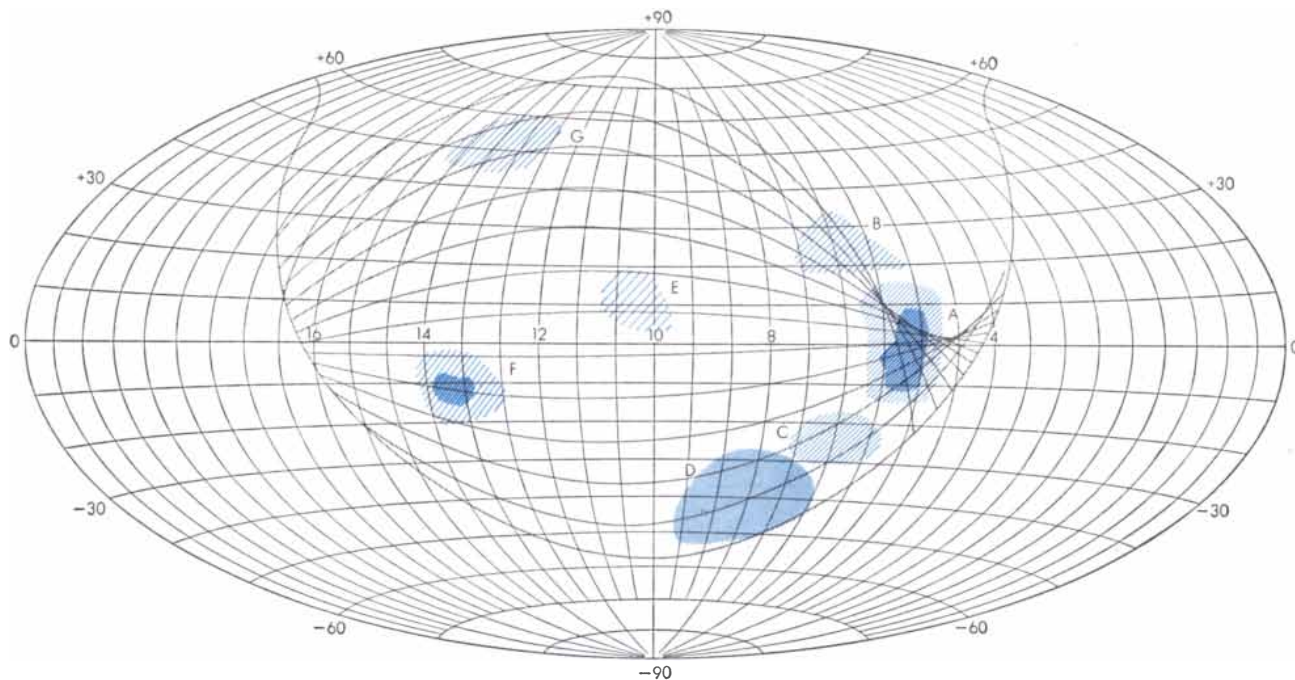
It is no easy matter, however, to fire a rocket during a solar flare. Even in a sunspot maximum there may be only one

interesting flare in each 50-hour period. To catch such a transitory event requires push-button rocketry. In 1956 the trap was set by launching a "rockoon"—a small solid-propellant rocket hoisted through the lower atmosphere by a balloon—from the deck of a ship in the Pacific Ocean early in the morning on each of 10 days. The ship would track the balloon, floating aloft at 80,000 feet, waiting to fire the rocket upon receipt of word that a flare had been detected. In 10 tries only one small flare was caught. But the record of the X-ray signals telemetered from the ionosphere clearly revealed a major enhancement and hardening of the X-ray spectrum. In August, 1957, a Naval Research Laboratory station on tiny San Nicolas Island 70 miles off the coast of California succeeded in firing a number of two-stage solid-propellant rockets within minutes after the appearance of solar flares. These soundings detected X-rays with wavelengths as short as one or two angstroms in the output of large flares. Such hard X-rays imply temperatures as high as 10 million degrees in the corona above the visible flare.

As these observations suggest, the sun is an intricate engine with many local events and variations to be observed in the structure of its atmosphere. Until quite recently, however, solar physicists

had been concerned primarily with the sun's average characteristics, treating the photosphere, chromosphere and corona as if they were a series of homogeneous concentric spheres. Then an accumulating mass of observations showed that all three regions are intimately associated in a dynamic complex of processes involving sunspots and their magnetic fields, bright local patches called plages, jets of hot gas called spicules and major eruptions in the form of prominences and flares. Rocket astronomers accordingly are now challenged to detect localized sources of ionizing radiation on the sun and to correlate these with the events observed in the visible spectrum.

The ultraviolet image of the sun has already been photographed with high fidelity by a rocket camera designed by Tousey and his colleagues at the Naval Research Laboratory. This camera employs two concave diffraction-gratings to produce a pure monochromatic image of the sun in the Lyman-alpha line, with sufficient brightness to resolve detail down to 20 seconds of arc in an exposure of two hundredths of a second. The picture made with it clearly shows that Lyman-alpha emission is enhanced in areas of bright hydrogen and calcium plages [see illustrations on pages 58 and 59]. Still another camera may make it



SKY MAP at the ultraviolet wavelength of 1,300 angstroms is based on another Aerobee flight. The numbers around the edge of the map denote declination (corresponding to geographic latitude) in degrees; the numbers across the middle, right ascension (corresponding to longitude) in hours. The lines superimposed on

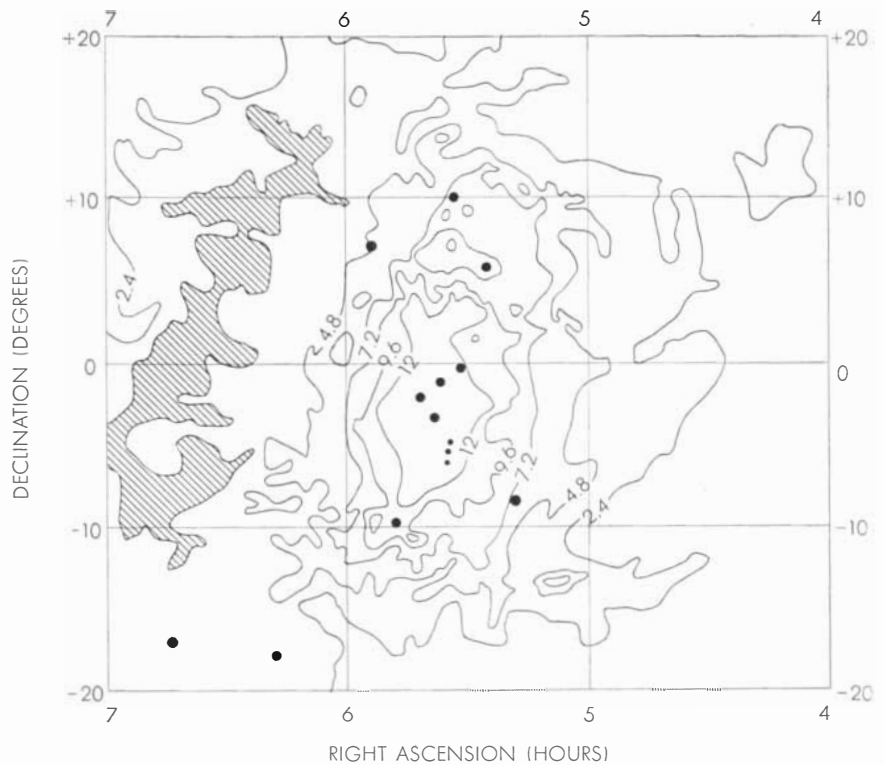
these coordinates show where the rocket's photon counter scanned the sky as the rocket spun on its axis. The colored areas, which strongly emit ultraviolet radiation, are in Orion (A), Taurus (B), Canis Major (C), Puppis and Vela (D), Leo (E), Virgo (F) and Ursa Major (G). The area in Virgo is centered on the star Spica.

possible to secure a telemetered television-style picture of the sun. This system employs a mirror with a photodetector mounted at its focus; by wobbling the mirror the photodetector can be made to scan the image of the sun and report its readings to the ground.

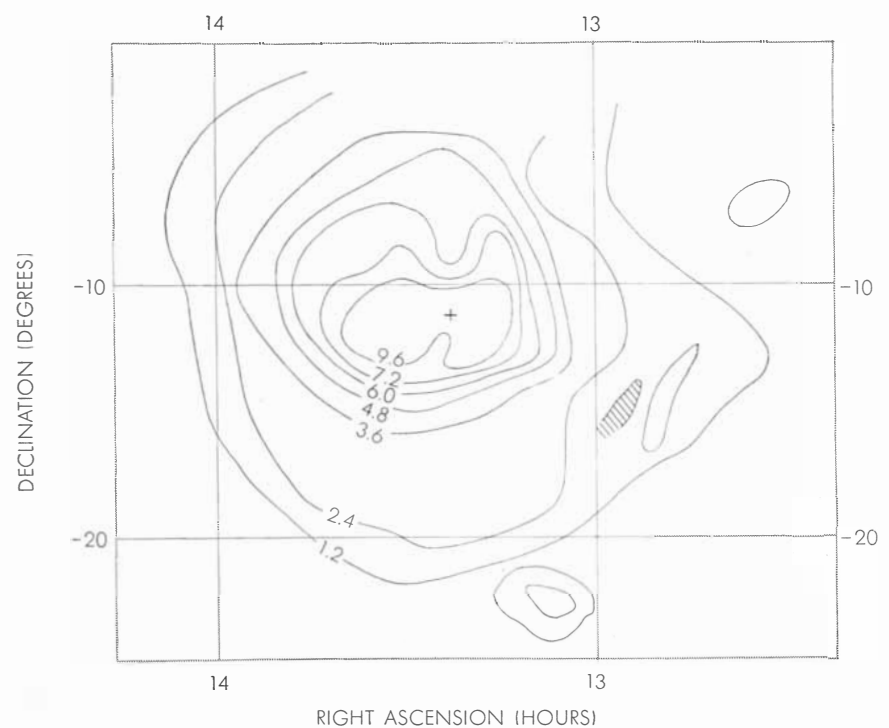
To record the X-ray image of the sun presents greater technical difficulties. Last fall, however, the Naval Research Laboratory seized an opportunity presented by nature to secure a picture of the X-ray sun. The occasion was the South Pacific eclipse of October 12, observed by rockets fired from the deck of the *U.S.S. Point Defiance*. As the moon crossed the face of the sun, six rockets were launched in sequence to take turns measuring the X-ray and ultraviolet emission coming from the un eclipsed portions of the solar disk [see illustrations on page 53]. From the still incompletely analyzed data, it appears that at totality the ultraviolet emission dropped to a low level, while the X-ray flux remained at an appreciable fraction of the intensity of the un eclipsed sun. The X-ray picture of the sun reconstructed from these measurements resembles a doughnut: dark in the center, bright near the rim and somewhat larger than the visible disk.

Emboldened by the progress of solar rocket-astronomy, our group at the Naval Research Laboratory set out in 1956 to investigate the ultraviolet and X-ray emissions of other stars. But the light from all the other stars combined adds up to only one billionth the light from the sun. To compound the difficulty, we could not expect to get more than the briefest glance at any piece of sky from our tumbling, spinning observatories. Talbot A. Chubb, Edward T. Byram and J. E. Kupperian, Jr., therefore fitted our first night rocket with the most sensitive photodetectors they could construct—instruments responsive to one out of 10 quanta of far-ultraviolet radiation. As the rocket cleared the top of the lower atmosphere the detectors were choked with an overwhelming flux of radiation. We had not been prepared to discover that the entire sky glows so brightly in the Lyman-alpha line. Counters operating on slightly longer wavelengths in the band from 1,230 to 1,350 angstroms, however, produced the first records of starlight in the far ultraviolet.

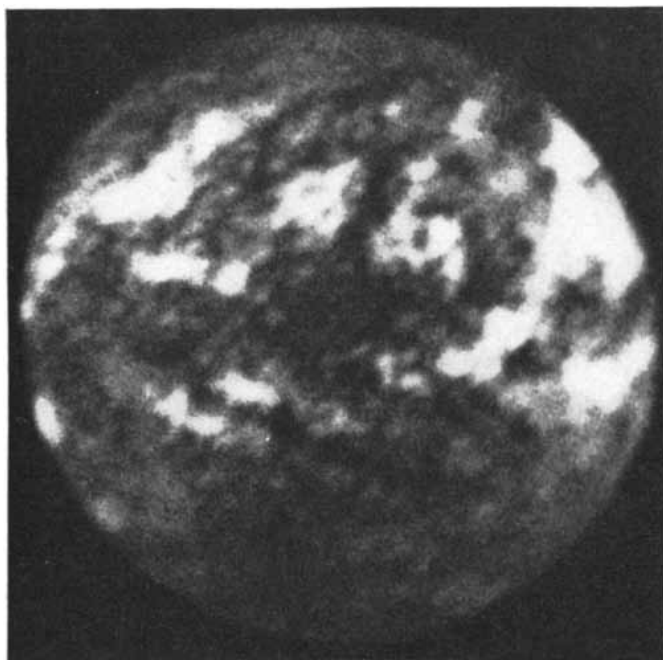
In our next flight, early in 1957, we determined to secure records of individual ultraviolet stars. In order to restrict the angle of vision of our counters we equipped them with collimators made of bundles of short lengths of hypodermic



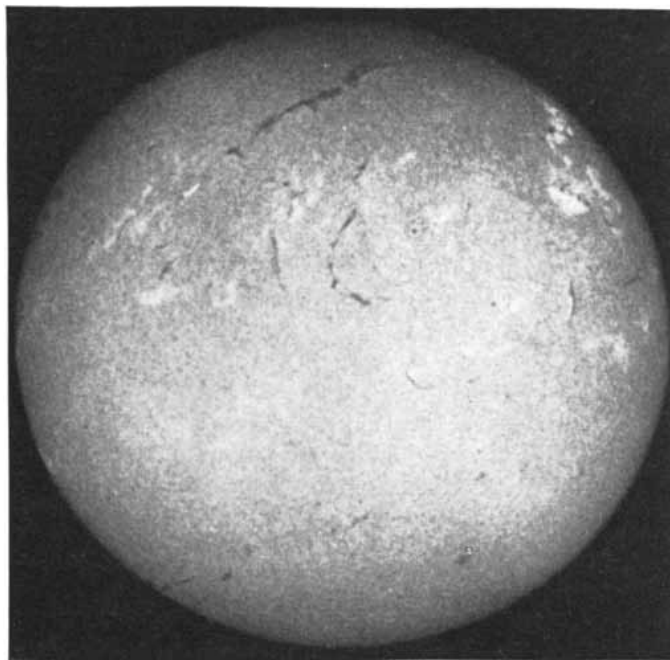
ULTRAVIOLET AREA IN ORION is plotted in greater detail. The coordinates correspond to those in the map on the opposite page. The dots represent bright stars. The numbers on the contours refer to units of .0001 erg per square centimeter per second at 1,300 angstroms.



ULTRAVIOLET AREA AROUND SPICA is plotted in the same manner. The position of Spica itself, the ultraviolet radiation of which is drowned out, is indicated by the small cross.



ULTRAVIOLET PHOTOGRAPH of the sun at left was made during the Aerobee flight of March 13. The three photographs to the



right were made at the same time from the ground. The photograph at left was made by Lyman-alpha radiation. The second

needles; the field of view through these tubes was about three degrees wide, roughly what you see when you look through a bundle of drinking straws. Clusters of four of these counters, tuned to the 1,230- to 1,350-angstrom band, were arranged around the rocket cylinder 120 degrees apart, and the counters in each cluster were pointed to sweep out a fan 30 degrees wide. When the rocket was flown, this arrangement of instruments, combined with the complex motion of the rocket, successfully scanned a major portion of the celestial hemisphere. To locate the sources of emission picked up by the counters the rocket carried a magnetometer and airglow detectors that continuously recorded the orientation of the rocket with respect to the earth's magnetic field and the airglow horizon. These records, plus visible-light signals from the brightest stars, made it possible to achieve an accuracy of about one degree in transposing the signal records to a map [see illustration on page 56].

As the map shows, we did not succeed in registering the discrete images of ultraviolet stars. Our survey yielded instead a completely unexpected and still unexplained discovery. Where we had hoped to find bright ultraviolet stars in the locations of extremely hot stars (identified by their visible-light images), the map shows extended regions of extreme ultraviolet brightness. The

brightest of these regions, in Orion, coincides with the familiar visible nebulosity surrounding the hot stars in that constellation. Even though the density of the particles in these clouds is about a ten millionth that of a good laboratory vacuum, the total volume of the clouds, 20 to 25 light years in diameter, is so great that they can be seen by the naked eye. It is therefore not surprising to find that the same region glows brightly in ultraviolet radiation. What is surprising is that this nebulosity glows as brightly in the ultraviolet as it does in the visible spectrum, covers an even larger region of sky and overwhelms the ultraviolet images of the individual stars. No known mechanism can explain this emission.

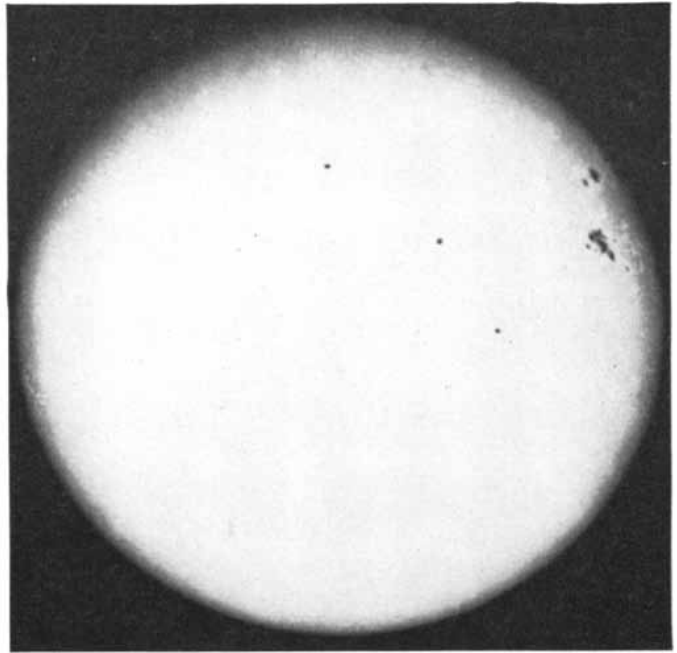
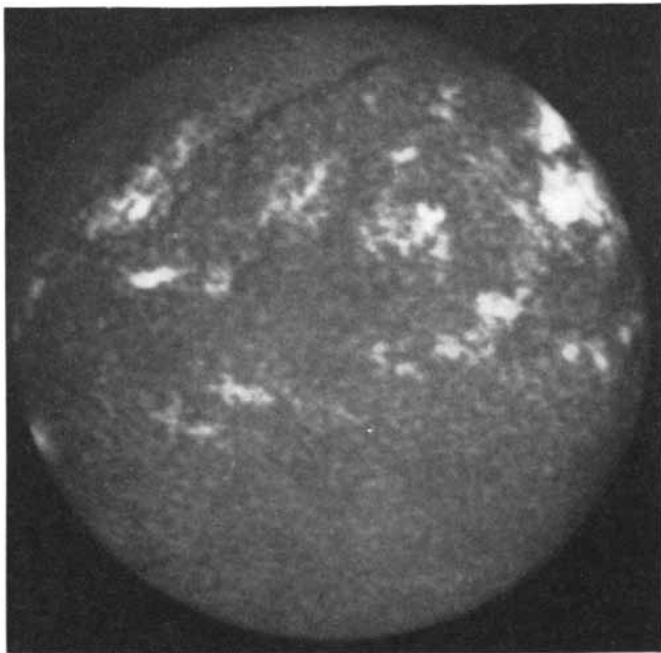
Even more puzzling is the ultraviolet nebulosity surrounding the star Spica. Analysis of the visible spectrum of this star had indicated that its temperature was 28,000 degrees. According to theory, such a hot star should ionize hydrogen in surrounding space out to a distance of 40 light-years, and this region should glow in the visible spectrum. But no visible nebulosity can be seen around Spica. In the ultraviolet spectrum, however, our records show that the star generates a nebulosity that extends over the vast space of 400 square degrees and has a surface brightness comparable to that of the nebulosity in Orion. In the midst of this bright cloud Spica itself remains hidden. But if we accept the temperature of 28,000 de-

grees, it should stand out 30 times brighter than its nebulosity.

Before we can begin to understand the full significance of these observations we must secure readings in other regions of the spectrum and at much finer resolution. Fortunately the ultraviolet nebulosities are so bright that we may confidently expect to resolve them in photographic spectrograms and thus secure finer detail than can be achieved by photodetectors.

Meanwhile the extended Lyman-alpha glow, which apparently obliterates all objects radiating in its wavelength outside our solar system, presents another riddle for further investigation. A phenomenon of interplanetary space, it appears to be solar Lyman-alpha emission that is reflected and diffused by resonance from atoms of neutral hydrogen. In brightness it exceeds the combined intensity of all visible starlight. This of itself may give us a new measure of the density of matter in interplanetary space. Calculation from the observed flux shows that there must be a few tenths of a neutral hydrogen atom per cubic centimeter and, since the interplanetary gases are 99 per cent ionized, about 100 times as many protons and electrons.

We must be cautious, however, in generalizing to interplanetary space from observations made in the vicinity of the earth. It may be that these gases



photograph was made at the Naval Research Laboratory by the red hydrogen-alpha spectral line; the third photograph, at the

McMath-Hulbert Observatory by the "K" line of calcium. The fourth photograph was made at the U. S. Naval Observatory by white light.

constitute an even more local phenomenon, a kind of corona traveling with the earth. The noted geophysicist Sydney Chapman has postulated that the terrestrial hydrogen atmosphere reaches 50 to 100 earth radii into space before it merges with the extended corona of the sun. Our rocket probes have so far operated well inside these dimensions. If the hydrogen that produces this diffuse glow is indeed restricted to the earth-moon system, it should be possible to map its distribution by measuring the variation in brightness with detectors carried aboard a moon-bound rocket.

High-resolution analysis of the glow may also help to settle the question. The bright line of radiation that traverses a cold neutral gas will show a dark absorption line at its center. If the Lyman-alpha glow in the night sky has its origin in interplanetary gases and is filtered by extended terrestrial hydrogen before it reaches our instruments, it should show such a line when it is observed in a direction away from the sun. Alternatively, if the glow is observed in the direction of the earth's motion on its orbit, the Doppler shift introduced by the velocity of the earth should be sufficient to displace the bright line of the glow away from the absorption line of terrestrial hydrogen.

Though the Lyman-alpha glow constitutes an interesting feature of interplanetary space, it extends into that region the barrier astronomy seeks to

escape by carrying its instruments outside the earth's atmosphere. The glow has so far prevented us from observing stars and interstellar hydrogen-clouds at this important wavelength. It may be possible to see through the glare if we can replace our hypodermic-needle collimators with mirror telescopes; sharper angular resolution should improve the intensity of star signals with respect to the background. As the field of view is narrowed, however, it will be necessary to develop better pointing controls. Another approach is suggested by the fact that the lines of emitted radiation tend to be broad, whereas resonantly scattered radiation is highly monochromatic. An instrument tuned to wavelengths just half an angstrom unit off center should be able to "see around" the night sky-glow and get a clear view of the broader Lyman-alpha emission line from hot stars. Such tuning should also make it possible to pick up the line from other sources displaced by the Doppler effect due to the earth's motion.

A pessimistic note has recently been sounded by Lawrence A. Aller of the University of Michigan, to the effect that interstellar hydrogen may absorb almost all of the Lyman-alpha and shorter-wavelength radiation from even the nearest stars. The density of neutral hydrogen in the plane of the galaxy may be such that only X-rays can penetrate to the earth from the galactic center. Perhaps the most immediate task of rocket

astronomy is to map the sky for holes or regions of relative transparency.

Rocket astronomy has not yet undertaken the observation of celestial objects in the X-ray spectrum. Such cosmic-ray sources as the Crab Nebula, however, have high priority in experiments now being designed and instrumented. At the other end of the spectrum rocket astronomers will have a special interest in the information that may be carried by infrared radiation. On these wavelengths we may be able to look inside the dense clouds of dust and gas in which, it is thought, stars are still being formed. Outside the filter of the earth's atmosphere it will also be possible to extend the range of radio astronomy 100-fold beyond the window through which terrestrial radio observatories now look at the universe. Studies of long-wave outbursts from the sun and Jupiter also have high priority.

In the not-too-distant future rocket astronomy will doubtless give way to satellite astronomy. Satellites of more than 1,000 pounds payload are already being designed in the U. S. They will provide stable platforms from which telescopes may be pointed to track stars, planets and nebulae, and to monitor events such as flares on the surface of the sun. Eventually, when it is possible to man these satellites, we may observe even the faintest stars. The first discoveries of rocket astronomy guarantee that the effort will be worthwhile.

An Ancient Greek Computer

In 1901 divers working off the isle of Antikythera found the remains of a clocklike mechanism 2,000 years old. The mechanism now appears to have been a device for calculating the motions of stars and planets

by Derek J. de Solla Price

Among the treasures of the Greek National Archaeological Museum in Athens are the remains of the most complex scientific object that has been preserved from antiquity. Corroded and crumbling from 2,000 years under the sea, its dials, gear wheels and inscribed plates present the historian with a tantalizing problem. Because of them we may have to revise many of our estimates of Greek science. By studying them we may find vital clues to the true origins of that high scientific technology which hitherto has seemed peculiar to our modern civilization, setting it apart from all cultures of the past.

From the evidence of the fragments one can get a good idea of the appearance of the original object [see illustration on page 62]. Consisting of a box with dials on the outside and a very complex assembly of gear wheels mounted within, it must have resembled a well-made 18th-century clock. Doors hinged to the box served to protect the dials, and on all available surfaces of box, doors and dials there were long Greek inscriptions describing the operation and construction of the instrument. At least 20 gear wheels of the mechanism have been preserved, including a very sophisticated assembly of gears that were mounted eccentrically on a turntable and probably functioned as a sort of epicyclic or differential gear-system.

Nothing like this instrument is preserved elsewhere. Nothing comparable to it is known from any ancient scientific text or literary allusion. On the contrary, from all that we know of science and technology in the Hellenistic Age we should have felt that such a device could not exist. Some historians have suggested that the Greeks were not interested in experiment because of a contempt—perhaps induced by the existence

of the institution of slavery—for manual labor. On the other hand it has long been recognized that in abstract mathematics and in mathematical astronomy they were no beginners but rather “fellows of another college” who reached great heights of sophistication. Many of the Greek scientific devices known to us from written descriptions show much mathematical ingenuity, but in all cases

the purely mechanical part of the design seems relatively crude. Gearing was clearly known to the Greeks, but it was used only in relatively simple applications. They employed pairs of gears to change angular speed or mechanical advantage, or to apply power through a right angle, as in the water-driven mill.

Even the most complex mechanical devices described by the ancient writers



THREE PRINCIPAL FRAGMENTS of the Antikythera mechanism are shown from both sides. One pair of views is at top on the left-hand page; the second pair, at bottom on the

Hero of Alexandria and Vitruvius contained only simple gearing. For example, the taximeter used by the Greeks to measure the distance traveled by the wheels of a carriage employed only pairs of gears (or gears and worms) to achieve the necessary ratio of movement. It could be argued that if the Greeks knew the principle of gearing, they should have had no difficulty in constructing mechanisms as complex as epicyclic gears. We now know from the fragments in the National Museum that the Greeks did make such mechanisms, but the knowledge is so unexpected that some scholars at first thought that the fragments must belong to some more modern device.

Can we in fact be sure that the device is ancient? If we can, what was its purpose? What can it tell us of the ancient world and of the evolution of modern science?

To authenticate the dating of the fragments we must tell the story of their discovery, which involves the first (though inadvertent) adventure in underwater archaeology. Just before Easter in 1900 a party of Dodecanese sponge-

divers were driven by storm to anchor near the tiny southern Greek island of Antikythera (the accent is on the "kyth," pronounced to rhyme with pith). There, at a depth of some 200 feet, they found the wreck of an ancient ship. With the help of Greek archaeologists the wreck was explored; several fine bronze and marble statues and other objects were recovered. The finds created great excitement, but the difficulties of diving without heavy equipment were immense, and in September, 1901, the "dig" was abandoned. Eight months later Valerios Staïs, an archaeologist at the National Museum, was examining some calcified lumps of corroded bronze that had been set aside as possible pieces of broken statuary. Suddenly he recognized among them the fragments of a mechanism.

It is now accepted that the wreck occurred during the first century B.C. Gladys Weinberg of Athens has been kind enough to report to me the results of several recent archaeological examinations of the amphorae, pottery and minor objects from the ship. It appears from her report that one might reason-

ably date the wreck more closely as 65 B.C. \pm 15 years. Furthermore, since the identifiable objects come from Rhodes and Cos, it seems that the ship may have been voyaging from these islands to Rome, perhaps without calling at the Greek mainland.

The fragment that first caught the eye of Staïs was one of the corroded, inscribed plates that is an integral part of the Antikythera mechanism, as the device later came to be called. Staïs saw immediately that the inscription was ancient. In the opinion of the epigrapher Benjamin Dean Meritt, the forms of the letters are those of the first century B.C.; they could hardly be older than 100 B.C. nor younger than the time of Christ. The dating is supported by the content of the inscriptions. The words used and their astronomical sense are all of this period. For example, the most extensive and complete piece of inscription is part of a *parapegma* (astronomical calendar) similar to that written by one Geminus, who is thought to have lived in Rhodes about 77 B.C. We may thus be reasonably sure that the mechanism did not find its way into the wreck at some later



left-hand page; the third pair, on the right-hand page. How the fragments were used to reconstruct the appearance of the original mech-

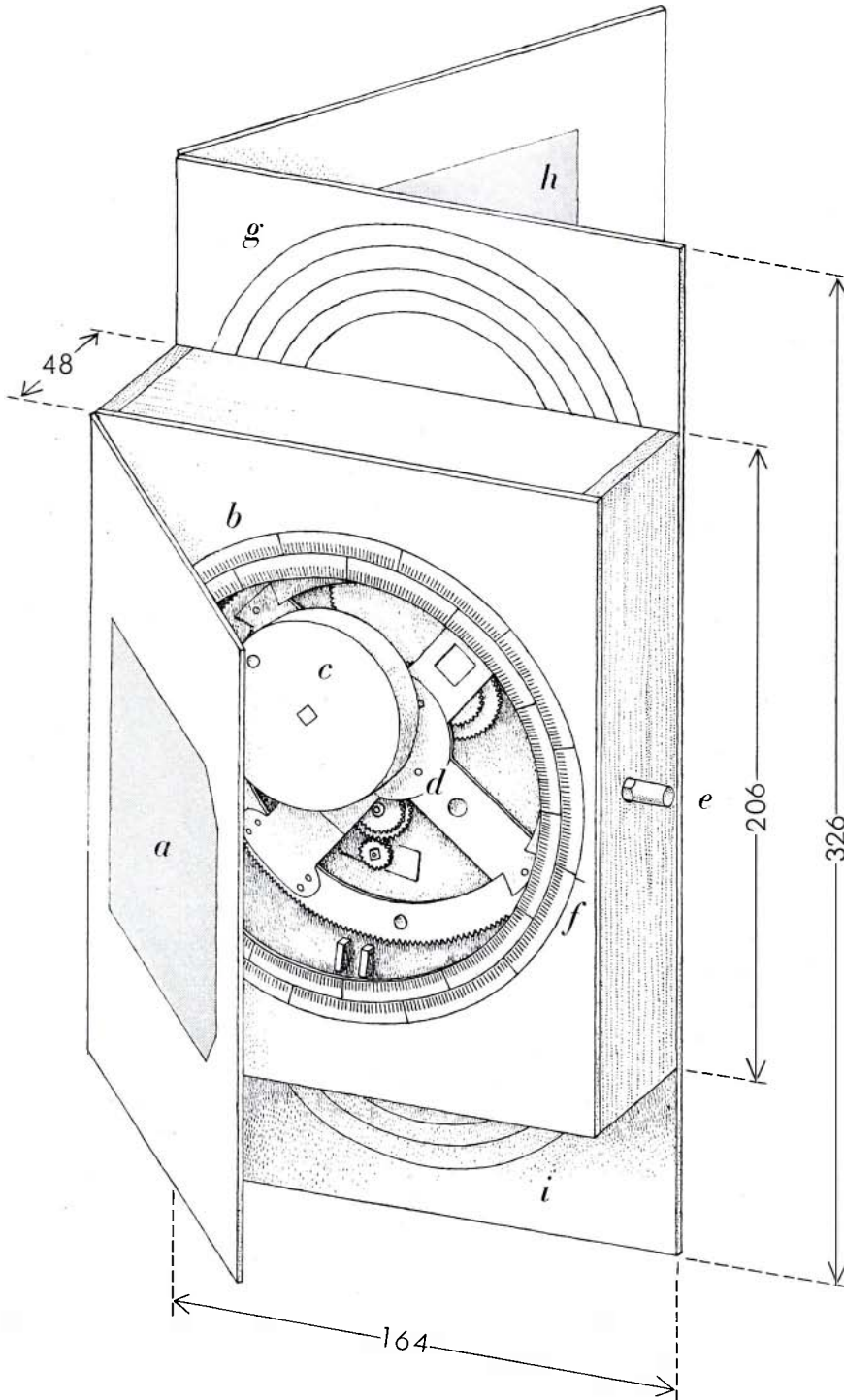
anism is shown on the next two pages. The fragments are presently located in the Greek National Archaeological Museum in Athens.

period. Furthermore, it cannot have been very old when it was taken aboard the ship as booty or merchandise.

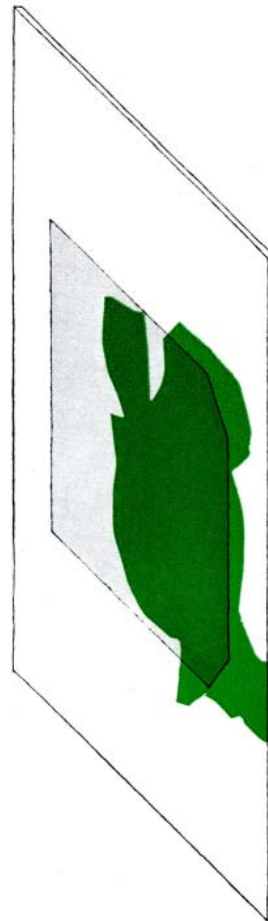
As soon as the fragments had been discovered they were examined by every available archaeologist; so began the long and difficult process of identifying the mechanism and determining its function. Some things were clear from the beginning. The unique importance of

the object was obvious, and the gearing was impressively complex. From the inscriptions and the dials the mechanism was correctly identified as an astronomical device. The first conjecture was that it was some kind of navigating instrument—perhaps an astrolabe (a sort of circular star-finder map also used for simple observations). Some thought that it might be a small planetarium of the

kind that Archimedes is said to have made. Unfortunately the fragments were covered by a thick curtain of calcified material and corrosion products, and these concealed so much detail that no one could be sure of his conjectures or reconstructions. There was nothing to do but wait for the slow and delicate work of the Museum technicians in cleaning away this curtain. Meantime, as the



FRONT DOOR



MECHANISM IS PARTLY RECONSTRUCTED at left. Exploded diagram at right shows how the fragments (color) are related to

the plates of the mechanism. Some fragments include parts of more than one plate. The labeled parts in the reconstruction are: front-

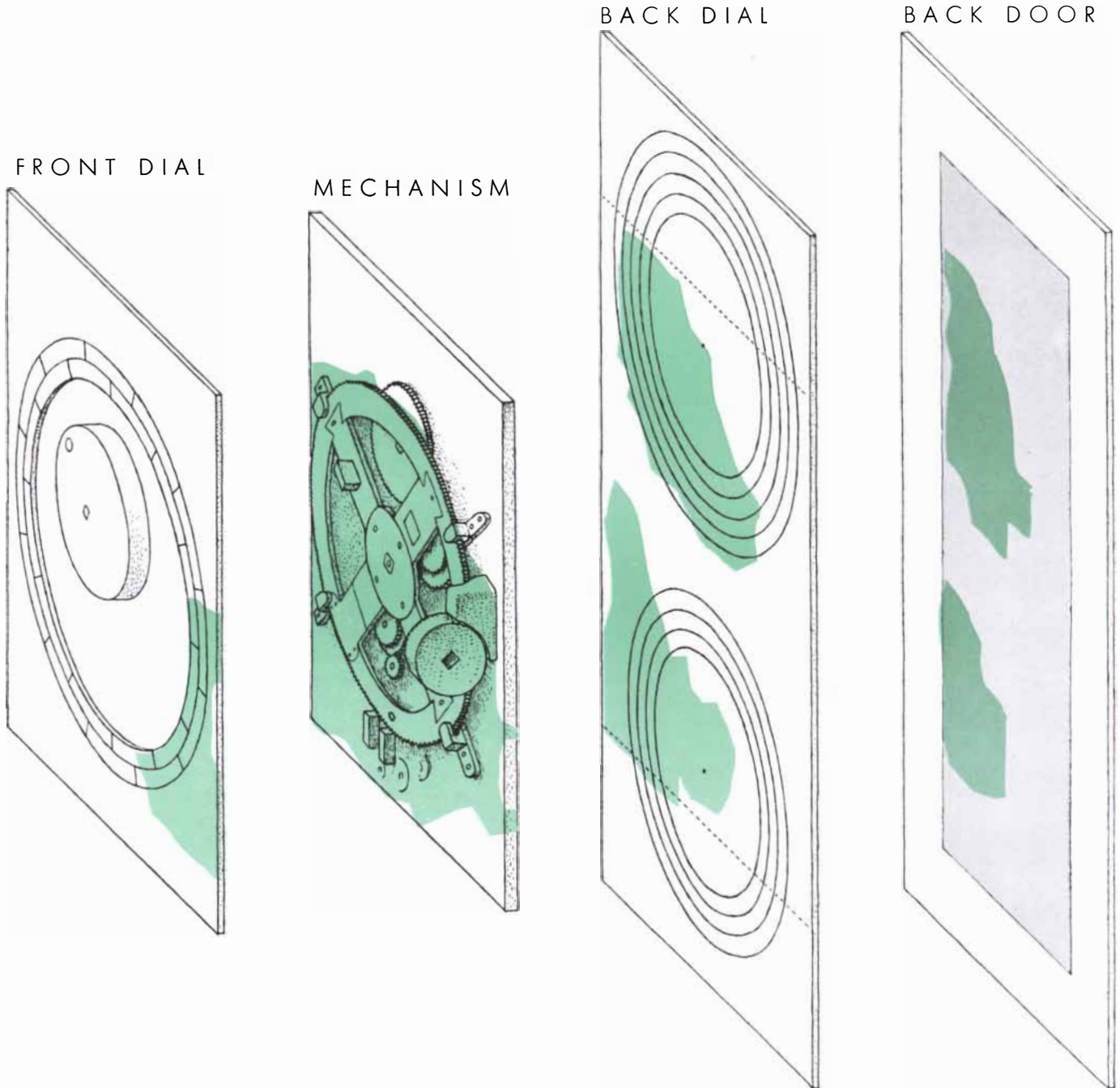
work proceeded, several scholars published accounts of all that was visible, and through their labors a general picture of the mechanism began to emerge.

On the basis of new photographs made for me by the Museum in 1955 I realized that the work of cleaning had reached a point where it might at last

be possible to take the work of identification to a new level. Last summer, with the assistance of a grant from the American Philosophical Society, I was able to visit Athens and make a minute examination of the fragments. By good fortune George Stamires, a Greek epigrapher, was there at the same time; he was able to give me invaluable help by deciphering and transcribing much more of the

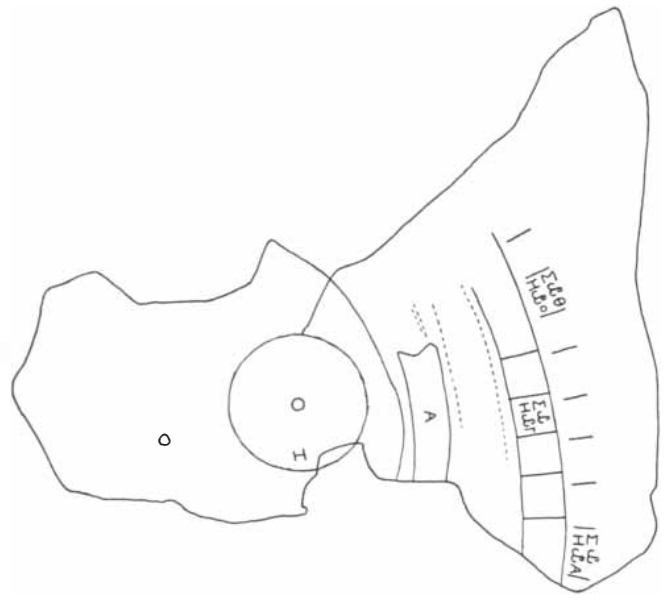
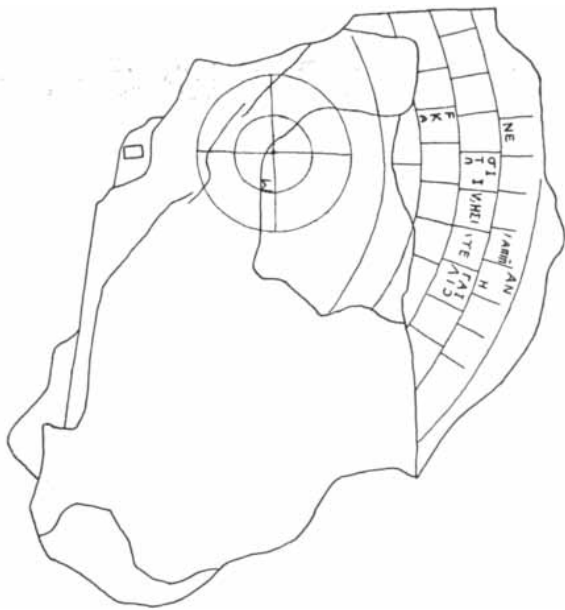
inscriptions than had been read before.

We are now in the position of being able to "join" the fragments and to see how they fitted together in the original machine and when they were brought up from the sea [see illustrations on these two pages]. The success of this work has been most significant, for previously it had been supposed that the various dials and plates had been badly squashed to-



door inscription (a), front dial (b), eccentric drum (c), front of mechanism (d), input shaft (e), fiducial mark (f), four slip rings

of upper back dial (g), back-door inscription (h), three slip rings of lower back dial (i). The dimensions are given in millimeters.



SEGMENTS OF THREE DIALS of the mechanism are visible in the fragments. At left is a simplified drawing of one fragment showing a segment of the upper back dial. At upper right in this

drawing may be seen the four slip rings of the dial; within the rings is a small subsidiary dial. Second from left is a segment of the lower back dial. At right in this drawing is a fixed scale; within it

gether and distorted. It now appears that most of the pieces are very nearly in their original places, and that we have a much larger fraction of the complete device than had been thought. This work also provides a clue to the puzzle of why the fragments lay unrecognized until Staïs saw them. When they were found, the fragments were probably held together in their original positions by the remains of the wooden frame of the case. In the Museum the waterlogged wood dried and shriveled. The fragments then fell apart, revealing the interior of the mechanism, with its gears and inscribed plates.

As a result of the new examinations we shall in due course be able to publish a technical account of the fragments and of the construction of the instrument. In the meantime we can tentatively summarize some of these results and show how they help to answer the question: What is it?

There are four ways of getting at the answer. First, if we knew the details of the mechanism, we should know what it did. Second, if we could read the dials, we could tell what they showed. Third, if we could understand the inscriptions, they might tell us about the mechanism. Fourth, if we knew of any similar mechanism, analogies might be helpful. All these approaches must be used, for none of them is complete.

The geared wheels within the mechanism were mounted on a bronze plate [third from right on preceding page]. On one side of the plate we can trace all the

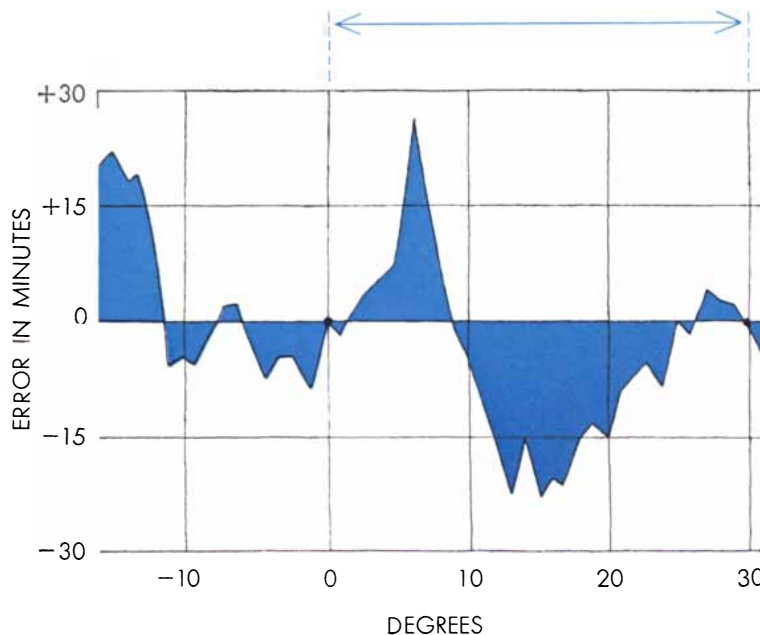
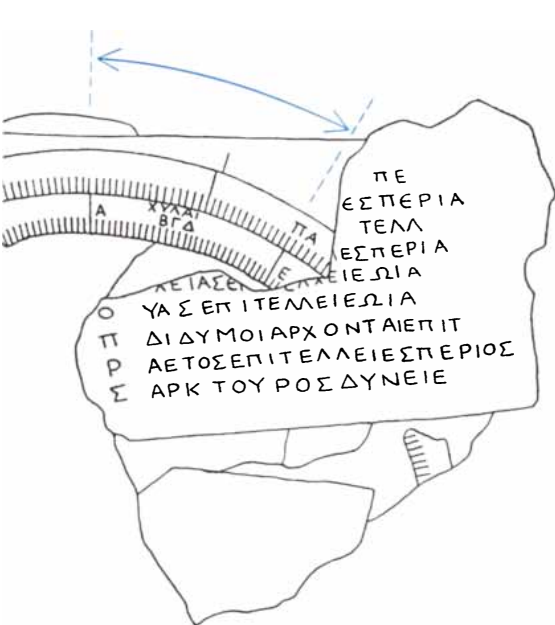
gear wheels of the assembly and can determine, at least approximately, how many teeth each had and how they meshed together. On the other side we can do nearly as well, but we still lack vital links that would provide a complete picture of the gearing. The general pattern of the mechanism is nonetheless quite clear. An input was provided by an axle that came through the side of the casing and turned a crown-gear wheel. This moved a big, four-spoked driving-wheel that was connected with two trains of gears that respectively led up and down the plate and were connected by axles to gears on the other side of the plate. On that side the gear trains continued, leading through an epicyclic turntable and coming eventually to a set of shafts that turned the dial pointers. When the input axle was turned, the pointers all moved at various speeds around their dials.

Certain structural features of the mechanism deserve special attention. All the metal parts of the machine seem to have been cut from a single sheet of low-tin bronze about two millimeters thick; no parts were cast or made of another metal. There are indications that the maker may have used a sheet made much earlier—uniform metal plate of good quality was probably rare and expensive. All the gear wheels have been made with teeth of just the same angle (60 degrees) and size, so that any wheel could mesh with any other. There are signs that the machine was repaired at least twice; a spoke of the driving wheel

has been mended, and a broken tooth in a small wheel has been replaced. This indicates that the machine actually worked.

The casing was provided with three dials, one at the front and two at the back. The fragments of all of them are still covered with pieces of the doors of the casing and with other debris. Very little can be read on the dials, but there is hope that they can be cleaned sufficiently to provide information that might be decisive. The front dial is just clean enough to say exactly what it did. It has two scales, one of which is fixed and displays the names of the signs of the zodiac; the other is on a movable slip ring and shows the months of the year. Both scales are carefully marked off in degrees. The front dial fitted exactly over the main driving-wheel, which seems to have turned the pointer by means of an eccentric drum-assembly. Clearly this dial showed the annual motion of the sun in the zodiac. By means of key letters inscribed on the zodiac scale, corresponding to other letters on the *parapegma* calendar plate, it also showed the main risings and settings of bright stars and constellations throughout the year.

The back dials are more complex and less legible. The lower one had three slip rings; the upper, four. Each had a little subsidiary dial resembling the "seconds" dial of a watch. Each of the large dials is inscribed with lines about every six degrees, and between the lines there are letters and numbers. On the



were three slip rings and within them a subsidiary dial. Third from left is a segment of the front dial. The upper scale in this drawing pertains to the months; the lower scale, to the zodiac. The in-

scribed area is a parapegma plate. The graph at far right shows the errors (in minutes of arc) of the graduations in the zodiac scale. The arrow above the scale is related to the arrow above the chart.

lower dial the letters and numbers seem to record "moon, so many hours; sun, so many hours"; we therefore suggest that this scale indicates the main lunar phenomena of phases and times of rising and setting. On the upper dial the inscriptions are much more crowded and might well present information on the risings and settings, stations and retrogradations of the planets known to the Greeks (Mercury, Venus, Mars, Jupiter and Saturn).

Some of the technical details of the dials are especially interesting. The front dial provides the only known extensive specimen from antiquity of a scientifically graduated instrument. When we measure the accuracy of the graduations under the microscope, we find that their average error over the visible 45 degrees is about a quarter of a degree. The way in which the error varies suggests that the arc was first geometrically divided and then subdivided by eye only. Even more important, this dial may give a means of dating the instrument astronomically. The slip ring is necessary because the old Egyptian calendar, having no leap years, fell into error by 1/4 day every year; the month scale thus had to be adjusted by this amount. As they are preserved the two scales of the dial are out of phase by 13½ degrees. Standard tables show that this amount could only occur in the year 80 B.C. and (because we do not know the month) at all years just 120 years (*i.e.*, 30 days divided by 1/4 day per year) before or after that date. Alternative dates are archaeologi-

cally unlikely: 200 B.C. is too early; 40 A.D. is too late. Hence, if the slip ring has not moved from its last position, it was set in 80 B.C. Furthermore, if we are right in supposing that a fiducial mark near the month scale was put there originally to provide a means of setting that scale in case of accidental movement, we can tell more. This mark is exactly 1/2 degree away from the present position of the scale, and this implies that the mark was made two years before the setting. Thus, although the evidence is by no means conclusive, we are led to suggest that the instrument was made about 82 B.C., used for two years (just long enough for the repairs to have been needed) and then taken onto the ship within the next 30 years.

The fragments show that the original instrument carried at least four large areas of inscription: outside the front door, inside the back door, on the plate between the two back dials and on the parapegma plates near the front dial. As I have noted, there are also inscriptions around all the dials, and furthermore each part and hole would seem to have had identifying letters so that the pieces could be put together in the correct order and position. The main inscriptions are in a sorry state and only short snatches of them can be read. To provide an idea of their condition it need only be said that in some cases a plate has completely disappeared, leaving behind an impression of its letters, standing up in a mirror image, in relief on the soft cor-

rosion products on the plate below. It is remarkable that such inscriptions can be read at all.

But even from the evidence of a few complete words one can get an idea of the subject matter. The sun is mentioned several times, and the planet Venus once; terms are used that refer to the stations and retrogradations of planets; the ecliptic is named. Pointers, apparently those of the dials, are mentioned. A line of one inscription significantly records "76 years, 19 years." This refers to the well-known Calippic cycle of 76 years, which is four times the Metonic cycle of 19 years, or 235 synodic (lunar) months. The next line includes the number "223," which refers to the eclipse cycle of 223 lunar months.

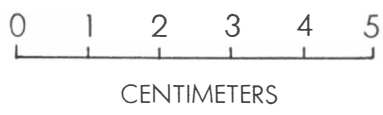
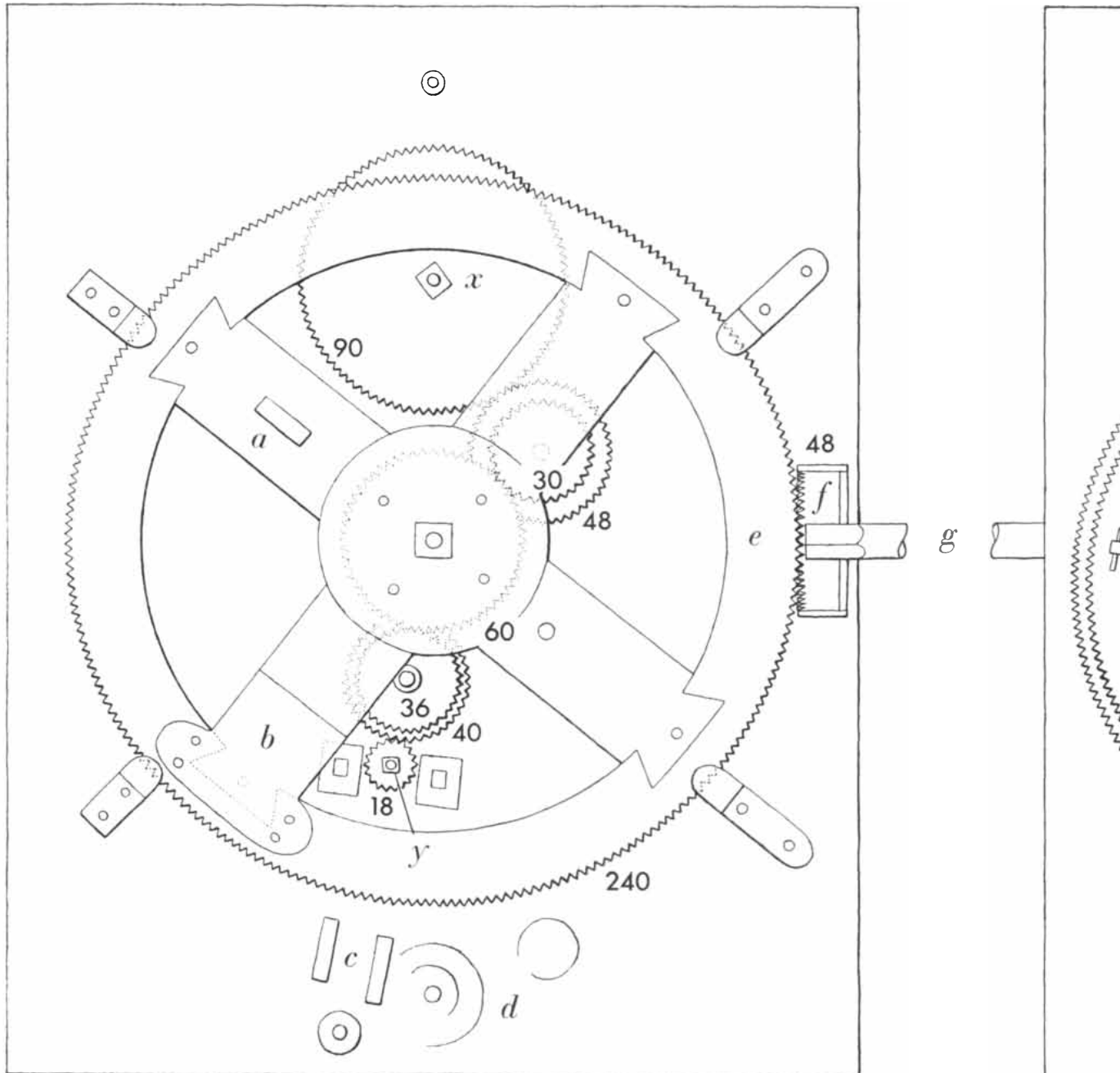
Putting together the information gathered so far, it seems reasonable to suppose that the whole purpose of the Antikythera device was to mechanize just this sort of cyclical relation, which was a strong feature of ancient astronomy. Using the cycles that have been mentioned, one could easily design gearing that would operate from one dial having a wheel that revolved annually, and turn by this gearing a series of other wheels which would move pointers indicating the sidereal, synodic and draconitic months. Similar cycles were known for the planetary phenomena; in fact, this type of arithmetical theory is the central theme of Seleucid Babylonian astronomy, which was transmitted to the Hellenistic world in the last few centuries B.C. Such arithmetical schemes are quite

distinct from the geometrical theory of circles and epicycles in astronomy, which seems to have been essentially Greek. The two types of theory were unified and brought to their peak in the second century A.D. by Claudius Ptolemy, whose labors marked the triumph of the new mathematical attitude toward geometrical models that still characterizes physics today.

The Antikythera mechanism must therefore be an arithmetical counterpart

of the much more familiar geometrical models of the solar system which were known to Plato and Archimedes and evolved into the orrery and the planetarium. The mechanism is like a great astronomical clock without an escapement, or like a modern analogue computer which uses mechanical parts to save tedious calculation. It is a pity that we have no way of knowing whether the device was turned automatically or by hand. It might have been held in the

hand and turned by a wheel at the side so that it would operate as a computer, possibly for astrological use. I feel it is more likely that it was permanently mounted, perhaps set in a statue, and displayed as an exhibition piece. In that case it might well have been turned by the power from a water clock or some other device. Perhaps it is just such a wondrous device that was mounted inside the famous Tower of Winds in Athens. It is certainly very similar to the



DETAILS OF THE MAIN MECHANISM are shown from the front (left) and the back (right). The numbers in the illustration refer to the approximate number of teeth on each gear. The parts labeled with letters are: lug to fix eccentric drum for the front dial (a), repair to spoke (b), guide channel for spring to hold gear of 18 teeth (c), rivets for

great astronomical cathedral clocks that were built all over Europe during the Renaissance.

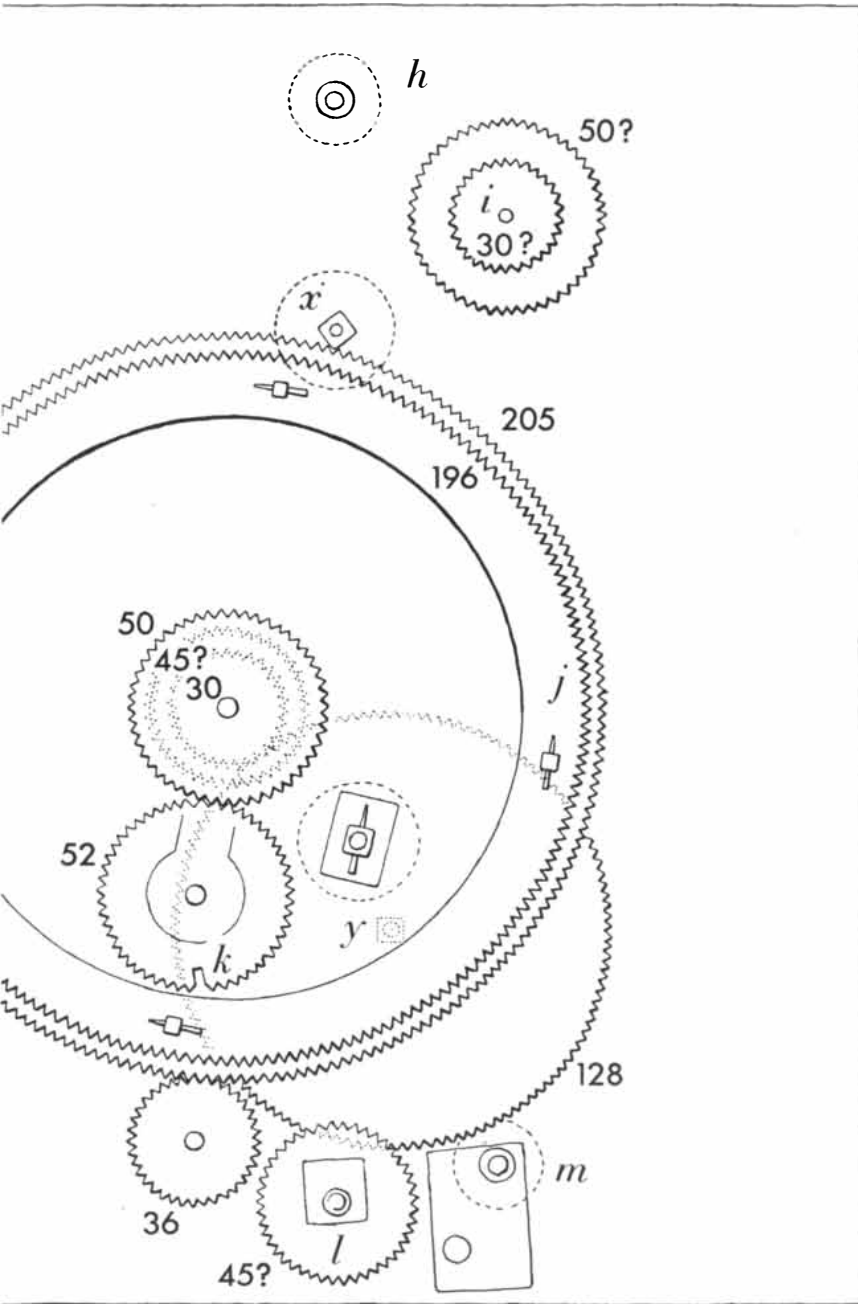
It is to the prehistory of the mechanical clock that we must look for important analogies to the Antikythera mechanism and for an assessment of its significance. Unlike other mechanical devices, the clock did not evolve from the simple to the complex. The oldest clocks of which we are well informed were the most

complicated. All the evidence points to the fact that the clock started as an astronomical showpiece that happened also to indicate the time. Gradually the timekeeping functions became more important and the device that showed the marvelous clockwork of the heavens became subsidiary. Behind the astronomical clocks of the 14th century there stretches an unbroken sequence of mechanical models of astronomical theory. At the head of this sequence is the

Antikythera mechanism. Following it are instruments and clocklike computers known from Islam, from China and India and from the European Middle Ages. The importance of this line is very great, because it was the tradition of clock-making that preserved most of man's skill in scientific fine mechanics. During the Renaissance the scientific instrument-makers evolved from the clock-makers. Thus the Antikythera mechanism is, in a way, the venerable progenitor of all our present plethora of scientific hardware.

A significant passage in this story has to do with the astronomical computers of Islam. Preserved complete at the Museum of History of Science at Oxford is a 13th-century Islamic geared calendar-computer that has various periods built into it, so that it shows on dials the various cycles of the sun and moon. This design can be traced back, with slightly different periods but a similar arrangement of gears, to a manuscript written by the astronomer al-Biruni about 1000 A.D. Such instruments are much simpler than the Antikythera mechanism, but they show so many points of agreement in technical detail that it seems clear they come from a common tradition. The same 60-degree gear teeth are used; wheels are mounted on square-shanked axles; the geometrical layout of the gear assembly appears comparable. It was just at this time that Islam was drawing on Greek knowledge and rediscovering ancient Greek texts. It seems likely that the Antikythera tradition was part of a large corpus of knowledge that has since been lost to us but was known to the Arabs. It was developed and transmitted by them to medieval Europe, where it became the foundation for the whole range of subsequent invention in the field of clockwork.

On the one hand the Islamic devices knit the whole story together, and demonstrate that it is through ancestry and not mere coincidence that the Antikythera mechanism resembles a modern clock. On the other hand they show that the Antikythera mechanism was no flash in the pan but was a part of an important current in Hellenistic civilization. History has contrived to keep that current dark to us, and only the accidental underwater preservation of fragments that would otherwise have crumbled to dust has now brought it to light. It is a bit frightening to know that just before the fall of their great civilization the ancient Greeks had come so close to our age, not only in their thought, but also in their scientific technology.



the axles and support blocks at the back (*d*), main driving wheel (*e*), crown wheel (*f*), input axle (*g*), shaft of the upper-dial main pointer (*h*), shaft of the upper-dial subsidiary pointer (*i*), epicyclic turntable (*j*), repair to tooth (*k*), shaft of the lower-dial main pointer (*l*), shaft of the lower-dial subsidiary pointer (*m*), axles through the plate (*x* and *y*).

Love in Infant Monkeys

Affection in infants was long thought to be generated by the satisfactions of feeding. Studies of young rhesus monkeys now indicate that love derives mainly from close bodily contact

by Harry F. Harlow

The first love of the human infant is for his mother. The tender intimacy of this attachment is such that it is sometimes regarded as a sacred or mystical force, an instinct incapable of analysis. No doubt such compunctions, along with the obvious obstacles in the way of objective study, have hampered experimental observation of the bonds between child and mother.

Though the data are thin, the theoretical literature on the subject is rich. Psychologists, sociologists and anthropologists commonly hold that the infant's love is learned through the association of the mother's face, body and other physical characteristics with the alleviation of internal biological tensions, particularly hunger and thirst. Traditional psychoanalysts have tended to emphasize the role of attaining and sucking at the breast as the basis for affectional development. Recently a number of child psychiatrists have questioned such simple explanations. Some argue that affectionate handling in the act of nursing is a variable of importance, whereas a few workers suggest that the composite activities of nursing, contact, clinging and even seeing and hearing work together to elicit the infant's love for his mother.

Now it is difficult, if not impossible, to use human infants as subjects for the studies necessary to break through the present speculative impasse. At birth the infant is so immature that he has little or no control over any motor system other than that involved in sucking. Furthermore, his physical maturation is so slow that by the time he can achieve precise, coordinated, measurable responses of his head, hands, feet and body, the nature and sequence of development have been hopelessly confounded and obscured. Clearly research into

the infant-mother relationship has need of a more suitable laboratory animal. We believe we have found it in the infant monkey. For the past several years our group at the Primate Laboratory of the University of Wisconsin has been employing baby rhesus monkeys in a study that we believe has begun to yield significant insights into the origin of the infant's love for his mother.

Baby monkeys are far better coordinated at birth than human infants. Their responses can be observed and evaluated with confidence at an age of 10 days or even earlier. Though they mature much more rapidly than their human contemporaries, infants of both species follow much the same general pattern of development.

Our interest in infant-monkey love grew out of a research program that involved the separation of monkeys from their mothers a few hours after birth. Employing techniques developed by Gertrude van Wagenen of Yale University, we had been rearing infant monkeys on the bottle with a mortality far less than that among monkeys nursed by their mothers. We were particularly careful to provide the infant monkeys with a folded gauze diaper on the floor of their cages, in accord with Dr. van Wagenen's observation that they would tend to maintain intimate contact with such soft, pliant surfaces, especially during nursing. We were impressed by the deep personal attachments that the monkeys formed for these diaper pads, and by the distress that they exhibited when the pads were briefly removed once a day for purposes of sanitation. The behavior of the infant monkeys was reminiscent of the human infant's attachment to its blankets, pillows, rag dolls or cuddly teddy bears.

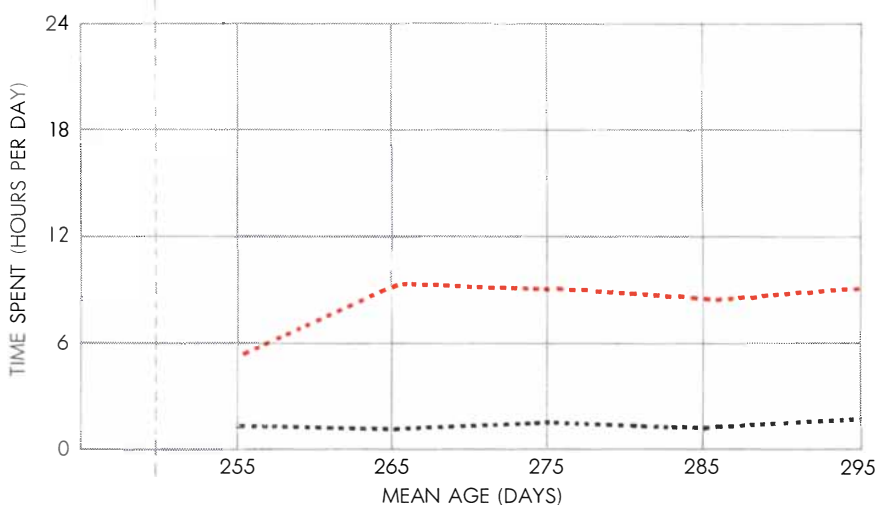
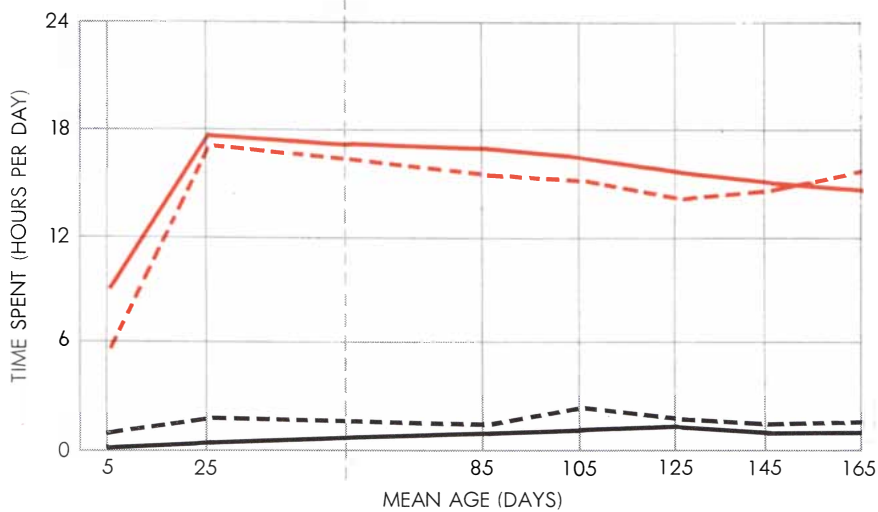
These observations suggested the series of experiments in which we have sought to compare the importance of nursing and all associated activities with that of simple bodily contact in engendering the infant monkey's attachment to its mother. For this purpose we contrived two surrogate mother monkeys. One is a bare welded-wire cylindrical form surmounted by a wooden head with a crude face. In the other the welded wire is cushioned by a sheathing of terry cloth. We placed eight newborn monkeys in individual cages, each with equal access to a cloth and a wire mother [*see illustration on opposite page*]. Four of the infants received their milk from one mother and four from the other, the milk being furnished in each case by a nursing bottle, with its nipple protruding from the mother's "breast."

The two mothers quickly proved to be physiologically equivalent. The monkeys in the two groups drank the same amount of milk and gained weight at the same rate. But the two mothers proved to be by no means psychologically equivalent. Records made automatically showed that both groups of infants spent far more time climbing and clinging on their cloth-covered mothers than they did on their wire mothers. During the infants' first 14 days of life the floors of the cages were warmed by an electric heating pad, but most of the infants left the pad as soon as they could climb on the unheated cloth mother. Moreover, as the monkeys grew older, they tended to spend an increasing amount of time clinging and cuddling on her pliant terry-cloth surface. Those that secured their nourishment from the wire mother showed no tendency to spend more time on her than feeding required, contradicting the idea that affection is a response that is learned or derived in asso-

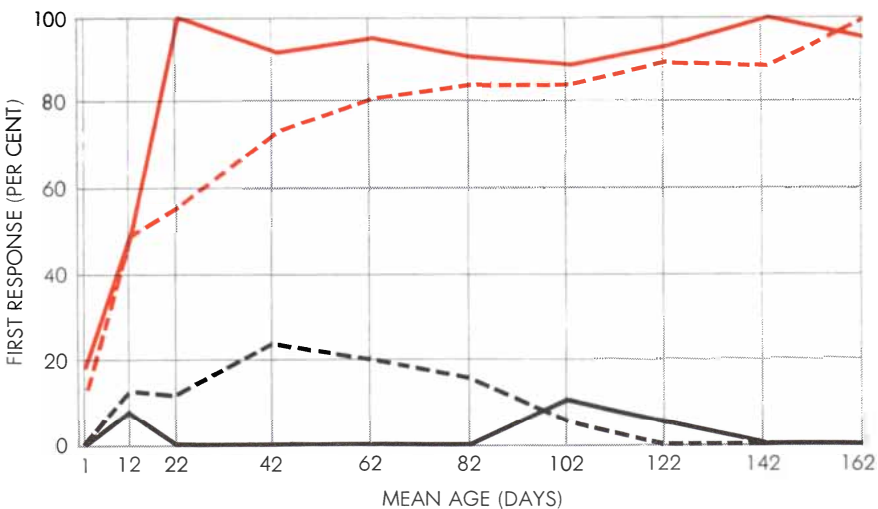


CLOTH AND WIRE MOTHER-SURROGATES were used to test the preferences of infant monkeys. The infants spent most of their

time clinging to the soft cloth "mother," (*foreground*) even when nursing bottles were attached to the wire mother (*background*).



STRONG PREFERENCE FOR CLOTH MOTHER was shown by all infant monkeys. Infants reared with access to both mothers from birth (*top chart*) spent far more time on the cloth mother (*colored curves*) than on the wire mother (*black curves*). This was true regardless of whether they had been fed on the cloth (*solid lines*) or on the wire mother (*broken lines*). Infants that had known no mother during their first eight months (*bottom chart*) soon came to prefer cloth mother, but spent less time on her than the other infants.



RESULTS OF "FEAR TEST" (*see photographs on opposite page*) showed that infants confronted by a strange object quickly learned to seek reassurance from the cloth mother (*colored curves*) rather than from the wire mother (*black curves*). Again infants fed on the wire mother (*broken lines*) behaved much like those fed on cloth mother (*solid lines*).

ciation with the reduction of hunger or thirst.

These results attest the importance—possibly the overwhelming importance—of bodily contact and the immediate comfort it supplies in forming the infant's attachment for its mother. All our experience, in fact, indicates that our cloth-covered mother surrogate is an eminently satisfactory mother. She is available 24 hours a day to satisfy her infant's overwhelming compulsion to seek bodily contact; she possesses infinite patience, never scolding her baby or biting it in anger. In these respects we regard her as superior to a living monkey mother, though monkey fathers would probably not endorse this opinion.

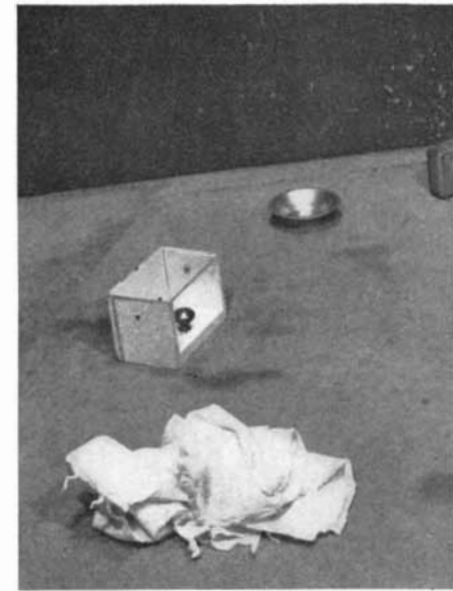
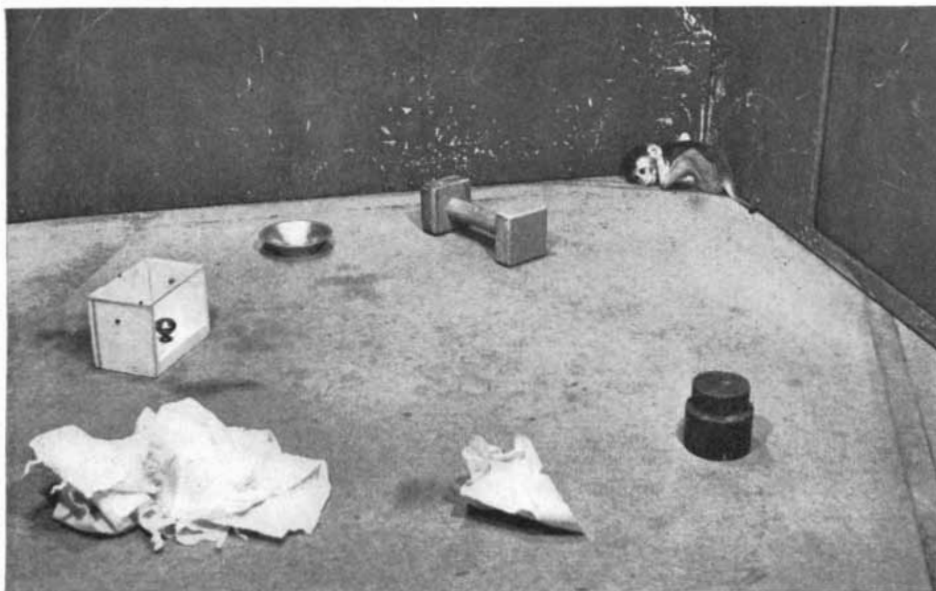
Of course this does not mean that nursing has no psychological importance. No act so effectively guarantees intimate bodily contact between mother and child. Furthermore, the mother who finds nursing a pleasant experience will probably be temperamentally inclined to give her infant plenty of handling and fondling. The real-life attachment of the infant to its mother is doubtless influenced by subtle multiple variables, contributed in part by the mother and in part by the child. We make no claim to having unraveled these in only two years of investigation. But no matter what evidence the future may disclose, our first experiments have shown that contact comfort is a decisive variable in this relationship.

Such generalization is powerfully supported by the results of the next phase of our investigation. The time that the infant monkeys spent cuddling on their surrogate mothers was a strong but perhaps not conclusive index of emotional attachment. Would they also seek the inanimate mother for comfort and security when they were subjected to emotional stress? With this question in mind we exposed our monkey infants to the stress of fear by presenting them with strange objects, for example a mechanical teddy bear which moved forward, beating a drum. Whether the infants had nursed from the wire or the cloth mother, they overwhelmingly sought succor from the cloth one; this differential in behavior was enhanced with the passage of time and the accrual of experience. Early in this series of experiments the terrified infant might rush blindly to the wire mother, but even if it did so it would soon abandon her for the cloth mother. The infant would cling to its cloth mother, rubbing its body against hers. Then, with its fears assuaged through intimate contact with the moth-



FRIGHTENING OBJECTS such as a mechanical teddy bear caused almost all infant monkeys to flee blindly to the cloth mother, as in

the top photograph. Once reassured by pressing and rubbing against her, they would then look at the strange object (*bottom*).



“OPEN FIELD TEST” involved placing a monkey in a room far larger than its accustomed cage; unfamiliar objects added an addi-

tional disturbing element. If no mother was present, the infant would typically huddle in a corner (*left*). The wire mother did

er, it would turn to look at the previously terrifying bear without the slightest sign of alarm. Indeed, the infant would sometimes even leave the protection of the mother and approach the object that a few minutes before had reduced it to abject terror.

The analogy with the behavior of human infants requires no elaboration. We found that the analogy extends even to less obviously stressful situations. When a child is taken to a strange place, he usually remains composed and happy so long as his mother is nearby. If the mother gets out of sight, however, the child is often seized with fear and distress. We developed the same response in our infant monkeys when we exposed them to a room that was far larger than the cages to which they were accustomed. In the room we had placed a number of unfamiliar objects such as a small artificial tree, a crumpled piece of paper, a folded gauze diaper, a wooden block and a doorknob [*a similar experiment is depicted in the illustrations on these two pages*]. If the cloth mother was in the room, the infant would rush wildly to her, climb upon her, rub against her and cling to her tightly. As in the previous experiment, its fear then sharply diminished or vanished. The infant would begin to climb over the mother's body and to explore and manipulate her face. Soon it would leave the mother to investigate the new world, and the unfamiliar objects would become playthings. In a typical behavior sequence, the infant might manipulate the tree, return to the mother, crumple the wad of paper, bring it to the mother, explore the block, ex-

plore the doorknob, play with the paper and return to the mother. So long as the mother provided a psychological “base of operations” the infants were unafraid and their behavior remained positive, exploratory and playful.

If the cloth mother was absent, however, the infants would rush across the test room and throw themselves face-down on the floor, clutching their heads and bodies and screaming their distress. Records kept by two independent observers—scoring for such “fear indices” as crying, crouching, rocking and thumb- and toe-sucking—showed that the emotionality scores of the infants nearly tripled. But no quantitative measurement can convey the contrast between the positive, outgoing activities in the presence of the cloth mother and the stereotyped withdrawn and disturbed behavior in the motherless situation.

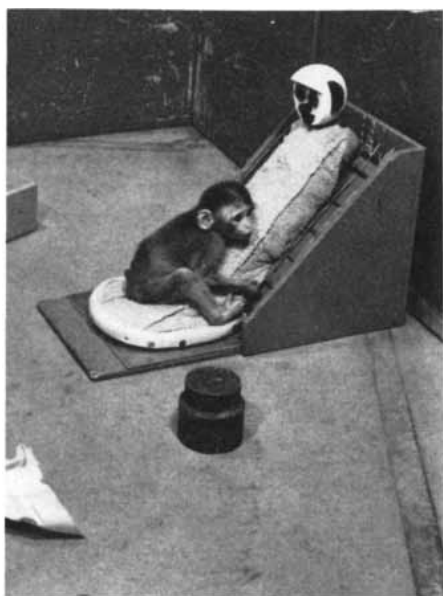
The bare wire mother provided no more reassurance in this “open field” test than no mother at all. Control tests on monkeys that from birth had known only the wire mother revealed that even these infants showed no affection for her and obtained no comfort from her presence. Indeed, this group of animals exhibited the highest emotionality scores of all. Typically they would run to some wall or corner of the room, clasp their heads and bodies and rock convulsively back and forth. Such activities closely resemble the autistic behavior seen frequently among neglected children in and out of institutions.

In a final comparison of the cloth and wire mothers, we adapted an experiment originally devised by Robert A. Butler

at the Primate Laboratory. Butler had found that monkeys enclosed in a dimly lighted box would press a lever to open and reopen a window for hours on end for no reward other than the chance to look out. The rate of lever-pressing depended on what the monkeys saw through the opened window; the sight of another monkey elicited far more activity than that of a bowl of fruit or an empty room [see “Curiosity in Monkeys,” by Robert A. Butler; *SCIENTIFIC AMERICAN*, February, 1954]. We now know that this “curiosity response” is innate. Three-day-old monkeys, barely able to walk, will crawl across the floor of the box to reach a lever which briefly opens the window; some press the lever hundreds of times within a few hours.

When we tested our monkey infants in the “Butler box,” we found that those reared with both cloth and wire mothers showed as high a response to the cloth mother as to another monkey, but displayed no more interest in the wire mother than in an empty room. In this test, as in all the others, the monkeys fed on the wire mother behaved the same as those fed on the cloth mother. A control group raised with no mothers at all found the cloth mother no more interesting than the wire mother and neither as interesting as another monkey.

Thus all the objective tests we have been able to devise agree in showing that the infant monkey's relationship to its surrogate mother is a full one. Comparison with the behavior of infant monkeys raised by their real mothers confirms this view. Like our experimental monkeys, these infants spend many



not alter this pattern of fearful behavior, but the cloth mother provided quick reassurance. The infant would first cling to her

(center) and then set out to explore the room and play with the objects (right), returning from time to time for more reassurance.

hours a day clinging to their mothers, and run to them for comfort or reassurance when they are frightened. The deep and abiding bond between mother and child appears to be essentially the same, whether the mother is real or a cloth surrogate.

While bodily contact clearly plays the prime role in developing infantile affection, other types of stimulation presumably supplement its effects. We have therefore embarked on a search for these other factors. The activity of a live monkey mother, for example, provides her infant with frequent motion stimulation. In many human cultures mothers bind their babies to them when they go about their daily chores; in our own culture parents know very well that rocking a baby or walking with him somehow promotes his psychological and physiological well-being. Accordingly we compared the responsiveness of infant monkeys to two cloth mothers, one stationary and one rocking. All of them preferred the rocking mother, though the degree of preference varied considerably from day to day and from monkey to monkey. An experiment with a rocking crib and a stationary one gave similar results. Motion does appear to enhance affection, albeit far less significantly than simple contact.

The act of clinging, in itself, also seems to have a role in promoting psychological and physiological well-being. Even before we began our studies of affection, we noticed that a newborn monkey raised in a bare wire cage survived with difficulty unless we provided it with a cone to which it could cling. Re-

cently we have raised two groups of monkeys, one with a padded crib instead of a mother and the other with a cloth mother as well as a crib. Infants in the latter group actually spend more time on the crib than on the mother, probably because the steep incline of the mother's cloth surface makes her a less satisfactory sleeping platform. In the open-field test, the infants raised with a crib but no mother clearly derived some emotional support from the presence of the crib. But those raised with both showed an unequivocal preference for the mother they could cling to, and they evidenced the benefit of the superior emotional succor they gained from her.

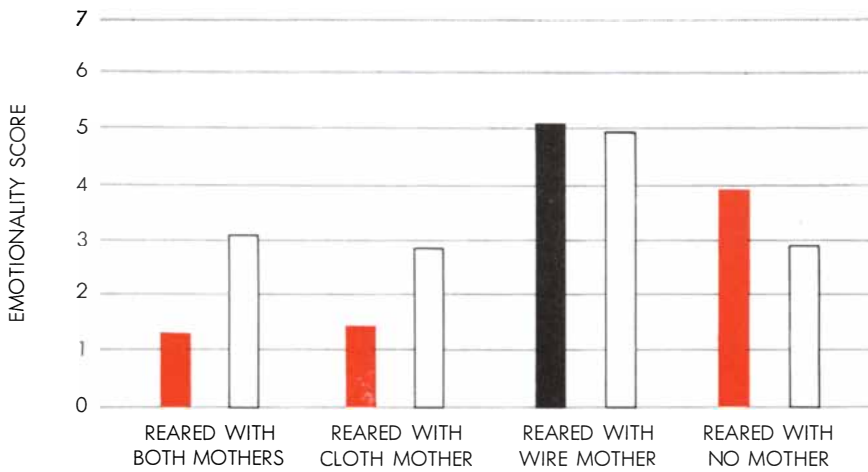
Still other elements in the relationship remain to be investigated systematically. Common sense would suggest that the warmth of the mother's body plays its part in strengthening the infant's ties to her. Our own observations have not yet confirmed this hypothesis. Heating a cloth mother does not seem to increase her attractiveness to the infant monkey, and infants readily abandon a heating pad for an unheated mother surrogate. However, our laboratory is kept comfortably warm at all times; experiments in a chilly environment might well yield quite different results.

Visual stimulation may forge an additional link. When they are about three months old, the monkeys begin to observe and manipulate the head, face and eyes of their mother surrogates; human infants show the same sort of delayed responsiveness to visual stimuli. Such stimuli are known to have marked ef-

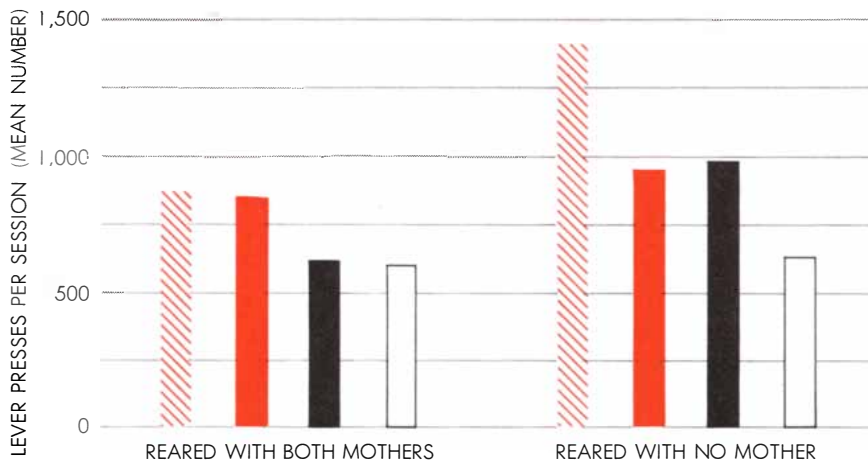
fects on the behavior of many young animals. The Austrian zoologist Konrad Lorenz has demonstrated a process called "imprinting"; he has shown that the young of some species of birds become attached to the first moving object they perceive, normally their mothers [see "'Imprinting' in Animals," by Eckhard H. Hess; *SCIENTIFIC AMERICAN*, March, 1958]. It is also possible that particular sounds and even odors may play some role in the normal development of responses or attention.

The depth and persistence of attachment to the mother depend not only on the kind of stimuli that the young animal receives but also on when it receives them. Experiments with ducks show that imprinting is most effective during a critical period soon after hatching; beyond a certain age it cannot take place at all. Clinical experience with human beings indicates that people who have been deprived of affection in infancy may have difficulty forming affectional ties in later life. From preliminary experiments with our monkeys we have found that their affectional responses develop, or fail to develop, according to a similar pattern.

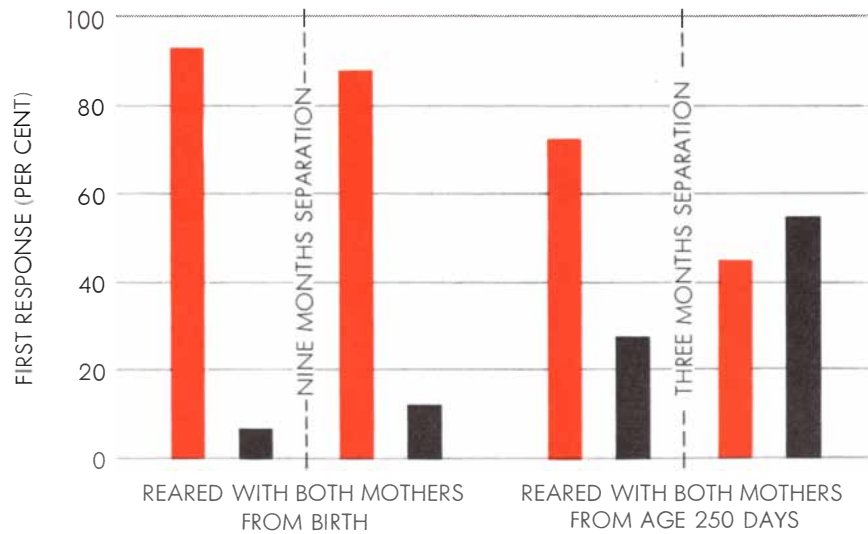
Early in our investigation we had segregated four infant monkeys as a general control group, denying them physical contact either with a mother surrogate or with other monkeys. After about eight months we placed them in cages with access to both cloth and wire mothers. At first they were afraid of both surrogates, but within a few days they began to respond in much the same way as the other infants. Soon they were



SCORES IN OPEN FIELD TEST show that all infant monkeys familiar with the cloth mother were much less disturbed when she was present (*color*) than when no mother was present (*white*); scores under 2 indicate unfrightened behavior. Infants that had known only the wire mother were greatly disturbed whether she was present (*black*) or not (*white*).



“CURIOSITY TEST” SHOWED THAT monkeys reared with both mothers displayed as much interest in the cloth mother (*solid color*) as in another monkey (*hatched color*); the wire mother (*black*) was no more interesting than an empty chamber (*white*). Monkeys reared with no mother found cloth and wire mother less interesting than another monkey.



EARLY “MOTHERING” produced a strong and unchanging preference for the cloth mother (*color*) over the wire mother (*black*). Monkeys deprived of early mothering showed less marked preferences before separation and no significant preference subsequently.

spending less than an hour a day with the wire mother and eight to 10 hours with the cloth mother. Significantly, however, they spent little more than half as much time with the cloth mother as did infants raised with her from birth.

In the open-field test these “orphan” monkeys derived far less reassurance from the cloth mothers than did the other infants. The deprivation of physical contact during their first eight months had plainly affected the capacity of these infants to develop the full and normal pattern of affection. We found a further indication of the psychological damage wrought by early lack of mothering when we tested the degree to which infant monkeys retained their attachments to their mothers. Infants raised with a cloth mother from birth and separated from her at about five and a half months showed little or no loss of responsiveness even after 18 months of separation. In some cases it seemed that absence had made the heart grow fonder. The monkeys that had known a mother surrogate only after the age of eight months, however, rapidly lost whatever responsiveness they had acquired. The long period of maternal deprivation had evidently left them incapable of forming a lasting affectional tie.

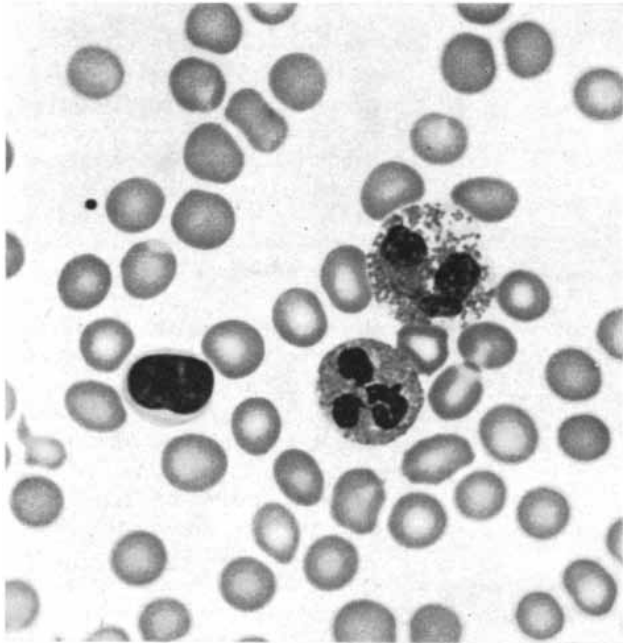
The effects of maternal separation and deprivation in the human infant have scarcely been investigated, in spite of their implications concerning child-rearing practices. The long period of infant-maternal dependency in the monkey provides a real opportunity for investigating persisting disturbances produced by inconsistent or punishing mother surrogates.

Above and beyond demonstration of the surprising importance of contact comfort as a prime requisite in the formation of an infant’s love for its mother—and the discovery of the unimportant or nonexistent role of the breast and act of nursing—our investigations have established a secure experimental approach to this realm of dramatic and subtle emotional relationships. The further exploitation of the broad field of research that now opens up depends merely upon the availability of infant monkeys. We expect to extend our researches by undertaking the study of the mother’s (and even the father’s!) love for the infant, using real monkey infants or infant surrogates. Finally, with such techniques established, there appears to be no reason why we cannot at some future time investigate the fundamental neurophysiological and biochemical variables underlying affection and love.

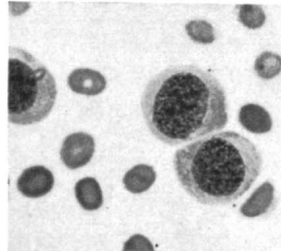
Kodak reports on:

blood in depth . . . a way to stiffen oil . . . a nice material to coat with photographic emulsion

The sanguinary details



Among the red cells, three of the principal types of white cells, left to right: a lymphocyte, representing about 30% of the white cells; a neutrophil, representing 60%; an eosinophil, representing about 2%.



Megaloblastic cells, characteristic of the pattern of red cell maturation in pernicious anemia.



Erythrophagocyte, seen in an uncommon blood condition, where white cells swallow red cells. Here is one that has eaten three.

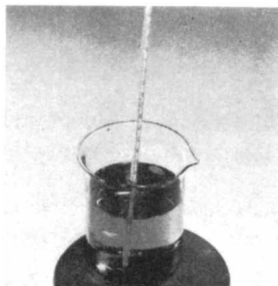
The objective documentation of hematological observations through properly controlled photomicrography is treated with some depth in the current issue of our periodical *Medical Radiography and Photography*. It contains some excellent color photomicrographs, including a series which depicts the maturation of human blood cells. However, if we were to go to the expense of reproducing the color on this page, it would use up money better spent in face-to-face instruction in hematological photomicrography for those who need it. You can look at the color all you want to by requesting a copy of the blood issue of *M. R. & P.* from Eastman Kodak Company, Medical Sales Division, Rochester 4, N. Y.

More film may be expended on Old Faithful in Yellowstone National Park than on all the blood in the world. Every man has his own idea of a natural marvel to photograph.

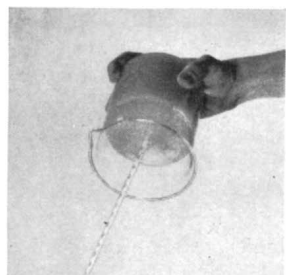
Look, ma! Practically no hydrogenation!



1. Into a liquid triglyceride such as cottonseed oil put a small percentage of monoglyceride made from any saturated fat.



2. Heat to about 75°C and cool.



3. The oil becomes a stiff solid. The crystalline matrix holds the oil for prolonged periods with practically no leakage.

This works only with exceptionally pure monoglycerides such as we make by molecular distillation in carload quantities. To find out more, write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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

Flatness

Complexity, complexity! Rest the mind on a simple product, a photographic-emulsion-bearing rectangle 6.0 millimeters thick, 190 millimeters wide, 215 millimeters long, and flat within 0.00002-inch per inch. We mean: **Nowhere on the surface bearing the emulsion will it be possible to draw a circle of one-inch diameter containing a point of the surface more than 0.00002-inch distant from the plane of the circle.** Though achievement of such flatness is not simple, that is none of the user's business.

The user's business is to know the path of a man-made object moving across the sky and to know it with the best precision that man can currently master for the task. The work requires dimensional constancy of the material which bears the image.

That material is glass, a substance known to the Phoenicians and since improved. Our kind alters its linear dimensions by 0.00045% for each degree Fahrenheit of temperature change. Polyester, the most dimensionally stable of commercially available plastics, is called "stabilized" when its temperature coefficient is brought down to twice that. For the hardened steel from which gage blocks are made, the linear expansion coefficient is down to 0.00056%. Steel is opaque and does wicked things to sensitive emulsions.

George Eastman quit his job as a bank clerk in 1881 when he found he could coat emulsion on glass and sell it. That's how our whole business started. Don't think of the photographic plate as an antique, however. To find out how wrong that would be, try putting a question to Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y. For one thing, you could ask about those ballistic camera plates announced above.

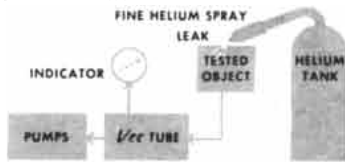
Kodak
TRADE MARK

LEAKS can be serious

...when a fixed pressure, vacuum or specific atmosphere must be maintained for the success of an experiment or the integrity of a finished product. And, the most sensitive method yet developed for pinpointing microscopic leaks is the VEECO Mass Spectrometer Leak Detector. It measures a leak with a "tracer gas", helium, by means of a constantly accurate "sensing element", the patented VEECO Veetube.

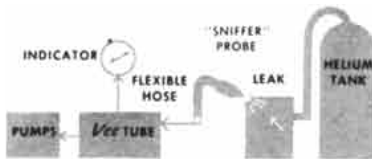
There are three major test methods possible with a VEECO Detector.

VACUUM TESTING



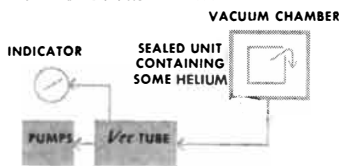
The evacuated test object, connected to the Leak Detector, is sprayed with a fine jet of helium, or for an over-all test, blanketed with the gas. If a leak exists, helium is sucked into the Veetube and converted into a precise Leak Meter reading.

PRESSURE TESTING



An object can also be tested by pressurizing it with helium. Then a "sniffer", attached to the Detector, is used to probe the test object. If a leak exists, helium is sucked into the Veetube and converted into a Leak Meter reading.

PRESSURE-VACUUM TESTING



A test object, pressurized with helium, is placed within a vacuum chamber connected to the Detector. If a leak exists, helium flows out of the object into the vacuum chamber, and thence to the Veetube where it's converted into a precise Leak Meter reading.

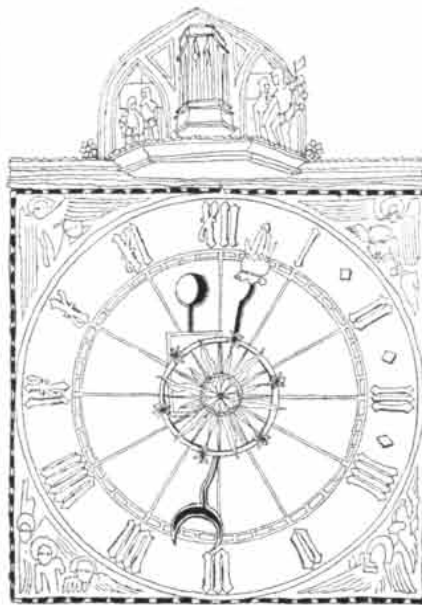
For more information, WRITE:



**VEECO
VACUUM
CORP.**

86-S Denton Avenue, New Hyde Park
Long Island, New York

HIGH VACUUM & LEAK DETECTION EQUIPMENT



Strontium in the Skeleton

A week of hearings before a subcommittee of the Joint Congressional Committee on Atomic Energy produced testimony that the fallout of fission products already injected into the upper atmosphere will ultimately double the population's exposure to radiation from this source. Witnesses agreed that resumption of tests at the rate prevailing during the past five years would ultimately constitute a world-wide threat to public health. But there was dispute as to the standards of permissible exposure to fission products (especially strontium 90), and so no agreement as to the hazard created by atomic-weapons tests.

According to the General Advisory Committee of the Atomic Energy Commission, nuclear explosions totaling 65 megatons of fission energy have burdened the atmosphere with fission products equivalent to 100 pounds of strontium 90. About 50 pounds have already fallen out, and most of the balance will come down over the next few years. Nearly three quarters of the fallout, the A.E.C. reported in a separate statement, is of Western, primarily U. S., origin. The General Advisory Committee noted, however, that the average lifetime exposure to external radiation from fallout would come to "less than 5 per cent as much as the average exposure to . . . background radiation." (The equivalent A.E.C. estimate in 1956 was 2.3 per cent.) It described internal radiation from strontium 90 in food and water as being "less of a hazard than the amount of radium normally present in public drinking water supplies

SCIENCE AND

in certain places in the United States."

Before the hearings began the National Committee on Radiation Protection and Measurements had issued a report downgrading the strontium-90 hazard. The Committee recommended that the permissible concentration of strontium 90 in the human skeleton might safely be doubled. At the same time the principal assumption underlying prevailing standards of permissible exposure was sharply questioned by W. O. Caster, a physiological chemist of the University of Minnesota. Writing in the *Minnesota Chemist*, he pointed out that these standards invariably assume uniform distribution of strontium in the human skeleton. Swedish investigators have shown, however, that local "hot spots" in the skeleton may contain up to 60 times the average concentration. Current standards of permissible concentration, Caster concludes, may be 60 times too high for safety. Thus an average concentration of 180 strontium units, which the A.E.C. now regards as "safe," would "double and perhaps triple a person's chances of having leukemia and place him just above the threshold for bone damage." Caster believes that the standard might well be set as low as three strontium units.

In the Joint Committee hearings Wright Langham of the Los Alamos Scientific Laboratory presented estimates showing that the average world level of strontium in human skeletons will rise to a maximum of seven strontium units in the mid-1960's. The level will be higher in the countries of the Far East because of differences in diet.

Another witness, Charles L. Dunham, director of the A.E.C. Division of Biology and Medicine, testified that strontium in the bones of young children in this country might reach an average of 10 units. Over the next 70 years, he said, this dosage could produce 3,500 to 7,000 cases of bone cancer, and perhaps twice as many cases of leukemia. He later indicated that these estimates assume uniform distribution of strontium in the skeleton.

Over-all Structure of a Protein

The tertiary structure of a protein—the three-dimensional arrangement of the chains of amino acid units in the

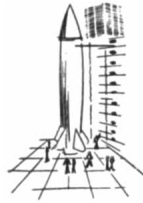
THE CITIZEN

protein molecule—has been worked out for the first time. Surprisingly the molecule is almost totally lacking in symmetry, and it is far more complex than could have been predicted by any existing theory of protein structure. This was stated by J. C. Kendrew of the Cavendish Laboratory at the University of Cambridge, who described his work on the protein myoglobin at the recent Atlantic City, N. J., meeting of the Federation of American Societies for Experimental Biology.

Kendrew explained that proteins have three levels of structure: the sequence of their amino acid units (primary structure); the way in which the amino acid units are coiled or folded in a long polypeptide chain (secondary structure); and finally the way in which the polypeptide chain is arranged in molecules of various over-all forms (tertiary structure).

Kendrew has constructed a solid model of the myoglobin molecule which has the polypeptide chains arranged like a ball of thick spaghetti; a heme group (which performs the oxygen-binding function of the molecule) sticks out on one side. The main body of the molecule, which facilitates the chemical action of the heme group in some still-unknown manner, appears to be a single convoluted polypeptide chain some 300 angstrom units long. Apparently the helical secondary structure of the main chain is not uniform throughout, because the molecule's 152 amino acid units would form a chain only 228 angstroms long if they were coiled in the tight "alpha-helix" predicted by theory. The 300-angstrom length suggests that the chain is pulled out in some regions.

Kendrew determined the protein's structure by using an X-ray-diffraction method of Max F. Perutz, a colleague who has been working to determine the tertiary structure of the complex molecule of hemoglobin. Perutz's difficulties led Kendrew to focus on the simpler and much smaller molecule of myoglobin: an oxygen-binding protein found mainly in the muscles of birds or of whales. Kendrew attached atoms of metals with high electron-density (such as mercury, silver and gold) on the polypeptide chain and then bounced X-rays from them to make electron-density maps of the molecule. The maps



available astronauts

(30 g TO 5000 CYCLES—200 mw
— TO SCALE)

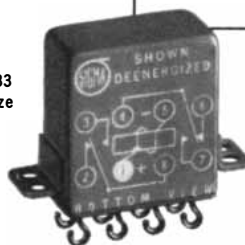
It's not easy these days to find a relay as ideally suited to fast, one-way, non-stop journeys as Morton P. Rodentia is. Morton's now-famous travels have proved conclusively that he can stand 30 g vibration to 5000 cycles while functioning, and shocks as high as 100 g do not even disturb his derby. The triumphant expression springs from his latest discovery—the Sigma Series 33 relay with vibration and shock ratings as good as his own, and a sensitivity of 200 mw to boot. As a matter of fact, this is the only switch with these specs Morton could find that also would fit into his 0.8" x 0.4" x 0.9" attache case. When last heard from, Dr. Rodentia (hon. Ph. D., Solid State U.) was dicking over delivery schedules with the supplier.

With its prime customer taken care of, Sigma is now ready to do business with anyone interested in these Series 33 relays. Similar in appearance to the perhaps better-known Series 32 magnetic latching relay, the "33" is a non-latching DPDT relay. Switching is accomplished by a signal of the correct polarity and magnitude (Sigma Form Y). Specs of major interest are as follows and are further discussed in a preliminary bulletin available on request.

SERIES 33 RELAY

VIBRATION	30 g to 5000 cps with no contact opening (energized or de-energized)
SHOCK, CONSTANT ACCEL.	100 g does not cause damage or open contacts (energized or de-energized)
SENSITIVITY	Operate 200 mw, release 2 mw.
CONTACT RATING	2 amperes at 28 VDC/120VAC, resistive load, for 100,000 operations min. at 125°C max.
SPEED	Operate time 2 to 20 ms, depending on overdrive; Release time 2.5 ms, max.
OPERATING TEMP. RANGE	-65°C. to +125°C.
CONNECTIONS	Plug-in, hook terminals or 3" leads
MOUNTING	Flange or stud
ENCLOSURE	Hermetically sealed

Series 33
Actual Size



SIGMA

SIGMA INSTRUMENTS, INC.
40 Pearl St., So. Braintree 85, Mass.

AN AFFILIATE OF THE FISHER-PIERCE CO. (SINCE 1939)

Here it is—

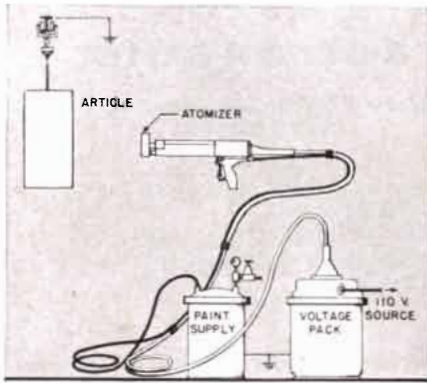
The **PAINTING TOOL**

ALL Industry
has been waiting for!

The **NEW**

RANSBURG

NO. 2 PROCESS ELECTROSTATIC HAND GUN



CUTS PAINTING COSTS!

Saves Paint because there's no waste. Now, for the first time, the high efficiency of Ransburg's No. 2 Process automatic equipment is available to you in the NEW Electrostatic Hand Gun.

Saves Labor, Increases Production because it is faster on many types of articles such as those fabricated from perforated and expanded metals, tubing, rod and wire. This is due to the "Wrap-around" nature of electro-spray which paints ALL sides of such articles from one side only.

Saves in Equipment because no conventional spray booth is required—no water-wash, no sludge recovery! Uses no compressed air for atomization.

Saves Building Heat Loss because only mild ventilation for removal of solvent vapors is necessary, and . . .

Maintenance Costs Are Cut because clean-up and maintenance labor is only a fraction of that required by other, less efficient painting methods.

See how YOU can save in your own finishing department, and at the same time, improve the quality of the work. Write for literature and information showing how the Electrostatic Hand Gun has been proven on different products in a variety of industrial plants.

RANSBURG

Electro-Coating Corp.

Box-23122, Adv. Dept., Indianapolis 23, Indiana

were combined mathematically in a digital computer to yield the geometry of the final model.

A Lively Moon?

The moon, long pictured as a cold, dead companion of the earth, may in reality have a hot interior and a shifting surface which periodically discharges gases.

At the annual meeting of the National Academy of Sciences in Washington, Dinsmore Alter, director emeritus of the Griffith Observatory in Los Angeles, reported that photographs of the moon made on October 26, 1956, with the 60-inch reflecting telescope on Mount Wilson revealed an "obscuration" over part of the crater Alphonsus. The Mount Wilson plates led a Soviet astronomer, Nikolai A. Kozyrev, to train the 50-inch Crimea Observatory reflector and a prism spectrograph on Alphonsus, and on November 3, 1958, Kozyrev obtained spectrograms confirming a discharge of gas from the crater. On the night of November 18-19, a cloud was seen over Alphonsus by astronomers and amateur observers in England, California and New Jersey.

The Alphonsus observations recall numerous reports by amateur astronomers during the past two centuries of changes in the lunar surface. Professionals have ignored all such claims since 1902, when Simon Newcomb described the moon with finality as "a world . . . on which nothing ever happens." A new theory, also presented at the National Academy meeting, not only suggests an explanation of the Alphonsus observations but also presents a new and radically different picture of the moon.

The theory was advanced by Harold C. Urey, Walter M. Elsasser and M. G. Rochester of the University of California. Its central feature is its rejection of the concept of a homogeneous moon with uniform internal density. Instead, Urey and his colleagues assert, the moon was formed from some tens or hundreds of thousands of accumulating masses of varying density. Since no melting occurred, heavier masses are distributed irregularly through the moon rather than concentrated at the center; and there are irregular variations in the moon's internal density.

The theory was developed in order to account for a troublesome irregularity in the shape of the moon, a projection of about a mile in the directions toward and away from the earth. Classical theory portrays the irregularity as a

frozen tidal wave, an explanation requiring, according to Urey and his colleagues, a moon with great internal rigidity and improbably low internal temperature.

The irregularity is easily accounted for by the new theory. Moreover, the new hypothesis allows for "considerable" movement of the lunar surface and the escape of gas as a result of heating of the moon's interior.

Toward the Mohole

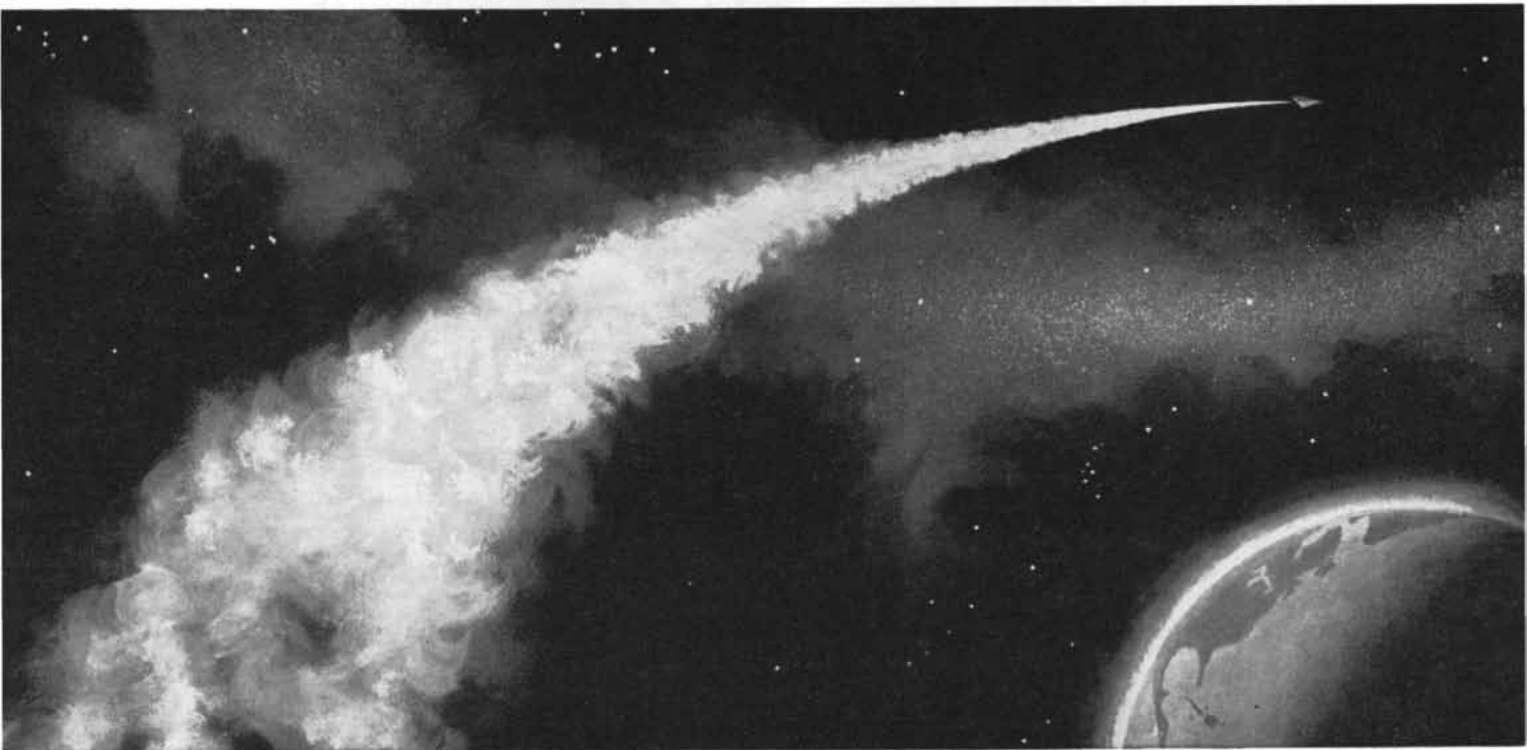
Late in May a flotilla of research vessels gathered in the Atlantic 200 miles north of Puerto Rico to carry out the first step toward transforming the Mohole [see "The Mohole," by Willard Bascom; SCIENTIFIC AMERICAN, April] from idea to reality. The flotilla met to examine a 200-by-150-mile rectangle of the ocean bottom as a possible site for the hole through the earth's crust to the mantle below.

Sponsors of the Mohole propose to drill in the open sea because the earth's crust is thinner beneath the sea than beneath the continents. The area now being surveyed is known as the Outer Ridge; it is a slight rise in the ocean floor from the abyssal plain east of the Bahamas. In the region of the Outer Ridge, which lies some 14,000 feet below the surface of the sea, the earth's crust is only three and a half miles thick. By contrast, in continental areas the Mohorovicic discontinuity—the boundary between the crust and the mantle—is 15 to 20 miles down.

Four ships are conducting the survey under the sponsorship of the AMSOC-Mohole Committee of the National Academy of Sciences. They are the *Vema*, from the Lamont Geological Observatory of Columbia University; the *Gibbs*, operated by Columbia's Hudson Laboratories for the Navy; the *Bear*, from the Woods Hole Oceanographic Institution; and the *Hidalgo* of the Texas Agricultural and Mechanical College. Coordinator of the survey is John E. Nafe of the Lamont Observatory, chief scientist aboard the *Vema*.

The four vessels are carrying out a variety of studies to determine whether the strata below the Outer Ridge are suitable for drilling. The program includes measurements of seismic refraction, gravity and ocean-floor heat-flow. In addition, cores will be taken from the bottom to determine whether fossil-bearing sediments are present. One of the chief objectives of the Mohole project is to find deep sedimentary layers with fossils from the first billion years of

DYNA-SOAR



Dyna-Soar (for dynamic soaring) is a joint project between the Air Force and the NASA, and is an attempt to solve the technical problems of manned flight in the sub-orbital regions. Advance knowledge on the project indicates how a boost-glide vehicle can operate from the outer fringes of the atmosphere where it can maneuver and be recovered undamaged. Studies show that by varying the original rocket boost,

and thus the velocity, and with the control available to the pilot, the Dyna-Soar aircraft can circumnavigate the earth, followed by a normal and controlled landing. Boeing Airplane Company, one of the competing companies for the development contract for the complete boost-glide system, has delegated to RCA the responsibility for the development of important electronic components of Dyna-Soar.

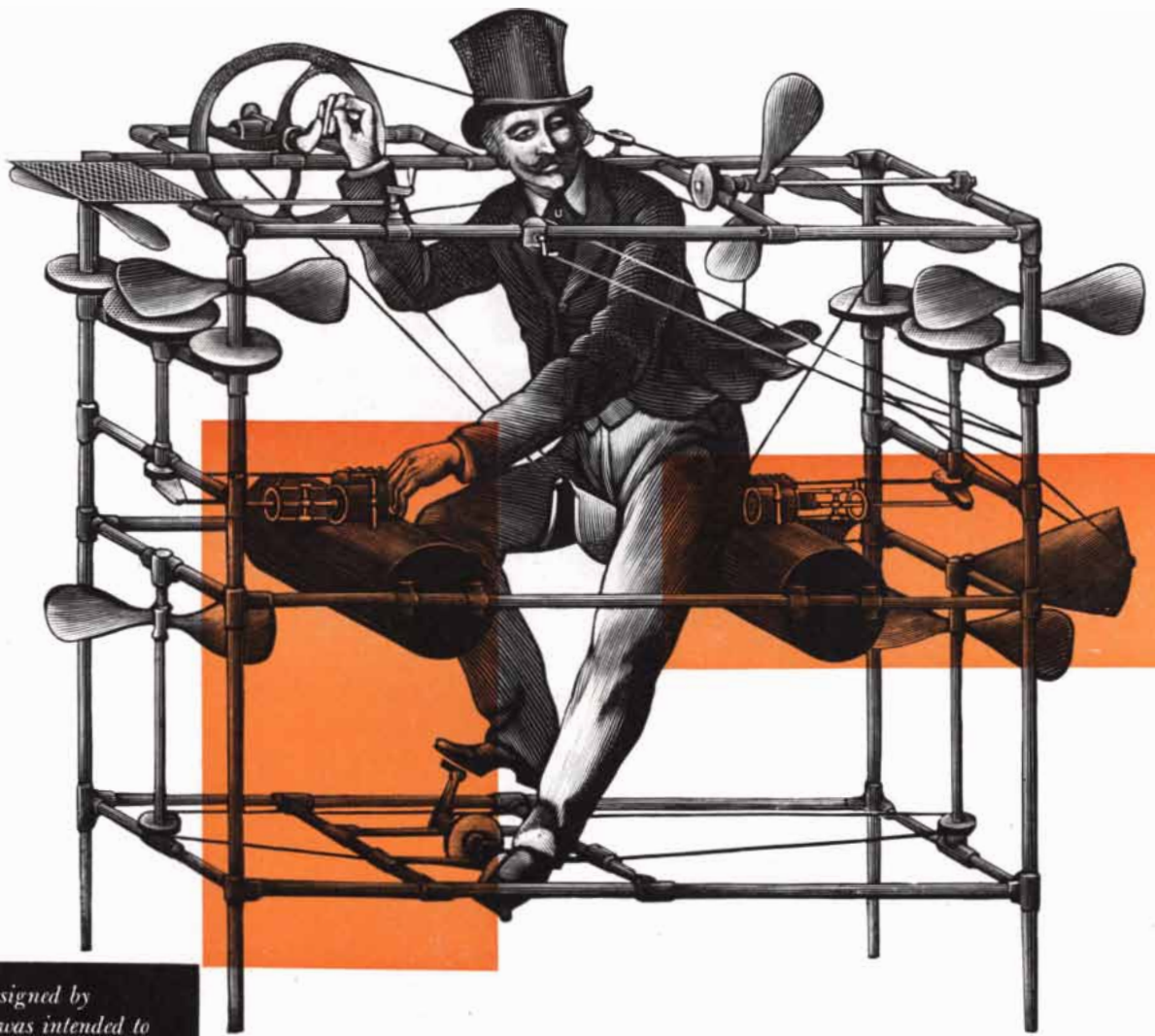


Tmk(s) ©

RADIO CORPORATION of AMERICA

DEFENSE ELECTRONIC PRODUCTS

CAMDEN, N. J.



Ayres' Aerial Machine, designed by Dr. W. O. Ayres in 1885, was intended to get off the ground through compressed air generated by foot power. In this illustration of the machine, Brussel-Smith, noted graphic artist, has used his unique wood engraving technique to depict for this advertisement another of man's efforts to find the power necessary for sustained flight.

IMAGINATION IN SPACE

Since Creation, man has looked out on space. At first, unknowing and incurious; then with the beginnings of understanding; now free and able to explore. Yet to move in space calls for wholly new concepts of energy.

This, then, is the working philosophy of Hercules in chemical propulsion: To design and manufacture highly concentrated packages of energy as propellants and rocket motors; each compatible, controllable, predictable; and each perfected for its specific mission.

HERCULES' BACKGROUND: A half-century of creative imagination in the evolution of propellants, from shotgun powder to the manufacture of every one of the millions of U. S. rockets fired during World War II, and now to space propulsion. Hercules facilities today encompass research, design, engineering, and staff organization for the production of the most advanced propellants. Illustrated brochure available on request.

HERCULES POWDER COMPANY

INCORPORATED

900 Market Street, Wilmington 99, Delaware

XP59-3



life, a period in evolutionary history that is now nearly a complete blank.

The survey will be completed by mid-June, but the results will not be known for several months. Drilling sites in the Pacific are also under consideration.

Porpoise Hydrodynamics

A secret well kept among porpoises is the way they manage to slide through the water at eight or 10 knots while hanging motionless in the bow wave of a ship. Certainly there is method in their motion, but what is the method? Writing in *Science*, P. F. Scholander of the Scripps Institution of Oceanography rejects one contemporary theory that explains the porpoise's movements in terms of gravity: When the porpoise exhales, the theory goes, it is heavier than water and can thus use its weight to slide down the slope of the wave. Scholander notes that, in a wave with a slope of 15 degrees, the forward component of the weight of a completely deflated porpoise would be only about one kilogram—barely enough to push the breathless animal along in smooth laminar flow, and not nearly enough to propel it through turbulently flowing water.

The porpoise's secret, says Scholander, lies in the tilt of its tail: It gets a forward push by leaning its tail fluke against the uprushing water of the wave. To measure this push quantitatively Scholander suspended a streamlined vane roughly the area of a porpoise's tail in the bow wave of a ship. A string made it possible to tilt the vane at various angles to the water rushing past it, and a lever attached to the vane indicated its drag in various positions. These measurements showed that the shear force of the bow wave at eight knots could impart a forward force of 18 or 20 kilograms to a porpoise that kept its tail properly down. Moreover, because the water rushes both upward and outward, the playful porpoise may roll over on its side—which many rail-hangers have seen them do—and still enjoy the effortless fluid drive. Scholander summarizes the significance of his hydrodynamic experiments by stating: "This, I believe, is the way dolphins [porpoises] ride the bow wave, and if it is not, they should try."

Colicine K

More than 30 years ago investigators in Europe turned up the fact that some strains of the ubiquitous colon bacillus (*Escherichia coli*) generate agents specifically and selectively toxic

You can explore new areas at IBM in

D	A	B	C	D		
E	F	G	H	I	J	K
L	M	N	O	P	Q	R
S	T	U	V	W	X	Y
Z	&	\$?	!	:	;

COMMUNICATIONS:

1	0	N	S
2	9		
3	8		
4	7		
5	6		

Creative people at IBM are hard at work on a problem that has vexed man since the dawn of history — communication with his fellow beings. One group of scientists and engineers, for instance, is working on multiplexing techniques to channel data. This data has to be made available at desired times and places. Another group is developing computer systems that will control complete warehousing or industrial operations. Careers in data communications are available at IBM in these areas: circuit design & research, computer analysis & design, cryogenics, industrial controls, inertial guidance, information theory, mathematics, optics, semi-conductor design, and solid state.

A New World of Opportunity. A career with IBM offers excellent advancement opportunities and rewards. You will enjoy unusual professional freedom, comprehensive education programs, and the assistance of specialists of diverse disciplines. Working independently or as a member of a small team, your individual contributions are quickly recognized. This is a unique opportunity for a career with a company that has an outstanding growth record.

Qualifications: B.S., M.S., or Ph.D. in Electrical or Mechanical Engineering, Physics, or Mathematics — plus proven ability to assume a high degree of technical responsibility in your sphere of interest.

For details, write, outlining background and interests, to:

Mr. R. E. Rodgers, Dept. 659F
IBM Corporation
590 Madison Avenue
New York 22, N. Y.

IBM®

INTERNATIONAL BUSINESS MACHINES CORPORATION



Questar is the finest and most versatile small telescope in the world. Its superb new optical system embodies the first basic discovery in telescope optics in 200 years. These optics belong to the new family of catadioptric, or mixed lens-mirror, systems, and permit a full-sized 3.5-inch telescope of 7-foot focal length to be compressed by optical folding into a closed tube only 8 inches long. Questar thus becomes the world's shortest high-powered telescope.

All Questar's advantages stem from this ultra-compactness of its unique design. Superfluous now is the great tripod, the heavy machinery and counterweights of the long-tubed single-purpose telescope. In their place is a beautiful little 7-pound example of hand craftsmanship which is not just one, but several instruments. It does many things superbly well. It does them so easily and conveniently that you might well ask why such an instrument was not made before. The answer is that an extremely short form of the new optics had to be developed, new methods devised for its manufacture, and radically new ways to mount a telescope invented and perfected.

Questar introduced the new optics to the world in this daringly short design in May, 1954, after 8 years of research and development. Since then its performance has astonished everyone, including us who make it. It has firmly established the superfine small telescope on a new level of serious respect. And it has made this company not only the world's largest manufacturer of short catadioptric telescopes but the only maker of $f/2$ Cassegrain high-power optical systems.

—These paragraphs open the 32-page Questar booklet which is illustrated by some astonishing photographs, showing 1 and 2 second detail, that let the instrument's high performance speak for itself. Questar costs only \$995 in English fitted leather case and is sold only direct at one factory price. Terms are available. May we send you a booklet?


 BOX 20 · NEW HOPE · PENNSYLVANIA

QUESTAR MAY BE SEEN IN THE TRAVELING EXHIBITION CALLED "20TH CENTURY DESIGN: U. S. A.," ALBRIGHT ART GALLERY, BUFFALO FINE ARTS ACADEMY, MAY 3 TO JUNE 11, 1959. CLEVELAND MUSEUM OF ART, JULY 8 TO AUGUST 1, 1959. CITY ART MUSEUM OF ST. LOUIS, SEPT. 14 TO OCT. 25, 1959.

to other strains of the bacillus. Investigation over the years has yielded a total of 17 distinct colicines (as these agents are called), and has opened an intriguing area of research.

Colicines are elaborated by 20 to 25 per cent of the nearly 200 strains of *E. coli* that can be distinguished by antigen-antibody testing procedures. While mainly active against strains of *E. coli*, some colicines show activity against certain strains of *Salmonella* and other enteric bacteria. A puzzling relationship exists between the ability to generate colicines and resistance to bacteriophages, the viruses which infect bacteria. For example, *E. coli* mutants resistant to the phage T6 are frequently resistant to colicine K. No chemical relationship seems to exist, however, between colicine K and phage T6.

A clue to the nature of the mysterious colicines was reported to the meeting of the National Academy of Sciences. Colicine K is a part of the so-called O antigen, a complex, variable antigen found in *E. coli* and several other species of bacteria.

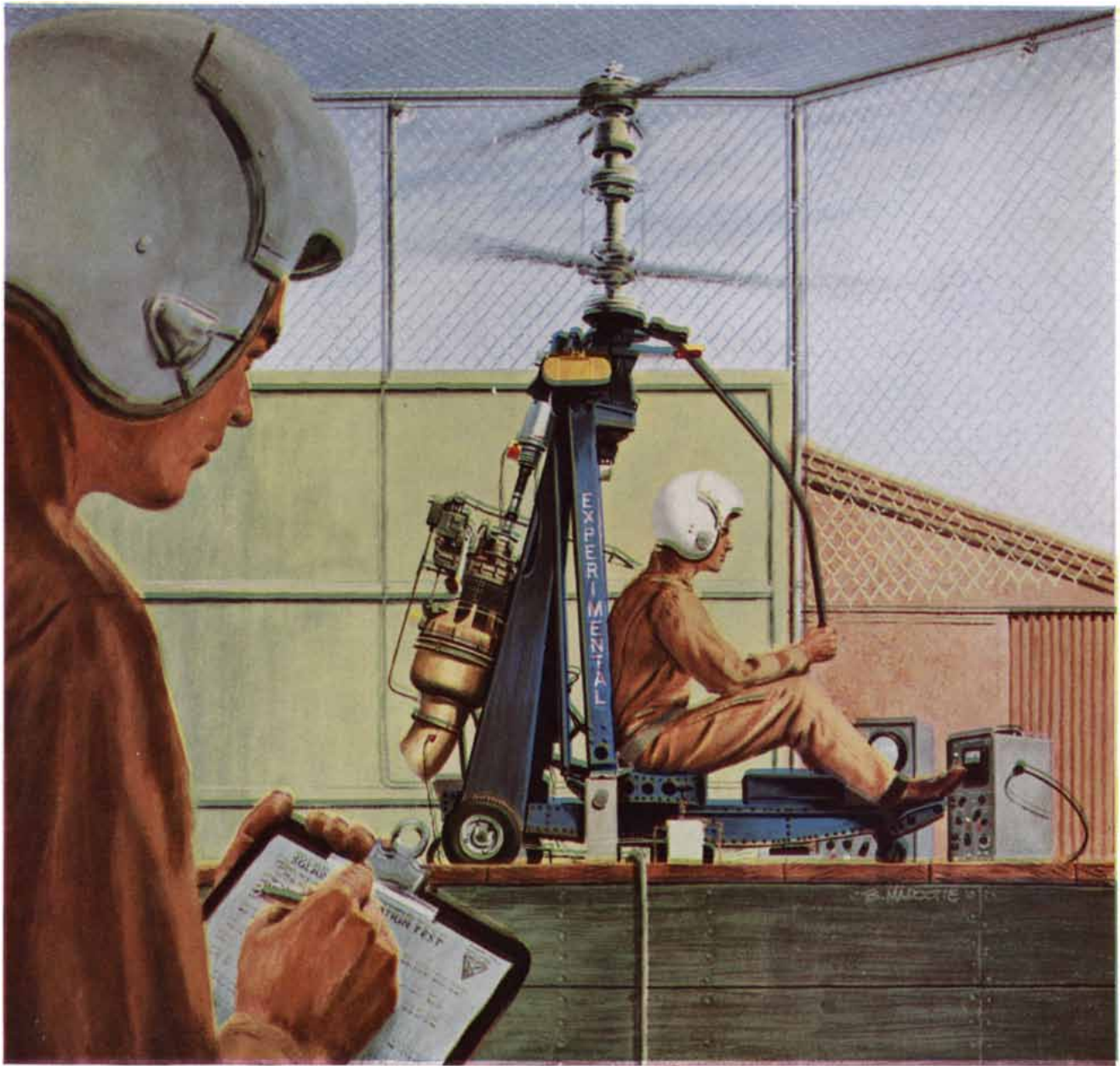
Walter F. Goebel of the Rockefeller Institute and Tsunehisa Amano of Osaka University obtained purified O antigen from a colicinogenic *E. coli* strain, K235, and also from a non-colicinogenic mutant of K235. Immunological tests showed the two O antigens to be identical in all respects save one. O antigen from the colicinogenic strain was highly toxic to certain *E. coli* strains that do not generate colicine K, whereas O antigen from the non-colicinogenic mutant was not. According to Goebel, the colicine-K property probably resides in the protein portion of the bactericidal O antigen.

For the present, research on colicines is of purely theoretical interest. Attempts to utilize O antigens during World War II for immunization against bacillary dysentery revealed that these antigens, when administered by injection, are highly toxic to many species, including man.

Space Menus

The problems of eating and drinking under weightless conditions in space, long a topic of speculation among science-fiction writers, are now under investigation in a flying laboratory. Preliminary results indicate that space travelers will drink from plastic squeeze bottles and that space cooks will specialize in semiliquid preparations resembling baby food.

Julian E. Ward, Willard R. Hawkins and Herbert Stallings of the U. S.



Test of Solar Titan gas turbine engine in one-man helicopter.

Newest Solar gas turbine ideal for wide range of applications

LIGHTWEIGHT, DEPENDABLE power is the keynote of this latest addition to Solar's growing family of gas turbine engines. Only 21 inches long and less than 13 inches in diameter, the 52 lb, 70 hp turbine is one of the simplest fuel-burning engines ever made. Originally developed for one-man helicopters, the compact power plant is nearing the end of a comprehensive test program. Instant starting, a high power to weight ratio and reliability make it an ideal

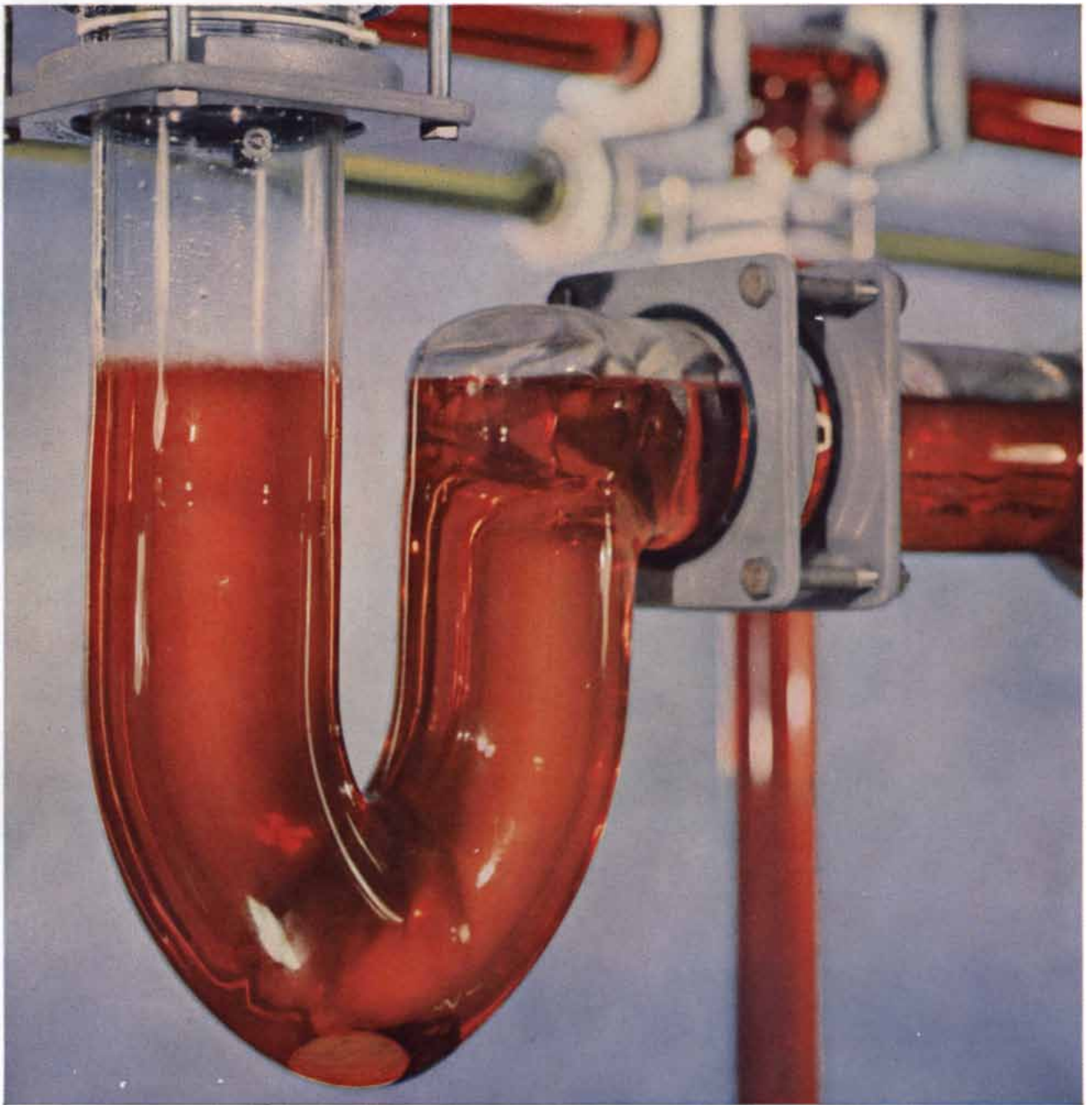
power source for airborne auxiliary power units, portable generators, missile ground support and other important applications.

Today, proven-in-service Solar gas turbines—ranging from 50 to 1100 hp—are creating new standards of performance and reliability. They are easy to maintain, start instantly after long periods of inactivity, are only a fraction of the size and weight of conventional engines of similar hp, and can burn a

wide variety of fuels—including gasoline, kerosene, diesel fuel, jet fuels and natural or manufactured gas. Investigate the Solar family of gas turbines for *your* power needs. Write to Dept. G-114, Solar Aircraft Company, San Diego 12, California.

ENGINEERS WANTED: Challenging projects, unlimited opportunities with Solar. Write today!





Idea: Transparent pipe that won't corrode!

You'll find pipe like this used for drainlines in industrial labs, hospitals, schools, chemical plants, and photo-engraving shops.

The reason? *No corrosion.* Which means no leaks, no costly downtime, no expensive patchwork maintenance.

Such piping is made from PYREX brand glass No. 7740. Besides being resistant to corrosion, it's unaffected by heat. It's smooth, inhibits build-up. It is inert, neither adding to nor taking from what comes in contact with it.

All good reasons why people use this pipe for *delicate* substances, too—like foodstuffs, beverages and pharmaceuticals.

Glass piping is only one of the thousands of forms in which you can get glass from Corning. And PYREX brand glass No. 7740 is only *one* of more than 65,000 different types of glasses in our files.

From laboratory ware to lighting ware, from radiation shielding to radiant heating, from hermetically sealed

capacitors to sparkling cooking ware—Corning can do almost anything with glass.

More facts? Ask for "This Is Glass," 64 pages crammed with exciting and profitable ideas. Or ask for Bulletin PE-3 on pipe, Bulletin PE-30 on drainlines. Write to 49 Crystal Street, Corning, N.Y.

CORNING GLASS WORKS
CORNING MEANS RESEARCH IN GLASS

CORNING CAN DO ALMOST ANYTHING WITH GLASS



Air Force School of Aviation Medicine have studied the experiences of 25 volunteers who attempted to eat and drink during "parabolic flights" in a jet fighter. (Parabolic flight temporarily balances centrifugal force against gravity to produce brief periods of weightlessness.)

According to a report in *The Journal of Aviation Medicine*, almost all the volunteers found that drinking from an open container was a frustrating and exceedingly messy process. Under weightless conditions even a slowly lifted glass of water was apt to project an amoeba-like mass of fluid onto the face. Drinking from a straw was hardly more satisfactory. Bubbles of air remained suspended in the weightless water, and the subjects ingested more air than water. Only the squeeze bottle provided a satisfactory means of conveying water to the mouth; sucking the water or squirting it as from a wine skin were equally effective.

The volunteers had no difficulty in swallowing water or semiliquid foods. Solid or semisolid foodstuffs, however, often tended to float upward into the nasal passages instead of downward into the stomach. Even liquids sometimes failed to stay down after being swallowed, especially following light pressure on the abdomen.

Heart-Lung Machines and Cancer

Heart-lung machines, originally developed to provide oxygenated blood for patients during heart surgery, have begun to find other applications. One of the most striking was reported at a recent American Cancer Society seminar. It is the use of the heart-lung apparatus to perfuse malignant tumors with blood "spiked" with doses of cancer-suppressing chemicals far more concentrated than could be administered to the patient as a whole.

The procedure was devised by Oscar Creech, Jr., of the Tulane University Medical School, but is also under investigation in other medical centers. Creech himself has employed it in 110 patients so far.

The technique is applicable only to cancers confined to one region of the body. Skillful surgery is required to single out and connect to the heart-lung machine blood vessels draining the cancer area, and to isolate the rest of the patient's circulation from the "spiked" blood. But it has proved possible to perfuse a surprisingly long list of organs. Perfusions of the leg, lung, breast, liver, colon, pelvis and brain have been car-



Are You interested in "Scientific Shorthand?"

DATASYNC Photo-Tape can permanently capture intimate, synchronized relationships of time, temperature and photogrammetric space-measurements, plus the "scientific shorthand" of multi-color radar and oscilloscope curves, and even the "inter-com" voices of engineers and technicians during the final count-down. These are all of vital importance for reliable evaluation, when synchronized data is all that remains by which to judge the "success" or "failure" of a multi-million dollar test!

Photo-Tape System prices start at \$12,000.00 and up.



Write for your free copy of this 40-page full-color Datasync "Catalog of Ideas." →

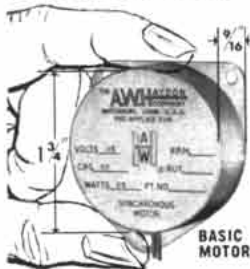
DATASYNC
A DIVISION OF
BERNDT-BACH, INC.

6936 Romaine St., Los Angeles 38, Calif. / HOLLYWOOD 2-0931



MANUFACTURERS OF ELECTRONIC-OPTICAL RECORDING EQUIPMENT SINCE 1931

ANOTHER FIRST...



THE ONLY

Electro-Reliable

A.C. TIMING MOTOR

Thinner... Quieter...

More Reliable... More Versatile

FINGER-THIN...

Only 9/16 Inches Short... Only 1 3/4 Inches in Diameter... very compact... reduces the size of your equipment.

WHISPER-QUIET...

Strictly an electrical motor... practically noiseless... no rattling of gears or ratchets.

HIGH TORQUE...

1/4 oz. inch at the rotor with an instantaneous start and stop... requires only 2 1/2 watts... can replace larger motors in recorders, controls and telemetering equipment.

HIGHEST RELIABILITY...

Longer life... no one-way gears or ratchets to fail... provides millions of operations without any trouble.

SPECIFICATIONS

Standard Voltage Ratings:
6, 12, 24, 115, 230 Volts
Frequency:
60 CPS Standard
25, 50 CPS Available
Power Input: 2.5 Watts
Maximum (60 CPS)

BASIC MOTOR

Weight: 4 ounces
Speed: 300 RPM
Torque: 1/4 oz.-in.
Length: 9/16 inch

WITH INTEGRAL GEAR TRAIN

Weight: 5 ounces
Speed: 300 RPM to 1/6 RPH
Torque: 30 oz.-in. @ 1 RPM
Length: 7/8 inch



WITH INTEGRAL GEAR TRAIN

© 1959



The **A.W. HAYDON Company**

243 NORTH ELM STREET
WATERBURY 20, CONNECTICUT

Custom Design & Manufacture Of Electronic
And Electro-Mechanical Timing Devices

Send for Special Illustrated
Bulletin AWH MO-806

Vari-Typer[®]
1 MACHINE
1,000 FACES
1,001 USES

One Vari-Typist and one machine can supply the type... attractively professional looking, as in the copy you are now reading ...for any method of printing or duplicating. Type fonts, in all the popular styles and sizes, are instantly changeable and automatically spaced. Savings are enormous.

A FEW STYLES
 A FEW USES

- FORMS
- Bulletins
- Reports
- Charts
- Literature
- Booklets
- Magazines
- LISTINGS
- Manuals
- Catalogs
- Price Lists
- PARTS LISTS**
- Drafting
- Instructions



Looks like a typewriter...
 Writes like printing.

Copy by Vari-Typer. Headlines by Headliner.

SUBSIDIARY OF
 ADDRESSOGRAPH-MULTIGRAPH CORPORATION
Cutting Costs Is Our Business

VARI-TYPER CORPORATION Dept. D-61
 720 Frelinghuysen Ave., Newark 12, N.J.
 Please send me VARI-TYPER Book D

NAME.....
 COMPANY.....
 ADDRESS.....
 CITY.....ZONE..STATE.....

ried out by Creech and other surgeons without dangerous leakage of anti-cancer chemicals to other parts of the patient's body. Patients have been perfused for up to an hour, and some of them have been perfused repeatedly without harm.

As yet, knowledge of the most effective drugs and dosages is limited. Nevertheless, perfusion has halted the progress of the disease for periods of up to two years in 32 of Creech's patients, all with advanced forms of cancer unmanageable by other means. Among the patients whose disease has been arrested are 19 with melanoma (of 31 melanoma patients treated altogether), ordinarily one of the most rapidly fatal types of cancer.

Atomic-Age Accident

It was a miniature nuclear explosion and one man died from it—that much was clear at the time. But exactly what caused the radiation burst at the Los Alamos Scientific Laboratory on December 30 was not clear until the inquiry report was published. In *Nucleonics* the investigating committee (headed by Hugh C. Paxton of Los Alamos) reconstructed the steps that led to the explosion.

At about 4:30 in the afternoon a technician peered through a viewing port at the plutonium solutions in a mixing vessel not much larger than a household hot-water tank. This tankful was a little different from the 75 other batches he had processed, because he had decided to handle two batches simultaneously, apparently to save time. The plutonium in the tank totaled 3.37 kilograms. He pressed the agitator switch and the solutions swirled together; there was a muffled roar and a blue flash—the telltale Cerenkov radiation from fissioning nuclei. Forty feet away another technician heard the explosion and saw its light reflected “like a photoflash” from the walls. He and another worker rushed to help the injured man, who ran from the tank shouting that he was “burning up,” mistakenly believing that he had been burned by acid. Not realizing what had happened, his fellow-workers hurried him back past the radioactive tank to get him to a shower. Their efforts were worse than useless: the injured man was already past help, and in passing the tank his rescuers picked up significant radiation doses themselves.

Although the mild explosion did not rupture the tank and no solutions escaped, the burst's 10^{17} fissions raked

the victim with radiation equivalent to 12,000 roentgens, 20 times the dose considered lethal to man. Within 15 minutes he had lapsed into deep shock; 36 hours later he died. The other two workers apparently suffered no serious ill-effects from the much smaller doses they had received.

It was the U. S. atomic-energy program's third fatal radiation accident. The previous fatalities, one in 1945 and one in 1946, also occurred at Los Alamos.

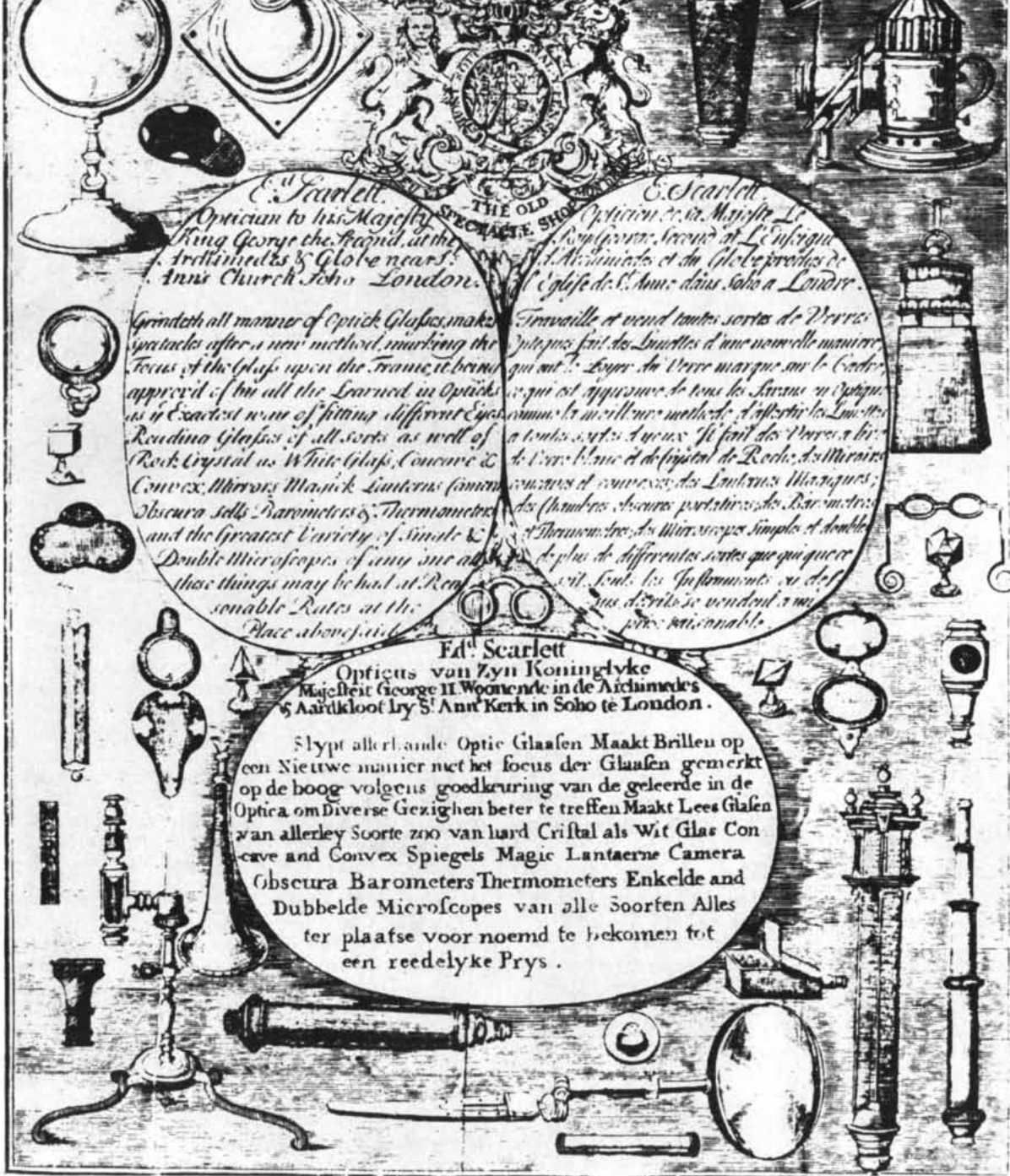
The Fainting Trumpeter

Professional trumpet players know that when they hold a loud high note for several bars they may grow dizzy or black out. The dizziness is caused by high air pressure within the chest which lowers the supply of blood to the brain. Small boys achieve the same effect by holding their breath while a friend squeezes them around the chest.

M. Faulkner, of the University of California at Santa Barbara, and E. P. Sharpey-Schafer, of St. Thomas's Hospital in London, recently set out to measure the pressures produced by blowing the trumpet and other wind instruments. Their subjects, as described in the *British Medical Journal*, were a surgeon once associated with a University of Cambridge dance band, “a novice . . . who purports to be learning the oboe,” and Faulkner himself, who plays and teaches the trumpet professionally.

The two investigators report that a professional trumpet player hitting high D reaches a mouth pressure of 160 millimeters of mercury (a little more than three pounds per square inch). Neither of the two nonprofessionals could reach either high D or 160 millimeters. The oboist achieved only 60 millimeters during loud, high notes on his own instrument; comparable notes on the French horn required even lower pressures.

Faulkner and Sharpey-Schafer note that many leading orchestras ease the strain on the first trumpeter by employing an assistant or “mate” who can take over during long, difficult passages such as are frequent in the music of Richard Wagner. In theory, orchestras desiring to economize could dispense with the mate by having the trumpeter lie supine on the floor, thereby increasing the blood supply to his brain. It would be equally effective, the two investigators state, to dress the trumpeter in a high-altitude pilot's pressure suit “which could be surreptitiously inflated by a switch on the conductor's desk” at appropriate points in the score.

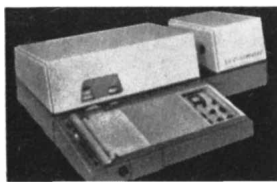


For a handsome lithograph of this trade card, suitable to frame, write us for Data File 2L-55-98

It's a far cry from Scarlett's day... when this purveyor of "all manner of Optick Glasses" sold his wares to King and commoner, to sycophant and scientist alike. Imagine your laboratory dependent on instruments like these. And yet—look around you—the equipment you're using may be almost as outmoded as Scarlett's. For science and technology advance, not only by building on accumulated knowledge, but by discovering new tools for new ways to see and to measure. ☒ That's the business of Beckman Scientific and Process Instruments Division...providing the ultimate in advanced laboratory analytical instruments...ultraviolet and infrared spectrophotometers, pH meters, gas chromatographs, oxygen analyzers and many more. ☒ Learn what Beckman instrumentation can mean to you. Ask for Data File 2L-55-98.

Beckman®
Scientific and Process Instruments Division

Beckman Instruments, Inc.
2500 Fullerton Road, Fullerton, California



It's a Fact: The unique double-monochromator of the Beckman IR-4 Infrared Spectrophotometer gives greater dispersion, energy and resolution than any instrument in its class.

Honeywell 800 costs thousands less than any other high-speed computer

New, all-transistorized Honeywell 800 matches the practical speed and performance of its fastest competition in the scientific field—yet costs at least one third less. Medium-scale in size (and price), Honeywell 800 can tackle and solve with ease scientific problems that would stretch the capabilities of some of the most expensive computers now on the market. New, exclusive features of design and logic equip Honeywell 800 to handle scientific computation with unparalleled economy—a vital consideration as research directors everywhere count engineering costs more closely.

High Internal Operating Speeds

Honeywell 800 gives you an internal operating speed of 30,000 three-address operations per second, the equivalent of 70,000 single-address operations as performed by conventional computers. Honeywell 800 can invert an 80 by 80 symmetric matrix in 75 seconds — or fit 100 points with a 10th degree polynomial curve in *one* second. The trajectory of an artillery shell can be determined in 1/30th the time it takes the shell to describe it.

Expandable Memory

The high-speed magnetic core memory of Honeywell 800 is available in modules of 4,096 words, up to a practical maximum of 4 modules (16,384). Of course, if your scientific problems demand an even greater capacity, upward adjustments can be made. And remember — the memory capacity of Honeywell 800 is expressed in 48-bit words, which are half again as long as those of most other systems.

Also available are magnetic tape units capable of operating at a peak rate equivalent to 112,000 decimal digits per second. With such high speed you can now invert large matrices or solve large linear programming problems — fast and efficiently — without the expense of a huge memory.

Both Decimal and Binary Floating Point

Honeywell 800's exclusive ability to work in either decimal or binary, fixed or floating point arithmetic enables you to choose the form most convenient to your purposes.

Longer Words Speed Problem Solutions

The greater length of the Honeywell 800 word permits the System to utilize single-precision arithmetic when other computers would be forced to slow down for double precision.

The floating decimal word in Honeywell 800 has a range of 63 digits before the decimal point to 64 zeroes plus 10 digits after it. This sharply reduces the overflow or underflow which complicates programming on other computers. Also, the mantissa (base number) has 10 digits, minimizing the need for drawn-out, multiple-precision computation.

The floating binary word provides even greater range and precision. Numbers may range from the equivalent of 75 decimal places before the decimal point to 76 zeroes and 12 decimal digits after it. The mantissa has 40 binary places, the equivalent of 12 decimal digits.

Maximum Flexibility in Programming Structure

As you would expect from the company "First in Control," Honeywell engineers and scientists have designed Honeywell 800 to give the programmer much greater control, freedom and flexibility in handling scientific computations. Besides three-address instructions, greater word length and the option to work in binary or decimal, floating or fixed-point arithmetic, Honeywell 800 offers the programmer several other major advantages in flexibility.

Indexing (64 index registers) reduces the number of orders required in inductive programming, hence steps up computing speed and conserves memory space. *Word Masking* adds the flexibility of variable-length words to the speed and efficiency of fixed-length words. *Indirect Addressing* enables you to perform such functions as a table look-up or an interchange of rows and columns of a matrix with a single instruction. Honeywell 800's exclusive *Bi-Sequence Operation Mode* gives you the flexibility to depart from the basic program sequence and return to the proper point — without writing special instructions.

Full Complement of Input-Output Devices

In addition to magnetic tape, Honeywell 800 features a full range of standard and high-speed input-output devices in both on-line and off-line models. These include keyboard, paper-tape, punched card and printing devices. Buffering, input-output trunks and internal control have also been designed to simplify the addition of special purpose equipment.

No other system can be adapted so closely to your immediate and specific requirements, or be expanded so easily and economically as those requirements grow.

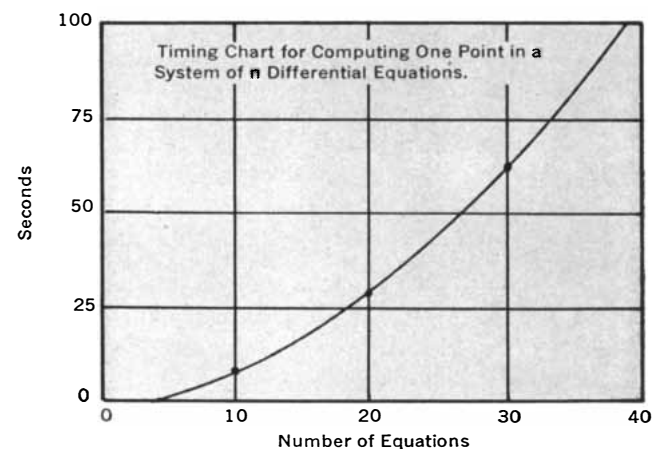
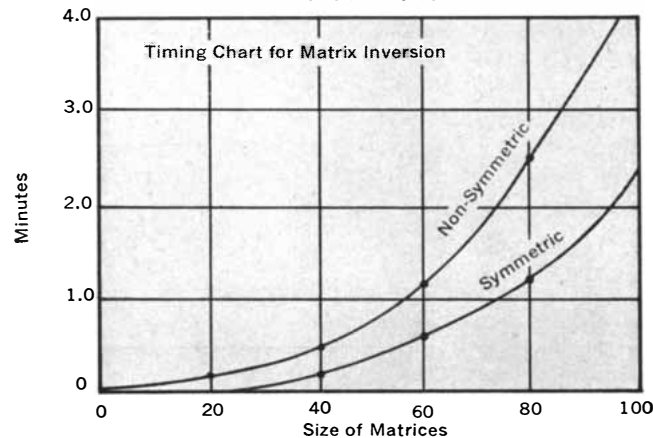
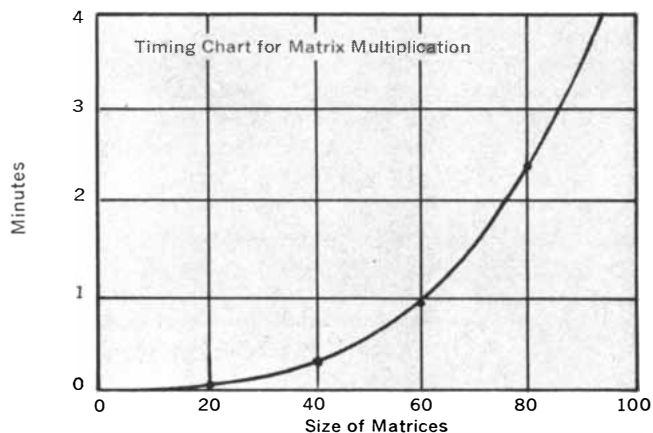
Automatic Error Correction

Completely self-checked internally and externally, Honeywell 800 offers you still more: *Orthotronic Control*. This exclusive means of tape error correction has economically raised the reliability level of Honeywell 800 far beyond the reach of any other computer.

With Honeywell 800 you could easily expect to perform — without interruption — a matrix inversion requiring $1\frac{1}{2}$ days of computer operation. Orthotronic Control is another reason why Honeywell 800 can introduce new economy to scientific computation.

Data Processing Goes On Simultaneously

Honeywell 800's much-heralded principle of Automatically Controlled Parallel Processing enables this System to process business data *at the same time* scientific problems are being solved. Several different and independently programmed jobs can be processed simultaneously — business, scientific or both. Even a minimum use of parallel processing insures your company of operating efficiency and economy that no other system can approach.



AUTOMATIC PROGRAMMING AND LIBRARY ROUTINES CUT COSTS OF PROBLEM PREPARATION

Automatic programming aids and library routines currently in preparation include the following:

Algebraic Compiler

The Honeywell 800 Algebraic Compiler utilizes the same scientific language used on several other popular computers. The subroutine library consists of routines commonly used in solving scientific problems. Thus, existing programs written in this language can be run on Honeywell 800. Because of the speed and efficiency of Honeywell 800, some of these programs will be processed faster than on the system for which they were written.

Assembly Program

The Honeywell 800 Assembly Program assists the programmer by providing automatic translation from simple pseudo codes to machine language, assigning memory addresses to symbolic tags — assembling various routines comprising the program, and various housekeeping functions associated with program preparation. The job of writing programs is greatly simplified, costs are reduced and accuracy in program preparation is increased.

Automatic Problem Checkout

The Honeywell 800 Automatic Problem Checkout is a set of routines designed to provide the programmer with a complete evaluation of his program under operating conditions. Errors are located more quickly, changes made more easily, machine time for checking purposes is minimized and program management is made more workable and predictable.

Scientific Routines

An expandable library of Honeywell 800 scientific routines is being made available for computations involving trigonometric functions, matrix multiplication, matrix inversion, interpolation, curve fitting, ordinary differential equations, and linear programming.

Data Processing Compiler

The Honeywell 800 Data Processing Compiler simplifies problem preparation and coding and provides for convenient utilization of pre-tested library routines. The programmer prepares his problem in easily-learned business-language codes, which are then automatically translated into machine language by the translator. Individual routines, whether prepared or extracted from the library, are compiled into a complete program at machine speeds. Provision for expanding, modifying and maintaining the subroutine library are included in the Honeywell 800 Data Processing Compiler.

In addition, generator routines for input and output editing and sorting further reduce programming costs.

"*Honeywell 800, a Superior Scientific Computer*" is a booklet containing full details and specifications of this new and exciting *economic* approach to complex scientific computation. To get your copy, just write Minneapolis-Honeywell, DATAmatic Division, Dept. S1, Newton Highlands 61, Massachusetts.

Honeywell



DATAmatic

ELECTRONIC DATA PROCESSING

BEER

Man has made this exquisite beverage for 6,000 years, but it is only in the past century that he has begun to understand the subtle enzyme chemistry and microbiology of the process

by Anthony H. Rose

Any solution of the sugary substances of grains, if permitted to stand, will soon become infected by microorganisms. With a little care, the fermentation process that follows can be made to yield a potable, mildly alcoholic beverage. Men have made this discovery wherever they have cultivated grains. Archaeological evidence shows that brewing had developed into a serious art as long as 6,000 years ago in the valley of the Nile. The peoples of the Orient long ago learned to brew sake and related beverages from rice. In the New World, in 1502, Columbus was presented with "a sort of wine made from maize, resembling English beer."

What we call beer—the brew of barley malt flavored with the bitter essences of the hop flower—has been the folk beverage of northern Europe from earliest times. In the monasteries of medieval Europe brewing was as widely practiced as baking. The monastic imprint is seen today in the symbols of quality XX and XXX; in Bavaria one nunnery still has a sister brewmistress! But beer was also one of the first commodities to be industrialized. By the middle of the 17th century such great brewing centers as Oxford, Burton-on-Trent and Munich were already establishing their reputations. It fell to Charles I of England to recognize beer as a source of tax revenue; he imposed the first beer duty in 1643. Brewed and consumed in increasing quantity throughout the 18th and 19th centuries, beer became a major source of nourishment, refreshment and solace to the peoples of Western civilization. In the words of A. E. Housman, "Malt does more than Milton can,/To justify God's ways to man." Today the Belgians, consuming 31 gallons per capita per year, lead the beer drinkers of the world; the U. S. ranks about sixth.

While brewing has not lacked for esthetic appreciation throughout its long history, it is only recently that we have begun to understand what a remarkable art it really is. Now that we know a little microbiology and biochemistry we can see that the brewmaster, by trial and error, has been manipulating some of the subtlest processes of life. To scientific studies we owe many improvements in brewing technology, especially under the heading of quality control. But in some ways the debt runs more heavily the other way. A study of the diseases of beer led Louis Pasteur to discover that yeasts bring about the desired fermentation to alcohol, and that "sickness" in beer is caused by bacteria that yield lactic acid, acetic acid or other unwanted end-products. This discovery not only laid the foundations of the scientific approach to brewing but also helped to open up the whole field of microbiology. The problems of brewing technology played a similar role in the birth of biochemistry. When the German brothers Eduard and Hans Buchner showed in 1897 that cell-free extracts of yeast could cause fermentation of sugar, they exploded once and for all the cherished notions of "vitalism." Their discovery opened the way for all subsequent work on the chemistry of life. As a result of two generations of scientific investigation, the ancient lore of brewing is now enriched by knowledge that has relevance to the enjoyment as well as to the brewing of beer.

The Barley Corn

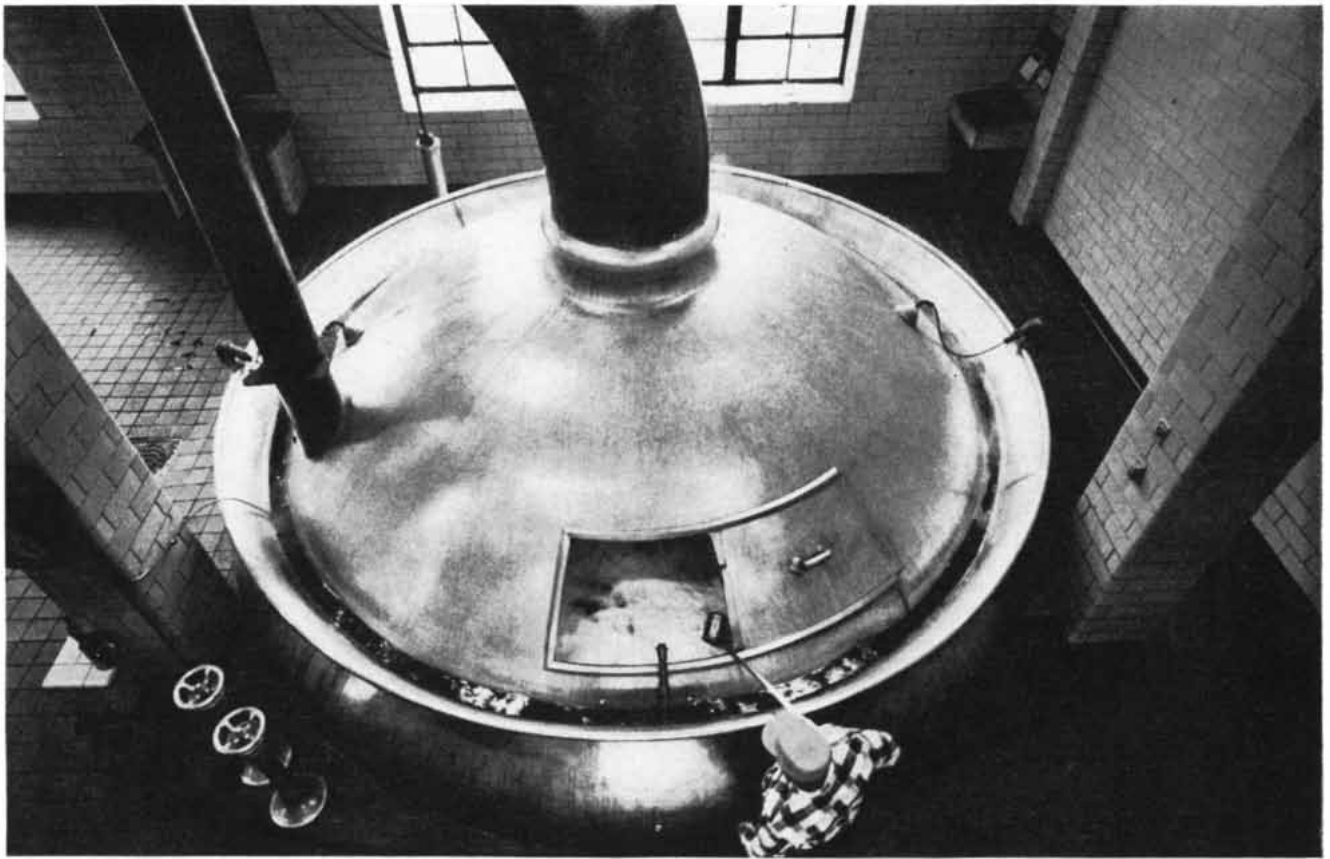
The key step in the brewing process is of course the addition of yeast to the brew; the yeast ferments or breaks down certain of the grain sugars to alcohol and carbon dioxide, producing "young" or

"green" beer. This step, however, comes only as the climax to a whole series of operations that play a decisive part in determining the ultimate taste, aroma and appearance of beer. Of the first importance is the character of the grain from which beer is made. The word "beer" comes from the Saxon word for barley: *baere*. Barley was one of the most important cereals in the early civilizations. Even when barley was displaced by wheat as a raw material for baking, it retained its pre-eminence in brewing.

The barley corn or seed is a spindle-shaped structure. If we remove the protective husk of the corn, we see the tiny embryo of the plant and the relatively large mass of endosperm tissue, which consists mainly of food reserves that support the germination of the embryo. It is the food reserves, in particular the polysaccharide constituents, that are important to the brewer. These polysaccharides are large molecules made up of smaller sugar units such as glucose and maltose.

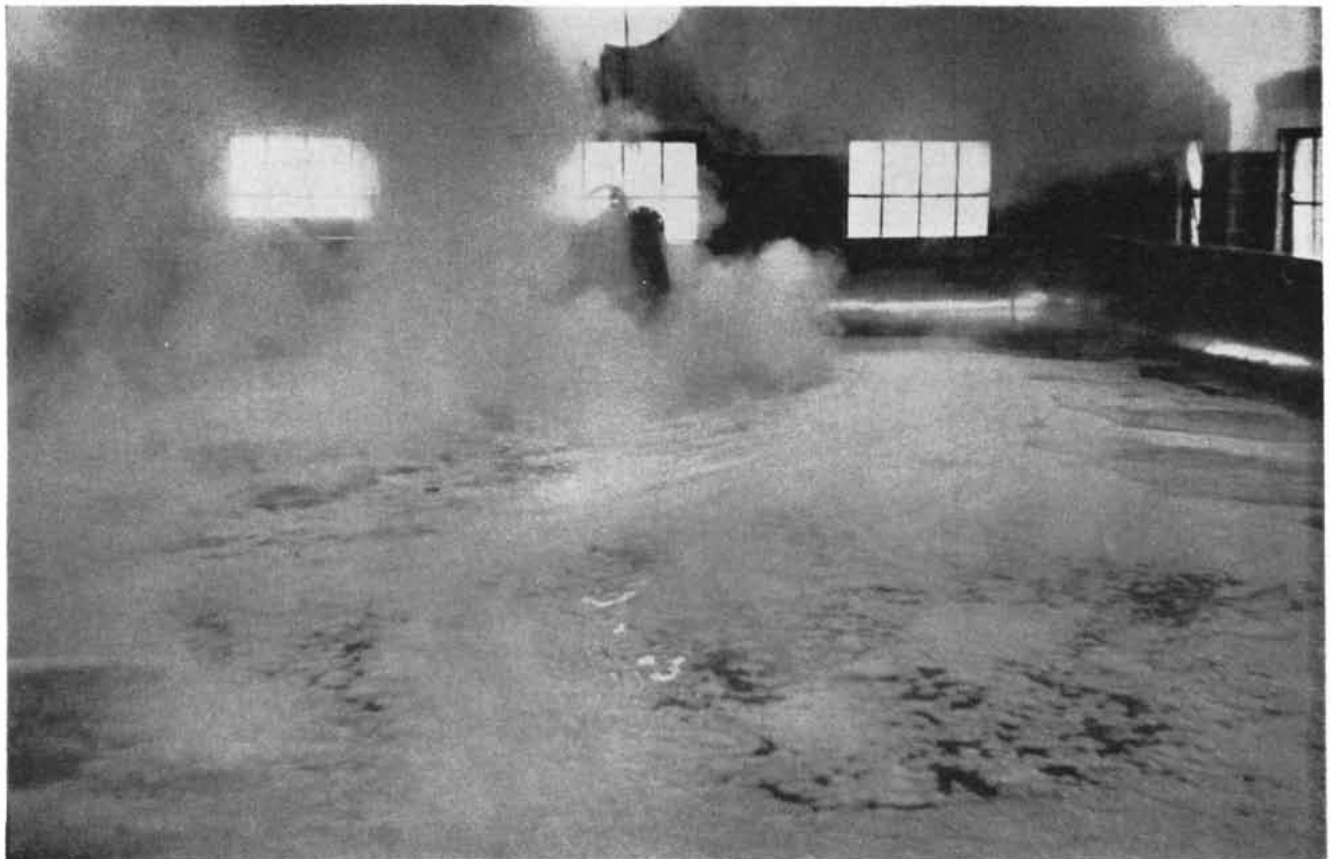
Now if brewer's yeast is merely added to a suspension of ground raw barley corns in water, no fermentation occurs. The yeast cannot convert the barley polysaccharides directly into alcohol and carbon dioxide; it can only act upon the simple sugars from which the polysaccharides are formed. The polysaccharides must therefore be hydrolyzed (broken down with the addition of water) to their component sugars. This could be accomplished quite simply by cooking the grain with a dilute mineral acid, but since the object is to produce a palatable beverage, such a procedure is far too drastic. The brewer employs a much gentler process.

It happens that the polysaccharides must be broken down in the process of



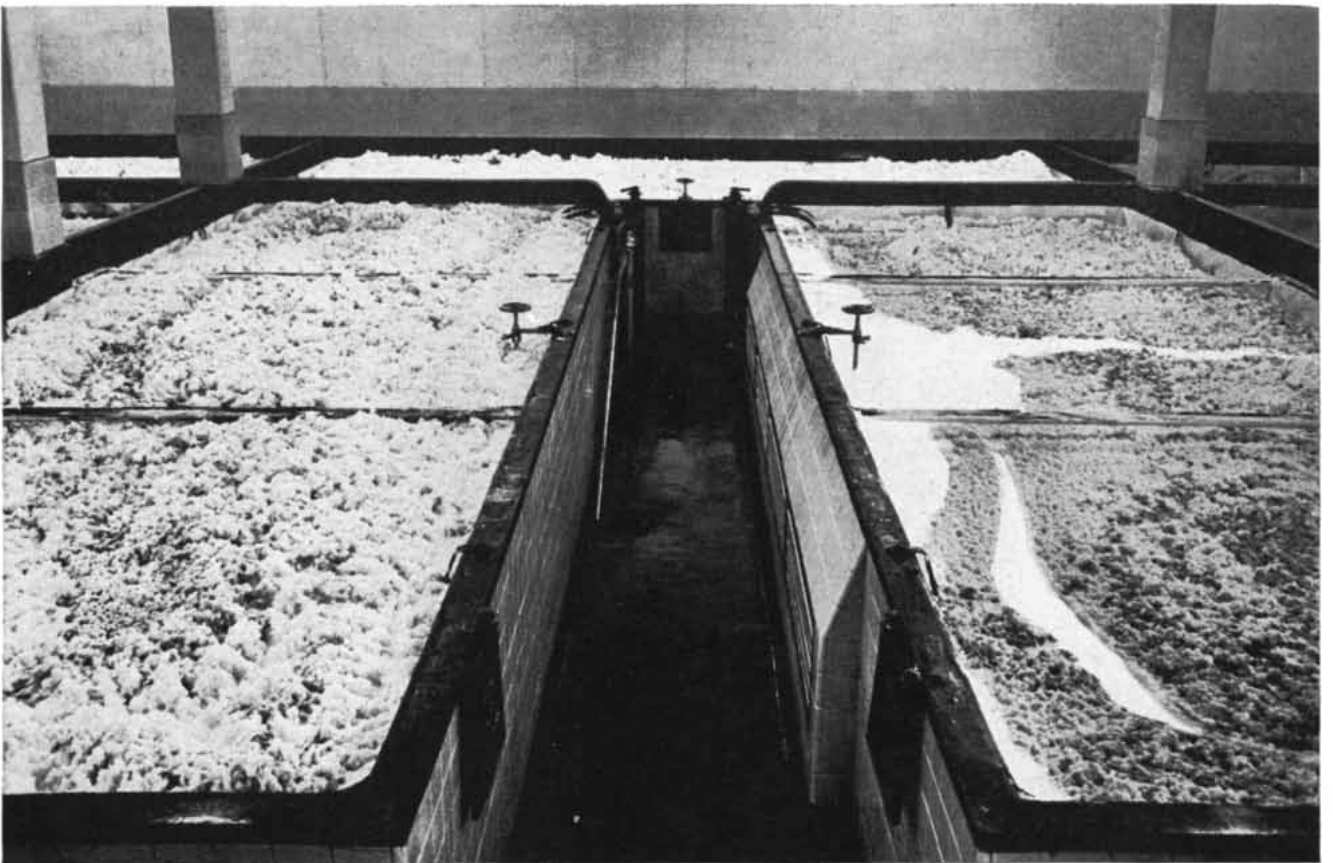
BREW KETTLE in a New York brewery is filled with malt wort produced by allowing the enzymes of barley corns to digest the pro-

tein and starch of the barley and of "adjuncts." Here the wort is boiled to destroy the enzymes. Hops are added by the man at bottom.



SETTLING TANK is where the wort cools and solids settle out of it after it has left the brew kettle. The wort is now further

cooled and sent to the fermenting tanks (*see illustration at top of next page*). The entire process is outlined on pages 94 and 95.



OPEN FERMENTING TANK is where yeast is added to the wort, which has been filtered of its hops and cooled. The yeast enzymes

now ferment the wort sugars to alcohol. Here the yeast sinks to the bottom of the tank; on the top is a foam caused by fermentation.



LAGER TANKS are where the "green" beer is aged for several weeks at 32 degrees F. The beer is then filtered to remove traces of

yeast and a suspension of protein that is precipitated by chilling. Finally the beer is carbonated and bottled, canned or barreled.

germination in order to supply the sprouting embryo with the simpler sugar units it requires for growth. This breakdown is brought about by the action of certain enzymes that are manufactured inside the grain, several different enzyme systems taking part in the breakdown of various endosperm constituents. The most important of these are the amylases, which hydrolyze the polysaccharides. But barley also contains proteins, and these large molecules are also broken down into their component peptides and amino acids. The brewers of old learned to prepare the grain for fermentation by utilizing this elegant built-in enzymic apparatus, even though they could hardly have suspected how it works.

The first step in brewing, then, is to germinate the barley. In this "malting" process the grain is steeped in water and then transferred to aerated chambers or slowly revolving drums in which careful control of temperature, moisture and oxygen promotes uniform germination. When the desired stage of growth has been reached, gentle heating brings germination to a halt, with temperature again carefully controlled to minimize the damage to heat-sensitive enzymes. Prolonged heating produces a darker grain, sometimes employed in the brewing of darker beers. At this point, however, only a small proportion of the endosperm polysaccharides has been broken down. The object in malting is not to get the hydrolysis well under way, but simply to allow the grain to manufacture all of the necessary enzymes. Malting is predominantly a mobilizing or "tooling-up" process. Nowadays, in fact, malting is not strictly a part of the brewer's operations; it is carried out by maltsters, who then deliver prepared malt to the brewery.

The Mashing Process

The brewing process proper begins with "mashing": Ground malt is mixed with hot water, and permitted to stand for a short time. Now the malt enzymes go to work, and the breakdown of the polysaccharides begins. Since the enzymic capacity of the malt far exceeds that required to break down all of the endosperm starch, other starchy materials are added to the mash. These "adjuncts" increase the volume of fermentable sugars but contribute little if anything to the taste and aroma of the beer. As the enzymes digest the starch and proteins of the malt, the breakdown products—sugars, peptides and amino

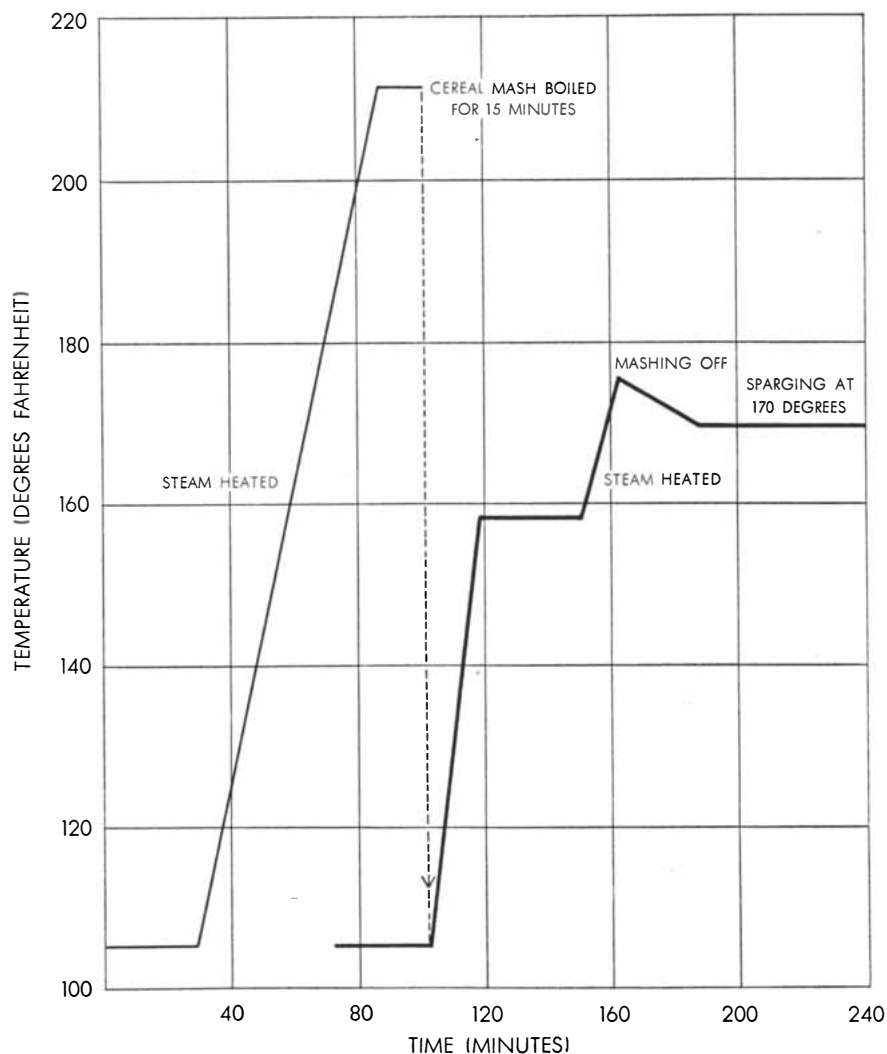
acids—dissolve and diffuse into the water to make sweet malt "wort," the liquor that the yeast is later to ferment.

Generations of brewmasters learned empirically to subject the mashing process to precise control by the regulation of temperature, the temperature cycle being designed in each case to yield the sugar content and other qualities in the wort called for by the type of beer being brewed. Usually the malt is first mixed with water at a temperature of 105 degrees Fahrenheit, and is kept at this temperature for an initial "resting" period of 30 minutes. Meanwhile, in a separate mash tub, the cereal adjuncts are infused with water at the same temperature and brought gradually to a boil. When the contents of this tub have been cooked to a gelatinous texture, they are added to the malt mash, resulting in a final mixing temperature of some 157 degrees F. After being maintained at about this temperature for another half

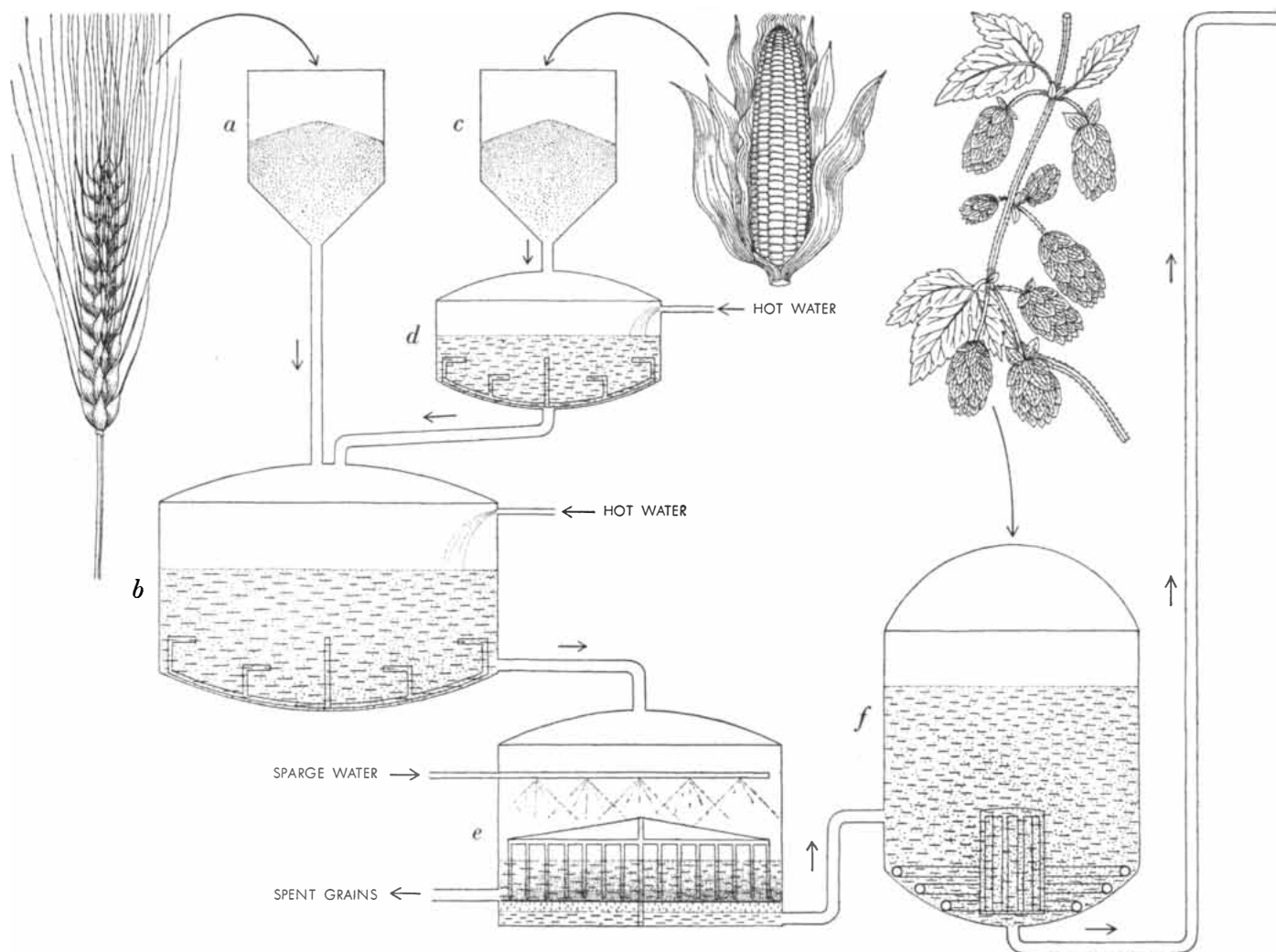
hour, the mixture is "mashed off" or stabilized by heating it up to 175 degrees, a temperature that destroys most of the enzymes.

Today we can explain the importance of temperature control during mashing because we have made the acquaintance of the principal enzymic actors in the process. Each of these enzymes functions best in a characteristic range of temperature. During the resting period, when the temperature is held at 105 degrees, the protein-decomposing enzymes find the environment most congenial. The peptides and amino acids produced by the breakdown of proteins do not contribute directly to the production of alcohol; however, they provide essential food substances for the yeast and give the beer body as well as head-retaining properties. Thus it is important that just the right amount of protein should be broken down in the mashing process.

As the mash is heated up by the addi-



TEMPERATURE of cereal-mash adjuncts (curve at left) and malt (curve at right) is plotted against time. The malt is heated largely by the addition (broken line) of the adjuncts.



ENTIRE BREWING PROCESS is outlined in this flow chart. The barley corns are ground and placed in the malt hopper (a); from thence they go to the mash tub (b). Corn (or other adjuncts) is

placed in the adjunct hopper (c), boiled in the adjunct cooker (d) and added to the mash. The malt wort is then filtered in the lauter tub (e). The clear wort goes to the brew kettle (f), where hops

tion of the adjunct mixture, the starch-digesting enzymes—the amylases—come into play. Starch is not a simple polysaccharide, but consists of a mixture of two glucose polymers: amylose, made up of straight chains of glucose units, and amylopectin, made up of branched chains. Moreover, there are at least two distinct starch-hydrolyzing enzymes in malt: alpha- and beta-amylase. The unbranched amylose chains are broken down by beta-amylase, which chops off the glucose units two at a time to give the disaccharide maltose. Theoretically beta-amylase can break down the amylose completely; in practice the reaction is inhibited by the accumulation of breakdown products. But beta-amylase cannot completely break down the amylopectin molecule, because its action is halted at points where the chain branches. The other enzyme, alpha-amylase, makes up for this deficiency; it is able to split the branched chains into smaller fragments and thus provide

additional straight chains that can be nibbled away by the beta-amylase. The beta enzyme prefers temperatures in the region of 140 degrees F., while the alpha enzyme acts most efficiently at the slightly higher temperature of 150 to 170 degrees. Thus the relative proportions of alpha- and beta-amylase activity can be controlled by the temperature of the mash and by the profile of the curve on which the temperature is shifted.

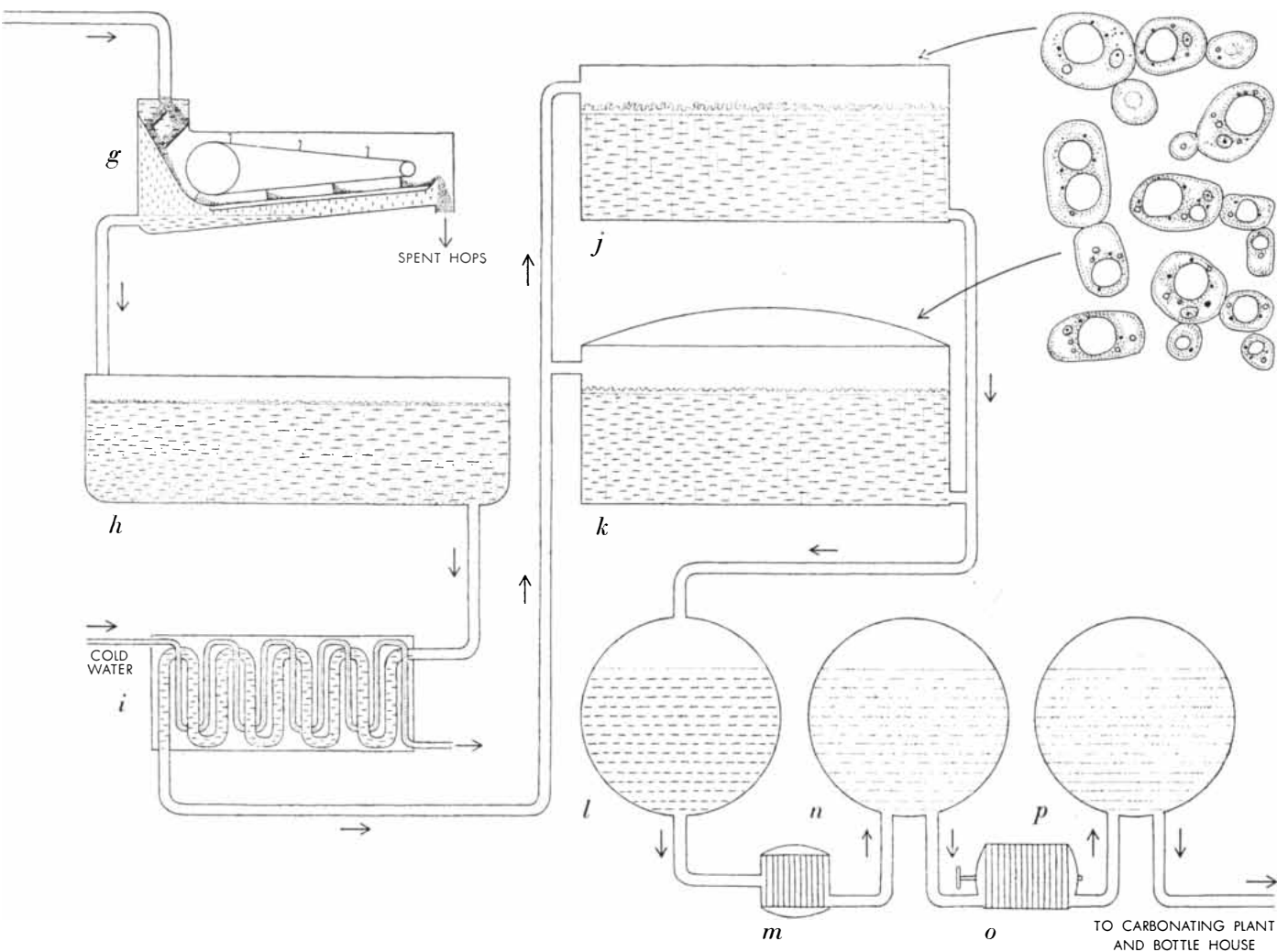
Higher temperatures will tend to promote alpha action and discourage beta, and will thus result in a smaller proportion of fermentable sugars. Worts of this type have a correspondingly higher proportion of dextrins (short units, both branched and unbranched), which cannot be fermented by brewer's yeast but which contribute to the character and body of the beer and help to maintain a stable foam. Brewers use worts of this type to brew beers with a low content of alcohol. Thus careful control of temperature during mashing has always

given the brewmaster an opportunity to exercise his skill. Only recently have we come to realize that he is in fact the choreographer of an enzymic ballet.

After mashing off, the contents of the tub are transferred to the "lauter" tub (*lauter* in German means "clear"). This is a cylindrical tank having a false bottom of slotted plates, through which the clear malt wort is run off, the cereal husks forming an ideal filter bed. The husks are further "sparged," or leached with hot water to augment the volume of wort extracted. At this point the brewing process yields a valuable by-product in the form of the spent grains, which make excellent cattle feed.

The Addition of Hops

The clear malt wort is now run into a steam-heated copper or stainless-steel brew kettle, in which it is boiled for 30 to 60 minutes. In the process any remaining enzymes are destroyed, and the



are added. The hops are removed by the hop strainer (g); other substances, by a settling tank (h). The wort is now cooled (i) and sent to open (j) and closed (k) fermenting tanks. In the closed

tank carbon dioxide is collected and later used to carbonate the beer. After fermentation the green beer goes to lagering tanks (l, n and p). As it passes from one tank to next it is filtered (m and o).

wort is sterilized and somewhat concentrated. More important, dried hops are added to the boiling wort in amounts and at intervals that vary with the type of beer. German beers and the U. S. beers that are modeled on them are usually hopped at the rate of about half a pound for each barrel, but for the English ales the rate is much higher, in some cases as high as a pound and a half per barrel. Hops are added primarily to impart the characteristic aroma and pleasant bitterness of beer. Although hops are now universally used for this purpose, it is interesting to note that prior to the 17th century mixtures of various herbs were commonly employed to flavor beer. Thus in Thomas Tryon's *A New Art of Brewing Beer, Ale and Other Sorts of Liquors*, published in 1691, we read: "Here give me leave to tell you that there are a great number of brave Herbs and Vegetations that will do the business in brewing as well as Hops. . . . Penny Royal and Balsam . . . are of excellent

use in Beer and Ale: the like is to be understood of Mint, Tansie, Wormwood, Betony . . . and good Hay." The hops of brewing are the cone-shaped flowers of the female hop plant, each cone consisting of a spindle with between 50 and 100 petals. The hop flowers are picked when ripe, and are dried and pressed before being shipped to the brewery. A century ago most of the hops in the U. S. came from New York and Vermont; the principal hop-producing areas are now along the Pacific coast and in Idaho.

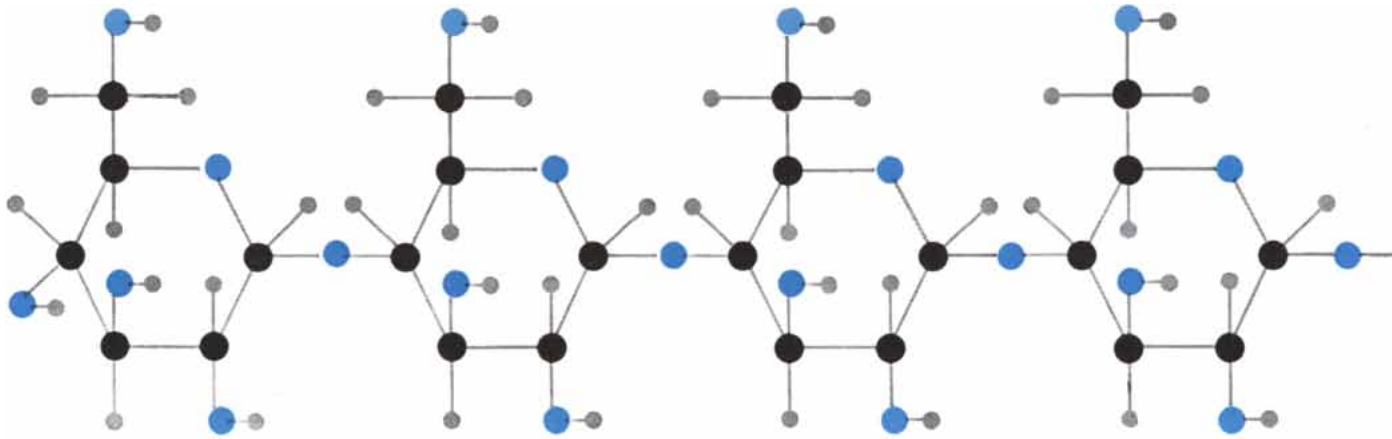
Boiling in the brew kettle extracts from the hops a variety of substances. These include oils and complex bittering substances such as humulone, cohumulone and adhumulone, all of which contribute to the flavor and aroma of beer. Antiseptic substances are also extracted; these help to prevent microbial spoilage in the finished beer. In addition, the hops contribute tannins. These are of special importance in the brewing process, for they combine with the protein in wort

to form an insoluble sludge that settles to the bottom of the brew kettle. If the protein is allowed to remain in the wort, it tends to precipitate later as a haze in the beer, a considerable hazard to consumer acceptance.

After boiling, the hops are strained off and the wort is cooled to 45 or 50 degrees F. Cooling throws down a further deposit of protein-tannin sludge, which is filtered off. Just before the cool wort is transferred to the fermentation tank, it is aerated with sterile air to make it more hospitable to the yeast that is to be planted in it.

Top- and Bottom-Fermentation

Here we come to one of the major differences between British and Continental practice. It is this difference that occasions so much confusion among U. S. consumers, who enjoy the privilege of choice between the products of both types of brewing. The distinction arises



STARCH of malt is a polymer of glucose, that is, a repeating chain of glucose units. A single glucose unit is shown to the right of the broken line, which indicates that the chain is repeated. The

black balls represent carbon atoms; the gray balls, hydrogen atoms; the colored balls, oxygen atoms. Starch is actually a mixture of two glucose polymers: amylose, consisting of a straight chain of

from the behavior of the yeast during fermentation. In Britain brewers still employ types of yeast that rise to the surface during fermentation. The "top-fermentation" beers come in many varieties, from relatively pale ales to porter (a dark, heavy ale popular in Ireland) and stout (also dark and heavy, but with a higher alcoholic content). In the U. S. top-fermentation and a taste for ales arrived on the *Mayflower*. The Pilgrims recorded that they landed at Plymouth with misgivings and were forced to settle on that forbidding shore because they had drunk all their beer. But they had brought their yeast balm, and ales are still preferred in New England.

Elsewhere in the U. S. the brewing industry derives its traditions from the brewmasters who came from Germany in the 19th century to set up large commercial breweries. The Germans brought the new technique of "bottom-fermentation," which, as the term indicates, employs a yeast that settles to the bottom during fermentation. The German "lager" beers are usually paler than ales, and are rather more mellow in flavor. There are three main types: Münchner, Dortmunder and Pilsener, named after the towns in which they were first brewed and here listed in order: of their color from dark to pale. Under the pressures of standardization arising from mass distribution U. S. beers have tended to become increasingly pale and thus to resemble the Pilsener beer; they have less hop flavor, however, and are much more highly carbonated. A seasonal exception to this trend is bock beer, the dark, full-flavored beer that certain U. S. brewers still put on the market in the spring. Originally brewed in Bavaria during the Easter celebrations, bock beer gets its name from the German word for goat, which animal is

the zodiacal sign for the month of March.

Whether top- or bottom-fermentation is used, about one pound of yeast slurry is "pitched" into the tank for each barrel of beer. Malt wort furnishes an ideal diet for yeast; during the fermentation period of six to nine days the organisms not only multiply about threefold but also break down a large proportion of the sugars in the wort to alcohol and carbon dioxide. The concentration of alcohol at the end of the process is about 4 per cent in lager beers and somewhat higher in ales. Thanks to investigations founded by the Buchner brothers, we now know of the dozen or so enzyme reactions involved in the fermentation of sugar to alcohol. Some of the energy that is produced is utilized for growth, but by far the greater part of it escapes as heat. To keep the fermenting brew at the optimum temperature (55 degrees F. for lager beers and 60 to 65 degrees for British ales) the fermentation tank must be refrigerated. Before the advent of mechanical refrigeration, beer was commonly fermented in caves or underground cellars; the fermentation section of a brewery is still quite often referred to as the "cellar." In addition to fermenting the sugar, yeast also brings about a host of other changes in the chemical composition of the wort; very little is known, however, of the nature of many of these changes.

The Yeast Organism

Most of the bottom-fermentation yeasts used in the U. S. and in Europe today are strains of *Saccharomyces carlsbergensis*, which takes its name from the great Carlsberg brewery in Copenhagen, or of *Saccharomyces cerevisiae*. Top-fermentation yeasts are all strains of *Saccharomyces cerevisiae*. Our familiar-

ity with these microorganisms goes back only to Pasteur. But even before the mid-19th century brewing yeasts were selected by spontaneous fermentation and by long-continued and repeated transfers from one brew to another. At least one archaeologist has claimed that traces of yeast found in urns dating back to 1440 B.C. were decidedly superior to those in vessels of 3400 B.C. The Danish botanist Emil Christian Hansen was one of the first to develop techniques for isolating yeasts in pure culture, and he introduced these yeasts into breweries. Today many brewers employ pure strains of yeast that are especially suited to brewing. The cultures are renewed at intervals varying from a few months to several years; by careful control the yeast may be kept reasonably free from contaminating microorganisms.

At the end of fermentation the yeast has settled to the bottom of the vessel. The green beer is now pumped into large lager tanks, where it is kept at about 32 degrees F. for several weeks. The yeast, separated from the beer, can be used again. Lagering permits the beer to mature, with the result that both taste and aroma become decidedly mellow. We are, however, almost completely ignorant of the nature of these maturation changes. In all probability they are largely attributable to the production of minute amounts of unidentified alcohols and esters by the traces of yeast that remain in the beer. After lagering, further filtration through diatomaceous earth removes these traces of yeast and also a fine suspension of protein that is precipitated by chilling. The beer is then carbonated, usually by the injection of carbon dioxide but occasionally by a secondary fermentation under pressure, known as "krausening." When the product is bottled or canned, it must be pas-

SAVE THE CHILDREN

FEDERATION



Christos has almost given up hope

Little Christos never has any fun. Life to this ten year old Greek boy is drudgery and bitter poverty. And yet, Christos has a dream . . . some day he will make life better for himself and his family. And so he walks many miles each day to attend third grade in a small, dark room that passes for a grammar school. He learns the lives of venerated men who gave so much to Greek culture and to the world—Aristotle, Plato, Socrates—and he dreams. In the late evening, he returns home leaving just enough time to do some errands and study his lessons. But life is so dark now . . . how long can he live and nurse his dream and carry hope in his heart?

Christos' parents were married just after the war when everyone hoped for a better future. Instead, Communist inspired uprisings spread over the country. Christos' father joined the National Guard and took part in many battles. When guerilla bands entered his village they destroyed his house and burned all his belongings.

Life for Christos' family began all over—from nothing. They now live in a hut with a roof of straw. They own three pieces of furniture. All must sleep on straw mats on the cold earthen floor. Their only property is a

quarter acre of land which the father cultivates early in the morning and after dark. During the daylight hours he must work on other farmers' land for daily wages to buy food.

Christos sees his father's plight and thinks. "My father struggles for a better future; I must help him." At the age of 10, Christos still has hope.

Save the children and you save the family

If only someone could extend a hand to help Christos and his family help themselves, give them courage for the future that looks so dark at this moment. Someone can, and that someone is you. A child like Christos becomes "your child" through an SCF Sponsorship and receives food packages, warm clothing and many other material benefits in your name. But the whole family receives the greatest gift of all—"hope." You may correspond with your child and discover for yourself what your understanding and generosity means to a struggling family. Won't you please fill in the coupon now?

SCF National Sponsors include: Mrs. Dwight D. Eisenhower, Herbert Hoover, Henry Luce, Norman Rockwell, Dr. Ralph W. Sockman.

glucose units, and amylopectin, consisting of branched chains. The straight chain of amylose may consist of as many as 300 units.

teurized by heating it to a temperature of about 140 degrees F. for 15 to 20 minutes, a treatment that is sufficient to kill most of the microorganisms capable of growing in beer. The beer marketed in aluminum or stainless-steel kegs to the restaurant and bar trades is not pasteurized, and so is kept under refrigeration until it is consumed.

The sequence of operations for converting barley and hops into beer that we have reviewed here is the result of centuries of empirical development. Though the knowledge gained in the past 50 years has disclosed the solid scientific foundations upon which the art has rested, it has so far improved upon it only in detail. However, with the deeper understanding provided by the biochemist, the brewmaster is better equipped to deal with problems that continue to arise even after 6,000 years.

The Problem of Haze

Probably the most pressing brewing research problem arises from the new habit of drinking beer from cans and bottles that have been kept in storage and are then decanted into clear glasses. For centuries beer was dispensed from kegs and drunk out of mugs and tankards; it was then judged solely by taste and smell. But in the recent past the locus of beer drinking has shifted to the home. It has now become necessary to produce beers that can be shipped long distances and kept on the shelf for unpredictable periods of time in a variety of temperatures, and will still be crystal-clear when they are poured into a glass. Unfortunately beers that have been so treated often tend to develop a haze, and consumer demand requires that this be eliminated.

One type of haze is caused by infec-

Registered with the U. S. State Department Advisory Committee on Voluntary Foreign Aid
"SERVING CHILDREN FOR 27 YEARS"

SAVE THE CHILDREN FEDERATION

Boston Post Rd., Norwalk, Connecticut

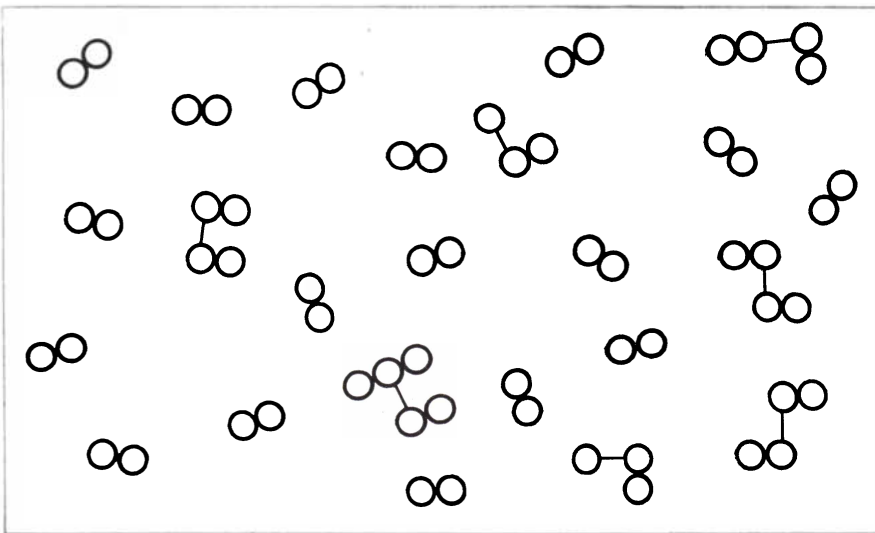
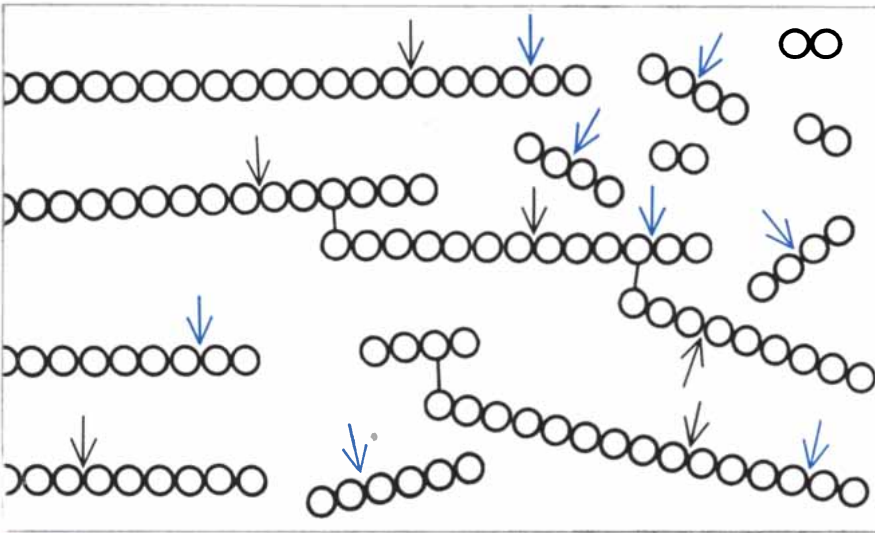
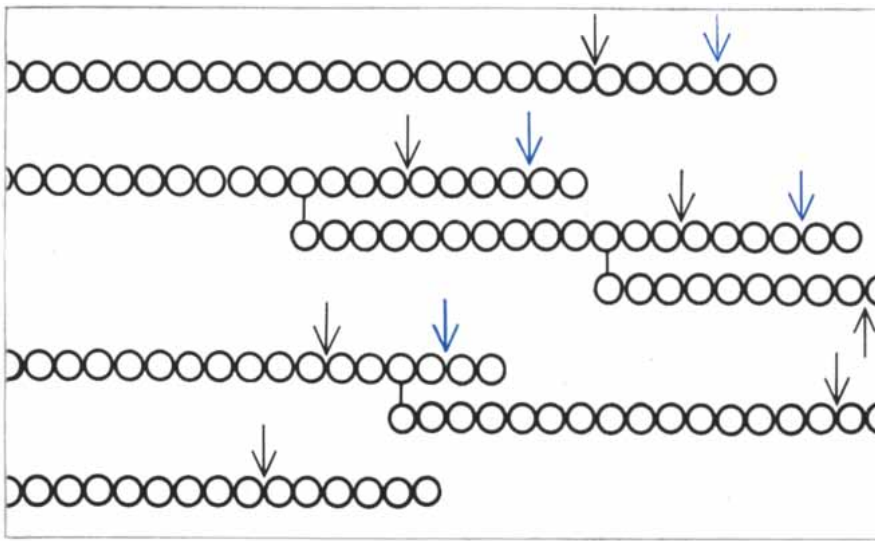
I want to sponsor a child for one year in: Korea . . . Greece . . . France . . . West Germany . . . Finland . . . Italy . . . Austria . . . Lebanon . . . or where need is greatest. . . . Enclosed is \$120 for 1 year . . . \$30 for 1st quarter . . . \$10 for 1st month. . . . I cannot be a sponsor but enclosed is my gift of \$

Please send me my sponsored child's name, story and picture.

NAME.....
ADDRESS.....
CITY.....ZONE.....STATE.....

Contributions are Deductible from Income Tax

SA-6-59



STARCH IS BROKEN DOWN by the enzymes alpha-amylase (black arrows) and beta-amylase (colored arrows). In the top drawing each glucose unit is represented by a small circle. At the top and bottom of this drawing are straight chains; in the middle are branched chains. In the middle drawing the beta-amylase splits off two glucoses at a time; the alpha-amylase splits off a larger number of glucoses, which are in turn broken down by beta-amylase. In the bottom drawing is the mixture of maltose (a two-glucose sugar) and dextrins (short, branched chains of glucose) that ultimately results from the process.

tion. Even after fermentation the finished beer contains sufficient food substances to support growth of a large number of microorganisms. Infection can occur in spite of pasteurization and the additional protection afforded by hop antiseptics in the beer. Fortunately the acidity of beer precludes the possibility of infection by microorganisms that cause disease in humans. The offending microorganisms are either bacteria (e.g., species of *Pediococcus*, *Lactobacillus* and *Acetobacter*) or so-called wild yeasts, microorganisms closely related to the yeast used in fermentation. Beers infected by these microorganisms become hazy, and develop undesirable flavors. Although such spoilage can be troublesome, it can usually be prevented by strict attention to cleanliness in the brewhouse.

Far more serious are the nonbiological hazes. Here the turbidity is the result of the precipitation of fine particles of organic matter, predominantly protein. As we have seen, most of the protein is removed from wort when it is boiled and infused with hops, the tannins in the hops (and some from the malt husk) combining with the proteins to form an insoluble sludge. However, this protein-tannin complex continues to precipitate slowly from the beer even after packaging, so that after a period of storage the beer may well develop a pronounced haze. One cure for the condition is to add protein-digesting enzymes to the finished beer. This "chill-proofing" is not entirely satisfactory because too much enzyme may break down those peptides that give the beer its head-retaining properties. Another approach is based upon the fact that oxygen is conducive to haze formation. Thus various antioxidants, including ascorbic acid (vitamin C), have been added to beer to improve its stability. In recent years, however, a more fundamental attack on the problem has been launched; this work aims at identifying the haze components, tracking down their origin and then removing them from the scene of action. Unfortunately the chemistry of the proteins and tannins that make up hazes is extremely complex. Recent work at the Brewing Industry Research Foundation in England suggests, however, that we may be on the right track. Chemical analysis has shown that the trouble is often caused by one particular group of tannin substances known as anthocyanogens; they are commonly found in association with the proteins in hazes. It happens that these anthocyanogens can be removed from beers by adsorption on a polyamide resin such as

Do computers really pay?

*47 users in the civil engineering field
alone, are proving that the Bendix G-15
more than pays its way.*

The repeated computations encountered by civil engineers in the design of highways, bridges, dams and other public works, are tedious at best. With electronic computation the engineers are relieved of such uncreative work because the computer performs repetitive arithmetic automatically at high speed.

In time savings alone, the Bendix G-15 is a profitable tool. But add to that the value of the extra productive hours available to each engineer and the fact that the computer eliminates compromise solutions by finding the *best* answer through many "trial and error" solutions at tremendous speed — you can begin to see the important hidden profits of electronic computing.

Many problems are being solved today on the Bendix G-15 that have never been solved before, because of the many man-years of math that manual methods would require. Profits here are so great that it is difficult to even measure them. Then there is the increased accuracy of electronic computing, with the resulting reduction of checking time.

The benefits are so many and varied that it is difficult to express them in dollars and cents. But consider the proof that 47 Bendix G-15s are being used in the civil engineering field alone. And in other fields — electronics, optics, tools, missiles, navigation, illumination, and even animal husbandry, the G-15 is making itself known as the computer that pays big profits in many ways. Full details are available on request.



DIVISION OF
BENDIX
AVIATION
CORPORATION



PARTIAL LIST OF CIVIL ENGINEERING USERS

Alfred Benesch and Associates
Barber-Colman Company
Bonneville Power Administration
Bucyrus-Erie Company
Butler Manufacturing Company
Clark, Daily and Dietz
Consoer, Townsend and Associates
Cook County Highway Department
Crawford, Murphy & Tilly
De Leuw Cather and Company
Edwards and Kelcey, Engineers & Consultants
Ellerbe and Company
Emmet J. McDonald Associates
Harley, Ellington & Day, Inc.
Highway Research Board, AASHO, Road Test
H. W. Lochner, Incorporated
Homer L. Chastain & Associates
Hurst-Rosche, Incorporated
Illinois Division of Highways
J. E. Greiner Company
J. Stephen Watkins, Consulting Engineers
Jenkins, Merchant & Nankivil
John F. Meissner Engineers, Incorporated
Lockwood, Kessler & Bartlett, Inc.
Michigan State Highway Department
Palmer and Baker Engineers, Inc.
Parsons, Brinckerhoff, Hall and Macdonald
Portland Cement Association
Reynolds, Smith & Hills
Richardson, Gordon and Associates
Rochester and Goodell Engineers, Inc.
Stanley Engineering Company
Tudor Engineering Company
U. S. Army Corps of Engineers
Vogt, Ivers, Seaman Associates
Warren & Van Praag, Incorporated
Wilson and Company, Engineers & Architects
Wyoming Department of Highways

DEPT. C-9a, LOS ANGELES 45, CALIFORNIA



Zircalloy 2 — containing 1.5% or more tin — was the cladding material used for the nuclear power unit which carried the submarine Nautilus across the North Pole. Zirconium alone couldn't do it. Addition of small quantities of tin strengthened the zirconium and reduced the variable effect of impurities. It also had a favorable effect on its corrosion resistance. This discovery led to development of Zircalloys containing 0.5 to 5% tin.

Factory fresh hosiery is now available to American consumers in tin cans. The manufacturers claim canning nylons reduces pilferage and handling costs, lets the lady select her nylons factory fresh from her grocer's shelf.

Foreign car manufacturers are capitalizing on latest developments in tin applications. Directional signals, subject to continuous wear and hard weather conditions, are electroplated with a tin-zinc coating. A tin-nickel electrodeposit shows good potential as a bright tarnish-resistant coating for automotive trim, bumpers and accessories. A tin-bronze coating of up to 12% tin and a tin-nickel coating of two-thirds tin are proving excellent undercoatings for chromium.



Write today for more data on these items or for a free subscription to TIN NEWS—a monthly bulletin on tin supply, prices and new uses.

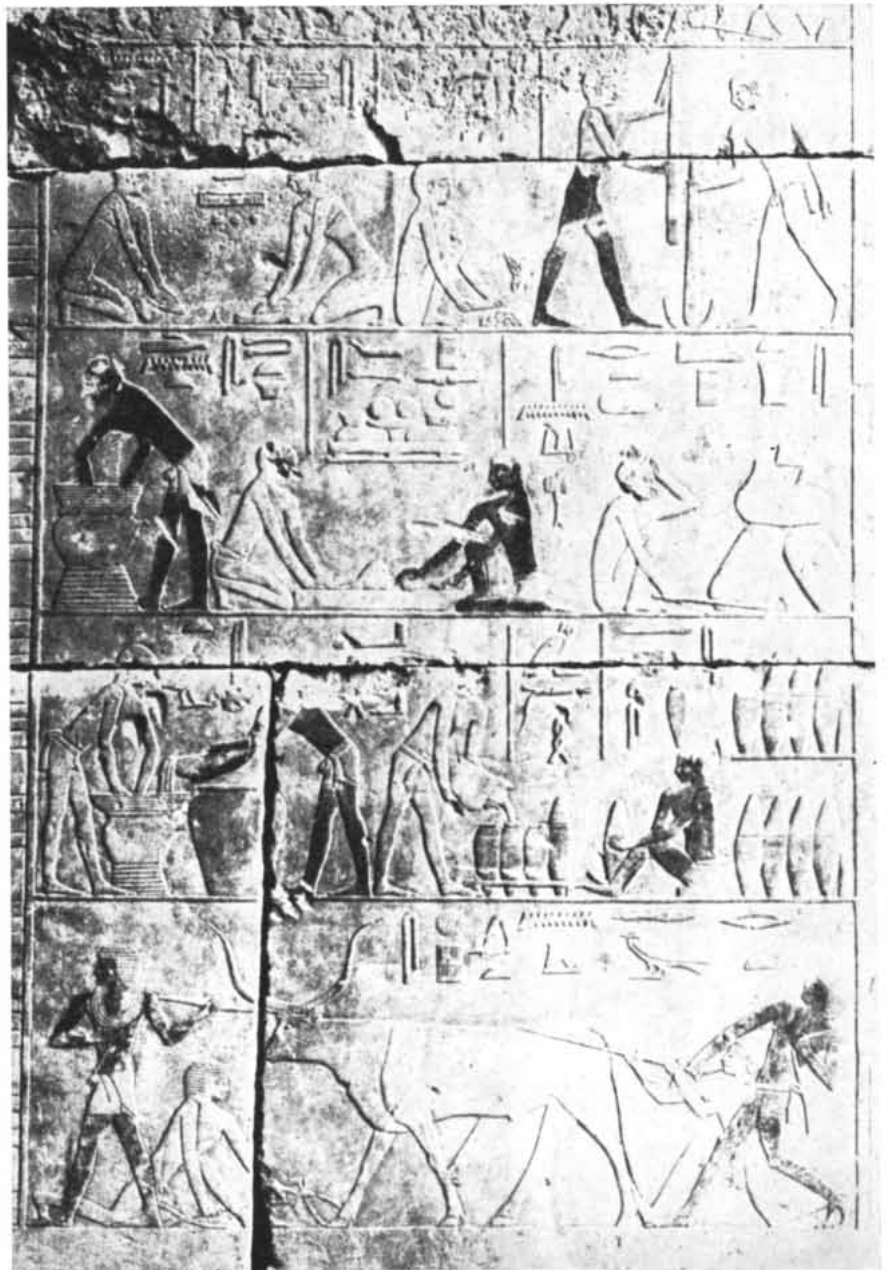
The Malayan Tin Bureau
Dept. 15F, 1028 Connecticut Ave., Washington 6, D.C.

nylon. Experimental brews treated in this way have shown a considerably extended shelf-life.

The Intrusion of Science

Since he deals in such evanescent commodities as taste and aroma, the brewer is understandably cautious in his approach to innovation in the brewing process. He has nonetheless been encouraged by the success of the scientific techniques so far employed and has begun to take a more critical view of the time-honored methods of his craft. The biochemist and microbiologist are now

well established in brewing research laboratories; soon they will be joined by representatives of other disciplines. Brewers are looking to geneticists, for example, to improve the strains of yeast. Perhaps chemical engineers will bring about the most revolutionary changes in brewing during the next decade or so. For example, techniques for replacing the traditional batch-method of brewing by a continuous process are already in the pilot-plant stage. Clearly the intrusion of science into the art of brewing promises to bring great changes in the procedures that have served so well for six millennia.



BREWING IN ANCIENT EGYPT is depicted by this relief in the Rijksmuseum of Leiden. At left in the third row a brewer pours water into a vat; at right the beer is poured into jars.



**Du Pont
announces**



Delrin[®]

ACETAL RESIN



**... a completely new engineering material offering
a combination of properties unmatched by any other thermoplastic**

This is Du Pont Delrin:[®]

"Delrin" acetal resin is a highly crystalline, stable form of polymerized formaldehyde. This completely new material offers you metal-like mechanical properties, such as a high degree of strength and rigidity, plus other properties that metals do not possess.

The combination of properties offered by "Delrin" is unequalled by any other thermoplastic. For example, "Delrin" has high dimensional stability, tensile and flexural strength, resilience and toughness. Most importantly, "Delrin" retains these desirable properties under a wide range of service conditions—temperature, humidity, solvents and stress.

Over the past three years, "Delrin" has been

Typical performance and production advantages of "Delrin"



A brass part in a commercial flush valve was duplicated in "Delrin". This part operated perfectly for 18 months—the period of test—although it was completely and continuously immersed in water. The outstanding dimensional stability of "Delrin" under a wide variety of service conditions has also been proved, for example, in showerheads (continuously running water at 150°F.), and movie projector gears (run over 2,000 hours at ambient humidity).

This textile solution pan is ordinarily made of stainless steel. It must have resistance to oils and organic solvents, a clean, smooth surface; it also requires several threaded inserts plus other details. In normal quantities, stainless steel pans cost approximately \$25 each. Injection molded in "Delrin", the cost was quoted at about \$3 each. Testing showed that "Delrin" provided the required finish without machining, the needed solvent resistance, plus a weight saving of 75%.

A zinc die-casting mold was used to make this instrument cluster of "Delrin". Weight was reduced over the zinc component by almost 80%. In addition to manufacturing economies, further savings in assembly are indicated: self-tapping screws can be used, since the creep resistance of "Delrin" prevents loosening or stripping. These clusters can be molded in integral color or painted, and with a conventional mold would require little, if any, mechanical finishing.

Aerosol containers made of "Delrin" were shelf-stored for over a year; others stored for 3 months at 130°F. In both cases, the contents were still completely dischargeable. "Delrin" retains its strength and toughness for long periods, even when exposed to elevated temperatures and organic solvents. Equally important are the new opportunities for high styling opened by "Delrin"—the freedom to design in new shapes and integral colors to suit purchasing trends.

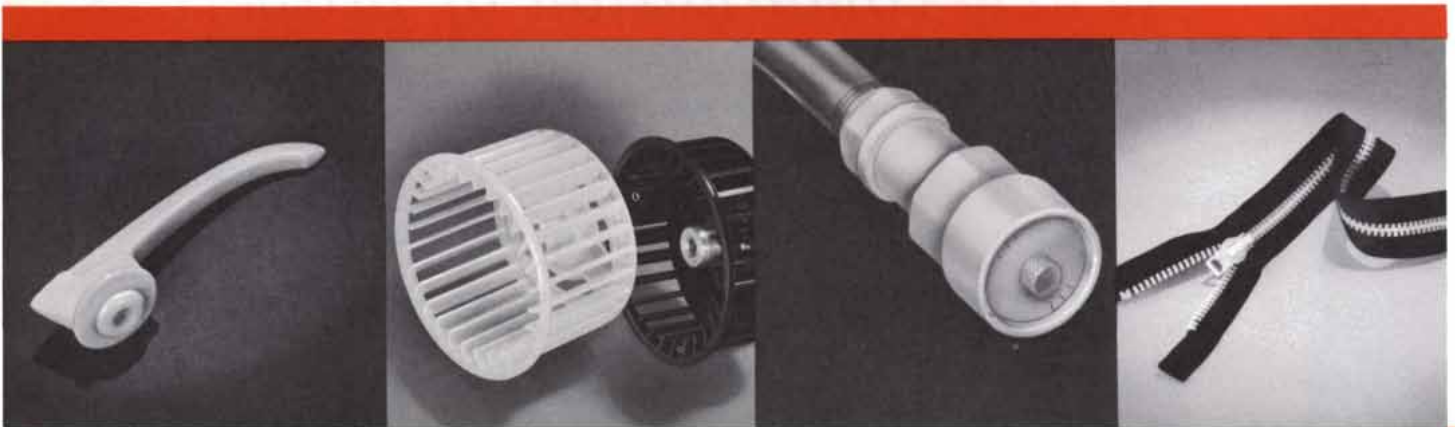
tested in hundreds of end-use applications by a host of industrial concerns. These tests have confirmed that parts made of "Delrin" can compete *on a performance and cost basis* with parts made of many metals, rubber, glass or wood. Of the various end-uses tested, 75% would normally be made of metal and another 10% of rubber, glass or wood. These tests have resulted in many applications of "Delrin" now being readied for commercial production—including gears, bearings, housings, containers, plumbing and hardware parts, pump impellers, "squirrel-cage" blowers, door handles, clothing fitments and many others.

In addition to metal-like performance, "Delrin" offers you the manufacturing economies inherent

in the production methods of the plastics industry. "Delrin" is easily injection molded, extruded, blow-molded or fabricated with conventional machine tools.

Illustrated below are a few of the applications of "Delrin" which have undergone extensive field service tests. The performance and economies listed were indicated during comparative evaluations made with materials in use at the time of the tests. These applications, together with additional data on the following page, may well suggest ways in which this versatile new engineering material can help *you* improve a product, lower its cost or develop new designs for your profit. Your inquiry is invited (see coupon on next page).

evaluated during three years of field tests . . .



Accessories usually made of metal, such as automotive window cranks and refrigerator door handles, can be economically mass-produced in "Delrin" by injection molding. "Delrin" provides required strength and rigidity. Integral colors, a variety of surface effects and functional details can be produced in one operation. Less weight, improved styling, dependable performance and potential cost savings are made possible by "Delrin".

Industrial components such as this "squirrel-cage" blower—as well as a variety of gears, bearings and other mechanical parts—have demonstrated the ability of "Delrin" to compete with various metals on a performance and cost basis. "Delrin" offers excellent fatigue life even when immersed in oil or water. Rapid production of lightweight, intricate components by the injection molding process can lead to substantial manufacturing economies with "Delrin".

Plumbing fixtures made of "Delrin", such as this showerhead, offer the manufacturer new styling and design advantages . . . and the home owner new latitudes in bathroom décor. Injection molded in integral color, fixtures made of "Delrin" assure builders and home owners of long-term dimensional stability, freedom from rust and mineral build-up. Modern in design, they are durable and dependable in service, and provide opportunities for potential cost savings.

Clothing fitments, such as zippers, clasps and snaps, are also readily and economically molded in "Delrin". Stiffness, toughness and resistance to heat, body oils and perspiration make "Delrin" a logical choice for such uses. Your customers would welcome the light weight, colorability and warm-to-the-touch benefits "Delrin" offers. Extensive field tests have demonstrated that "Delrin" is one of the most promising new materials available to the fitments industry.

TYPICAL PROPERTIES OF "DELTRIN" ACETAL RESIN

PROPERTY	ASTM NO.	AVERAGE VALUES FOR "DELTRIN"	
		500X	150X
Elongation	-68°F. D638	13%	38%
	73°F. D638	15%	75%
	158°F. D638	330%	460%
Impact strength, Izod	-40°F. D256	1.2 ft.lb./in.	1.8 ft.lb./in.
	73°F. D256	1.4 ft.lb./in.	2.3 ft.lb./in.
Tensile strength and yield point,	-68°F. D638	14,700 psi	
	73°F. D638	10,000 psi	
	158°F. D638	7,500 psi	
Compressive stress	at 1% deformation D695	5,200 psi	
	at 10% deformation	18,000 psi	
Flexural modulus,	73°F. D790	410,000 psi	
	170°F. D790	190,000 psi	
	250°F. D790	90,000 psi	
	100% RH 73°F. D790	360,000 psi	
Flexural strength	D790	14,100 psi	
Shear strength	D732	9,510 psi	
Heat distortion temperature,	264 psi D648	212°F.	
	66 psi D648	338°F.	
Fatigue endurance limit, 50 to 100% RH	70°F.	5,000 psi	
	100% RH 150°F.	3,000 psi	
Water absorption, 24 hours immersion	D570	0.12%	
	equilibrium, 50% RH D570	0.2%	
equilibrium, immersion, 77°F.		0.9%	
Specific gravity	D792	1.425	
Rockwell hardness	D785	M94, R120	
Flammability	D635	1.1 in./min.	
Melting point (crystalline)		347°F.	
Flow temperature	D569	363°F.	

PROPERTY	ASTM NO.	AVERAGE VALUES FOR "DELTRIN"
Deformation under load (2,000 psi at 122°F.)	D621	0.5%
Coefficient of linear thermal expansion	D696	4.5 x 10 ⁻⁵ per °F.
Taber abrasion (1000 gm. load, CS-17 wheel)	D1044	20 mg/1000 cycles
Thermal conductivity		1.6 BTU/hr./sq. ft./°F./in.
Specific heat		0.35 BTU/lb./°F.
Modulus of rigidity		178,000 psi
Poisson's ratio		0.35
Dielectric constant, 73°F., 10 ² -10 ⁵ cps	D150	3.7
Dissipation factor, 73°F., 10 ² -10 ⁵ cps	D150	.004
Dielectric strength, short time	D149	500 V/mil
Volume resistivity	D257	6 x 10 ¹¹ ohm/cm
Resistivity	D257	2 x 10 ¹³ ohm
Arc resistance	D495	129 seconds (burns)

P Factor at 73° F.:

Permeability:		
Water	1.9	gms loss/24 hrs/100 in ² area/mil thickness. Determined on bottles with 35-50 mil wall thickness.
Ethanol	0.2	
Freon® 12-114 (20/80)	< 0.2	
Methyl Salicylate	0.3	

Room Temp. 122° F.

Resistance to Organics:				
Resistance to Organics:	CCl ₄	1.2	5.7	% wt. gain—12 mo. total immersion Vol. change proportional to wt. change.
	Toluene	2.6	2.8	
	Acetone	4.9	2.6	
	Alcohol	2.2	1.9	
	Ethyl Acetate	2.7	2.9	

*These values are representative of those obtained under standard ASTM conditions and should not be used to design parts which function under different conditions. Since they are average values, they should not be used as minimums for material specifications.

DELTRIN[®] offers design engineers a new combination of properties

ACETAL RESIN

"Delrin" acetal resin offers you a combination of properties and potential cost advantages never before offered by any single material. Specific values of typical properties of "Delrin" are listed in the table above . . . and the advantages implicit in these figures have been thoroughly tested in a wide variety of end-uses.

Today is your best opportunity to consider how Du Pont "Delrin" can help you improve the design of a product or develop your designs on new products. Within the next few weeks a new plant to manufacture "Delrin" in commercial

quantities will come on stream at Parkersburg, W. Va. This plant is your assurance that your design improvements can fast become practical realities. Commercial molders, already familiar with "Delrin", can provide you with valuable assistance in your problem.

A specialized group of Du Pont engineers, as well, can help you with their experience and knowledge gained during years of market development work with "Delrin". They may well have tested the very product or component you are considering.

FOR MORE SPECIFIC INFORMATION MAIL THIS COUPON

E. I. du Pont de Nemours & Co. (Inc.), Advertising Department
Nemours Building, Rm. 99D, Wilmington 98, Delaware

I am interested in evaluating "Delrin" for the following use: _____

NAME _____

COMPANY _____ POSITION _____

STREET _____

CITY _____ STATE _____

In Canada: Du Pont of Canada Limited, P.O. Box 660, Montreal, Quebec.

DELTRIN[®]
ACETAL RESIN



REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
... THROUGH CHEMISTRY

SELF-REPRODUCING MACHINES

In which simple units are built which assemble themselves into larger units, which in turn make copies of themselves from other simple units. The process sheds light on the self-reproduction of biological molecules

by L. S. Penrose

The mass production of multiple copies of the same object by printing or by assembly of prefabricated parts is an event so commonplace that examples can immediately be called to mind. The reader has one at hand in the copy of *SCIENTIFIC AMERICAN* in which he reads these words. The idea of an object reproducing itself, however, is so closely associated with the fundamental processes of biology that it carries with it a suggestion of magic. Indeed, the construction of a machine capable of building itself might be judged to be impossible and to belong to the category of perpetual-motion engines. At the present time, however, advances in genetics are rapidly leading biologists to focus their attention upon the structure and function of self-reproducing molecular chains which, in the nuclei of living cells, preside over all their functional activities. The structure of these chains of nucleic acid is already quite well understood. But the general theory of self-reproduction, in which the replication of nucleic acid would represent a special case, has not been much investigated.

The theory has two aspects, which can be called the logical and the mechanical. The logical part was first investigated by the late John von Neumann of the Institute for Advanced Study in Princeton, N. J. He decided in 1951 that it must be possible to build an engine that would have the property of self-reproduction. The method would be to construct a machine that is capable of building any describable machine. It would follow logically that such a machine would be able to build another machine just like itself. Each machine would carry a sort of tail bearing a code describing how to make the body of the machine and also how to reprint the code. According to von Neumann's associate John G. Kem-

eny, the body of the machine would be a box containing a minimum of 32,000 constituent parts and the "tail" would comprise 150,000 units of information. On the mechanical side the elementary parts, out of which this object was to be built, were considered to be likely to include rolls of tape, pencils, erasers, vacuum tubes, dials, photoelectric cells, motors, batteries and other devices. The machine would assemble these parts from raw material in its environment, organize them and transform them into a new replica of itself [see "Man Viewed as a Machine," by John G. Kemeny; *SCIENTIFIC AMERICAN*, April, 1955]. Since the aim of von Neumann's reflections was to resolve the logical conditions of the problem, the stupendous mechanical complexity of the machine was of no consequence.

The mechanical problems involved in constructing such a machine have been investigated by Homer Jacobson of Brooklyn College in New York. In one experiment he built an electrically powered railroad track around which two kinds of trucks, respectively called "head" and "tail," could circulate. Initially these trucks were arranged in a random order. If a head and a tail were

first assembled upon a siding, however, they would signal to another head and another tail to connect up on an adjacent siding. So long as there were trucks and sidings available this process could continue, and the head-tail machines would be assembled automatically. The design of the trucks and of the railroad itself involved considerable complexity and a great many different elements such as wires, tubes, batteries, switches, wheels, photoelectric cells and resistances. This intricate apparatus generated only one kind of building operation, but the operation was indeed a kind of self-replication.

Together with Roger Penrose I have approached the problem in a more radical manner, without the encumbrance of prefabricated units such as wheels and photoelectric cells. Our idea was to design and, if possible, to construct simple units or bricks with such properties that a self-reproducing machine could be built out of them. One everyday example of mechanical self-replication involving simple units is the "zipper" fastener. Here the self-replicating unit is the pair of interlocked hooks; the zipper-slide provides the energy to push each pair of hooks together. As soon as one pair is connected, a whole chain made up of similarly connected pairs can be formed. The example is defective in that only one type of connection is formed in the zipper, and the units are not completely separate before the action takes place. Another simple instance of self-replication is offered by a suitably designed mold, template or photograph. Ordinarily such replication calls first for a negative from which a positive like the original can be recovered. A negative can, however, be combined with the positive in such a



SELF-REPRODUCING DESIGN is identical with its own photographic negative, except for checkerboard border surrounding it.

way that, by replicating both at the same time, the two steps are reduced to one. Thus in the illustration on the preceding page we have a design whose negative will be identical with the original because of its peculiar symmetry. This suggests that it is convenient, and perhaps necessary, for a self-replicating object to carry its own template or negative.

In the design of the units or bricks for our self-replicating machine we laid down certain arbitrary standards. The units, we decided, must be as simple as possible. They must be of as few different kinds as possible. And they must be capable of forming at least two (preferably an unlimited number) of distinct self-reproducing structures. Finally we decided that the energy necessary to engage these units in the process of self-replication should be supplied in the simplest manner, by merely shaking the units in a confined space but otherwise allowing them as much freedom of movement as possible.

One essential condition was to be that the units would not form self-reproducing machines just because they were moved about. They were to reproduce themselves only when the object to be replicated was introduced as a pattern for copying. The logic of this condition is to be found in William Harvey's maxim: *Omne vivum ex ovo* (in modern form: No life except from life). By definition, self-reproduction requires a "self" to be reproduced.

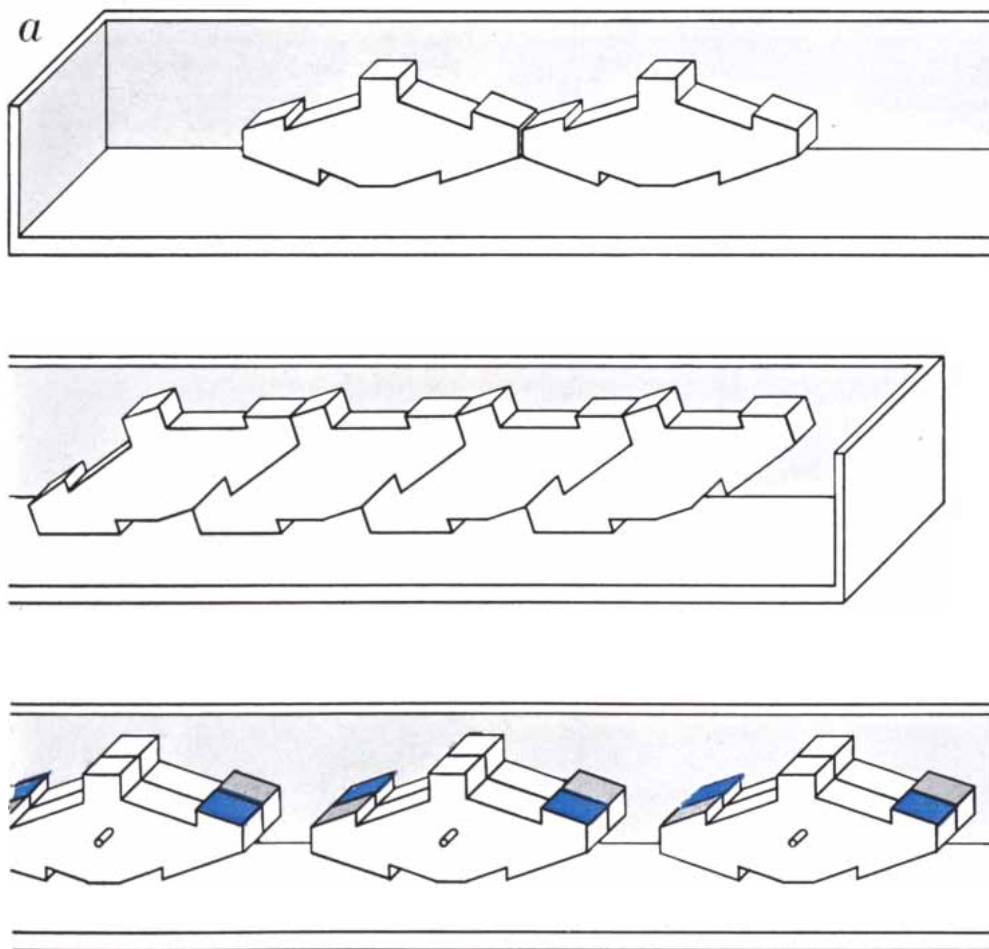
In fanciful terms, we visualized the process of mechanical self-replication proceeding somewhat as follows: Suppose we have a sack or some other container full of units jostling one another as the sack is shaken and distorted in all manner of ways. In spite of this, the units remain detached from one another. Then we put into the sack a prearranged connected structure made from units exactly similar to those already within the sack. Such a structure might arise, of course, by chance in response to random shaking, but this would be very unlikely indeed, as is the case with the analogous process of mutation in genetics. Now we agitate the sack again in the same random and vigorous manner, with the seed structure jostling about among the neutral units. This time we find that replicas of the seed structure have been assembled from the formerly neutral or "lifeless" material. It follows that each replica is capable of self-reproduction like the original seed, and that reproduction will continue until all the "food" is used up.

The building of actual models in our investigation began with a much sim-

pler experiment in mind. In the inorganic world the most obvious analogy to self-reproduction in living matter is the growth of a crystal. The construction of an artificial crystal that would repeat some prearranged pattern indefinitely seemed to offer a useful starting point. The first machine built on these lines proved most illuminating. It consisted of two pieces of plywood cut to a special shape, each about four inches long and a quarter-inch thick, standing end to end on the inner surface of the long side of a shallow rectangular box resting on its side [see illustration labeled "a" on these two pages]. The box can be subjected to side-to-side agitation of a vigorous and irregular character, causing the pieces of plywood to move in one dimension from side to side, each colliding with its nearest neighbors. In the "neutral" position in which the pieces of plywood appear, however, they do not link under the influence of shaking alone. But if a "seed" consisting of two linked pieces is added,

this seed will link up with adjacent pieces standing on either side of it on the track. Eventually all the available neutral pieces will become attached to the "crystal." If the seed is inclined in the opposite direction, a complementary aggregate is built.

Certain principles become evident from the study of this machine. Here copying consists in imparting the same tilt to each unit. The seed carries, as it were, a positive pattern at one end and a complementary negative pattern at the other. These patterns influence the neutral units as they come into close contact with the seed, causing them to tilt in the positive or negative manner. Once tilted or "activated," the units are caught and locked to the growing crystal by the complementary notches cut into the profiles of the plywood pieces. These notches enable energy to be trapped and thus convert the energy of motion conveyed by agitation into the potential energy



MECHANICAL "CRYSTAL" demonstrates some of the underlying principles of self-reproducing machines. At upper left in *a* appear two identical units at the "neutral" position in which they are unable to link up with one another. Introduction of two linked units

that binds the structure. Energy traps are characteristic of living matter, although they occur also in artificial and natural structures. A pool that retains water after a tide has receded is typical. In chemistry the bonding of an endothermic compound is analogous to a latch. Unless our synthetic structures contained more potential energy than their constituent units separately, it would be difficult to prevent spontaneous aggregation.

The crystallizing or, we might say, the polymerizing machine can be greatly improved by making units out of two plywood elements tied together by an axle so that they can pivot in opposite directions [see illustration labeled "b" on these two pages]. As can be seen, there are four ways of arranging the seed, of which two are essentially the same and the other two are mirror images. Besides giving rise to more types of seed in the case where the two parts of each unit are tilted in opposite senses, the double

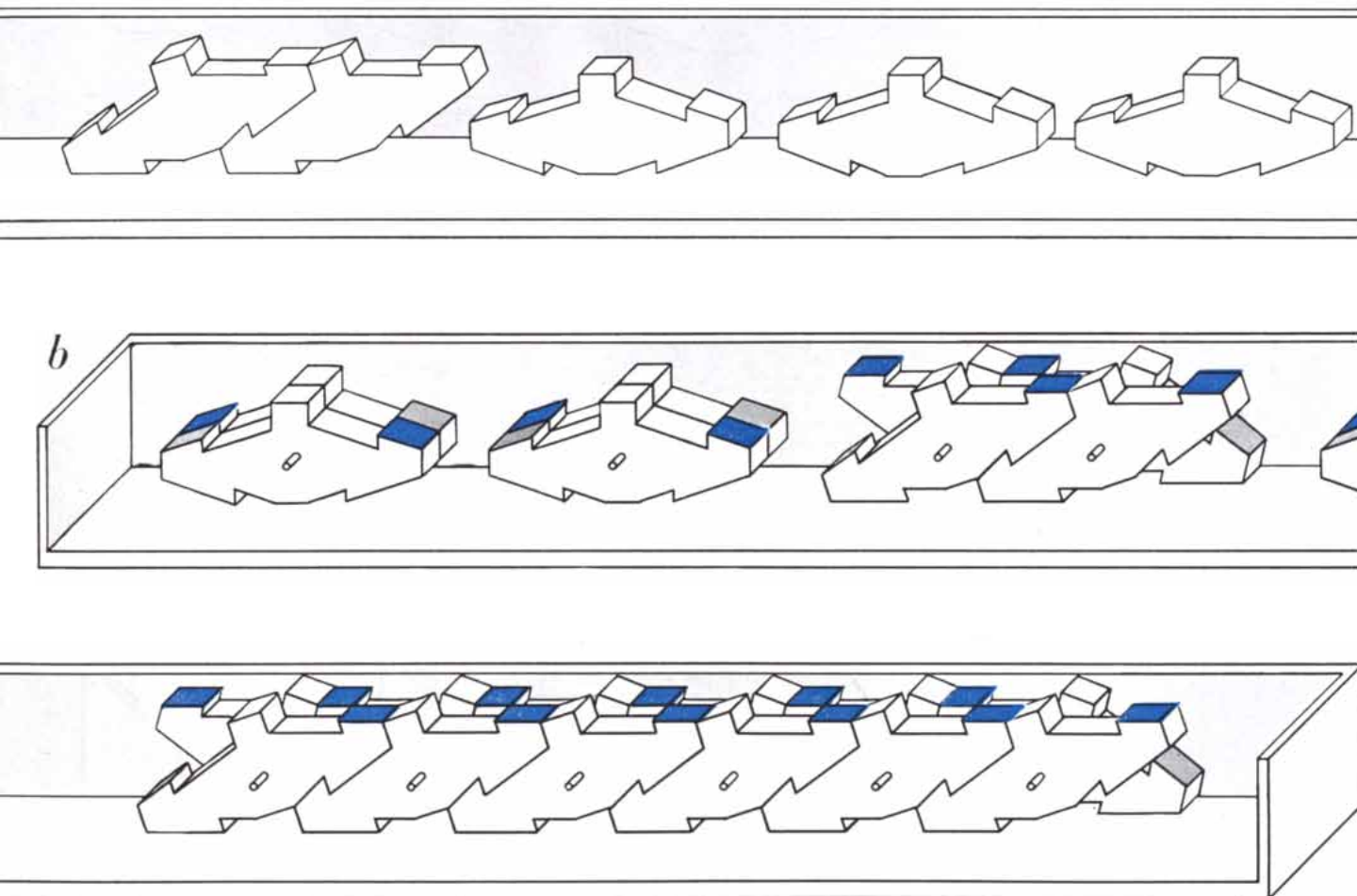
units form much stronger structures than single units.

The problem of reproducing an object the same size as the seed has now to be solved. This is done with surprising facility. It is only necessary to alter the basic units by removing one pair of notches from each of them. In effect the crystal is broken up into discrete bodies, each made of two units [see top illustration on next page]. Two stable mirror-image seeds can be constructed, and either may be used as a starter. In a long box or track, populated with neutral units randomly arranged, the presence of a seed causes other structures of its own kind to be built wherever two neutral units are in the appropriate relative positions.

This design provides a simple and convincing demonstration of artificial self-reproduction. Either type of seed may be introduced into the track; since they and their offspring are easily distin-

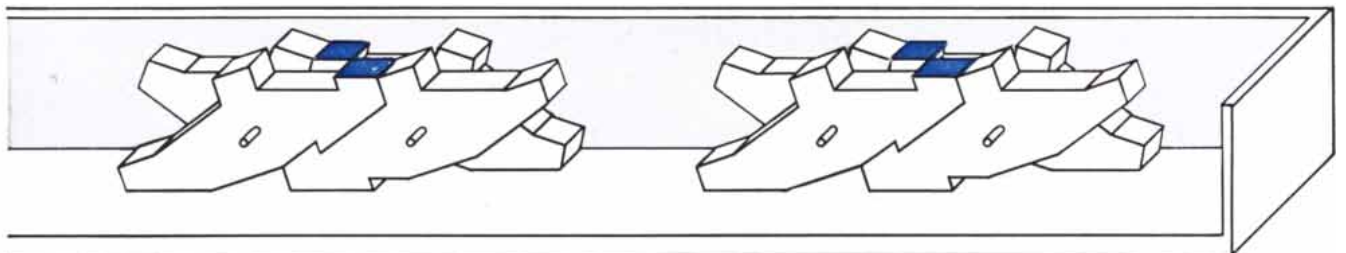
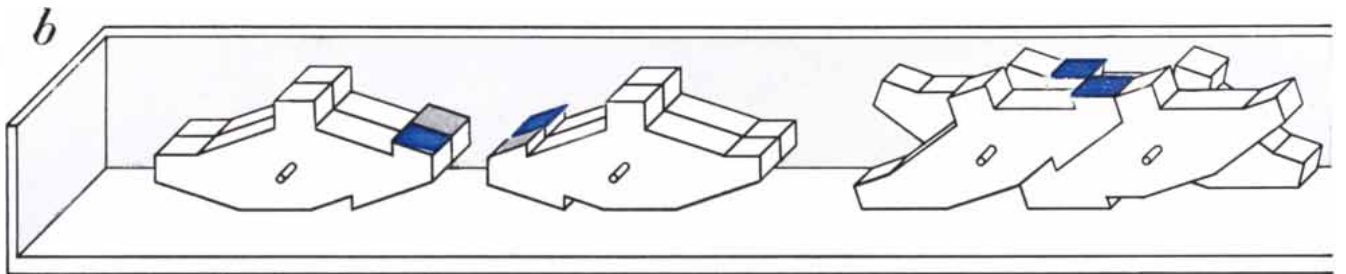
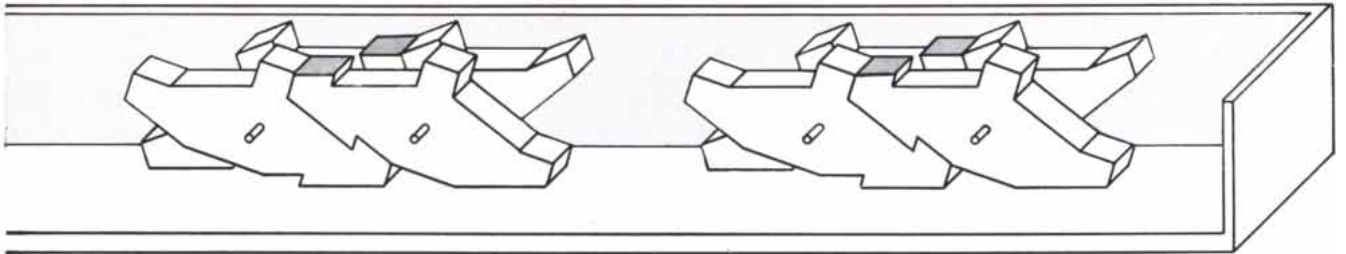
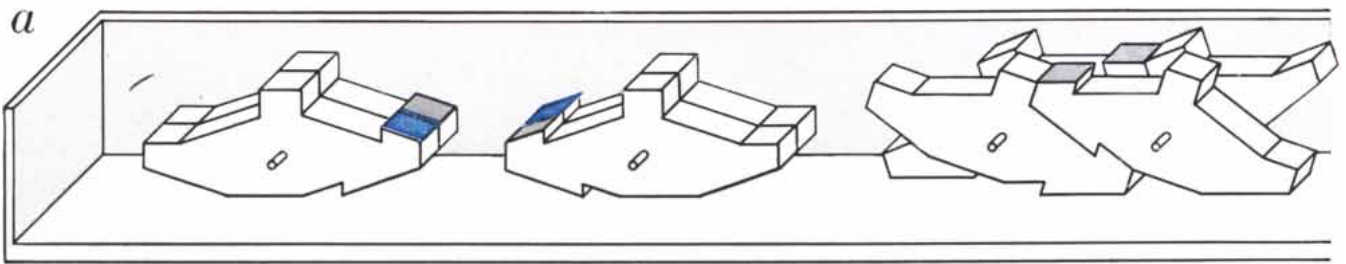
guished, it can be seen that each breeds true to type.

A point that emerges here, when the process is critically examined, is that during agitation some units transmit the tilted pattern of the seed although they do not find a partner to link with. These temporarily activated units tend to slide away from one another and from the completed structures, thereby tending to push some of the completed structures apart when agitation has subsided. It is convenient in self-reproduction to arrange that the fresh complexes should repel one another once they have been formed. If they separate widely, they can pick up "food" from different places and they do not interfere with one another's subsequent reproduction. In a restricted one-dimensional track this point is irrelevant. But it becomes significant in the next phase of the discussion, when we consider how we might lift the one-dimensional restriction of the track and make it possible for our self-replicating



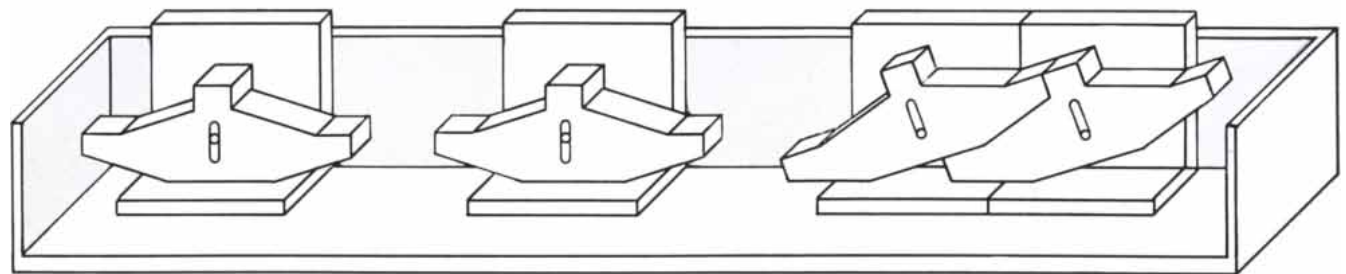
as a "seed" in panel at upper right imparts tilt and makes it possible for entire group of units to link up and form a single structure when subjected to agitation in the horizontal plane. In *b* two

doubled units are shown, first in neutral position and then linked up to form a seed. When this seed is agitated with neutral units at lower left, all join to form the crystal structure at lower right.



SELF-REPRODUCTION is here demonstrated by units of a simple kind, identical with those that form the "crystal" on the preceding two pages except that the units each lack hooks at one end. In *a* the seed is formed with the gray telltale mark showing at the linkage;

in *b* the seed unit is formed with the colored telltale mark showing. When the seed of each kind is agitated in the horizontal plane with neutral units, the appropriate tilt is imparted to the neutral units and they link up to reproduce the structure of their seed.



ACTIVATING CAM-LEVER incorporates the simple tilting principle of the self-reproducing machines shown above for use with

more complex structures shown on page 111. These cams, held in tilted position by dowel in slot, transmit activation but do not link.

structures to move about freely in two dimensions.

In order to fit the units for self-reproduction into the larger world of two dimensions, it is necessary to complicate their design beyond the rudimentary shapes that have worked thus far. With units moving over a plane surface, without the support of the back wall of the one-dimensional track, a firm base for each must be provided. A simple solution is to mount the plywood element on a horizontal pivot fixed to an upright, which is in turn attached to the base of the unit. The element capable of tilting and transmitting its tilt then becomes a sliding cam-lever. To allow greater variety of interaction between units, the hooking mechanism can now be separated and made independent of the tilting process by transferring it to a different part of the unit [see bottom illustration on opposite page].

In the two-dimensional situation the simpler design permitted an activated unit to slide away and lose contact with a "live" group after it had gone part of the way toward building a new replica. This is quite uneconomical from the energy standpoint. We must therefore arrange matters so that a unit may hook on to a two-unit live group temporarily and be released when a fourth unit becomes attached to the group. We are thus led to consider mechanisms for making and releasing links in special circumstances. One such latch depends for its release upon the presence of another unit in close contact. The effect of this, as shown in the illustration at right, is to maintain combinations already built out of new pieces. But this arrangement produces no fresh structures. It would give us a sort of steady state. In order to make a reproducing complex with this device, the system of linkage and release must be doubled as shown in the illustration on the next page. Here each unit contains two releasable hooks facing in opposite directions. Though they are shown one above the other, they would in practice be mounted side by side on the same axle. With such an arrangement of latches the addition of a third unit to a linked pair creates a triple complex that does not separate until a fourth unit is added. When this has taken place, the two similar pairs of units disengage and gently repel each other as their hooks settle down to their lowest possible states of energy.

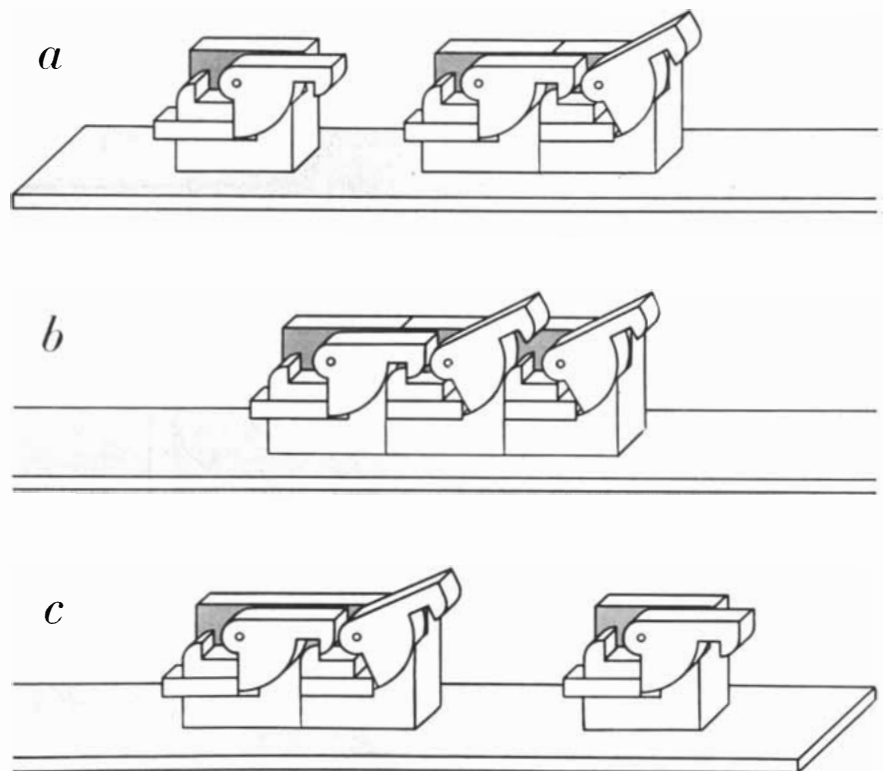
activation, that is, tilting caused by contact with a special seed. An activating element of some kind must be supplied so that neutral units cannot form links except in the presence of a live group that carries the activating principle. For this purpose the sliding cam-lever can be used to preserve a tilt and transmit it to neutral units; only those units that have been thus activated can approach each other close enough to link.

An interesting feature of this system is that it can replicate in two ways. If a live structure made of two units receives two neutral food units, both of them from either its left or right side, it will link them to itself and then release them linked to each other. On the other hand, if the original structure receives two food units, one on either side, it will link them to itself and then come apart in the middle [see bottom illustration on page 111]. As in the case of a single-celled organism, the original unit is destroyed in the process of replication. By the addition of special devices to the units it is possible to distinguish between these two kinds of replication; that is, one device will ensure that two units of food will always be taken in on one side, and another device will ensure that the two neutral units are added one on each

side. If there is no scarcity of food, it is likely that neutral units will be simultaneously available on both sides. For efficient reproduction, therefore, the second type of replication, that is, addition on either side and division of the seed, should be adopted as the standard.

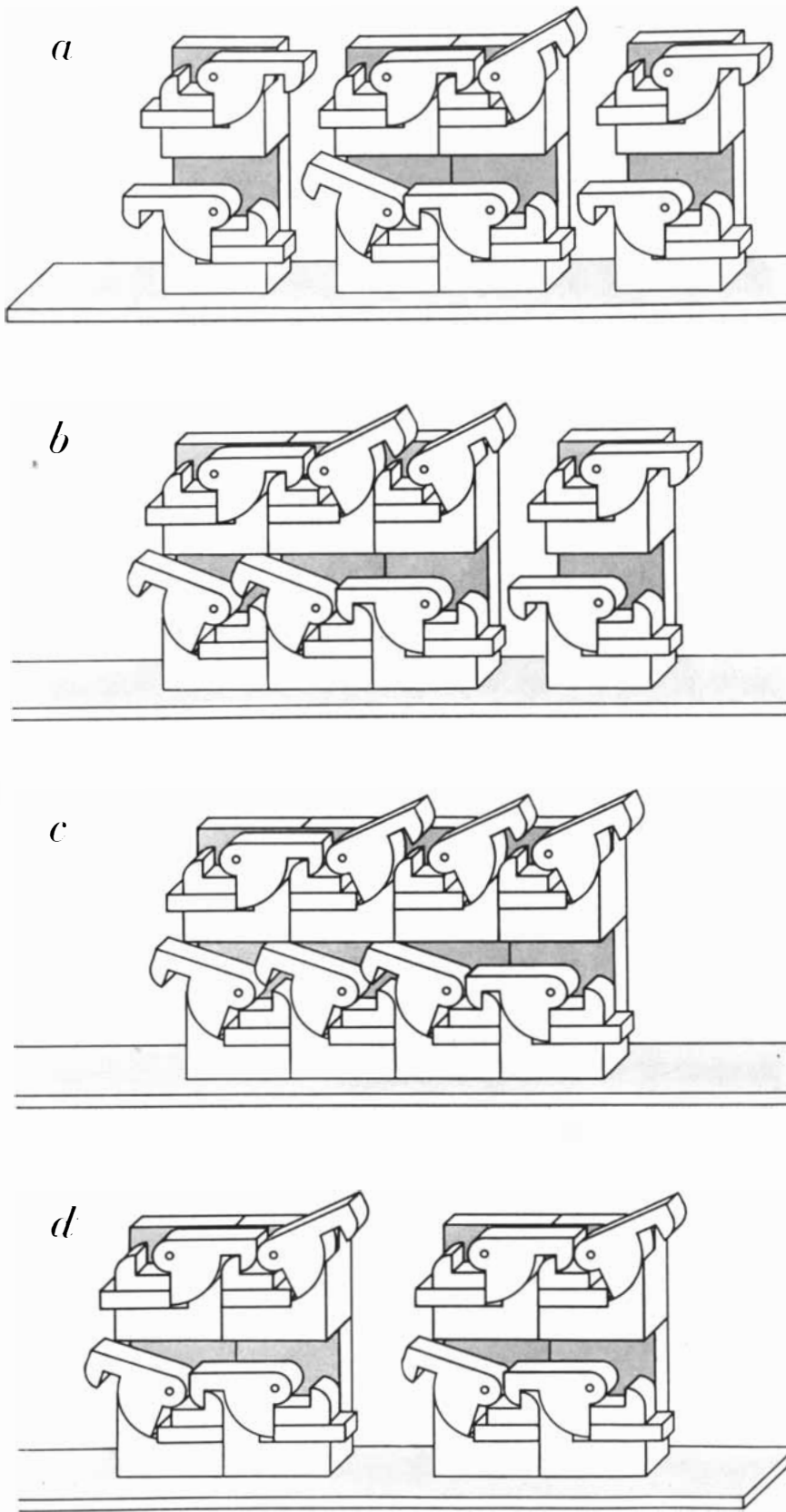
Another useful adjunct is a counting device. This can take the form shown in the top illustration on page 111. Such an element, which prevents more than four units from coming into close contact with one another, can be attached to each unit. The counter exerts its effect in that phase of reproduction, just before division, when the complex must cease accepting food. Before reproduction can be resumed the accretion of neutral units must stop long enough to enable the enlarged complex to come apart. The self-reproducing machine may also be equipped to make a kind of protective covering for itself out of "skin" units available in the environment. The skin would have to be thrown off in order to repeat self-replication.

The self-reproducing machine now requires one more adjunct to fit it for activity in two-dimensional space. To bring units into proper alignment for interlocking when random motion causes them to collide, their bases must be pro-



STEADY-STATE SYSTEM of hook and release is demonstrated here. When two units abut one another (a), one hooks onto the other, but the one that is hooked is itself set in release position. The addition from the left of a third unit (b) causes the first two to unhook (c).

It must be noted that this system of reproduction is incomplete because two pieces can link without any previous



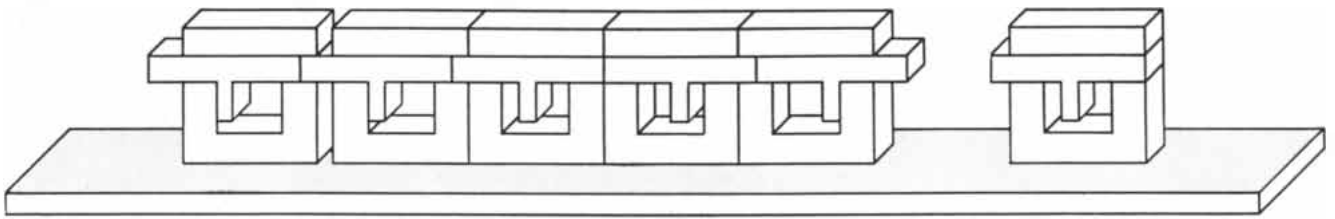
DOUBLE-HOOK UNITS, in contrast to steady-state system, possess capacity for self-reproduction. Cycle begins with linked group and two neutral units (a). Addition of neutral unit at left (b) causes one of two hooks in linked group to release. Addition of fourth unit (c) causes second hook in linked group to release. Linked group parts (d) in two replicas.

vided with interdigitating guides. The guides can also serve passively as hooks [see top illustration on page 112]. Some of the guides ensure correct apposition of hooks or activating levers and others cause the firm attachment of rows of pieces. With this additional device our units are endowed with a sufficient number of mechanical principles to enable self-reproducing machines of any desired degree of complexity to be built from them. Yet the units are of fairly simple construction and are either all of one kind or of a few different kinds.

The replication scheme of one such machine, made out of a set of units of two kinds, is shown in the bottom illustration on page 112. To ensure that replication proceeds regularly and that attempts at interconnection do not end in a tangle of hooks and guides, an ordering mechanism is included; an asterisk in the diagram indicates positions where the ordering mechanism permits new units to be added. The units each have two levers of the kind which can be activated positively or negatively, that is, tilted up or down; thus four types of activated units or rows of units are possible. The chain of units acting as a seed may be built in any predetermined number of rows and each row can be set with any one of four types of activation. When a fresh unit is added on either side of the double chain, no additional units of the same kind can attach themselves in that row. A different type of unit now forms a nonreplicating protective "skin" chain in response to the activating pattern of the complex. When all the open positions are filled with appropriate units, the self-replicating machine splits in two, sheds its skin, and the process may begin again.

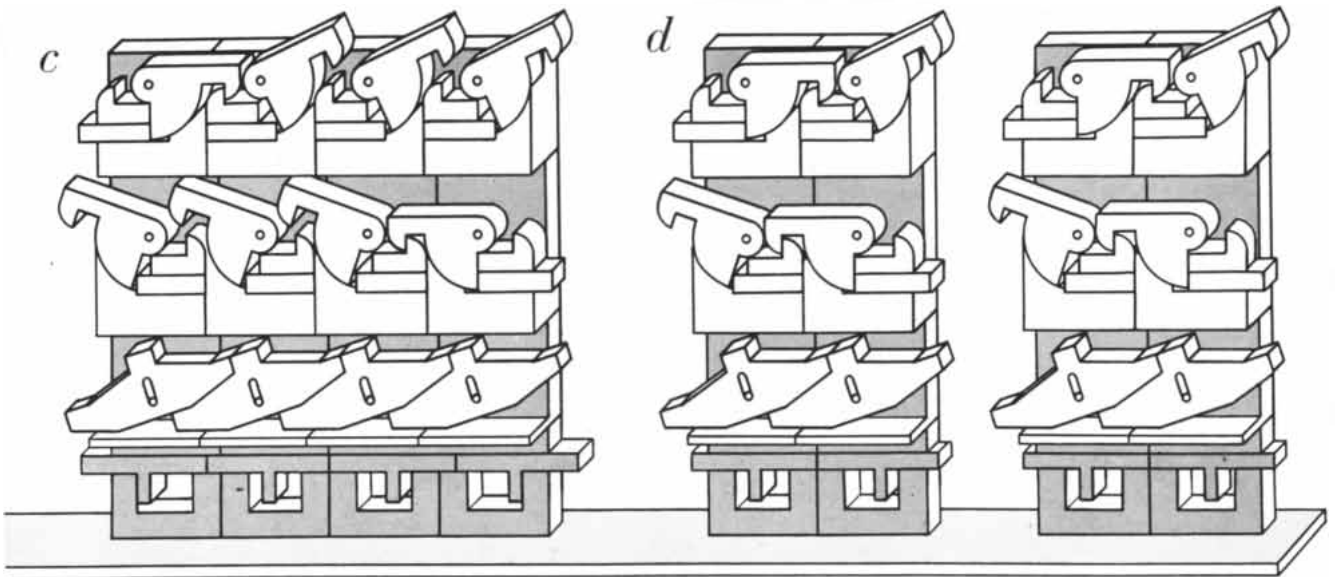
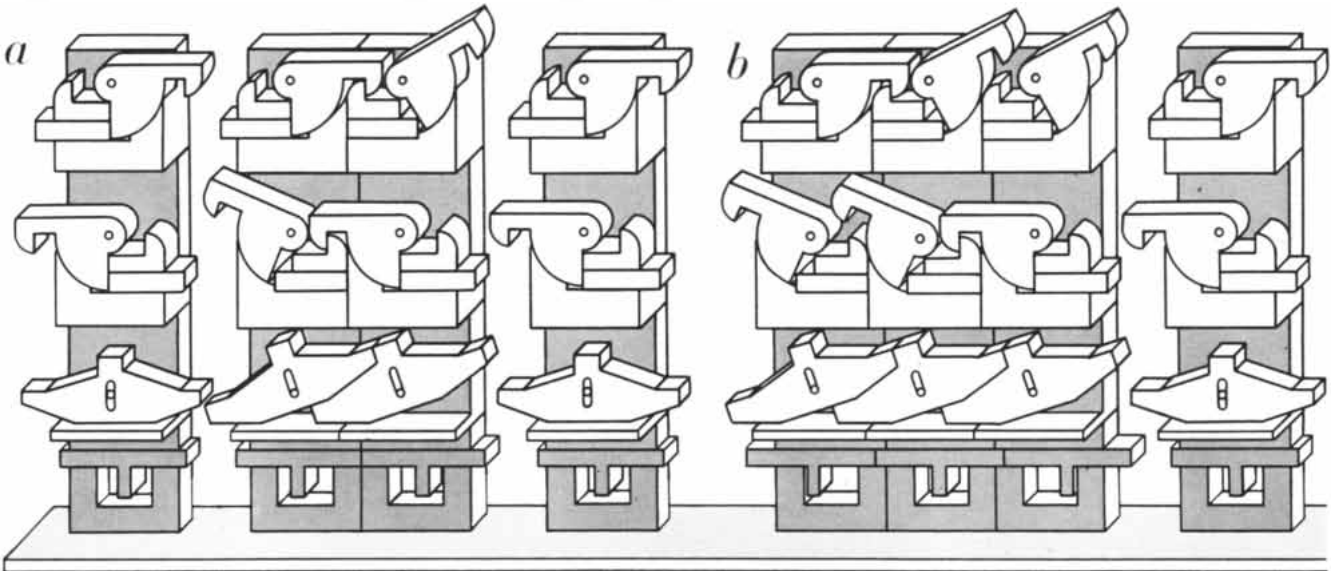
The design of units suitable for forming the protective chains presented peculiar difficulties; in overcoming these I came upon a new method of controlling and sequencing the latching and unlatching which provides an elegant solution of the von Neumann problem. A single string of determinate length, made up of units of a slightly different design, can replicate itself in the manner shown in the illustration on page 114. The addition of each new unit to the daughter chain has the effect of releasing the one behind it from the original chain. The final unit to join the new chain does not attach itself to the old chain at all, although it releases the new one from the old.

Here it should be emphasized that



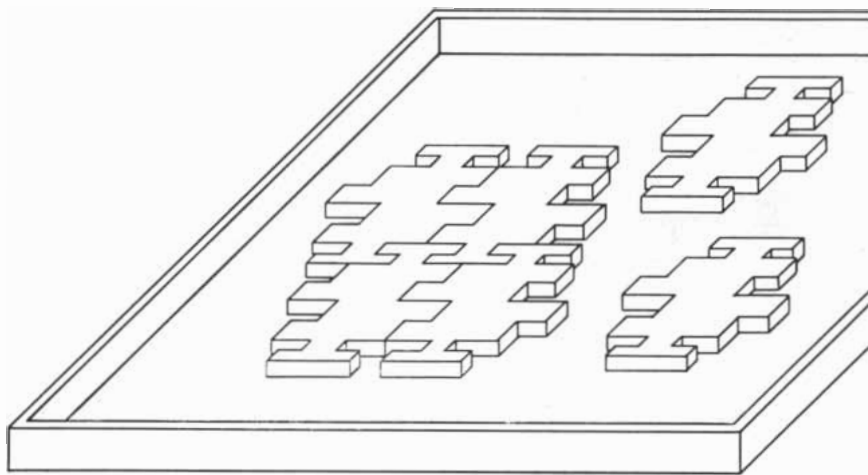
BLOCKING DEVICE prevents more than four units from coming close together. When four units are in close contact, the sliding

bar protrudes at either end of the group, keeping other units away. Device keeps groups from growing too large before they divide.



COMPLETE SELF-REPRODUCING MACHINE incorporates the basic elements and principles depicted in the preceding illustrations. The seed (at center in *a*) is linked by double hooks, incorporates the tilted cam-lever activating principle and is protected by the blocking device in its base. When the neutral unit at left joins

the seed (*b*), it disengages one of the hooks holding the seed together and sets the blocking mechanism so that only one more neutral unit can be added. When the fourth unit joins the triple group (*c*), it disengages the second hook in the original seed, causing it to come apart in the middle and form two replicas of itself (*d*).



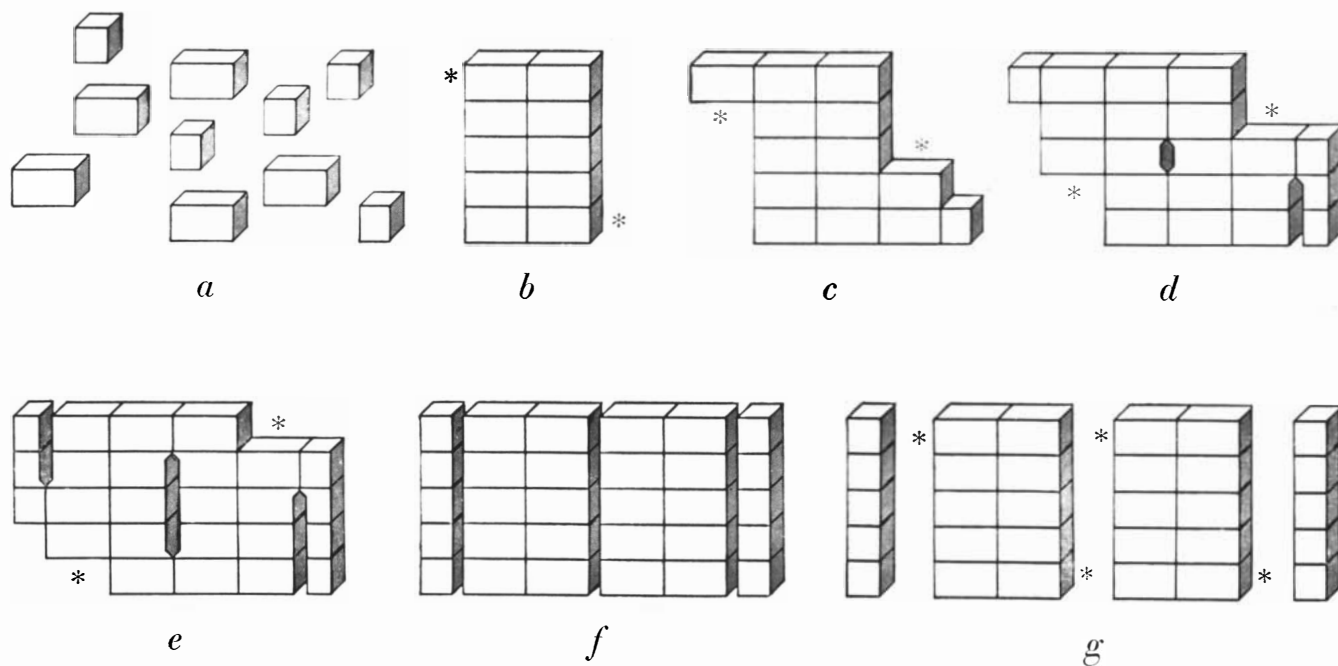
INTERDIGITATING BASES, on which superstructures capable of activation, hooking and release can be mounted, are designed to permit self-reproducing machines to operate in two dimensions and to orient themselves to one another for the purposes of self-reproduction.

each activated unit contains a message, that is, information that it transmits to neutral units. The total quantity of information depends upon the number of tilted levers and sometimes upon other features. The nucleus of a living cell also contains information that enables it to collect and build the substances necessary for its own replication. Natural selection encourages the reproduction of

nuclei that have the most efficient information for dealing with their surroundings. In artificial self-reproduction, equivalent programs of information would equip the machine not only to assemble themselves, but to build up their own structures out of their environment, to release energy sources and, in a sense, to provide their own track or table to guide interactions. Such an elaborate

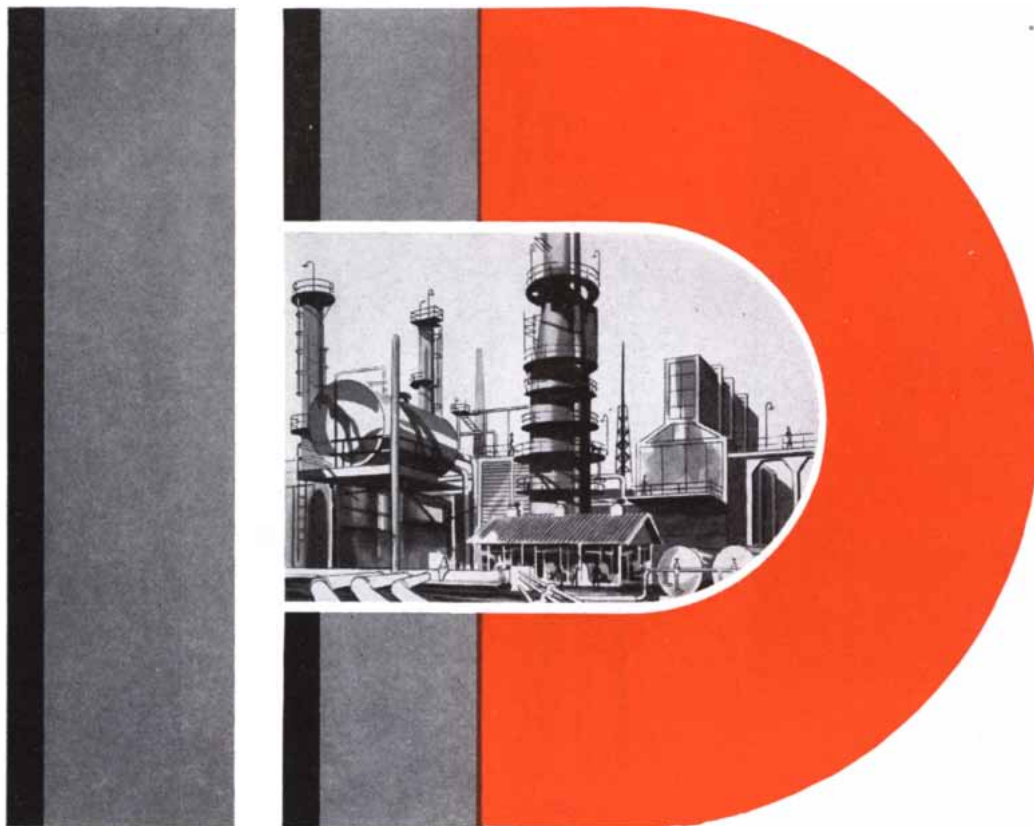
scheme is so far unattainable in practice. We have to be content with making a very parasitic organism. It is not, however, much more helpless than a virus. With such an object we can even provide a mechanical demonstration of the role of information in natural selection. To two machines, distinguished by key arrangements of their tilting cam-levers, we present neutral units locked up in a kind of matrix. These food units can be unlocked and brought into circulation by certain arrangements of tilting and not by others. Thus one mechanical creature will be able to unlock a plentiful supply of food while the other will starve and be shown to be relatively unfit in the struggle for self-replication.

Another feature of living things can be incorporated in the self-replicating machine. This is the capacity to change the program of information it transmits to its daughters. Of course change might be introduced by mistakes in reproduction even with well-constructed machines, but this, like genetic mutation in living things, is likely to be unfavorable and must be avoided by an efficient designer. Living organisms, however, exchange parts of their programs in a process known as recombination. In a very elementary form, something like this can be imitated mechanically. Now



GENERALIZED SYSTEM of self-reproduction is based on units of two kinds (a). The larger "body" units (b) form a live group; the asterisks indicate activated points at which units of the same kind can be added. The group begins to grow (c), with a smaller "skin" unit attaching itself at lower right. When units are attached

at corresponding points on both sides (d), the body units come apart and the skin units also begin to peel off (e). With growth completed, the original group splits, yielding two replicas of itself (f). As the skin units come loose (g) the two daughter groups become activated and are ready to begin the reproduction cycle again.



 +  = An important

announcement to the petroleum refining industry!

Daystrom Systems and Universal Oil Products Co. announce a cooperative effort in the application of computers to the control of industrial processes.

For the first time, the facilities and engineering talents of leading process designers and computer systems specialists are combined to offer a unique service to the customer. Daystrom contributes experience and leadership in the design and manufacture of highly reliable computer equipment. Universal Oil Products Company contributes extensive experience and know-how in process design.

Two and one-half years of intensive work have yielded important progress in a pilot plant installation incorporating a Daystrom digital computer control system.

This project marked the first process control application of a solid state digital computer specifically designed for on-line operation in the process industries.

The Daystrom Systems computer completely eliminates vacuum tubes and moving parts. More than two years of field operating experience permits Daystrom to guarantee system operational availability of more than 99%. A substantial number of Daystrom computer systems have already been purchased for control and data reduction.

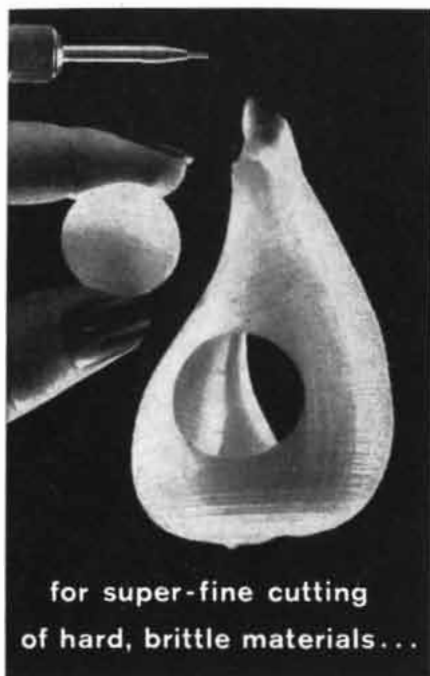
Daystrom has been granted license to manufacture and market control systems developed by Universal Oil Products and Daystrom Systems. Processes and techniques considered confidential by Daystrom clients will be handled by Daystrom Systems independently.

The advanced techniques and equipment developed by Daystrom Systems are available to you. For conference arrangements, write or telephone Daystrom Systems, A-100, Miramar Rd., La Jolla, Calif., GLencourt 4-0421.



INPUT CONSOLE FOR PROGRAMMING COMPUTER.

 **DAYSTROM SYSTEMS**
DIVISION OF DAYSTROM, INC.
Reliable computer control systems



the *S. White*

Industrial Airbrasive Unit

We cut a section from this fragile sea shell just to show that *in a matter of seconds* almost any hard, brittle material can be cut or abraded with the S.S. White Industrial Airbrasive Unit.

Cool, shockless, super-precise, the unit uses a controlled stream of fine abrasive, gas-propelled through a small nozzle. It is so flexible in operation that the same simple tool can frost a large area or can make a cut as fine as .008" ... on a production basis!

Almost every day new uses are being discovered for the Airbrasive Unit, in the lab or on the production line... shaping ... deburring ... wire-stripping ... drilling ... engraving ... frosting ... materials testing ... cleaning off surface coatings.

All types of hard brittle materials... glass, germanium and other fragile crystals, ceramics, minerals, oxides, metal, certain plastics.

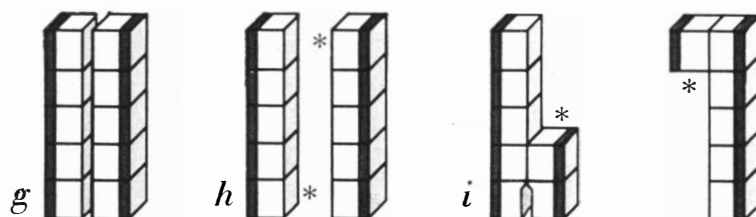
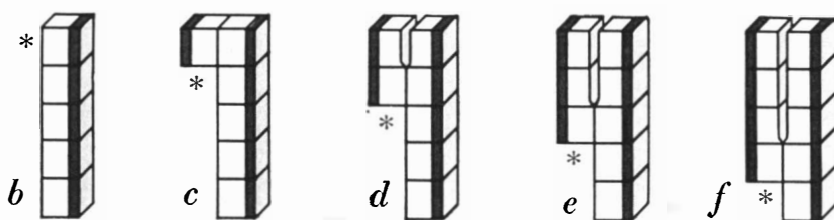
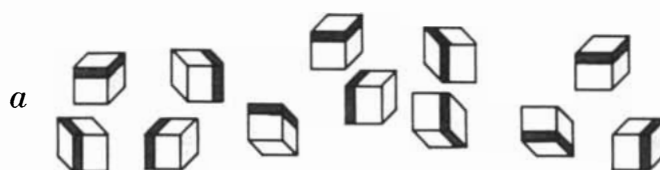
Send us samples and requirements and we will test them for you at no cost. For further information write for bulletin 5705A.

WRITE or CALL COLLECT

S. White



S.S. White Industrial Division
Dept. 5A, 10 East 40th Street, New York 16, N. Y.
Western Off.: 1839 W. Pico Blvd., Los Angeles 6, Cal.



MORE ELEGANT DESIGN for a self-reproducing system is depicted. Identical units (*a*) form a live five-unit group (*b*), activated for growth at the point indicated by asterisk. As growth proceeds (*c*, *d* and *e*) each new unit causes the preceding unit in the new column to become detached from the old. Addition of the last unit (*f*) causes the two groups to come apart (*g*). The activated daughter groups (*h*) now reproduce from neutral units (*i*).

if two machines carrying different programs should stand for a moment side by side, new units, approaching in one particular direction, might pick up their program half from one and half from the other. Thus if the program of one parental complex is described as AA and the other as BB, the new complex generated in these circumstances would have the program AB. This is easy to accomplish with a machine consisting of a single pair of units, but for a chain it presents many mechanical difficulties. These complexes would, in the ordinary way, breed true; only on rare occasions would the pieces come into apposition in the manner that is necessary to produce recombination.

It has been said that the fundamental mechanisms of the biological machine may perhaps be elucidated with the aid of theoretical models. The machines discussed here, however, are not models in this sense. They are machines in their own right, conceived for the specific purpose of self-reproduction. In some ways they may resemble living organisms and, insofar as this is so, they may help to explain how some primitive forms of life originated, maintained

themselves and eventually developed into more complex and more stable structures.

Self-reproductive chains of mechanical units may help to explain the way in which nucleic acids in living cells actually replicate. But they are more likely to assist in the understanding of systems of simpler character, like those that must have preceded the nucleic acids in the evolution of life. These structures may have occurred in molecules composed of polysaccharides, amino acids or phosphates. At least we need not suppose that they were anything like as complex as the nucleic acids. Such organic counterparts of the self-replicating machine are not, perhaps, accessible to our observation today in nature. Charles Darwin suggested in 1871 that the spontaneous appearance of very elementary forms of life might still be occurring. But he also pointed out that if a protein compound ready to undergo complex changes were spontaneously produced in the present day, it "would be instantly devoured or absorbed, which would not have been the case before living creatures were formed."

LINDE packaged oxygen plant sets nine-year record for availability!

THE LINDE oxygen plant shown here has been serving a leading chemicals producer "over-the-fence" continuously since 1949. Its operating log shows a 98%+ availability factor. Next year, capacity will go up from 360 to 800 tons of oxygen a day.

You can expect the same continuity of supply with a LINDE packaged plant serving your process. Your LINDE plant will be the product of fifty years' experience in the design, manufacture, and operation of air separation plants and low temperature equipment. LINDE is uniquely qualified to provide air separation plants for the supply of oxygen and/or nitrogen as well as the associated low temperature equipment for:

- liquefying hydrogen, helium and fluorine
- purifying hydrogen and helium
- separating hydrogen from coke oven gas
- ammonia and methanol synthesis
- upgrading of natural gas
- other extremely low temperature processes.

Put LINDE's more than 50 years' experience in gas separation techniques to work for you. Write Dept. R-6, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N.Y. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

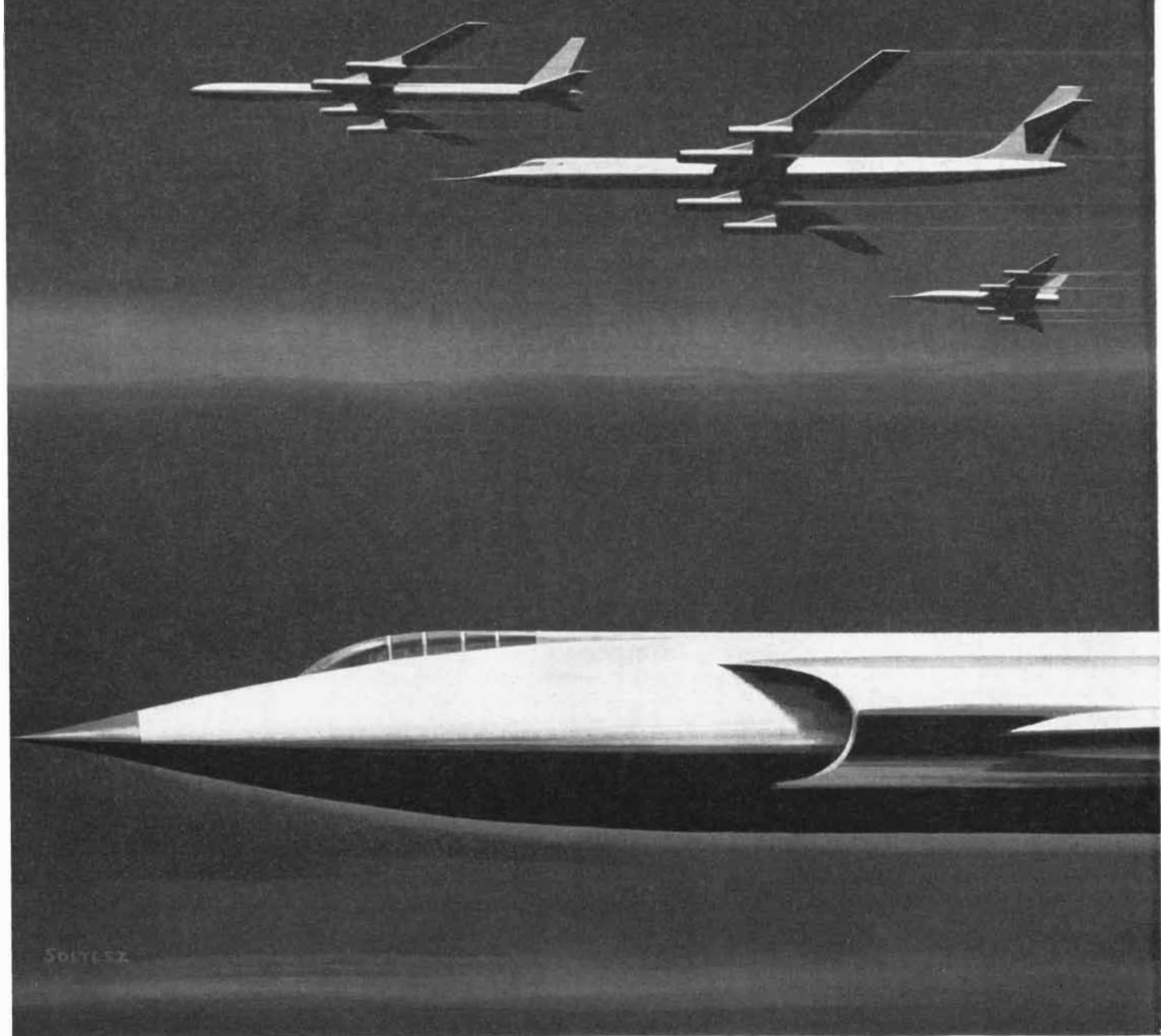
"Linde" and "Union Carbide" are trade-marks of Union Carbide Corporation.



Linde
TRADE-MARK

Industries that regularly require large quantities of oxygen or other atmospheric gases can obtain those they need from a LINDE plant on their own sites. The oxygen plant illustrated—built, owned, and operated by LINDE—is at a plant of one of the nation's largest chemical processors.

**UNION
CARBIDE**

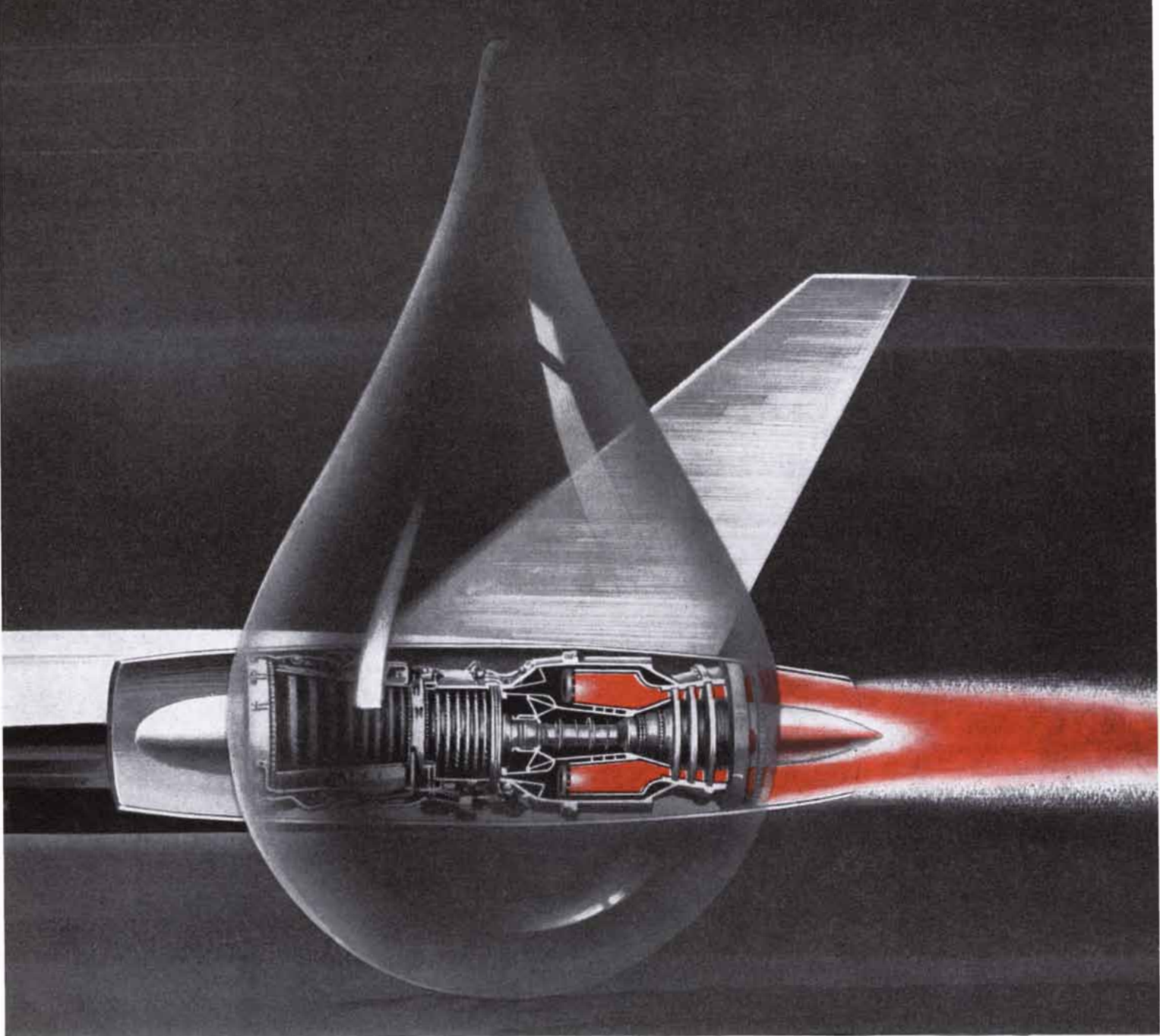


Lube "breakthrough" by *Celanese*

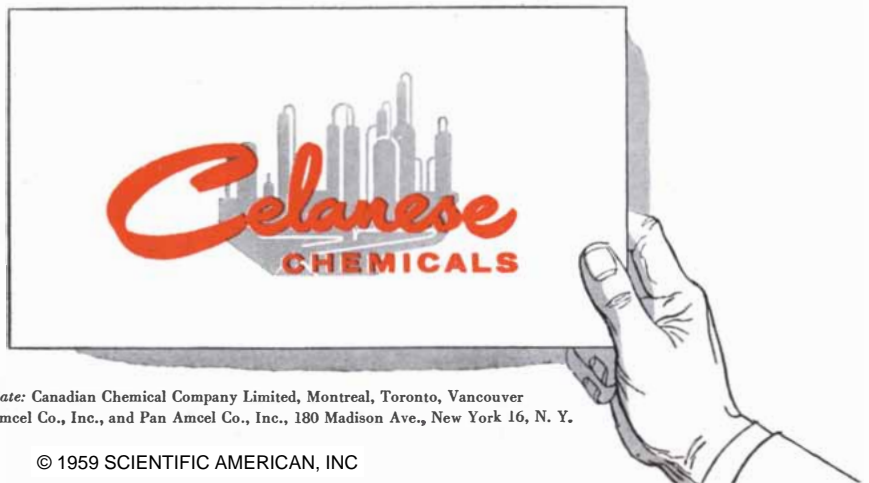
New Celanese synthetic lubricants have hurdled the heat barrier set up by high bulk oil temperatures in jet engines. These lubricants withstand 425°F . . . more than 100° higher than any previously available. Highly significant, too, is the fact that they efficiently meet viscosity requirements at temperatures down to -65°F. Their potential has barely been tapped. For instance, they may become of utmost importance in such broad fields as heat transfer, automotive, and steel and aluminum forming. Continuing research and progress by Celanese in high-temperature lubricants has broadened and sharpened our national defense capabilities and has enabled great improvement in industrial machinery design. If you have a high-temperature lube problem, why not ask us to help? Simply write to

Celanese Corporation of America, Chemical Division, Dept. 582-F, 180 Madison Avenue, New York 16, New York.

Celanese®



opens the way for new superspeed jets



Canadian Affiliate: Canadian Chemical Company Limited, Montreal, Toronto, Vancouver
Export Sales: Amcel Co., Inc., and Pan Amcel Co., Inc., 180 Madison Ave., New York 16, N. Y.

© 1959 SCIENTIFIC AMERICAN, INC

Junction-Diode Amplifiers

They are simpler than the maser, quieter than the vacuum tube. Their low internal noise permits them to amplify radio signals much too faint for conventional receivers

by Arthur Uhlir, Jr.

The faint radio signals of celestial objects, artificial satellites and long-range radar often reach us as no more than whispers from a noisy sky. Once captured by an antenna, these signals must be sharply amplified in a radio receiver. But conventional receivers have an unhappy tendency to generate more radio noise than the sky itself. In such receivers weak signals are often so scrambled with noise that they emerge with their messages distorted or completely drowned out. It is not enough for a receiver amplifier to boost

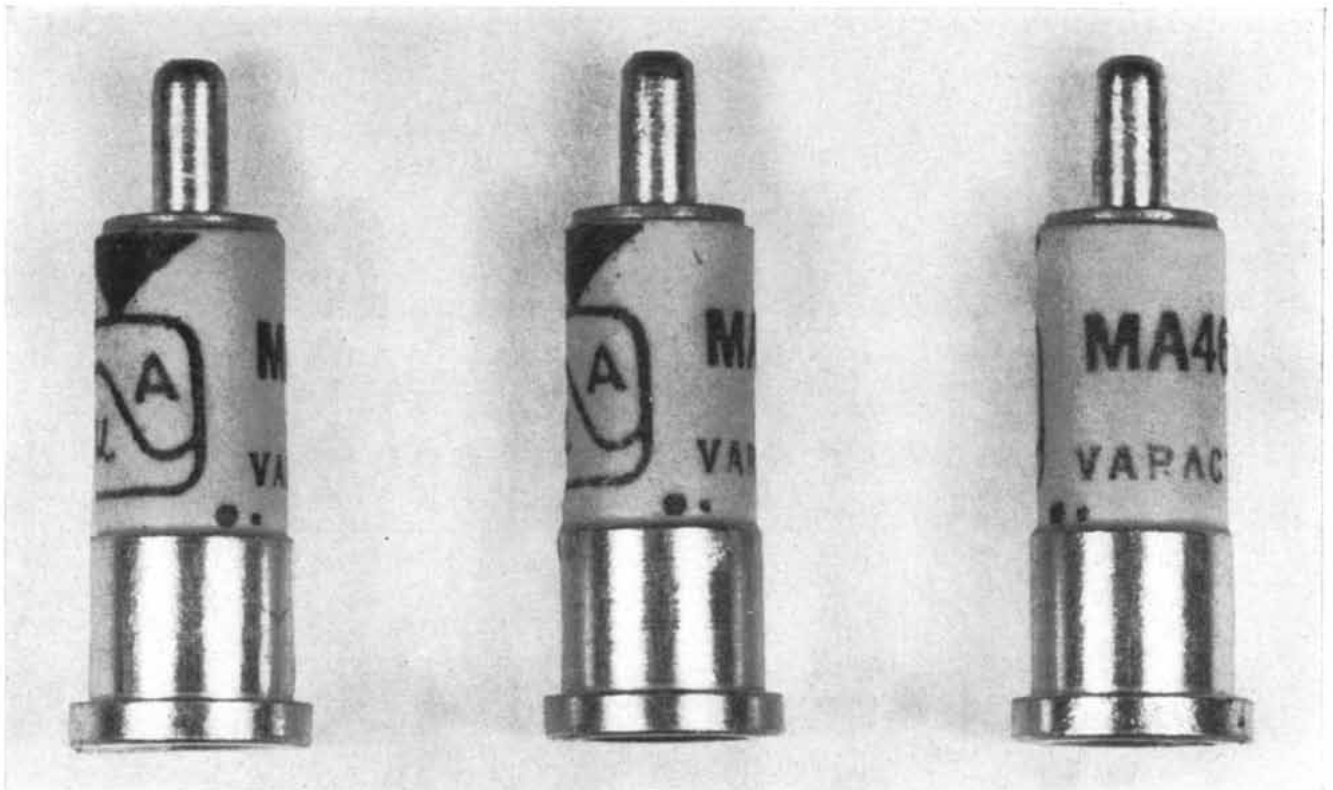
signal strength; it must do its job quietly, without submerging the signal in noise.

A familiar example of radio noise is the "snow" that appears on television screens. Usually noise originates in the three-element vacuum tubes (triodes) employed in the receiver circuit. In vacuum-tube development great pains have been taken to fashion microscopic tube-elements to reduce high-frequency noise. Progress has been good, but the conquest of noise has not yet been granted to the vacuum-tube art.

Recognizing the need for still less

noise, researchers have tried radically new approaches. Elaborate solid-state devices known as masers [see "The Maser," by James P. Gordon; SCIENTIFIC AMERICAN, December, 1958] have been operated with considerable success. Within the past year the junction diode—a two-element solid-state device—has come into its own as one of the best all-around amplifying devices.

Junction-diode amplifiers are much smaller and less complex than masers, yet they are practical rivals of masers as low-noise amplifiers over a wide



MOUNTED DIODES (shown greatly magnified) are roughly the size of a .22-caliber cartridge: about 7/8 inch long and 1/4 inch

in diameter. A metal anode-contact extends from the top of the casing; the metal bottom of the casing is the cathode contact.

range of the radio-frequency spectrum. They also have many of the virtues of the well-known transistor: they are cheap, reliable and rugged, and they require very little power. But properly designed junction diodes amplify quietly at much higher frequencies than transistors, which permits their use in long-range radar and in radio telescopes. Junction-diode amplifiers have been used to track a rocket 400,000 miles into space; they have picked up ultrahigh-frequency (UHF) television signals at a distance of 100 miles; and they have now been installed in the giant Jodrell Bank radio telescope in England.

Maser and junction-diode amplifiers share one great advantage in weak-signal reception: they both add very little operating noise to the signals they amplify. Noise is basically caused by the disorganized motion of atoms or electrons. The "sensible" temperature of a device—that is, whether it feels hot or cold to the touch—is a measure of this disordered motion at the microscopic level. Thus the vacuum tube, which has a hot cathode that continuously boils off electrons, starts at a noise disadvantage with respect to junction diodes and transistors, which usually operate at room temperature. These devices are in turn at a noise disadvantage with respect to the maser, which is refrigerated with liquid helium at -268 degrees centigrade.

For any device to work as an amplifier, organized motion must be imposed on the basic disorder caused by the thermal motion of its electrons and atoms. The effectiveness of any organizing force depends on the speed of the electrons involved. In a vacuum electrons can move at very high speed, and this speed, in a painstakingly constructed vacuum tube with a very small spacing between cathode and anode, partially compensates for their high temperature. In the semiconductor materials of which most solid-state devices are made, electrons move hundreds of times more slowly than they do in a vacuum. But semiconductor devices can be made much smaller than even the smallest vacuum-tube electrodes, although as yet they cannot be made small enough to compensate for their slower-moving electrons. Thus in spite of their lower operating temperature transistors still generate more noise than vacuum tubes in amplifying high-frequency electrical signals.

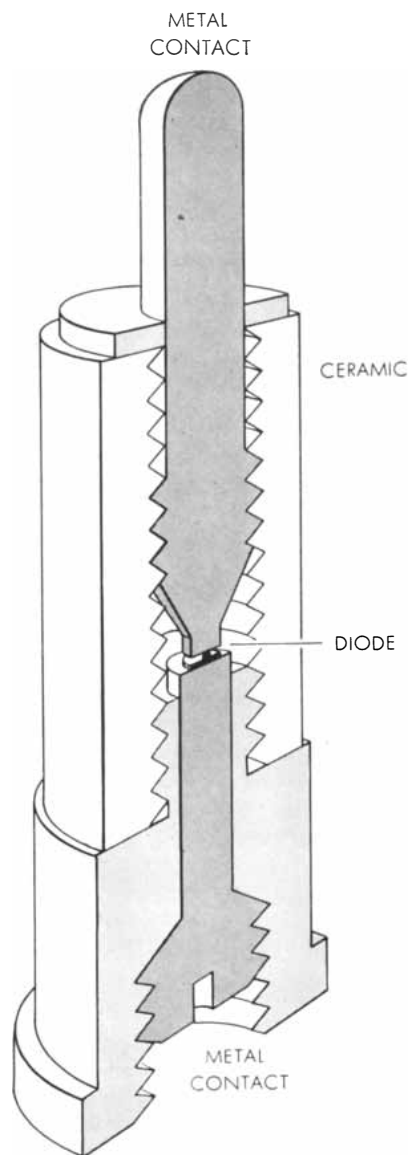
How can the junction diodes have such low noise when they are made of the very same semiconducting materials

as transistors? Basically it is a matter of size. The distance that electrons travel in transistors must be reduced by cunning techniques to obtain low-noise performance; junction diodes, on the other hand, are inherently free of this limitation because their operation depends on charges moving back and forth in a very narrow area.

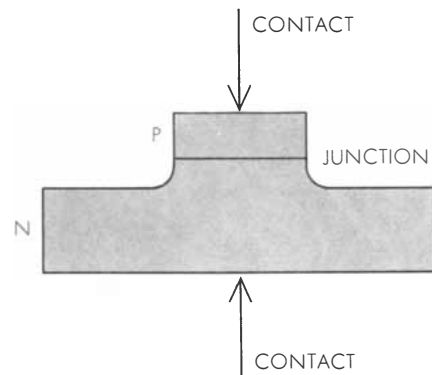
Only in the maser, then, is low noise directly due to low temperature. Present maser materials must be refrigerated to very low temperature to obtain atomic action organized enough for any amplification at all. But at low temperatures the maser is the quietest amplifier ever developed.

In explaining the action of semiconductor and vacuum-tube devices, one can exaggerate the differences between them. Actually, interesting electronic devices can be made from semiconductors because a semiconductor is a solid-state approximation of a vacuum. A perfect vacuum contains no charged particles; neither does a pure semiconductor, in which almost all of the electrons are firmly bound in a crystal lattice. Thermal agitation of the semiconductor lattice will occasionally shake an electron loose and send it bumping through the crystal as a wandering negative charge. The "hole" vacated by the electron will then be positive; it may be filled by another electron, leaving another hole. Thus holes, too, appear to drift through the lattice, as roving positive charges. Thus fundamentally both the vacuum and the semiconductor lattice serve as a medium in which charges can move. In a semiconductor they move more slowly and meet more resistance.

Almost all useful semiconductor devices are made by adding impurities to the crystal which increase the number of mobile charges wandering through it. The number of valence electrons in the added impurity determines whether it will produce a hole or a free electron in the crystal. A "donor" impurity such as phosphorus, which has five valence electrons, will form only four bonds with the four valence electrons of a semiconductor such as silicon, leaving one un-bonded electron free to carry current. The phosphorus-doped region will thus have negative (N-type) conductivity. Conversely, an "acceptor" impurity like aluminum has only enough valence electrons to form three bonds, which leaves a hole in the lattice where the fourth bond should be. Another electron can easily fill this hole, bonding the aluminum ion into the lattice and moving the hole. The wandering hole gives the



CUTAWAY VIEW shows how diode and its contacts are arranged inside casing. Diode is only $4/100$ inch in diameter.



DIODE ITSELF is a silicon crystal divided into positive (P-type) and negative (N-type) areas which contain mobile charges; the junction layer contains no mobile charges.

aluminum-doped region positive (P-type) conductivity.

There are a number of ways to add donor and acceptor impurities to semiconductors. One of the simplest and most satisfactory is solid-state diffusion, in which impurity atoms are applied to the surface of a heated crystal. The heat is not sufficient to melt the crystal, but only to increase the thermal motion of the lattice atoms, permitting the impurity atoms to diffuse through it.

If a donor impurity is diffused into one side of a crystal and an acceptor impurity is diffused into the other, one region of the crystal will have an excess of free electrons and exhibit N-type conduction; the other region will have an excess of holes and exhibit P-type conduction. The boundary between these regions is called a P-N junction.

A transistor is made by adding impurities to form three conducting regions (in either a P-N-P or an N-P-N arrangement) and two P-N junctions. The spacing between them is critical; if the space

is wide, the transistor will be noisy. Transistors are triodes whose electrons conduct current by moving through a crystal lattice instead of through a vacuum [see "The Junction Transistor," by Morgan Sparks; SCIENTIFIC AMERICAN, July, 1952].

To make a junction diode, only two oppositely charged conducting regions, with a single P-N junction between them, are required [see illustration at bottom of preceding page]. A very thin region (typically two millionths of an inch thick in diodes designed for high-frequency amplification) at the junction is free of mobile charges and is called the "depletion layer." The exceedingly small thickness of the depletion layer is one of the features that make junction diodes fast and quiet amplifying devices.

Although the junction diode is made in the same way and from the same materials as a transistor, it has a distinctly different principle of operation. Unlike the transistor, the diode does not falter at the ultrahigh frequencies used in space communication. Like masers, junction diodes must have an external high-frequency power supply, but the diodes do not require refrigeration.

Because junction diodes obtain their power from a high-frequency "pump" oscillator, their circuits differ considerably from the triode circuits used in conventional amplifiers. Of course all amplifiers require a power supply, since they deliver an output signal of greater power than the input. But triodes, either transistors or vacuum tubes, use a direct-current power supply to generate their own high-frequency power. Triodes do this so well, in fact, that they are often used to pump high-frequency energy into diodes. Still, the triodes used in these pump circuits could not by themselves begin to approach the noise performance of the junction diodes as high-frequency amplifiers.

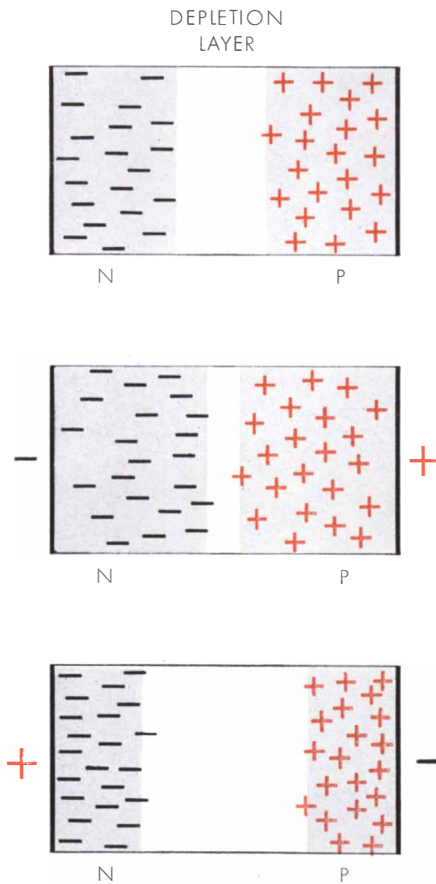
In diode-amplifier circuits, the diode merely controls the pump power in response to a weak incoming signal. The main difference, then, between diode and triode amplifier circuits is that diode circuits have two separate parts: a pump (a high-frequency oscillator) and a control element (the diode itself). Triode amplifiers have only one circuit which must both generate and control high-frequency power. It is not surprising that triodes cannot perform both of these functions as noiselessly as diodes can perform one.

When a high-frequency pump voltage is applied to the terminals of the diode, the thickness of its depletion layer varies [see illustration on this page].

As the pump puts a positive potential across the P-type region and a negative potential across the N-type region, the holes and electrons in the diode move toward the junction, narrowing the depletion layer; as the voltage reverses, the charges move toward the ends of the crystal, widening the depletion layer. Because the charges move extremely fast and have less than a millionth of an inch to travel, the time required for the depletion layer to widen or narrow is almost immeasurably small; probably less than 10^{-11} second. This means that the depletion layer can expand and contract millions of times in the time it takes a rifle bullet to travel an inch.

The depletion layer may be compared to the space between the two charged plates of a parallel-plate condenser. If the condenser plates in a simple condenser circuit are rapidly pulled apart and pushed together, current will flow back and forth in the circuit. The energy expended to pull the charged plates apart is put into the circuit, where it is in turn available to do work. If a weak input-signal is fed into the circuit properly, the circuit will amplify the signal by doing work on it. This is approximately what happens in a junction-diode amplifier. The work necessary to widen the depletion layer—analogue to the work required to separate the condenser plates—is done by the powerful high-frequency oscillations of the pump signal. Some of the pump's energy is transferred to a weak input-signal by the diode junction; the resulting output is an amplified signal with the same frequency as that of the input signal. (It is also easy to arrange for the output to have a different frequency.)

To draw another analogy, we may think of the advancing and receding charges in the diode as a ping-pong paddle swinging back and forth very rapidly. The weak input-signal may be compared to a slow-moving ping-pong ball floating toward the paddle. If the ball strikes the paddle at the right instant during its swing, the paddle will whack the ball back in the direction whence it came, but at a much greater speed. In doing this the paddle will transfer some of its energy to the ball in much the same way that the oscillating charges at the junction of the diode transfer some of their energy to a weak microwave-signal. As electrons and holes move back and forth, current flows in the diode circuit. A semiconductor presents a certain amount of resistance to the flow of current. Holes on



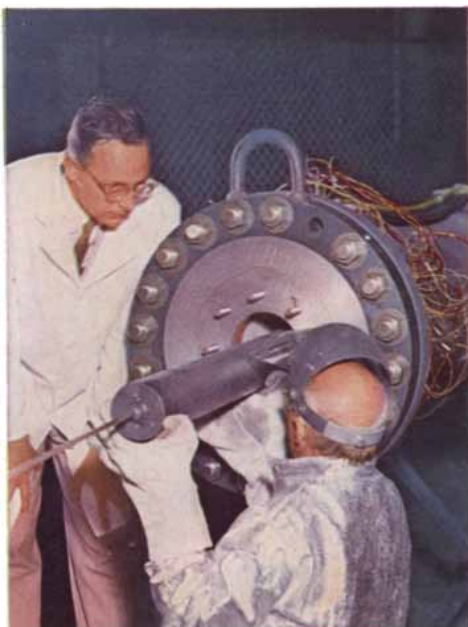
VOLTAGE APPLIED TO THE DIODE changes width of "depletion layer" at the junction. With no voltage across the diode (top), width of depletion layer is constant. A forward voltage (center) narrows it; a reverse voltage (bottom) makes it wider.



ENVIRONMENT for EXPLORATION—

Engineers and scientists at General Atomic's John Jay Hopkins Laboratory for Pure and Applied Science are conducting nuclear research and development in an atmosphere of cre-

ative freedom. Mechanical, metallurgical, chemical and electrical engineers — physicists, chemists and mathematicians. Together they are engaged in such diversified, long-term projects as advanced high-temperature gas-cooled reactors for land-based applications — maritime gas-cooled reactors—controlled thermonuclear reactions—space propulsion—research reactors—basic research in the sciences. Because of the rapid expansion of these programs, there are openings for



scientists and engineers, including senior positions, at the Laboratory.

Write Dept. 6-S, P. O. Box 608, San Diego 12, California.

GENERAL DYNAMICS
GENERAL ATOMIC DIVISION





Rampart against Destruction

Bombarded by relentless impact and grinding abrasion, seared by fiercely corrosive action and extreme high temperatures, a unique fused-cast refractory offers the closest approach to indestructibility yet achieved by a man-made material. Its unusual combination of properties, *discussed on the opposite page*, opens new opportunities for control and containment of severe operating conditions found in many industrial processes. For help with such problems, beyond the capabilities of conventional materials, write to Carborundum, Dept. AMT, Refractories Division, Perth Amboy, N. J.

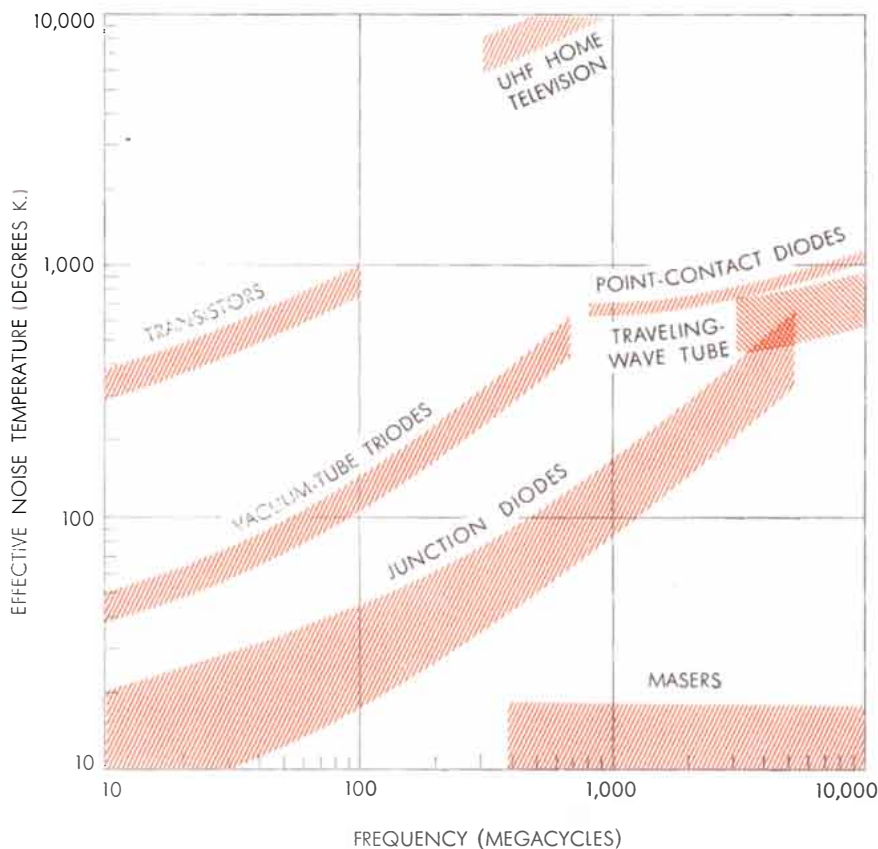
Where conventional materials fail... call on



ADVANCED
MATERIALS
TECHNOLOGY

CARBORUNDUM

Registered Trade Mark



RELATIVE NOISINESS of several different types of amplifiers can be determined by comparing their effective noise temperatures. The only amplifier quieter than junction-diode types at the high frequencies shown above is the maser, which requires refrigeration.

one side of the diode and electrons on the other collide with impurities and with irregularities caused by thermal agitation in the crystal lattice. Charges detouring around these defects in the crystal generate resistive noise, and the resistance dissipates the energy of the signal. Resistance in the diode crystal thus limits the frequency at which diodes can amplify; in present diodes this limit is about 10 kilomegacycles (10^{10} cycles per second).

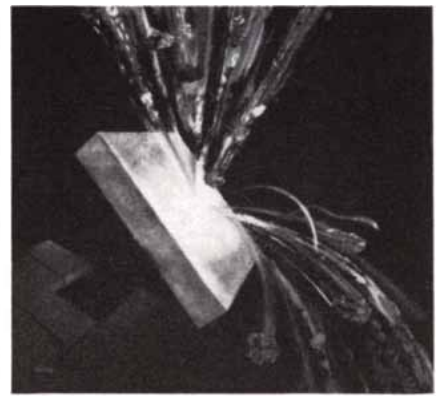
If the junction diode is to be used at high frequencies, its junction area must be kept quite small; the area of the P-N junction in most of the diodes now in operation is less than the cross section of a human hair. These tiny junctions are more rugged than one might think; they can pass electrical currents of one ampere without damage.

Word-coiners have had a field day with junction-diode amplifiers. Some have called them "reactance amplifiers" or "variable-reactance amplifiers" because circuit elements that store energy are said to have "reactance," in the terminology of the electrical engineer. Junction-diode amplifiers have also been called "parametric amplifiers" and

"mavars" ("Modulation Amplification through Variable Reactance"); both of these terms are generally regarded as synonyms for "reactance amplifier." In electronics junction diodes for high-frequency amplification are widely known as "varactors," a name suggested by Marion E. Hines of Bell Telephone Laboratories as a contraction of "variable reactors."

The use of variable reactance for amplification has a long history in the form of magnetic amplifiers for amplifying low-frequency signals. These devices are physically similar to ordinary transformers having one or more coils of wire wound around an iron core. Such magnetic amplifiers may antedate even the vacuum tube, and still have many present-day applications.

The first amplifiers that employed semiconductor diodes were built with germanium diodes made by Harper Q. North of the General Electric Company in connection with World War II radar work. The physical mechanism involved was correctly interpreted, and duly reported as an interesting and promising phenomenon. No appreciable use was



Fused-cast refractory resists extreme corrosion, wear, heat

Melted in electric furnaces and poured into molds at 4500° F., fused-cast refractories offer unique structures and properties. Dense, strong and impermeable, they top all man-made materials in resistance to wear. Ability to withstand considerable impact is an exceptional feature. Inert to chemical action, they resist corrosion even at extreme temperatures.

Supplied as cast blocks and other shapes, these fused-cast refractories are now used for:

- **CORROSION RESISTANCE** in electrolytic cell liners for magnesium production, liners for synthesis gas generators and guides for pickling tanks.
- **WEAR AND IMPACT RESISTANCE** in coke and sinter chutes and in special types of ball mills for grinding abrasive materials.
- **HIGH TEMPERATURE RESISTANCE** in glass melting tanks where temperatures range close to 3000° F., as well as hearth pavings and skid rails for metallurgical furnaces.

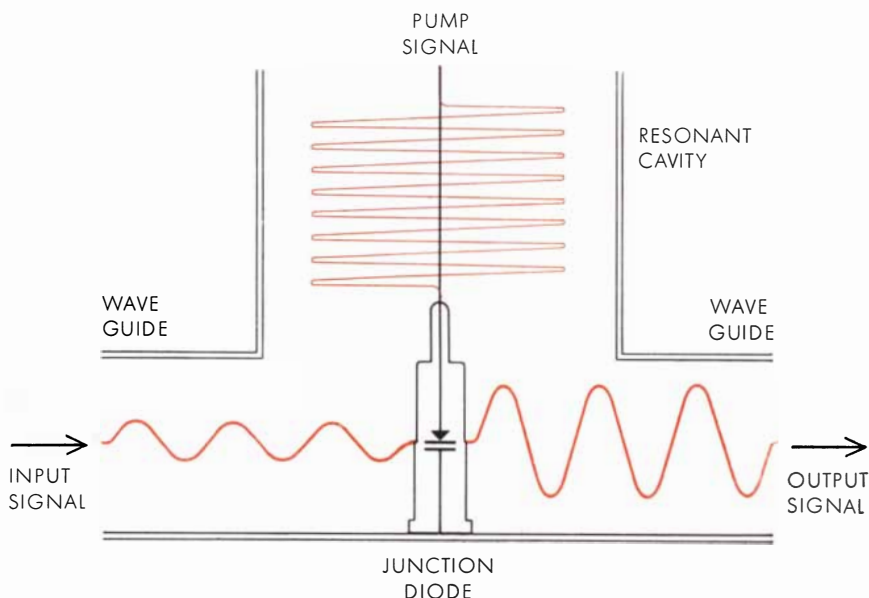
With these proven capabilities, many opportunities exist for applications in products and processes where unusual problems may call for unconventional solutions. To learn more about this and other interesting advanced material developments . . .



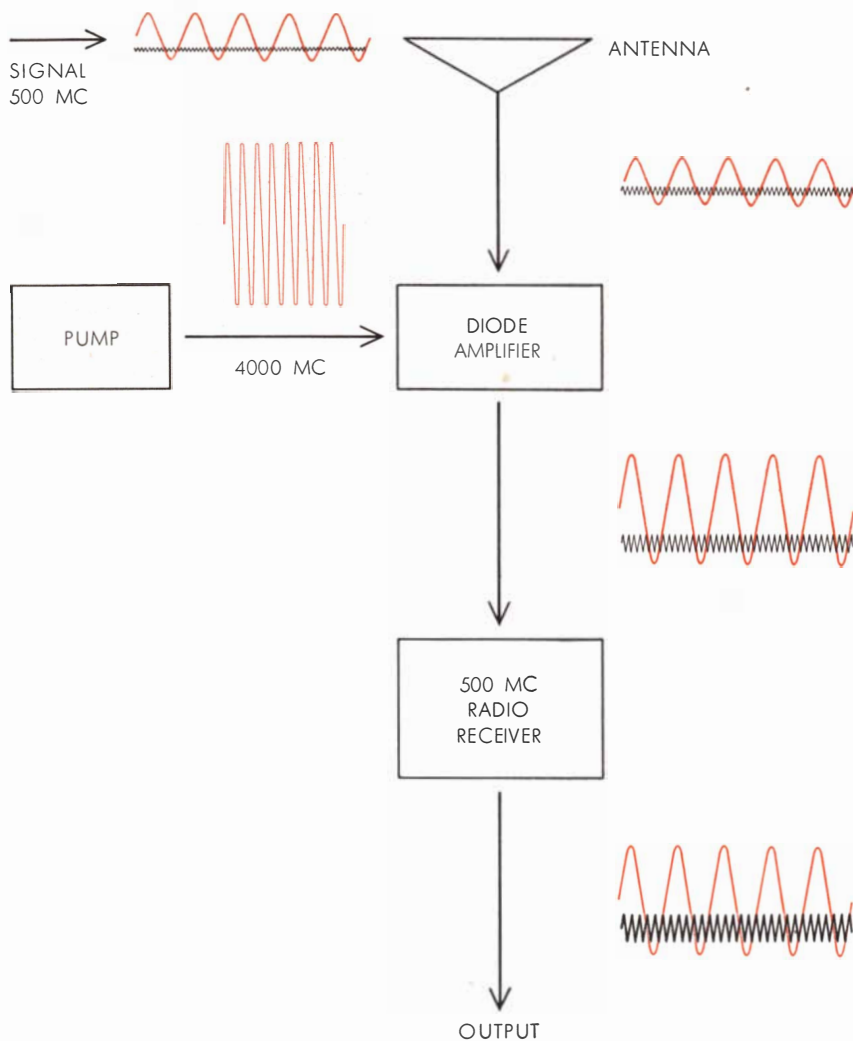
send for your
**FREE COPY of
ADVANCED
MATERIALS
TECHNOLOGY**

A new quarterly publication dealing with materials for severe service applications, published by Carborundum. For your FREE subscription, write to Carborundum, Research & Development Division, Dept. SA-4, Niagara Falls, New York.

CARBORUNDUM
Registered Trade Mark



SIMPLE DIODE-AMPLIFIER consists of diode (shown schematically) mounted in a tuned resonant cavity. The rapidly changing pump voltage forces the electrons and holes in the diode to vibrate back and forth, which permits the diode to store energy like a movable-plate condenser. The diode uses this stored energy to amplify a weak incoming signal.



SOURCES OF INTERNAL NOISE in radio receivers tend to drown out weak input-signals. Each component adds its operating noise (black wave) to the signal (colored wave) passing through it. This noise is cumulative; once added, signal and noise are amplified together.

made of the discovery, however, until Bell Laboratories installed germanium-diode amplifiers in a transmitting modulator of a microwave-relay system in 1956. Then a Bell Laboratories group under Robert M. Ryder (of which I was a member) began the development of the diffused-silicon diode as a low-noise amplifying device under a U. S. Army Signal Corps contract for improving the noise performance of radar receivers. The fabrication and evaluation of the first such unit was done by A. E. Bakanowski. The early results were described in the summer of 1957 to a conference of semiconductor-device engineers, who regarded the proposal with interest but were skeptical about its low-noise properties. In the months that followed, experiments at Bell Laboratories, at Stanford University, and at Airborne Instruments Laboratory confirmed that the noise level was indeed low.

The measurement of noise in experimental amplifiers can be very tricky, however, so it was important to see how these amplifiers worked as radio receivers, if indeed they worked at all. So far as is known, the first person to put a junction-diode amplifier to practical use was F. S. Harris, a radio amateur on the staff of Microwave Associates, Inc. He built his own amplifier and tried it out in receiving ordinary radio signals. He found that it worked very well indeed. Then he aimed his amateur antenna at an ultrahigh-frequency (UHF) television transmitter 100 miles away. An ordinary UHF television set connected to this antenna would barely produce an image. With superb close-spaced vacuum-tube triodes a faint picture could be brought in. But with the diode amplifier the picture was still better—as good as one ordinarily receives with a local UHF television station. Thus low noise was proved in the actual reception of information. Furthermore, it was shown that this very different type of amplifier did not mangle the signal in some peculiarly unpredicted fashion, as might well have been the case had the theory and the laboratory experiments overlooked some small but fatal point.

Among the laboratory experimenters M. Uenohara and G. F. Herrmann of Bell Telephone Laboratories deserve special mention. They made a diode amplifier for a wavelength of five centimeters (6,000 megacycles). Theoretical calculations suggest that they obtained very nearly the ultimate performance that the present diodes can yield and that extensions to appreciably shorter wavelengths will require improved diodes. At longer

INDUSTRIAL INSTRUMENTATION

OPERATIONAL FEATURES

COIL

Coil of anodized aluminum wire.

SUSPENSION

Suspension wire is made from gold, platinum, or silver alloy ribbon.

POLE PIECES

Pole pieces are mounted in case adjacent to the coil. Permits rotation.

AGING

Aging process minimizes mechanical defects, such as, permanent zero shift and balance defects, which otherwise might occur after the galvanometer has been in use.

DAMPING

Model 210 galvanometers are normally damped to 64% of critical.

MAGNETIC ASSEMBLY

A permanent magnet type assembly is used in conjunction with the galvanometers.

PHYSICAL CHARACTERISTICS

Mirror: Cylindrical, focal lengths 5.88" Pole Pieces: Integral with tubular case, or 3.1" except in fluid damped units.
 Size: 2.5" length; .125" diameter. Terminals: Within magnetic assembly.
 Weight: 0.11 oz. All elements are electrically isolated.
 Mounting: Plug in—no external wire connection. Balance Factor: 0.008 inch per g at 12 inches.

The performance of any recording oscillograph is governed primarily by the quality of the galvanometers used in the instrument. Century galvanometers with their many unique features have been the accepted "standard" for the past decade. Intensive research and study of various recording problems coupled with the latest in improved manufacturing techniques, assures the maximum in reliability, efficiency, and factor of merit. Century galvanometers and magnetic assemblies can be installed in any photographic recording oscillograph.

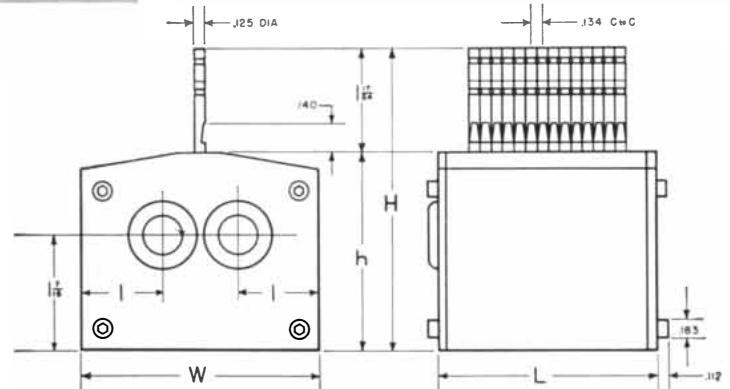
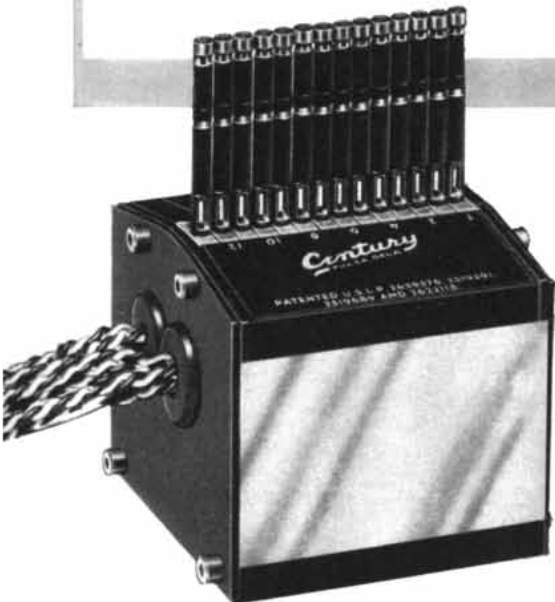
Model 210 galvanometers are available in a wide range of frequencies and sensitivities. (See table on opposite side). Several types are designed for direct excitation from many kinds of transducers, such as, strain gages, pressure pick-ups, accelerometers, thermocouples, etc. This eliminates the need for costly amplifiers and in most instances the output impedance of the transducer provides the optimum damping impedance for the galvanometer.

The galvanometer suspension is hermetically sealed in a tubular case. This provides protection from most atmospheric environments, eases installation and removal problems, reduces maintenance due to handling, etc.

Electrical connection to the moving coil is made through the tip and a lower portion of the galvanometer case. These surfaces mate automatically with positive leaf spring contacts in the magnetic assembly as the galvanometer is being installed. Twisted pairs of lead wires extend from the leaf spring contacts through one end of the magnetic assembly to the source of excitation. All contact surfaces are gold over silver plate to assure minimum contact resistance.

STANDARD MAGNETIC ASSEMBLY OUTLINE DIMENSIONS — Other Magnetic Assemblies Available on Special Order.

Assembly No.	Number of Galvos.	L	H	h	W	Cable Length
110C100-1	6	1 $\frac{3}{4}$ "	3 $\frac{1}{16}$ "	2 $\frac{2}{64}$ "	2 $\frac{29}{32}$ "	18"
110C101-1	12	1 $\frac{5}{16}$ "	3 $\frac{1}{16}$ "	2 $\frac{2}{64}$ "	2 $\frac{29}{32}$ "	18"
110C102-1	18	2 $\frac{3}{4}$ "	3 $\frac{1}{16}$ "	2 $\frac{2}{64}$ "	2 $\frac{29}{32}$ "	18"
110C103-1	24	3 $\frac{3}{64}$ "	3 $\frac{1}{16}$ "	2 $\frac{2}{64}$ "	2 $\frac{29}{32}$ "	18"
110C104-1	30	2 $\frac{23}{64}$ "	3 $\frac{1}{16}$ "	2 $\frac{2}{64}$ "	2 $\frac{29}{32}$ "	18"
110C200	2	1 $\frac{3}{4}$ "	3 $\frac{1}{16}$ "	2 $\frac{2}{64}$ "	2 $\frac{29}{32}$ "	24"
109C100	14	2 $\frac{3}{64}$ "	3 $\frac{15}{64}$ "	1 $\frac{31}{32}$ "	2 $\frac{1}{4}$ "	5"



Century Electronics & Instruments, Inc.

1333 NORTH UTICA, TULSA 10, OKLAHOMA
 P. O. BOX 6216 — PINE SQUARE STATION
 TELEPHONE LUTHER 4-7111

Represented in all principal cities of U. S. by the Garrett Corporation
 Airsupply and Aero Engineering Divisions
 In Canada by Garrett Manufacturing Corporation of Canada, Ltd.

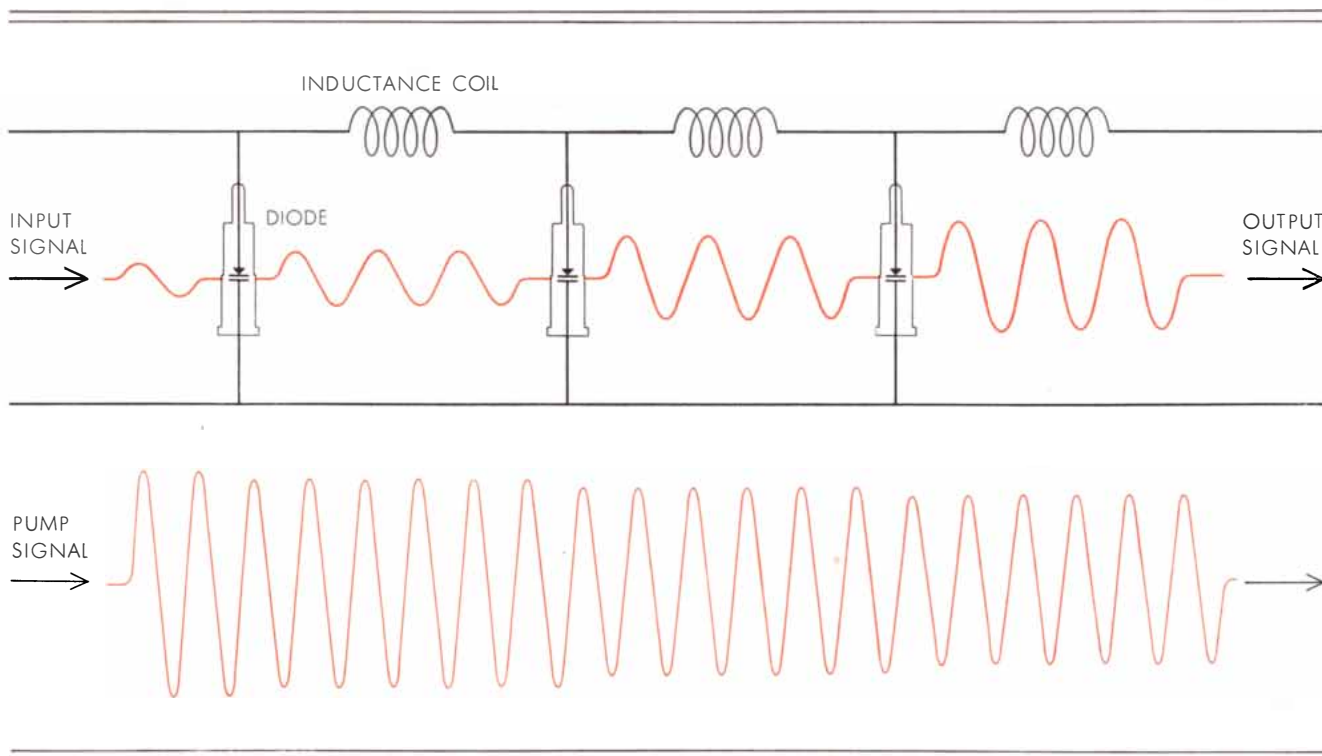
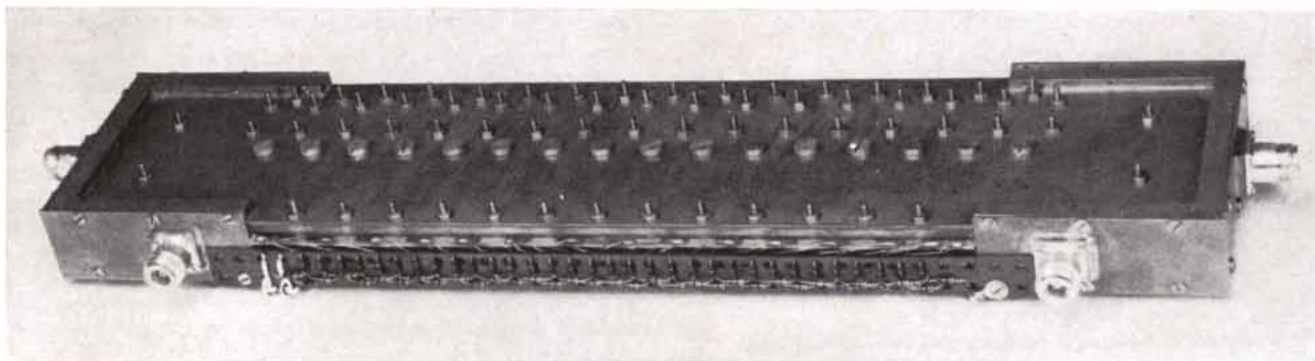
wavelengths (lower frequencies) the diode amplifier becomes increasingly easy to use, and thus it covers a wide range of the radio spectrum. For wavelengths longer than about 10 meters, diodes, transistors and vacuum tubes all operate quietly enough for most radio reception purposes, and the choice of device depends on other properties.

Most radio signals reach the amplifier mixed with sky noise which originates in such radio disturbances as lightning, the aurora, solar storms and the many celestial radio emitters within

and without our galaxy. There are a few things that can be done to avoid some of this noise. For example, we can transmit our man-made signals on frequencies where natural noise is lowest. This is one consideration in the choice of a radar frequency—a relatively important consideration now that receiver noise can be reduced by junction-diode amplifiers. The sky is also quieter in some directions than in others; although we do not always have a choice we would prefer to aim our antennas toward the galactic pole, where there are fewer stars or interstellar gas-clouds to set up

a radio din. In the past receivers have generally been noisier than the sky. When a faint input-signal nearly saturated with sky noise is picked up by an antenna, the antenna and its lead-in lines add their noise to it and forward the signal to the amplifier [see illustration at bottom of page 124]. The amplifier multiplies both the signal and noise strength, and adds its noise to the signal before feeding it to the rest of the receiver.

If the original input-signal stands out strongly against its radio background—in other words, if the input signal-to-



DIODE TRAVELING-WAVE AMPLIFIER consists of a series of junction diodes mounted in the path of the signal, so that input signal and the much-stronger pump signal traverse the circuit together; at each successive diode the weak signal is amplified, be-

coming progressively stronger as the pump signal becomes weaker. Traveling-wave amplifiers can handle a much wider range of frequencies than simpler types containing only one or two diodes, and thus they have a much greater information-handling capacity.

noise ratio is high—chances are that the output signal, even with the burden of noise added at the receiver, will still be intelligible. On the other hand, very faint signals—radar echoes from Venus, say—can tolerate almost no additional noise burden. Thus low noise in a receiving amplifier becomes more important than high gain (amplifying power).

It is possible to measure amplifier noise quantitatively. An index of noisiness is "effective temperature," which is given in degrees Kelvin (degrees centigrade above absolute zero), with zero degrees equivalent to no noise at all. Junction diodes at room temperature (about 300 degrees Kelvin), can amplify with effective temperatures of 50 to 100 degrees at most frequencies used in long-range radar-tracking, satellite transmission and television.

In long-range radar-tracking the substitution of a 75 degree-K. junction-diode amplifier for a 500 degree-K. vacuum-tube amplifier will increase the range by 30 per cent if the combined sky noise and antenna losses have a typical noise temperature of 150 degrees K. When the object being tracked has its own radio transmitter, the relative improvement is greater; in this case, the range would be increased 70 per cent. Junction diodes developed by our group at Microwave Associates, Inc., were used by the General Electric Company tracking station at Schenectady to receive signals from the Pioneer IV satellite at a distance of 410,000 miles.

For reasons of cost, commercial UHF television receivers do not contain the expensive vacuum tubes necessary for 500-degree noise temperatures; generally their noise temperatures range from 10,000 to 20,000 degrees. Noise reductions of 100-fold are therefore predictable for these receivers, since diode amplifiers can be made economically that will have far lower noise than vacuum tubes.

While most of the early experimenters used just one diode in an amplifier, R. S. Engelbrecht of Bell Telephone Laboratories built a multiple-diode amplifier using the traveling-wave principle. The bottom illustration on page 126 shows how input microwaves travel beside pump microwaves, and how the input is amplified stepwise by each successive diode. The advantage of this type of amplifier is that it can respond to a wide range of signal frequencies, thus giving it great information-handling capacity.

In speculating about the future applications of junction diodes, we should

Dear Virginia:

Ever since time began, children like you have asked the question: "Is there really a man on the moon?"

So far we haven't contacted anyone from there, but we are working on some ideas in COMMUNICATIONS, MISSILES and RADAR that may soon help get a man to the moon ... and back.

Right now, though, we need a few experienced electronic engineers with your curiosity and imagination, Virginia, who can introduce important contributions in these fields. With them on our team, it won't be very long before we can truthfully say:

**Yes, Virginia,
there is a man
on the moon!**

P.S. If your dad is an engineer who wants to help us prove our point, have him write to:
R. S. EARY, Technical Staffing
Director, The Magnavox Company,
2131 Bueter Road, Fort Wayne, Ind.

Magnavox

"But my magnetic tape recording needs are different. My tests crank out transient responses . . . and I have to know what conditions precede and follow those responses."



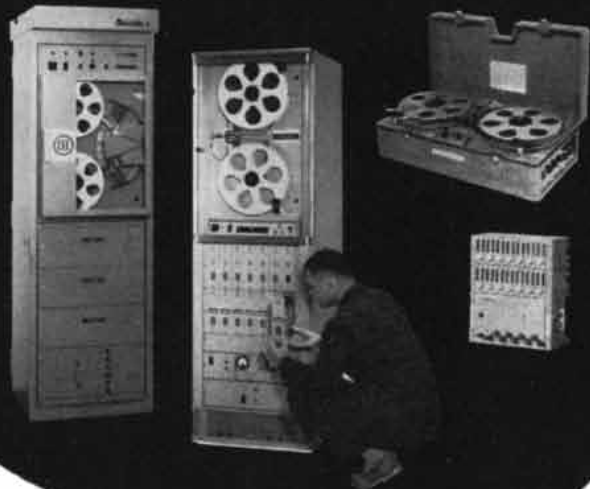
CEC
DataTape Division



"That's where our continuous-loop recorder/reproducer comes in. You can use it for repetitive studies of bunched up data and stretch out those transients until they look like the Alps. Just set it up to record and erase sequentially for an indefinite period until your data comes along. You'll end up with a complete test history.

But that's only one phase of DataTape operations. Our systems span all requirements from telemetry reel and continuous loop recorder/reproducers to lightweight mobile units — for Analog, FM, PDM, and PCM (digital) data acquisition and evaluation. We can set up these instruments in your lab, on an island, or in a boat or submarine. Been doing it for years. And remember this important fact! DataTape supports its products with qualified personnel wherever you are.

Installation, application, operation, and maintenance — we're with you all the way."



DATATAPE DIVISION

Magnetic tape recording and reproducing equipment for ground-station, airborne and mobile applications.

! Write for Bulletin CEC 1312-S.

ANALYTICAL & CONTROL INSTRUMENT DIVISION

Mass spectrometers, leak detectors, chromatographs, moisture monitors . . . lab or process models. Bulletin 1313-S.

CONSOLIDATED SYSTEMS CORPORATION

Subsidiary of CEC. Systems for industrial process control, digital data handling, chemical analysis, missile checkout. Bulletin 1304-S.

DATALAB DIVISION

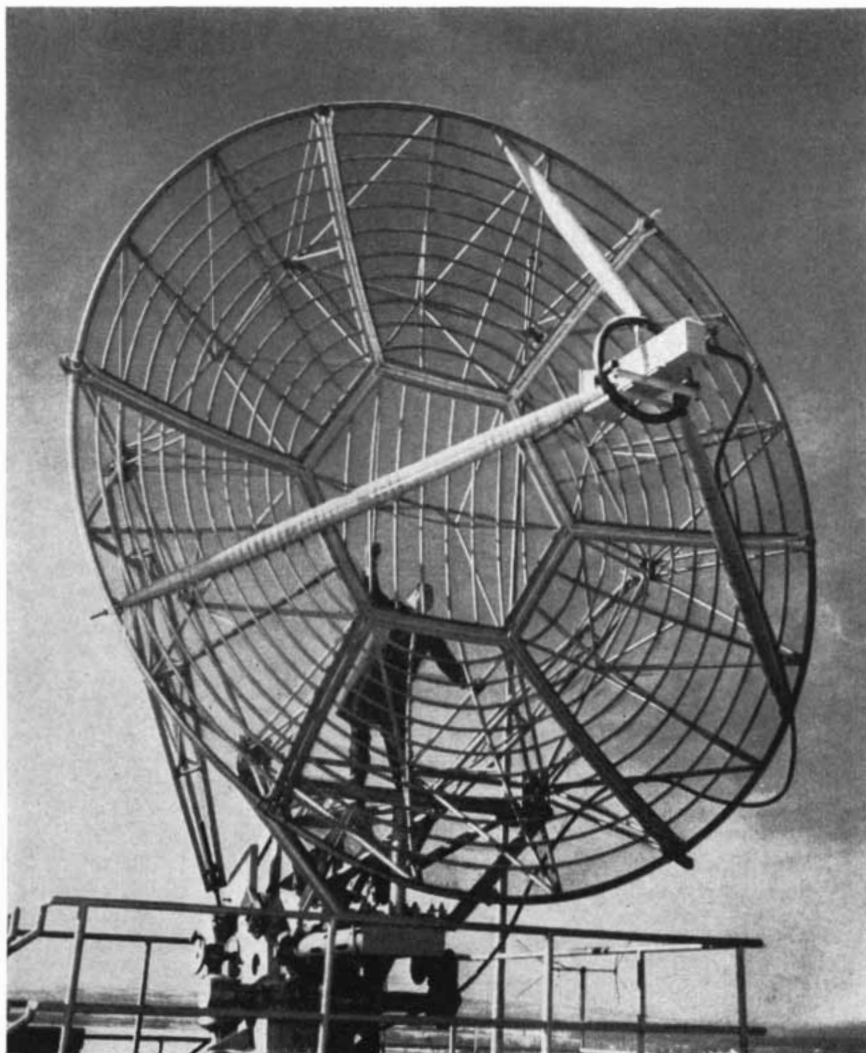
CEC's Advanced Electronic Data Laboratory . . . conceives and develops new instrumentation under R & D contracts. Bulletin 1314-S.

ELECTRO MECHANICAL INSTRUMENT DIVISION

Direct-writing oscillographs, data amplifiers, vibration meters and power supplies . . . for dynamic tests in missile, industrial, and flight-test environments. Bulletin 1310-S.

TRANSDUCER DIVISION

Sensing devices for industrial and military applications, pressure and vibration instrumentation, galvanometers, and telemetry equipment. Bulletin 1308-S.



EIGHTEEN-FOOT PARABOLIC ANTENNA coupled with a junction-diode amplifier picked up the radio signals transmitted by the Pioneer IV lunar probe more than 400,000 miles away. The antenna is located at the General Electric Company in Schenectady, N. Y.

mention the proposal of the late John von Neumann for digital computers that could operate 1,000 times faster than present computers. In them we would use diode amplifiers as oscillators. It is well known that oscillators can be made from amplifiers by feeding their output signal back into the input.

Because of their excellent high-frequency response, the diodes in our computer could be pumped with signals far higher in frequency than those presently used in digital computers. In a tuned circuit with a resonant frequency exactly half the pump frequency, the diodes would oscillate at a frequency just one half that of the pump. Such oscillations can take place in two equivalent but distinguishable ways, 180 degrees out of phase. The two states of oscillation could be used to denote the binary digits 0 and 1. Von Neumann has shown that such oscillators could be interconnected

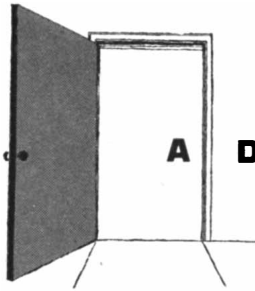
to construct a complete logical machine.

Junction-diode amplifiers will also have many applications in the bowels of electronic apparatus in ways that will not affect external performance, but will rather achieve great simplification, improved reliability and reduced power consumption. There are many uses for junction diodes in high-frequency circuits that can be worked out on paper from the supposedly known properties of the diodes. In cases where laboratory work has carefully followed the calculated prescription, the circuit performance has been in remarkable accord with prediction. But laboratory experiments that range off the beaten path are already turning up effects that are difficult to explain theoretically. Some of the new phenomena, when understood, will probably extend the command of high-frequency radio that is offered by the junction diode.



Consolidated Electrodynamics Corporation

360 Sierra Madre Villa
Pasadena, California



A DOOR IS OPENED...

TO NEW ADVANCES IN MISSILE PROPELLANTS

"... a high throughput, lightweight flying chemical process plant in which quantities up to the order of a ton per second of liquid (or solid) reactants are converted to hot gaseous products at a precise, automatically controlled rate."

BY NOW YOU'VE PROBABLY GUESSED that the first paragraph is a description of a rocket engine from the chemist's point of view.* Of course, there are other viewpoints, such as those of the electronics expert, or the airframe specialist. Chemicals, however, are a specialty with us, and we would like to stick to that side of the subject and cover a few of the more interesting developments in propellants for the "flying chemical process plant."

A good starting point is the question of solid and liquid fuels. Generally speaking, most solid fuels have good storability. However, we're glad to say that you can also get excellent storability with some liquids. Chlorine trifluoride and nitrogen tetroxide, for example, require no refrigeration and have been stored without difficulties for a period of over ten years. They can be shipped easily in ordinary steel containers. Both of these liquids are excellent storable oxidizers, each having certain advantages for specific missions. Let's look at some of the more important characteristics of N_2O_4 . It is an effective oxidizer which can be used with most fuels, including those containing carbon. And it's effective because of high combustion efficiency. This is especially important. Generally, we feel lucky if most oxidizers reach within 90% of theoretical Isp during combustion. N_2O_4 hits well over 95% efficiency during actual combustion. In addition, count-down can be reduced to seconds with nitrogen tetroxide as an oxidizer. Since it is hypergolic with amine-type fuels, ignition is simple and reliable. Ignition delay is so brief you eliminate rough starts due to accumulation of unreacted propellants in the thrust chamber. Moreover, motors burning such propellants are throttleable.

All of this makes our chemists pleased with the product—a chemical which they really know and understand because we have produced it *commercially* (we deliberately italicized) for more than 10 years at our

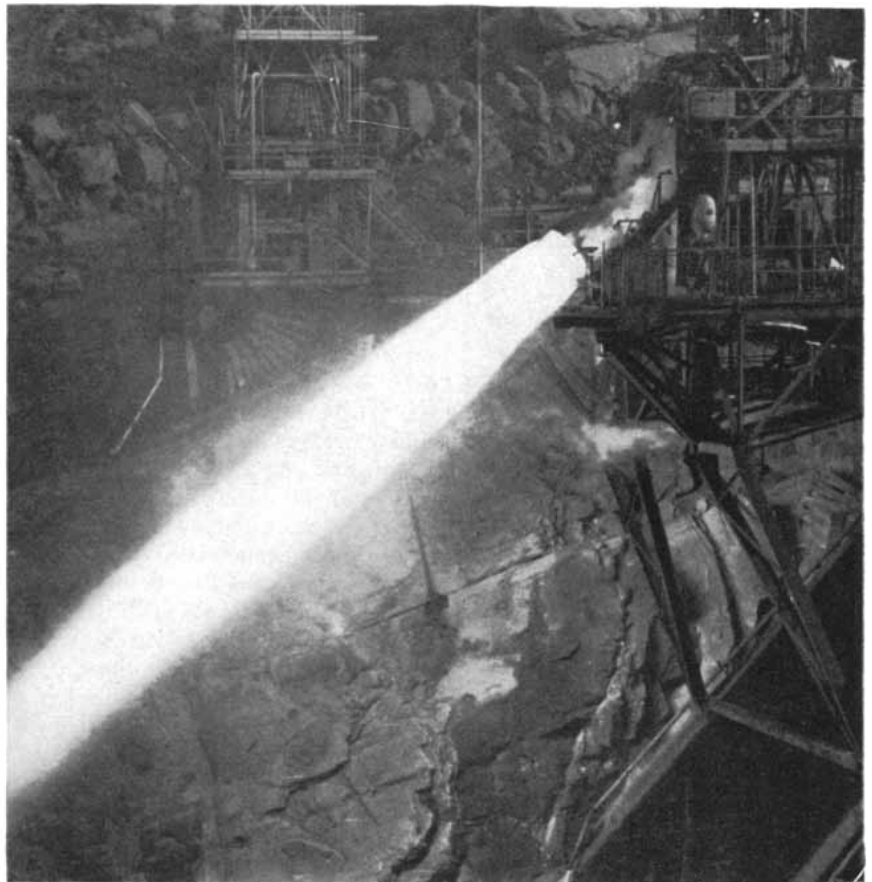
Nitrogen Division. If you are in the missile business and looking for a storable oxidizer, why not check with us? We have special 125-lb. and 2,000-lb. cylinders available for experimental purposes. And if you feel that's rushing it, we also have plenty of literature, including a 59-page Product Bulletin that covers everything from applications and physical properties to specifications and a bibliography.

THE BATTLE FOR THRUST OR Isp. In addition to nitrogen tetroxide and chlorine fluoride, another entry creating more and more interest in the propellant field is fluorine. Our chemists point out that fluorine is not suited for *all* missiles. But for any space projects or other special missions

where ultrahigh performance is needed, they feel fluorine is worth investigating. There have been published reports, for example, that booster rocket systems for a manned satellite laboratory would consist of a 321,000-lb. thrust engine burning a hydrogen-fluorine combination for 200 seconds. This is only one of several possible applications. Naturally, the question of handling arises. Here's an area where experience counts—and that's where our General Chemical Division enters the picture.

Fluorine, as you know, once presented seemingly insurmountable problems in handling and transportation. Our research people of the General Chemical Division,

Measuring rocket power of guided missile engine in static test stand at Rocketdyne, a division of North American Aviation, Inc.





Rocket thrust chamber firings using liquid fluorine at Bell Aircraft Corporation's rocket facility.

in cooperation with the Air Force, have solved many of these problems and have come up with a safe and practical solution for transportation of liquid fluorine. They designed a refrigerated and insulated tank truck of a special type. Essentially a giant "thermos bottle," the truck consists of three horizontal tanks, one inside the other, with spaces between serving as insulating mediums. Fluorine is kept in the inner tank in a liquid state. Liquid nitrogen is located in the second tank. The nitrogen cools the fluorine below its boiling point of minus 306° Fahrenheit and keeps it liquid. In the third outside tank, a granular insulator under vacuum is used to minimize boil-off losses of liquid nitrogen. The idea has proved practical and effective.

Result: Instead of shipping six pounds of gas in a 200-lb. cylinder, we can now ship fluorine in 5,000-pound units by *tank truck*; and have been doing so for over three years.

If you are interested in learning more about practical handling methods for fluorine, and would like to hear how this material can be used wherever high specific impulse is required, why not get in touch with our product development people? They have worked with elemental fluorine for over 10 years, and would be

glad to tell you some of the important things they have found out about the material as a propellant.

MORE "INPUT" for the flying chemical plant. Many other chemical materials also help put rockets into space. And some of that help comes from several of our products. Urethanes, for example, are made with isocyanates produced by our National Aniline Division. Used alone, or combined with polyester resins, these materials form combustants and binders for solid fuels. They also cushion sensitive instruments.

From our Plastics & Coal Chemicals Division come high-temperature-resistant phenolic resins which show possibilities for use in the fabrication of rocket nose cones. Also, from this same division, come polyester resins which are used in reinforced plastics in certain parts of rockets now under test.

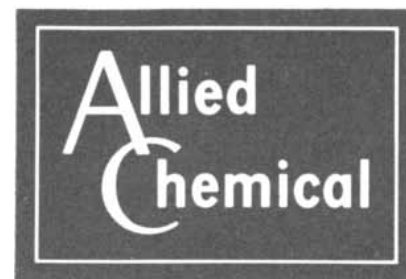
Basic chemicals play important roles, too. Hydrogen peroxide, hardly a new product, is made by our Solvay Process Division. It was originally used as an oxidizer in the German V-2 rockets and in early American rocket developments. It has now been replaced by more sophisticated chemicals and is employed in some specialized applications. And MUTUAL chromic acid

from Solvay is used in the chrome plating of precision parts for guided missile components.

THESE APPLICATIONS, however, are only a few of what we like to call the *chemical side of the missile and propellant business.* If you want to find out more about any of the subjects we have discussed, we would be glad to share our background and experience with you. Please write to Allied Chemical Corporation, Dept. 69-S, 61 Broadway, New York 6, N. Y. (In Canada: Allied Chemical Canada, Ltd., 1450 City Councillors Street, Montreal.)

*Quotation cited from article entitled "Rocket Propellants" by R. J. Thompson, Jr., appearing in *Chemical & Engineering News*, June 23, 1958.

MUTUAL is an Allied Chemical trademark.



BASIC TO AMERICA'S PROGRESS

Worm Autobiographies

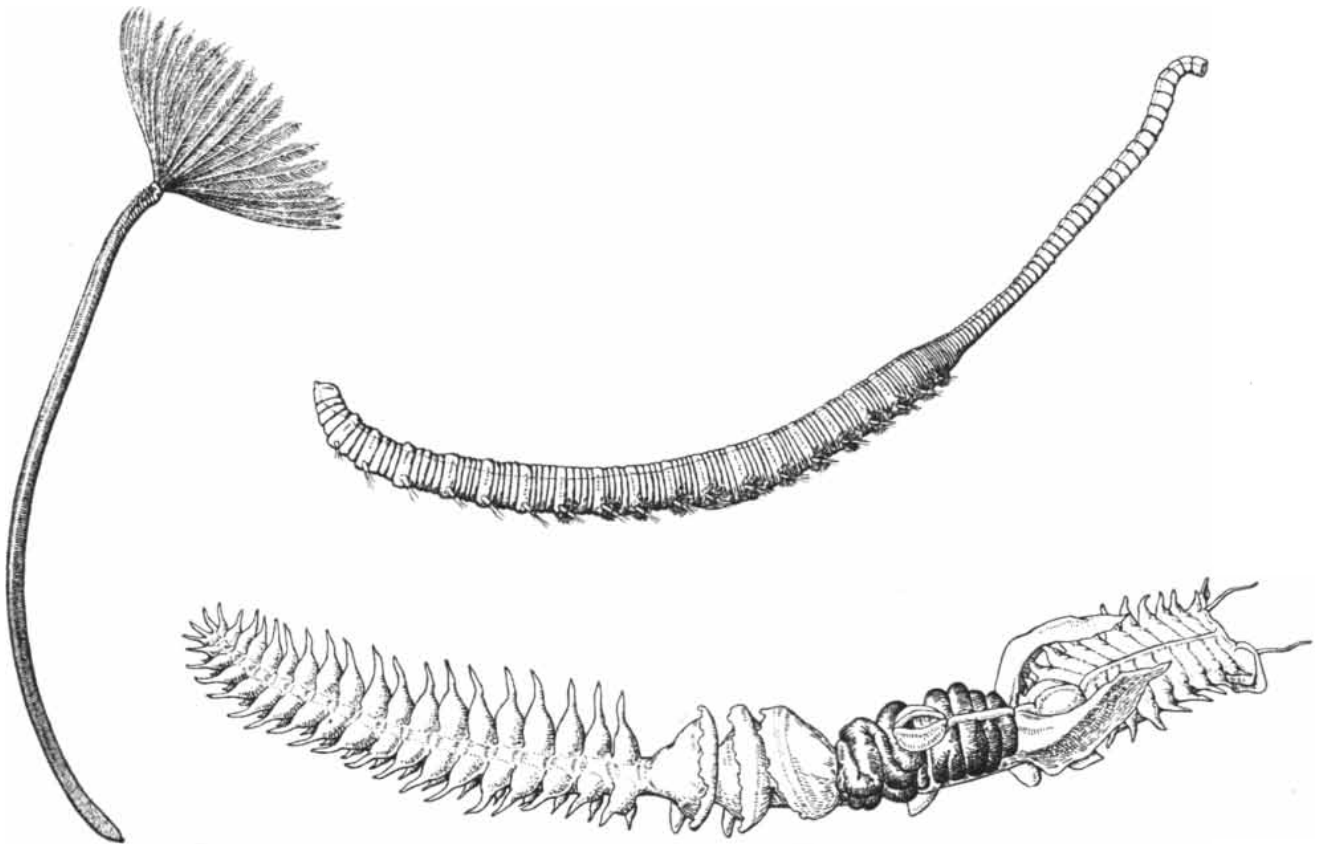
In which certain marine worms record their own activities on a revolving drum. Because these activities are relatively simple, they provide a convenient means of studying biological rhythms

by G. P. Wells

To study how a worm spends its time may seem a waste of one's own. But if the object is to observe the undisturbed behavior of an animal in something like its natural habitat, and to keep it under continuous observation for long periods, we can hardly find a more convenient subject. The great merit of the worm is that it does so little and does it slowly. A higher animal, like a bird, does so much so fast that anything

approaching a complete record of its behavior is well-nigh unobtainable. As a matter of fact, it is nearly always easier to stimulate an animal and watch its reaction in some experiment contrived in the laboratory than to discover how it spends its time when left in peace. Even in the field the almost unavoidable interaction of the observer and the observed may be such that the behavior ceases to be natural. But worms are remarkably

indifferent; their simple sense organs make it easy for the observer to remain unobserved. Above all, certain marine worms can be persuaded to write on paper a continuous record of what they are doing and to write it for days and weeks on end, while living their normal lives. To see how their lives are organized and to comprehend the springs of their behavior, we have only to learn to read their writing.



MARINE WORMS used in the author's experiments are the lug-worm *Arenicola marina* (center), *Chaetopterus* (bottom), and the

feather-duster worm *Sabella pavonina* (left). The bodies of *Sabella* and *Chaetopterus* are usually hidden in tubes of their own making.

Observations in the laboratory have led many writers to describe animal behavior as if it were a series of mere reflex responses, either to stimuli from without or to such inner urgencies as an empty stomach or a full rectum. A well-known college text refers to "that series of responses which constitutes an animal's behavior." Our knowledge of the organism's own contribution to the patterning of its life is comparatively backward, but in the accounts that worms are now able to give us of their lives we can clearly see that the organism is not so abject a slave of its environment as has been supposed.

In Britain, wherever flat beaches of muddy sand are exposed at low tide, one may see thousands of little coiled ropes of sand, up to 30 or 40 per square yard over vast stretches of beach. Each of these coils consists of sand that has been swallowed by a lugworm (*Arenicola marina*), robbed of its nutritious ingredients by the worm's digestive juices, then shot out on the surface of the beach, much as toothpaste may be squirted from a tube. One can find similar castings, and closely related worms, on suitable beaches all around the world. The lugworm is commonly about the size of a fountain pen, and its color may be anything from pink through greenish brown to nearly black. It has a thin tail, used in ejecting the sand-coil onto the surface, and 13 pairs of tufted gills, crimson because the blood contains a hemoglobin rather like our own. The worm leads a sheltered life in a U-shaped burrow underground, staying there for weeks or even months if conditions are favorable. It feeds at the lower end of one arm of the "U," the so-called head shaft, ingesting a column of sand that slides downward as fast as it is consumed, supplying the worm with food in the form of microorganisms and organic matter left by each receding tide.

The lugworm spawns for the first time at two years of age and normally lives to spawn a second time a year later. Then, in most cases at least, it dies. But in this article we are not so much concerned with the crises and climaxes of its life as with its ordinary day-to-day activities.

To make the worm record its activities in the laboratory we use the apparatus depicted at left on the next two pages. This consists of two glass plates, each 15 inches square, held about a half-inch apart by pieces of modeling clay, one forming a lopsided U, the other providing a semipartition inside the U.



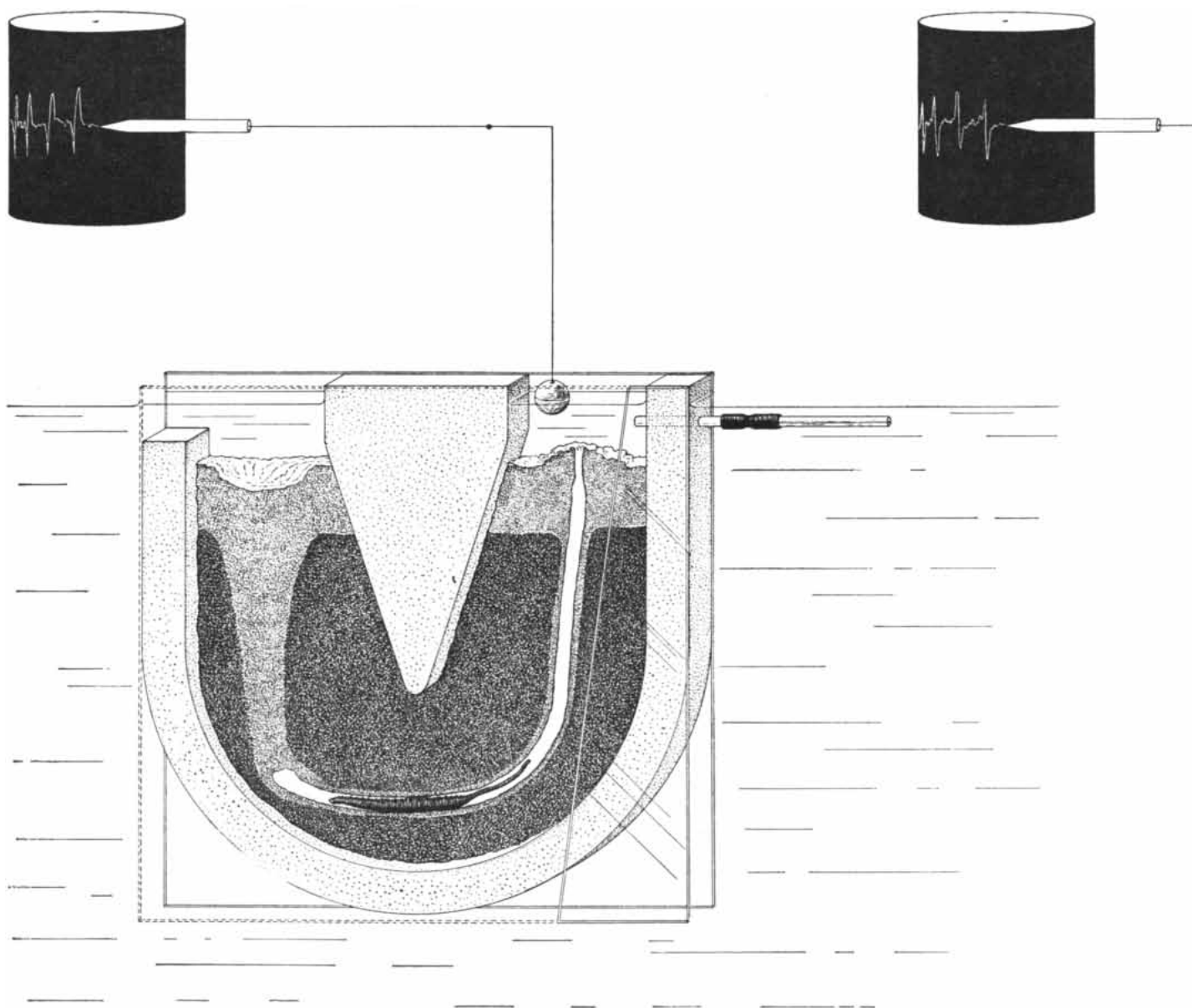
BEACH OF MUDDY SAND, photographed in Britain by D. P. Wilson, is covered with the mounds and depressions marking the burrows of lugworms. Sand falls into the head end of a burrow, is swallowed by the worm and is ejected in toothpaste-like coils at tail end.

The space between the plates is nearly filled with sand, and the resulting vivarium is immersed in a tank of sea water. A worm placed on the sand digs itself in and presently sets up a burrow which, if the dimensions of the worm and apparatus are properly matched, reaches its two arms up on either side of the partition. Soon castings begin to appear on one side and the sand surface subsides on the other. On the head-shaft side of the partition, water flows freely into the vivarium from the outer tank. On the tail-shaft side, however, the exchange of water with the outer tank is through a glass capillary; the water level on this side thus rises or falls very slightly in response to the worm's activities in its bur-

row. A float communicates the fluctuation of water level via a lever to a stylus that scratches a continuous record on a drum of smoked paper. The drum turns very slowly: about one revolution per day, or even per week. In this setup the animal is free to do what it likes in tolerably congenial surroundings; almost anything it does will cause a displacement of water and so leave its mark on the tracing. The only experimental interference (apart from the probably unimportant constraint caused by the narrowness of the vivarium) is the imperceptibly small resistance placed on the worm's water currents.

The lugworm, even in its natural habitat, has few activities to occupy it.

After feeding for a time it creeps backward up the tail shaft to eject its casting. Occasionally, but only at long intervals, it moves forward up the head shaft, reshaping the column, working up its texture, and perhaps dragging some particularly attractive object, such as a fragment of seaweed, from the sand surface into the shaft. At high tide the worm pumps water through its burrow, mainly to get a supply of oxygen. The stream is driven by swellings that move along the worm's body, closing the burrow and conveying the water by a kind of external peristalsis. At low tide, when the water table falls below the sand surface, the worm must creep backward until it has exposed most of its gills to the moist



WORMS "WRITE" by means of a stylus pivoting up and down as an attached float rises and falls with their pumping. With the lug-

worm the author uses a vessel (*left*) made of pieces of modeling clay (*light stippling*) between two sheets of glass. The sand inside

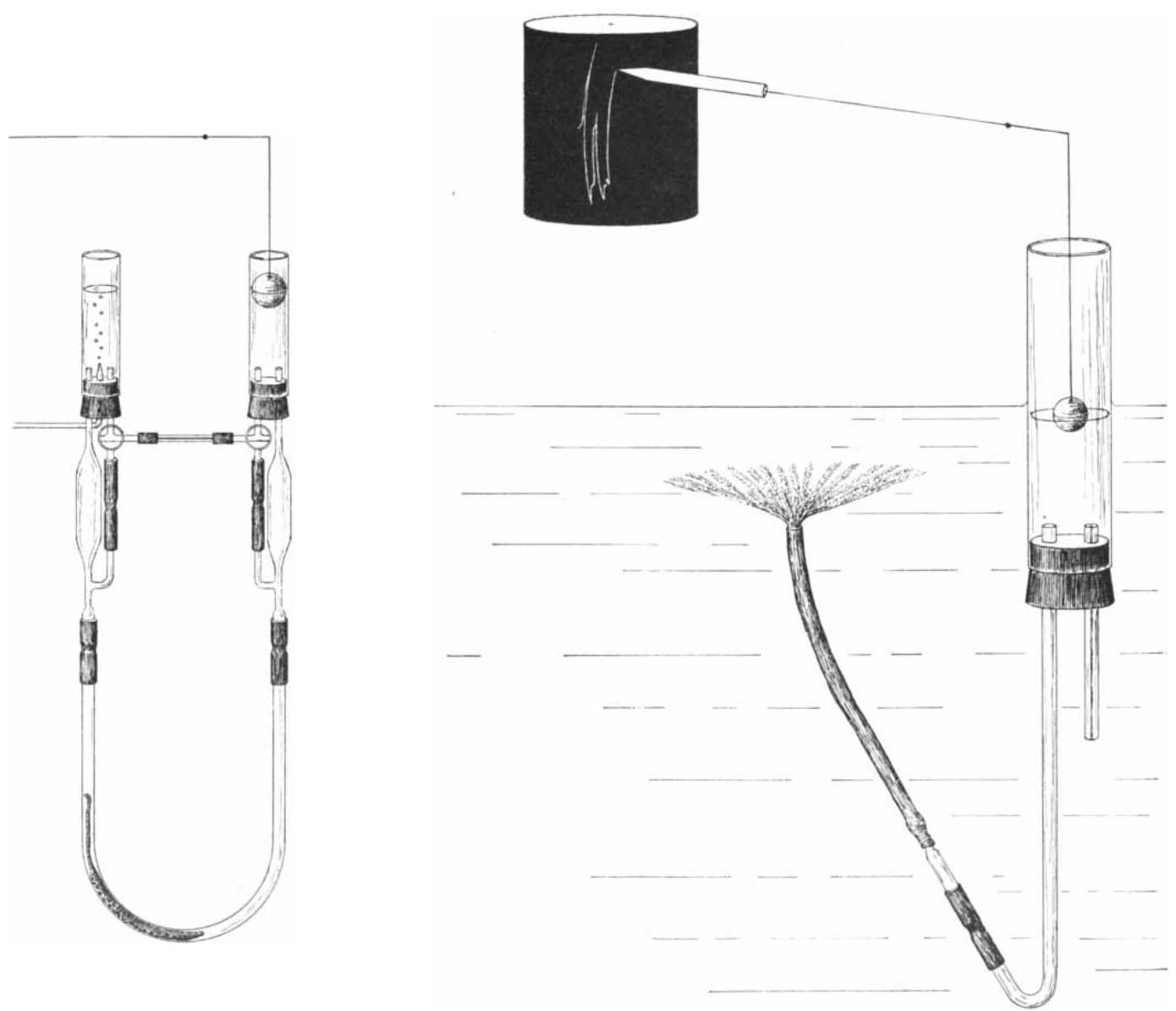
air in the upper part of the tail shaft. When the blood hemoglobin is oxygenated, the worm may return to the stagnant oxygen-deficient water in the bottom of the burrow. If worst comes to worst, a lugworm can live without any oxygen supply at all for several hours.

Now the worm's normal situation deep in the sand is comparatively secure, but its regular backward trips to the surface are perilous. At high tide these trips expose it to predatory crabs or fishes; at low tide, to sea birds and the dangers, very real to a marine invertebrate, of hot sunshine, hard frost or salt-free rain. However, the worm is well adapted anatomically to its mode of life. Its vital organs—heart, kidneys, stom-

ach, and testes or ovaries—are placed in the forward part of its body, which usually remains below. The exposed tail is little more than a muscular tube enclosing a sand-filled rectum. The tail is highly sensitive, however, and shrinks rapidly away from a hurtful stimulus, even throwing off its own extremity if the stimulus is violent enough. When matters have come to such a pass, nothing is lost, for the tail is continuously renewed by growth from its base. The tail is the lugworm's protection and its sacrifice to the terrible gods of the World above the Sand.

As we shall now see, the lugworm's behavior, no less than its anatomy, is well adapted to its way of life. At top

left on the next two pages is an extract, about five hours in length, from a lugworm autobiography. Against a fluctuating background, due to variation in the speed of the respiratory stream, is a repeated pattern, occurring regularly at intervals just under 40 minutes. The pattern begins with a downward movement of the curve as the worm creeps backward to the sand surface and the rising water level depresses the writing lever. This is followed by a downward "needle" as the animal shoots out a casting. Then the curve swings upward to a peak as the worm creeps to the bottom of its burrow again and for a while pumps water in a headward direction with exceptional vigor, lowering the water level above the



the vessel has been cut away to show the burrow. With *Sabella* and *Chaetopterus*, the natural tube is attached to a glass tube

(shown at right for *Sabella*). In the middle illustration is a glass U-tube used to investigate the effects of lack of food or of oxygen.

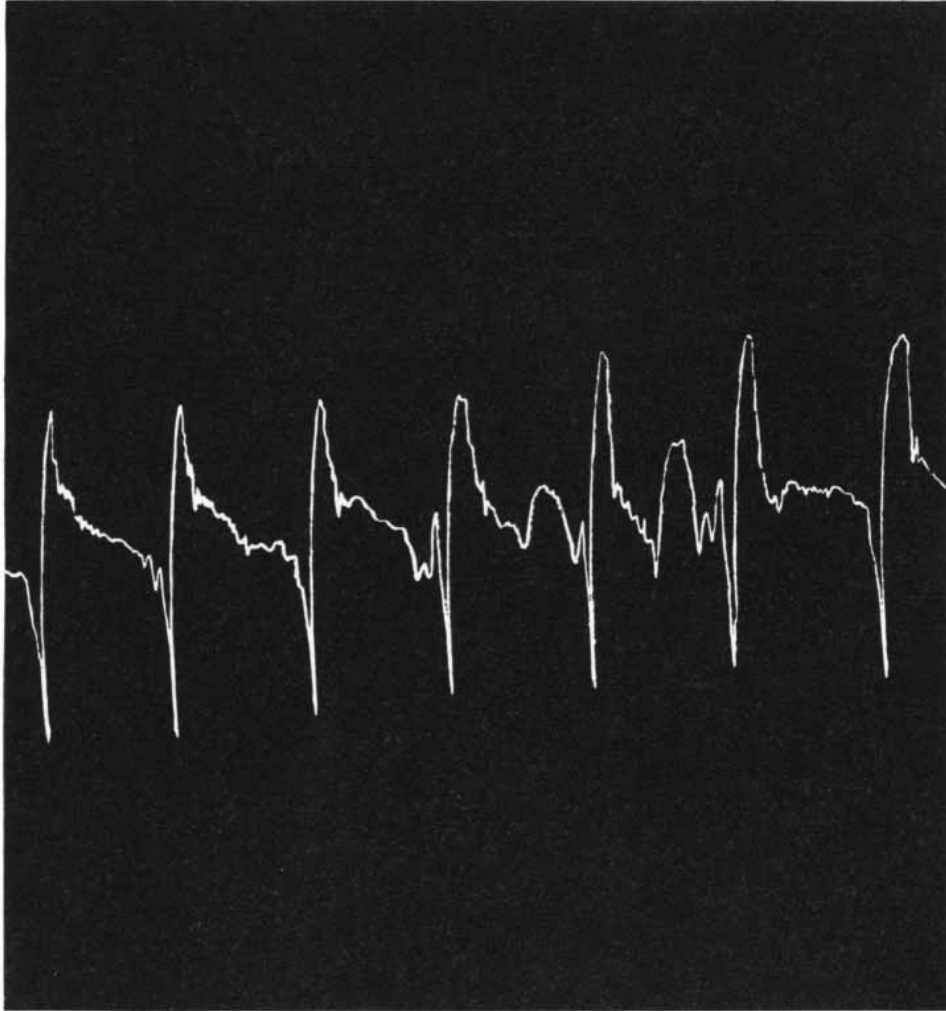
tail shaft. And so the cycle repeats hour after hour.

Whenever a worm is actively feeding and casting, it writes this characteristic pattern. But the creature may also lie still and do nothing, the lever tracing a plain horizontal line; or it may write violent, chaotic wiggles that have still to be interpreted; or it may trace other rhythmic patterns that there is no space here to describe. A long-term record of its be-

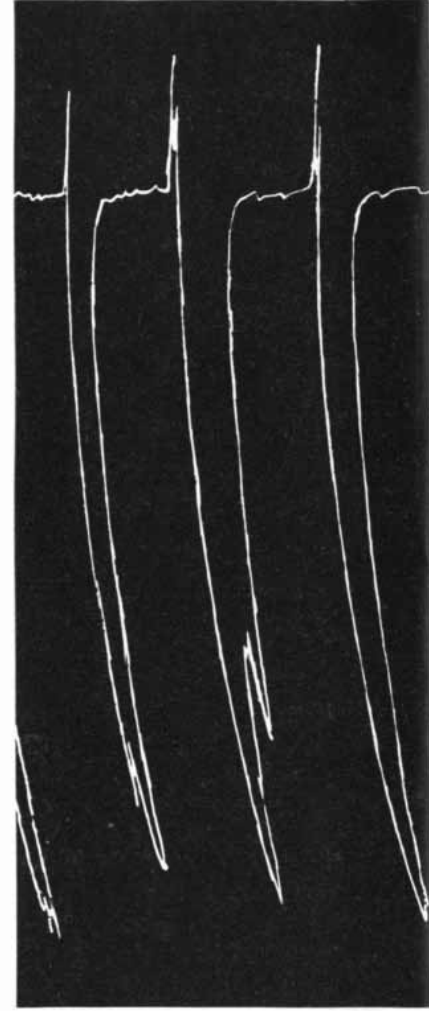
havior always shows these "moods," each of them generally persisting for several hours and then passing suddenly into another. If we observe worms other than *Arenicola marina* in our experimental setup, we see that each species shows different time patterns. A worm can be recognized by its writing on the smoked paper, just as a bird can be recognized by its song.

Chaetopterus variopedatus, a relative

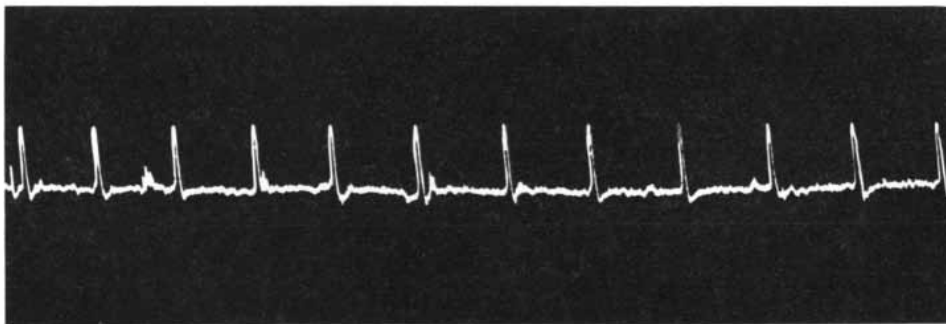
of the lugworm in spite of its very un-worm-like appearance, ordinarily lives in a parchment-like tube attached to rocks or stones on the sea bottom. It can be made to write by connecting one end of its natural tube to a reservoir with a capillary leak. Like the lugworm, *Chaetopterus* is a creature of moods and may write one of several patterns. The pattern at bottom left on these two pages is that of a feeding worm.



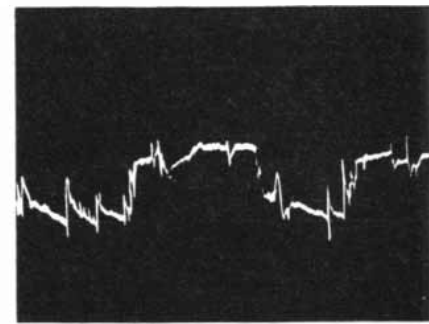
FEEDING LUGWORM made the record at left. At intervals of about 40 minutes it moved backward to the sand surface and shot



out a casting, causing the sharp downward "needles." Fasting worm in U-tube made similar excursions although it had nothing to eat or

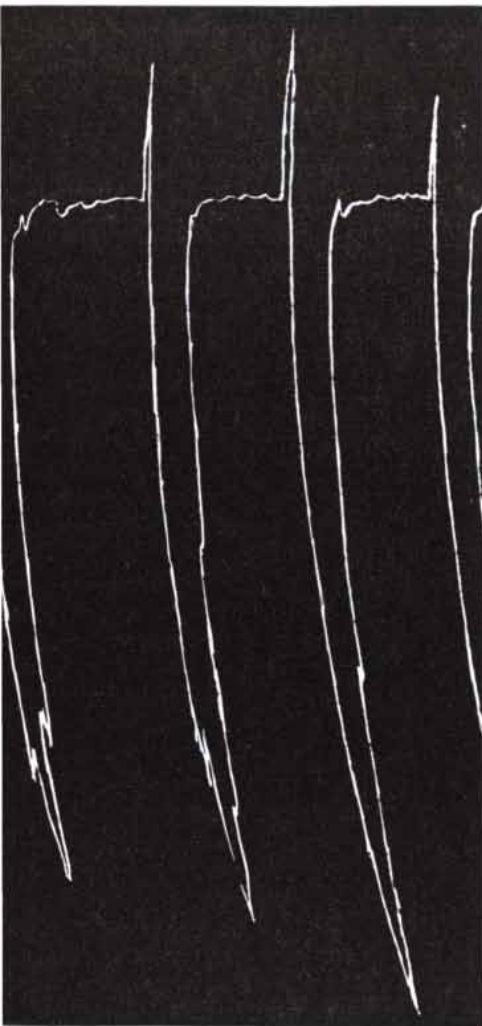


CHAETOPTERUS wrote the record at left while feeding. Its steady tailward pumping was interrupted at regular intervals of about 18

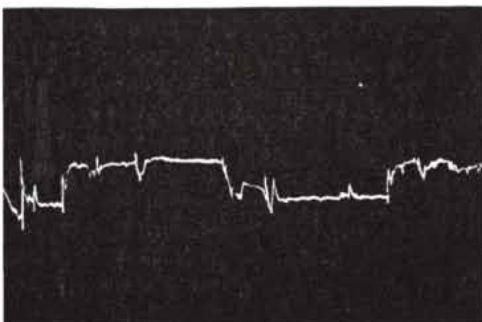


minutes (upward needles). Animal making the record at right was mildly irritated. It fanned irregularly and reversed its position

The tracing shows a water stream, driven steadily toward the worm's tail by the three fans in the middle of its body, with brief interruptions (seen as upward needles on the graph) at intervals of about 18 minutes. During each fanning period the animal exudes a net of mucus across the inside of the tube to trap small particles in the sea water. At the next interruption it rolls the net into a ball and swallows it. The graph shows



cast. Its writing (right) is upside down because its head faced the recording float.



in the tube at half-hour intervals, producing the general wave pattern of the tracing.

THIS KEY

eliminates "backtracking" hand operations that eat up time in the multi-step calculations of science and engineering.



THE MARCHANT *transflo...*

A NEW KIND OF AUTOMATIC CALCULATOR THAT TAKES THE "BACKTRACKING" OUT OF FIGUREWORK

The Marchant *transflo* breaks through the old limits of calculator automation by means of a unique mechanism called "back transfer."

A touch of the back transfer key *instantly and in a single cycle* transfers the intermediate result in a multi-step problem back into the keyboard dials *without* the tedious re-entry of each digit by hand. There's no "backtracking" over masses of figures or work-sheet notations.

The Marchant *transflo* moves figures swiftly from dial to dial, stores them and recalls them whenever needed. This unique ability creates new standards of operating ease, accuracy and speed, reducing chances for operator error and giving key personnel more creative time to make use of figurework results.

To fully appreciate the new *transflo*, you have to watch it perform. Get a demonstration on your own types of current problems by calling your nearby Marchant office. Or, send the coupon for further information.

Modern Management Counts on Marchant

**MARCHANT
CALCULATORS**

Division of SMITH-CORONA MARCHANT INC.
OAKLAND 8, CALIFORNIA

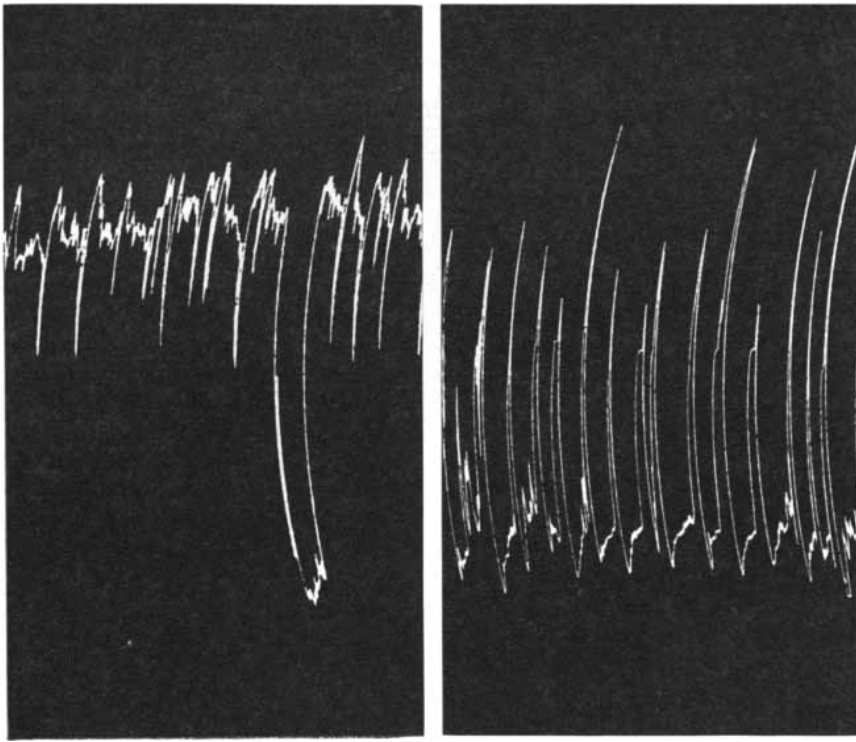
MARCHANT CALCULATORS • OAKLAND 8, CALIFORNIA

Send me more information about the new *transflo* calculator and how it can give us faster, more accurate figurework.

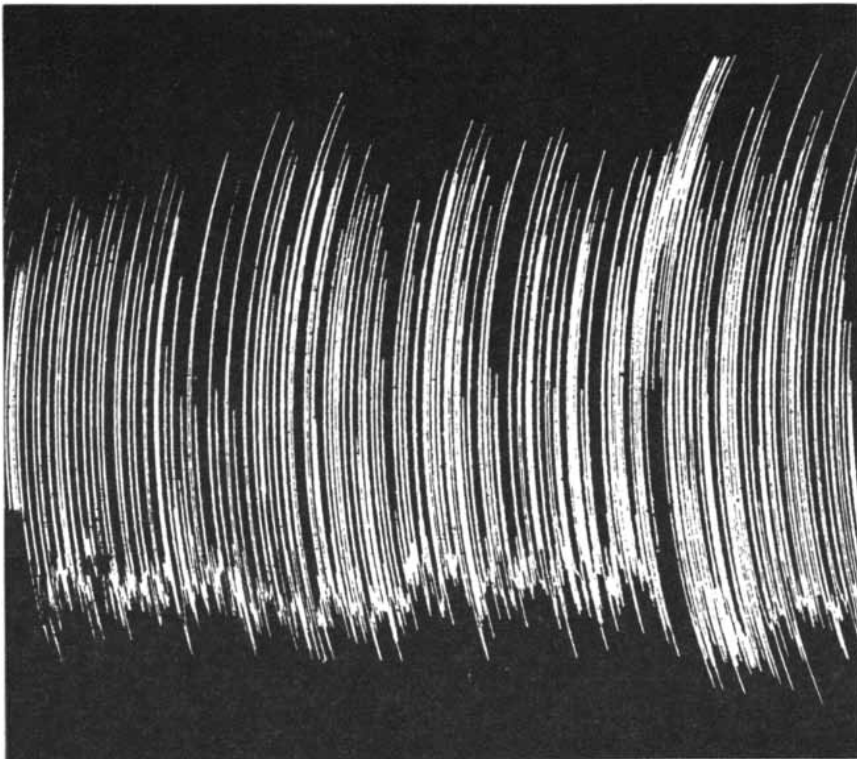
L-6

NAME _____

PLEASE ATTACH COUPON TO YOUR ORGANIZATION'S LETTERHEAD



RECORDS OF *SABELLA SPALLANZANII*, each five hours long, show two typical moods. During most of the left-hand extract the worm's crown of tentacles was spread out, and it drove water through the tube toward its head. For half an hour near the end of the record it pumped water tailward (*drop in tracing*). The worm making the record at right had withdrawn into its tube and pumped water in a tailward direction most of the time. About every half hour its tentacles peeped out, and it gave a burst of headward pumping (*peaks*).



SLOW-MOTION RECORD of *Sabella spallanzanii* repeats the same monotonous pattern for days. Even beheading the animal (*arrow*) disrupted the pattern for only a few hours.

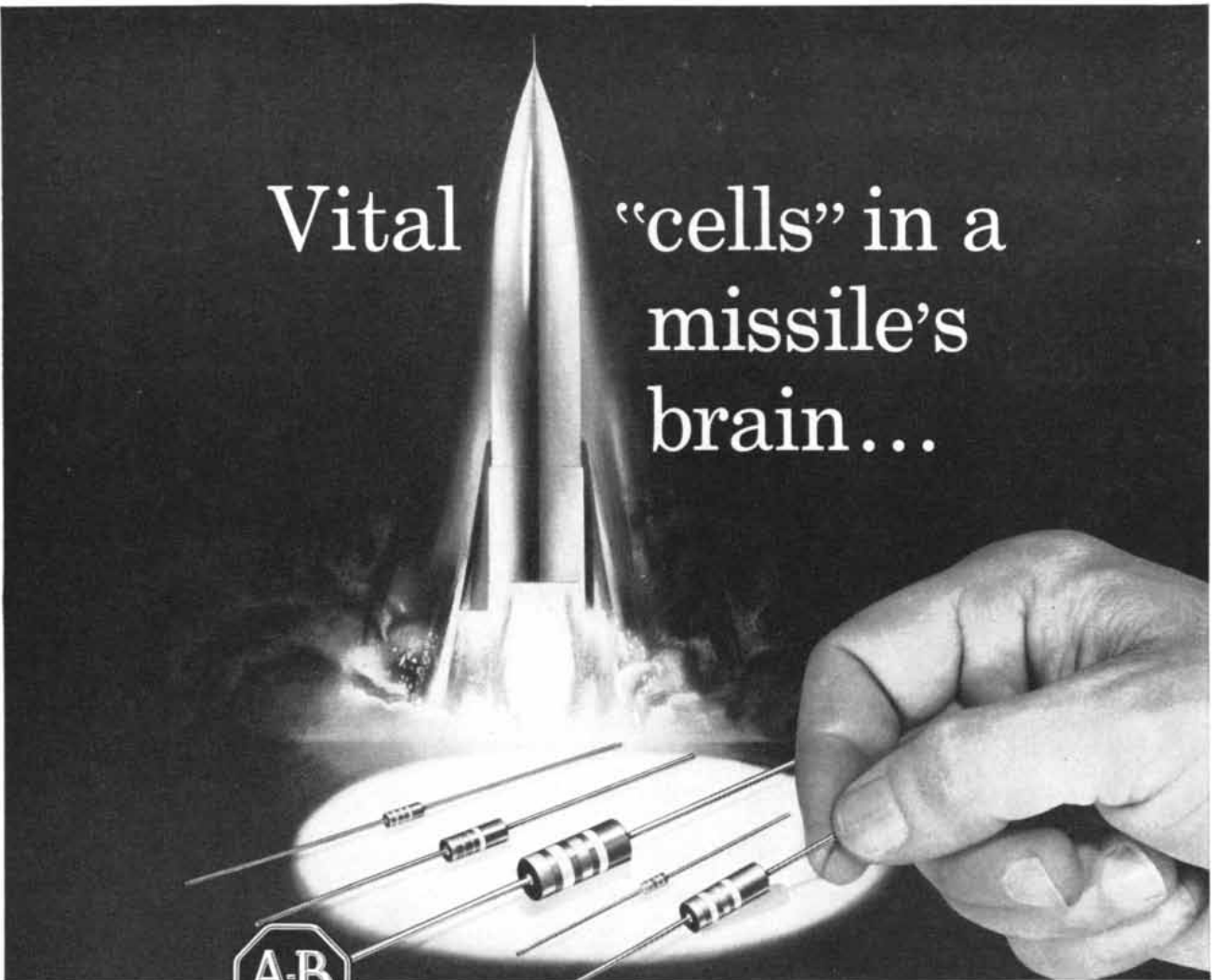
that the volume of water filtered through each net is rather more than a quarter of a liter. Another characteristic pattern that appears quite often in the writings of *Chaetopterus* seems to result from mild irritation, perhaps from some feature of the experimental setup. The animal that made the record at bottom right on the preceding two pages continually disturbed its water stream by little bursts of petulant kicking, and eight times, at intervals of about half an hour, it turned around so as to reverse its position in its tube, causing the slow wave pattern of the tracing.

Like the space patterns of anatomy, the time patterns of inherited routines are subject to natural selection and are adapted to the animal's way of life. This is clearly seen when we compare two species of the so-called feather-duster worms. These worms bear a crown of feathery tentacles that act as a living net to catch particles carried in the sea water. One species, *Sabella spallanzanii*, found embedded in gravel or attached to a hard object on the sea bottom, lives in a U-shaped tube in which one arm of the U is shorter than the other. Typically it drives water through its tube in a headward direction while the crown of tentacles is spread out, and then, when its mood changes, withdraws completely into its tube and pumps mainly in a tailward direction. One sees these behavior patterns over and over again in specimens after specimen of *spallanzanii*.

A second species, *Sabella pavonina*, prefers a muddy rather than a gravelly area. Its straight, non-U, tube runs deep into the mud, serving to anchor it more firmly. The inherited routines of this species consist solely of patterns of tailward pumping and never include reversal of the current. This is important because to drive water the other way would draw in mud and tend to clog the tube. So the difference of preferred habitat is connected not only with the difference between the U-tube of *spallanzanii* and the non-U of *pavonina*, but also with a difference in inherited routines. As a matter of fact, *pavonina* is perfectly capable of headward pumping if the necessity should arise—if, for example, it sucks something nasty into the upper end of its tube—but it never does so of its own accord.

We know nothing of the form in which behavior routines are inherited, or how they are stored for future use when not being performed. It is, however, worth noting that the worm's brain plays no part in their production. The crown of *Sabella* is quite vulnerable to

Vital "cells" in a missile's brain...







Tiny Allen-Bradley Resistors deliver maximum reliability in critical military applications

The very "life" of a huge missile may well rest upon tiny surges of current through Allen-Bradley resistors in its guidance system. These signal impulses in a missile's brain are essential to its flight direction—they must accurately agree with the designer's "figures."

A-B hot molded resistors have proven their reliability over the last 25 years or more—and in the most critical applications. Their uniform

electrical characteristics and conservative ratings assure superior performance at all times. *Allen-Bradley hot molded composition resistors have never experienced a catastrophic failure in service . . . and billions of these resistors are in daily service throughout the world.*

Let us send you more information on the complete Allen-Bradley line of quality electronic components. Write today.

<p>Superior Quality A-B Electronic Components find scores of important industrial applications.</p>	 <p>FERRITES Types available for TV and industrial uses</p>	 <p>CAPACITORS One physical size for high-speed assembly</p>	 <p>POTENTIOMETERS For quality radio & audio equipment</p>	 <p>FILTERS For radar and other microwave equipment</p>
---	---	--	---	---

ALLEN - BRADLEY | *Quality* Electronic Components

Allen-Bradley Co., 134 W. Greenfield Ave., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ont.



Fabricating Columbium Alloys

First, let's settle the question "When is columbium niobium?" It depends on whether you're a chemist or a metallurgist. And since we are interested mostly in metallurgy at the TAPCO Group, we call it *columbium*.

Columbium is growing more and more interesting to the people with product design problems involving high operating temperatures, greater stresses, and severe oxidizing conditions. In fact, it is rapidly overtaking molybdenum as the expert's choice for refractory structural materials.

Because of this increased interest in columbium, now available in sufficient quantities, the TAPCO Group has been conducting an extensive columbium development program during the past eighteen months. This program, a joint venture with E.I. duPont de Nemours & Co., Inc., has contributed much information about the properties of columbium and has produced better methods of working with it.

ABOUT WORKABILITY—At TAPCO, forging methods have been investigated with a variety of columbium extruded bars. Excellent progress is being made on jet engine parts and missile structural components. One method used to produce turbine blades includes heating blanks to forging temperature in an Argon-flooded furnace, then press-forging them in conjunction with a TAPCO-developed die lubricant. Simple surface-polishing is all that is needed to finish these precision-forged parts.

An important phase of the TAPCO program is the development of welding procedures for columbium alloys. TAPCO welding engineers have successfully joined columbium by spot and seam resistance methods, have also fusion-welded columbium sheets successfully.

WHAT DOES COLUMBIUM OFFER? If you design or build aircraft engines, missiles or supersonic airframes, you'll be interested in the research the TAPCO Group and duPont have done to improve columbium properties.

It has excellent strength and shock resistance at greatly elevated temperatures... up to 2600 F, even 3000 F with some alloy compositions.

Now, about columbium vs. molybdenum. Columbium is easier to fabricate than moly. And much, much more resistant to elevated-temperature oxidation. For example, a simple columbium alloy is as much as 100 times better than moly on oxidation resistance. And a complex columbium alloy may be as much as 500 times better.

At TAPCO, coating materials for columbium are being developed, including one that reduces the oxidation of columbium at 2200–2300 F to practically zero.

WHERE TO USE COLUMBIUM—Columbium blades for jet engine turbines are an actuality... we'll be glad to show you finished forgings. Columbium also makes sense for such other jet engine "hot zone" parts as vanes, turbine wheels, after-burner liners, nozzles and nozzle flaps, and burner holders.

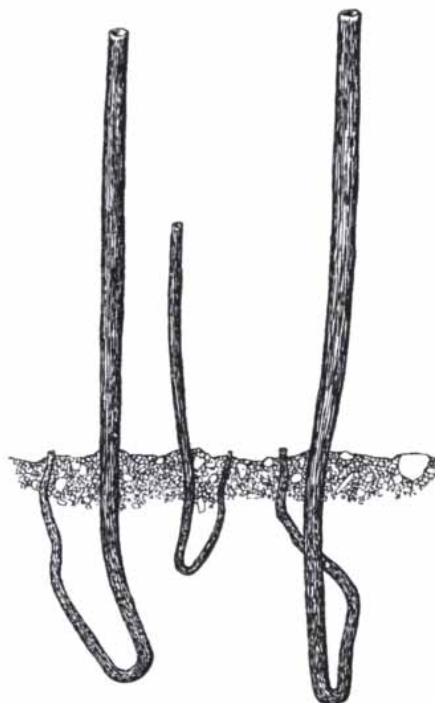
The use of columbium sheet seems very promising for missile structural components, such as leading edges, hinges, brackets, and the "ribs" and "skin" for airframes.

We would welcome an opportunity to tell you more about TAPCO's columbium research, and to discuss with you the many exciting possibilities of this space-age metal.



TAPCO GROUP
Thompson Ramo Wooldridge Inc.

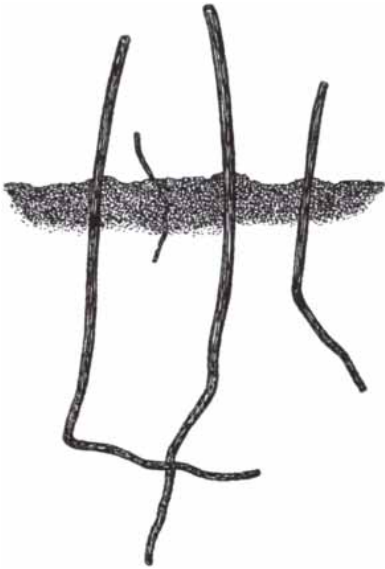
Dept. SA-1659 • Cleveland 17, Ohio



TUBES OF *SABELLA* are leathery and have a parchment-like root. At left are the U-tubes of *Sabella spallanzanii*, in which the

prowling predators when spread out in the sea water, and a worm may not always slip back into the tube quickly enough to escape a hungry fish. Fortunately a worm that has lost its head is able to grow a new one almost, but not quite, the same as the original. Under natural conditions more than half the worms show that they have had this experience at one time or another. During the slow-motion record at the bottom of page 138, the experimenter played the fish; I crept up with a pair of scissors and snipped off the entire head and crown with a short length of neck. It will be seen that the now-headless worm was put out, but only for a couple of hours; thereafter it calmly settled down to write the same old story. The resemblance between the complicated patterns traced by a decapitated *Sabella*, of either species, and those of a normal worm is remarkably close.

Even though the brain is unimportant, we can be sure that the patterns are not mere chains of reflexes. The tailward excursions of the lugworm look like reflex responses to a full rectum. Yet a lugworm can be kept in clean sea water, and after fasting for days, it some-



root returns to the surface of sand or gravel. At right are tubes of *Sabella pavonina*, which extend deeper into muddy sand.

times makes its regular excursions at normal intervals, though it has nothing in its rectum to discharge. Such experiments show that the lugworm has some kind of physiological clock in its nervous system that ticks spontaneously (if the worm is in the right mood) and compels it to go through its performances even in the absence of physiological need.

The clock that controls the lugworm's feeding has, in fact, been located. Under natural conditions the worm feeds in little bursts, each lasting for a few minutes, with a rest of a minute or so in between. In a glass tube of sea water with no sand to eat, the worms often make the same movements with about the same timing. If the front part of the gut—the esophagus—is removed from the worm and placed in a dish of sea water, it too exhibits this rhythm automatically. For a few minutes it is vigorously active, with waves of contraction running along it in regular sequence from the front end to the back; then it becomes quiet for a couple of minutes, and so on. One can show convincingly by appropriate experiments that the behavior of the esophagus is the



COLUMBIUM ...ready for space-age service

For over a hundred years, the metal that answers to two names—columbium and niobium—sat happily around with no real job all its own, although the stainless steel people have used small quantities of this “rare” metal as a stabilizing element.

Then about 1957 the people at TAPCO decided columbium, now no longer “rare”, ought to go to work...at the hot spots in missiles and aircraft.

In the past 18 months, the TAPCO Group, in joint research projects with E.I. duPont de Nemours & Co., Inc., has worked out commercial ways to produce columbium alloy forgings and sheet-metal parts. These columbium parts will withstand very high combustion temperature in gas turbines and very high friction temperature in missile structural and surface parts. TAPCO columbium-working experience includes precision-forging of turbine blades and forging of leading edge preforms, as well as stamping, welding, and machining columbium alloy sheet and extrusions.

If your project needs heat-resistance to 2600 F, sustained strength at elevated temperatures, good resistance to high-temperature oxidation, let us show you how TAPCO experience can supply the columbium alloy parts to meet these requirements.

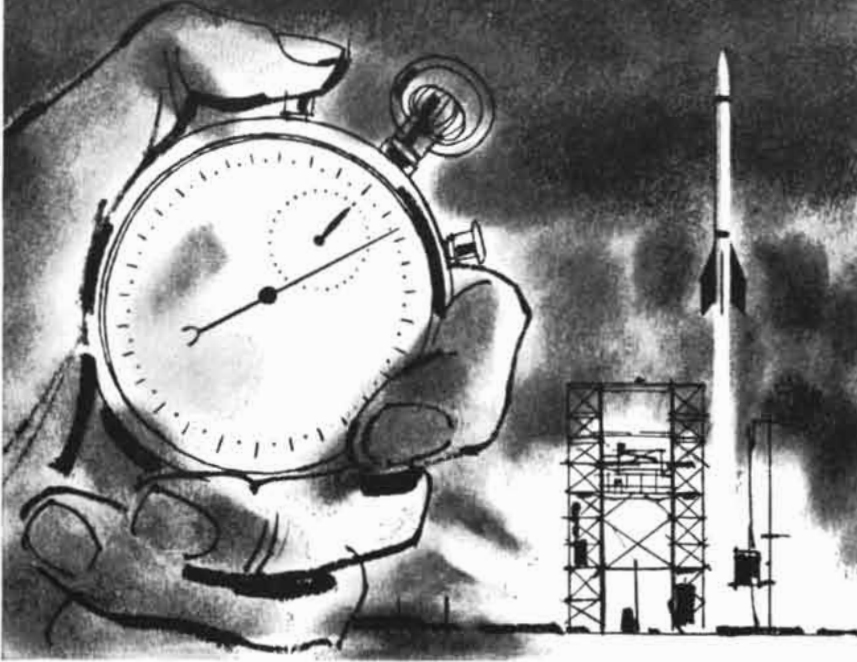


TAPCO GROUP
Thompson Ramo Wooldridge Inc.

DEPT. SA-2659 • CLEVELAND 17, OHIO

DESIGNERS AND MANUFACTURERS OF SYSTEMS, SUBSYSTEMS AND COMPONENTS
FOR THE AIRCRAFT, MISSILE, ORDNANCE, ELECTRONIC, AND NUCLEAR INDUSTRIES

ARE YOU AT ZERO HOUR
IN YOUR ENGINEERING JOB ?



Plan Range Instrumentation for "Project Mercury" —man's first space flight!

This is it: now you can take part in Man's greatest and most challenging venture—travel into space! This is Project Mercury. RCA's charter: to engineer, plan and design a world-wide range instrumentation system to control manned space flights. Work is in the Norfolk, Virginia area.

If you're an electronics engineer with broad experience in radar, telemetry, and advanced range communications, here is your chance to work on this most exciting project.

To arrange an immediate interview, send résumé to:

Mr. James Bell
Employment Manager, Dept. Y-21F
RCA Service Company, Inc.
Cherry Hill, Camden 8, New Jersey



RCA SERVICE COMPANY, INC.

A Division of Radio Corporation of America

determining cause of the intermittent feeding of the intact worm. When the esophagus is active, its activity spreads through the nervous system to most of the muscles of the body, affecting them in various ways and producing the complicated movements.

The rhythms of the lugworm can of course adjust themselves to suit external conditions. If the sand surface dries during low tide, the worms commonly cease to feed and defecate. The periodic excursions persist, however, and now serve as a means of aerial respiration, air being swept down into contact with the gills by the pumping motions. After a period of enforced oxygen lack, the excursions follow each other at unusually short intervals. But basically the rhythms are intrinsic.

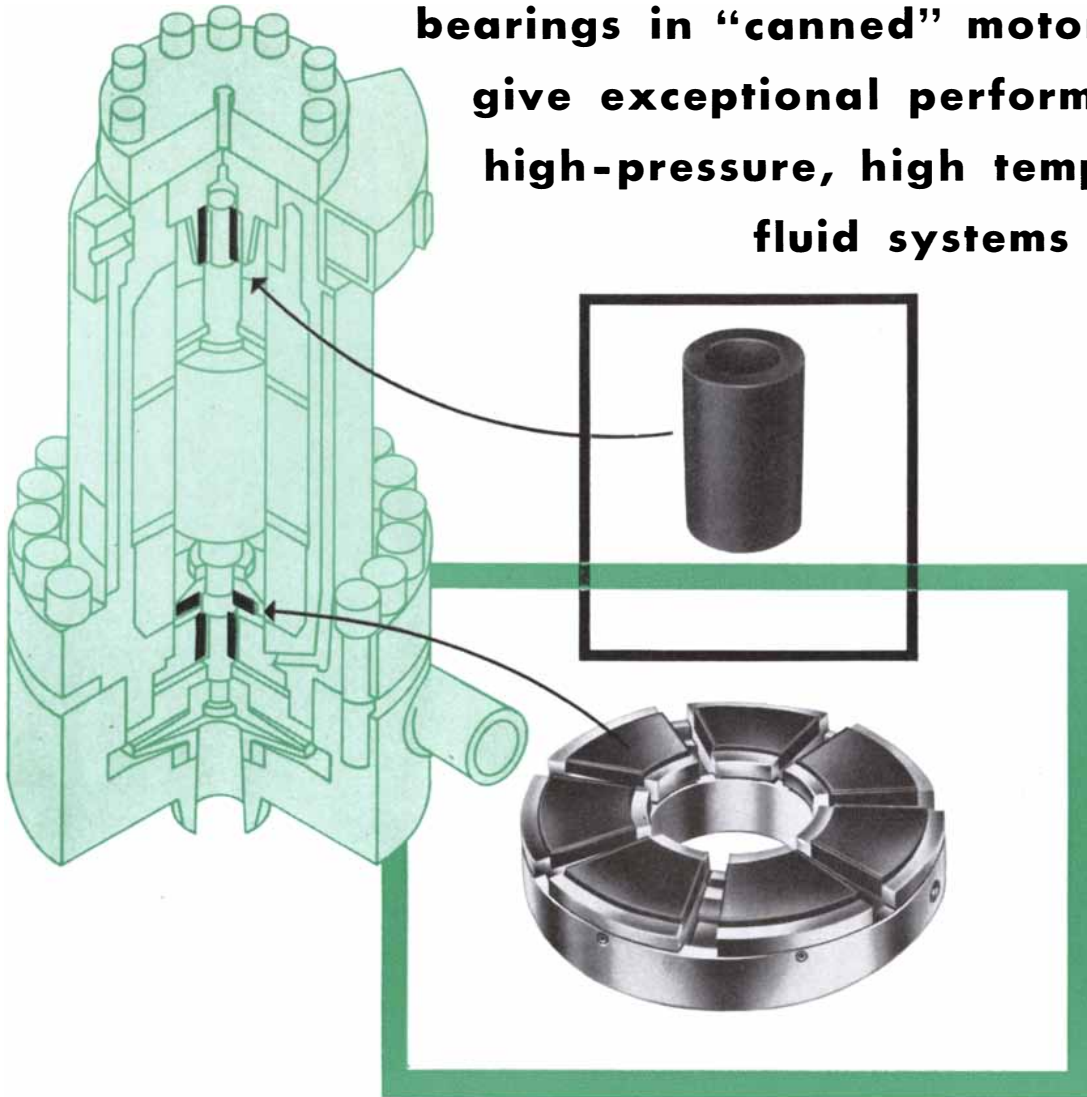
A lugworm esophagus may be compared with that well-known classroom object the isolated heart of the frog. Even a little shred of heart muscle contracts rhythmically as long as it stays alive and healthy. The rhythmicity of the heart is as much a built-in feature as the anatomical structure of its cells. Similarly a lugworm esophagus, cut into pieces either lengthwise or across, shows the characteristic alternation of rhythmic activity and rest. Just as the heartbeat can be modified by factors external to it, such as hormones and nerves, so the rhythm of the esophagus is affected by changes in its surrounding fluid. By increasing the amount of magnesium in the fluid, the esophagus can be slowed up so that its outbursts of activity appear at regular intervals of over half an hour. How a clock of cellular dimensions can tick as slowly as this is indeed an intriguing problem. It is presumably related to many other problems of physiology, such as the exact mechanism of the heartbeat. Under certain abnormal conditions a heart may beat in bursts, very like the activity pattern of an isolated lugworm esophagus. Perhaps when the investigators of the vertebrate heart have found out how it beats, their answers may also explain the contractions of the lugworm esophagus.

The behavior of the lugworm is no less inherently spontaneous than the beating of the heart. The worm tends to express itself by generating characteristic patterns of events arranged in time, though the patterns may be interfered with, and more or less modified, by environmental influences. In other words, at the moment of fertilization, when it comes into existence, the lugworm acquires a blueprint for its body and a program for its life, though both are subject to environmental approval.

water-lubricated **GRAPHITAR**[®]

(CARBON-GRAPHITE)

bearings in "canned" motor pumps
give exceptional performance in
high-pressure, high temperature
fluid systems



Special hermetically sealed motor-pumps, known also as "canned" motor pumps, were developed by Westinghouse Electric Corporation to handle radioactive water with zero leakage. These same pumps have proven a convenient means of pumping high temperature fluids for a number of nuclear reactors and other high pressure, high temperature fluid applications.

The thrust bearing utilized in the "canned" motor pump is a self-equalizing, water-lubricated, pivoted-pad bearing with inserted GRAPHITAR bearing surfaces. The radial sleeve bearings are also made of GRAPHITAR and are designed to be lubricated by the pumped fluid only . . . in the case of pumps used in nuclear reactors, only

radioactive hot water is employed as lubrication.

GRAPHITAR is utilized extensively in tough applications because of its many unusual properties. It is non-metallic, resists chemical attack, has self-lubricating properties, a low coefficient of friction, is mechanically strong, hard as steel and lighter than magnesium. GRAPHITAR will not warp and shows no expansion or contraction in extreme temperature changes.

This versatile engineering material, GRAPHITAR, may well solve one of your difficult design problems. For further information on GRAPHITAR and its many applications, send for our engineering manual No. 20.



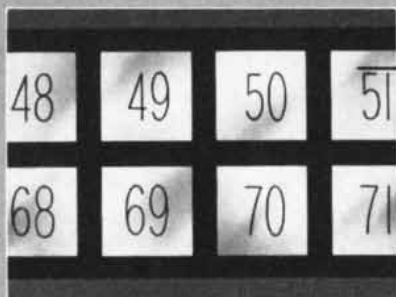
R-266-1

THE UNITED STATES GRAPHITE COMPANY

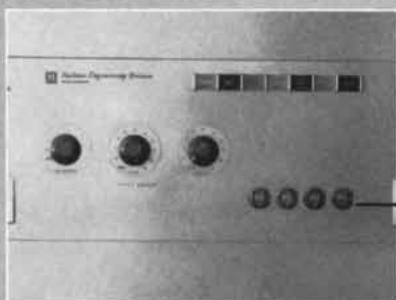
DIVISION OF THE WICKES CORPORATION, SAGINAW 6, MICHIGAN

GRAPHITAR[®] CARBON-GRAPHITE • GRAMIX[®] POWDERED METAL PARTS • MEXICAN[®] GRAPHITE PRODUCTS • USG[®] BRUSHES

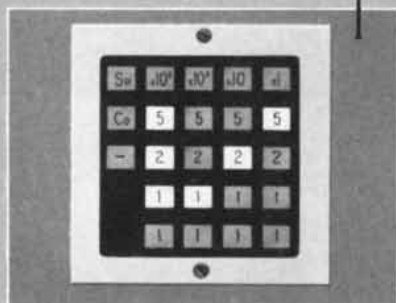
New packaged



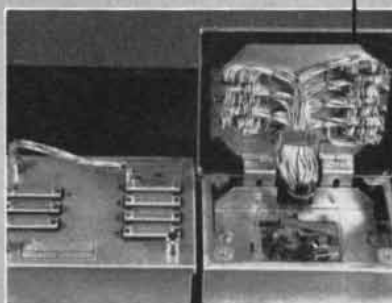
THREE 40-POINT ANNUNCIATORS make it easy for the operator to tell at a glance which variables are off-normal.



DIGITAL VISUAL DISPLAY and variable selector switches make it easy to select any single variable and watch all trends and changes continuously.



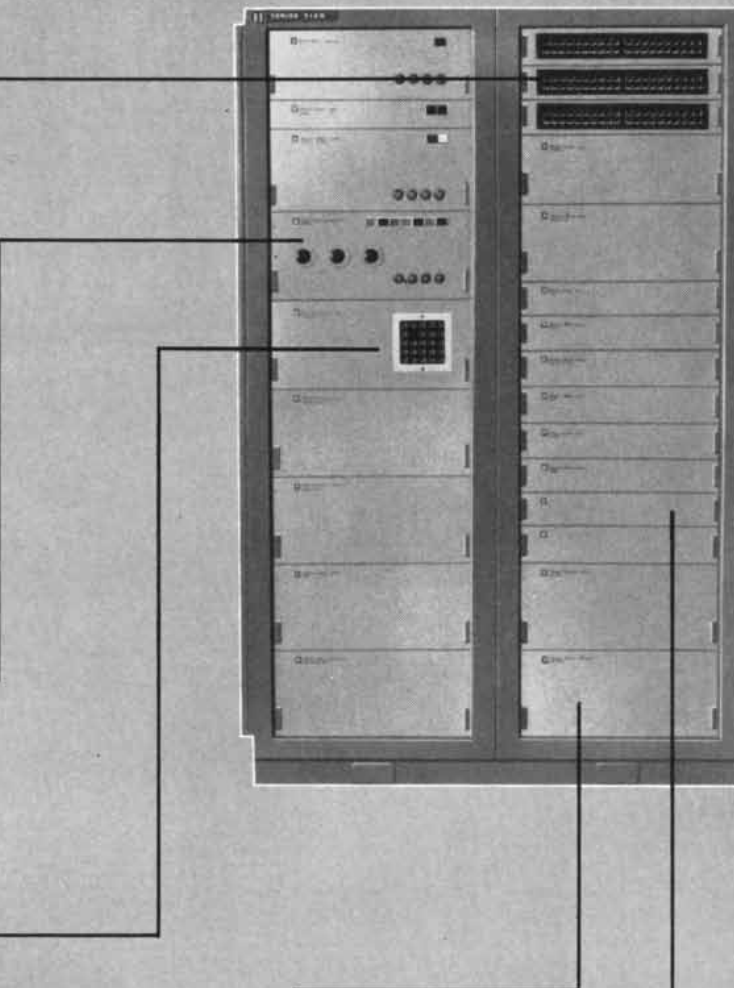
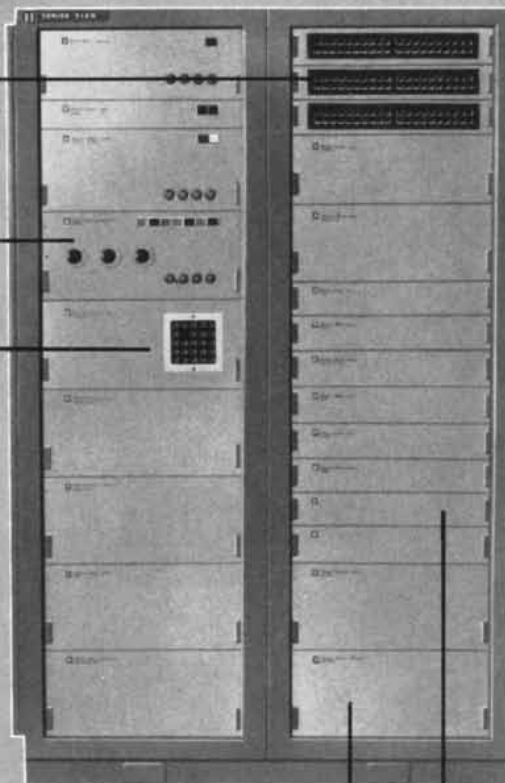
SERVICING IS SIMPLIFIED by an indicator-light panel showing the completion of each step in the analog to digital conversion. The sequence programmer can be changed from automatic to hand advance to permit operator to check each step.



UNIQUE INPUT SELECTOR is unusually dependable because of its sealed, oil-immersed construction. Servicing is normally limited to visual inspection every 6 months. Drawers pull out so voltage checks can be performed without shutting down system.



PINBOARD PROGRAMMING adds flexibility. You can change the logging or scanning sequence at will . . . substitute one type of input for another. Range, span, and zero adjustment are set by inserting pins in their proper places. No calculations are required. The pinboards are pinned in familiar units of measurements.



Honeywell logger-scanner

...accurate within $\pm 0.1\%$ of reading

...pinboard programming for maximum flexibility

Here's a standard, all-purpose 120-point logger-scanner system with features formerly found only in more expensive, custom-designed equipment . . . the first of several packaged logger-scanners being introduced by Honeywell. It offers the ultimate in accuracy, flexibility, dependability and simplicity of maintenance. Wide ambient temperature operating limits—60 to 120°F—eliminate the need for special air conditioning equipment.

The Series 3120 accepts signals from primary measuring instruments—thermocouples, flow, pressure or other transducers. It measures these signals, digitizes them, and prints their values in immediately usable form. A thermocouple reference oven can be supplied to accommodate three types of thermocouple inputs—types T, J, and K—which are automatically linearized over their entire range to within 0.1% accuracy.

The operator can select either automatically or manually initiated logging cycles. He can set the system to log all variables automatically at preset intervals, or manually energize the system to operate on demand, between logging cycles.

Between logging cycles, the system can scan off-normal alarm points—high, low or both—at a rate of 7 points per second. Upon detecting an off-normal point, the system sounds an alarm, lights a point-identification light, and prints the time, point number and off-normal value on adding machine tape. During log cycles, off-normal points are printed in red on the log sheet.

Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell



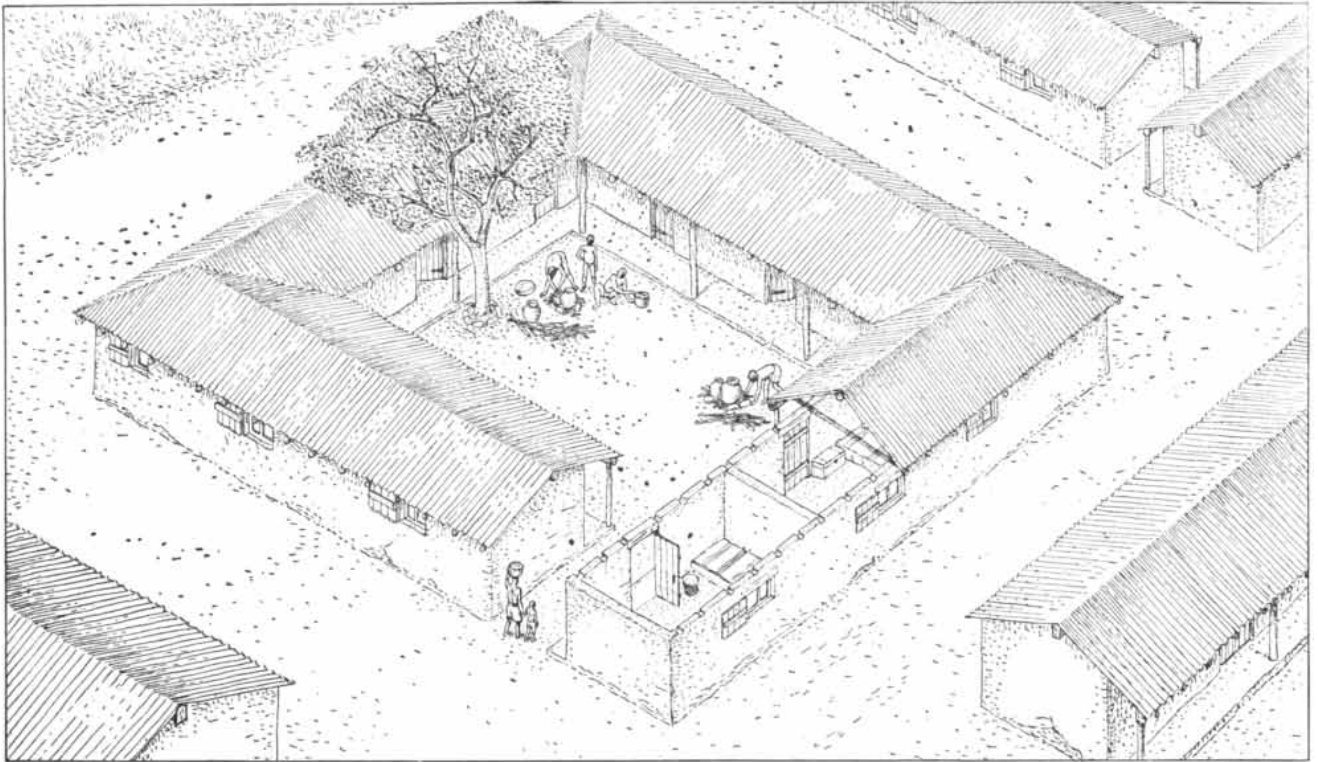
First in Control



TWO TYPEWRITERS permit a single line log allowing columnar comparisons. Separate alarm printer records all off-normal variables.



STANDARD MODULAR COMPONENTS are assembled on chassis mounted as individual drawers in relay racks. All drawers are connected by plugs for easy servicing.



MATRILINEAL HOUSEHOLD is characteristic of the Ashanti tribe in Ghana, West Africa. A typical Ashanti household includes a grandmother, her sons and daughters and their children. Each

adult occupies one room. Their spouses live apart from them in their own matrilineal households nearby. In this drawing part of the tin roof is removed, showing the interior of the adobe rooms.



PATRILINEAL HOUSEHOLD typifies the Tallensi tribe, also of Ghana. While more primitive than the Ashanti, they have more highly structured households. Outside the gate, by the sacred tree and conical ancestor shrine, is a social area for the men of the house. Inside the gate the patriarch of the household stands in the cattle yard, his special domain. To the right is the flat-roofed

cattle shed where his ancestral spirits dwell. Behind him, at the hub of the homestead, is its granary, from which only he may dispense grain. Clockwise around the homestead, starting to the left of the gate, are a room for adolescent boys; the bedroom, pantry and unroofed dry-season kitchen of the patriarch's mother; and the bedroom, kitchen and pantry of his wife, himself and his children.

PRIMITIVE KINSHIP

In most primitive societies the family is an organization far more complex than the family of Western civilization. This organization reflects the larger role played by the family in primitive cultures

by Meyer Fortes

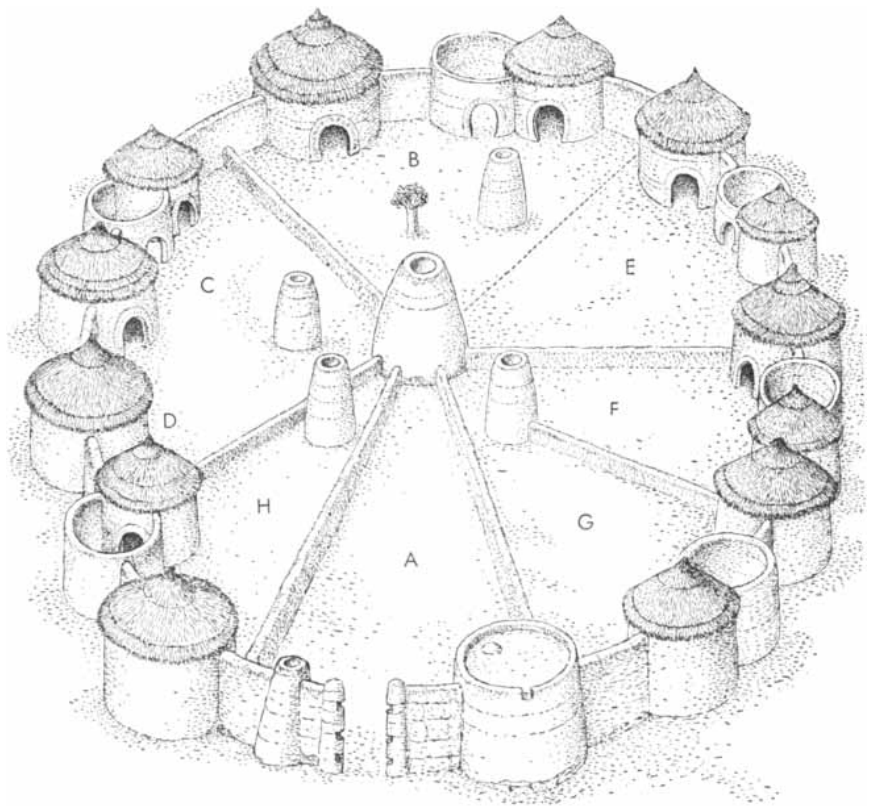
Ministers, political orators and editorial writers are apt to tell us that the family is the keystone of society. From the biological point of view it would indeed seem to be the ultimate social institution. The conjugal family—husband and wife and their children—gives social expression to the function of human reproduction. Early travelers from our civilization were sometimes shocked because they could find no obvious counterpart of our family among primitive peoples. When they found large communal households, inhabited by men, women and children having the most bizarre and sometimes downright indecent relationships to one another (in the terminology of our family), they took this as conclusive evidence that these cultures were barbaric.

We have come to know primitive peoples at closer range in recent years. What they have taught us has radically altered our judgment of their family organizations and given us a humbler understanding of our own. Primitive family types vary in their constitution, but they are always precisely structured institutions, embracing the primary loyalty and life activity of their large memberships and enduring from generation to generation. The exact prescription of relationships among members gives each individual a significantly defined connection to a wide circle of his kin. To the individual member, the family's property is the source of livelihood, its ancestors are his gods, its elders his government and its young men his defense and his support in old age. In simpler cultures (e.g., the Australian aborigines) family and society are actually coterminous: all men are either kinsmen or potential enemies.

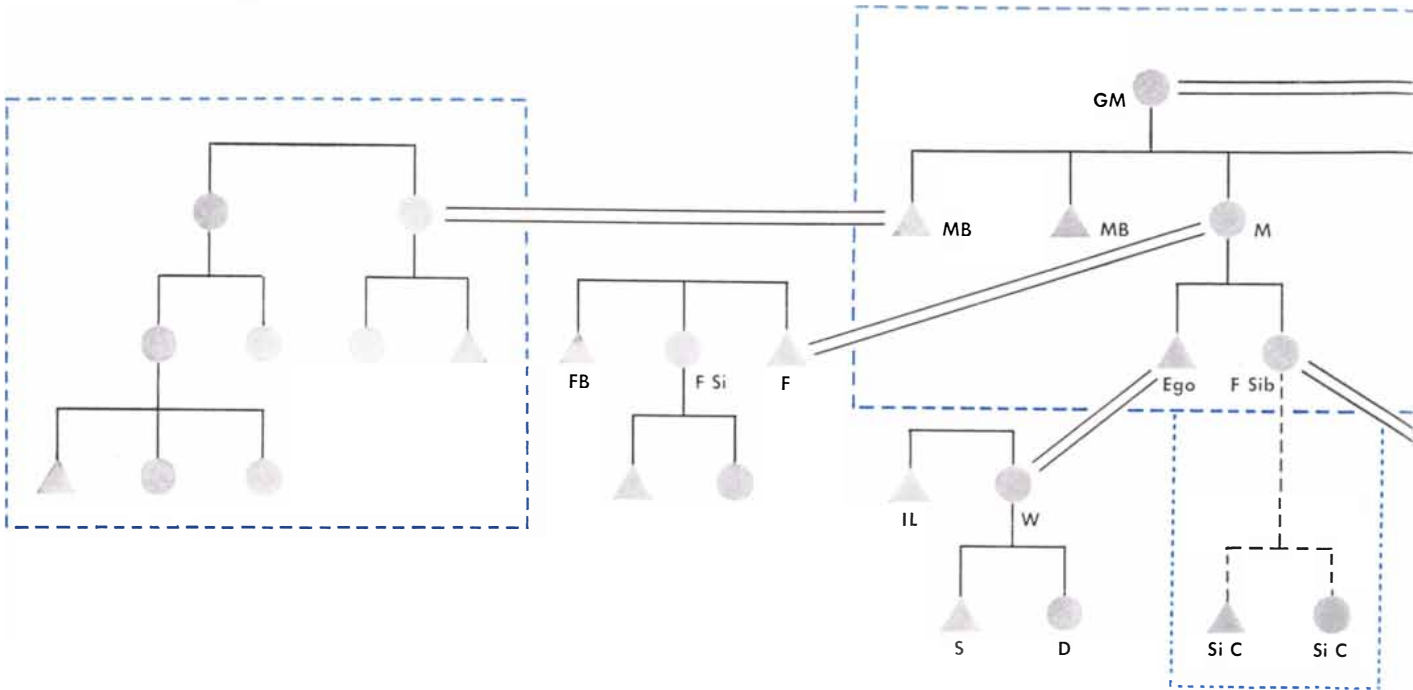
We, in contrast, are primarily citizens, not kinsmen. The family is organized anew with each marriage. It must

share our allegiance with the many competing claims of our society: the loyalties we owe to the institutions that employ us, to our professional organizations, to political parties, to community and nation. A family of such reduced status and scope is, as a matter of fact, distinctly out of the ordinary as families go. The Hebrew families of the Bible

and the Roman *gens* more closely resemble the extended family systems of contemporary primitive cultures than they do our own. Of all the primitive societies I know, the one that most closely resembles ours in isolating the conjugal family as the basic social unit is the Iban, a tribe of head-hunters in North Borneo. The vocabulary we employ to

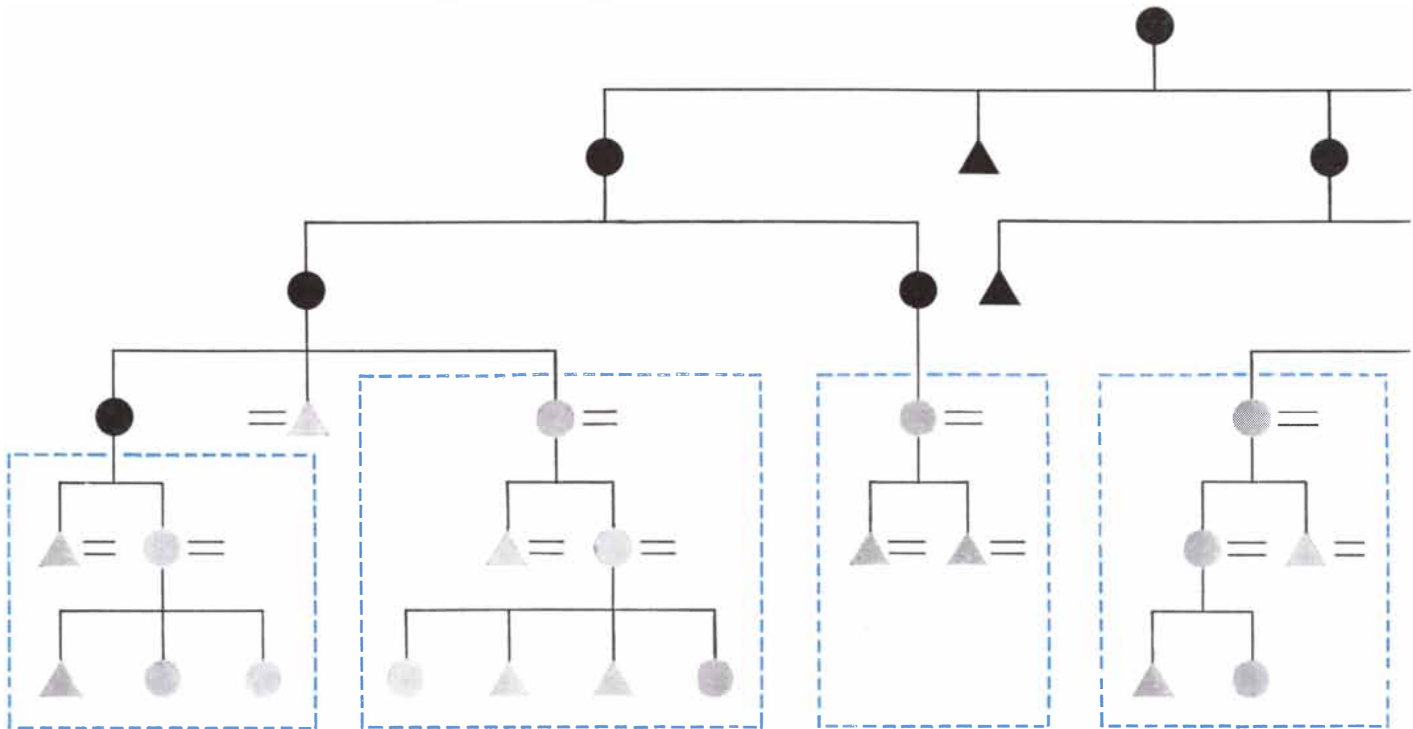


TALLENSI DWELLING depicted in this schematic drawing is far more elaborate than the one shown in greater detail on the opposite page. It includes the patriarch's cattle yard (A); his senior wife's bedroom, pantry and kitchen (B); a similar unit for his second wife (C), including a hut (D) for her adult child, his second son; a unit for his third wife (E); his eldest son's domain, including units for the latter's first wife (F) and second wife (G); a unit for the third son (H). The basic Tallensi house plan can be expanded to any size. Large joint families of this kind are typical of primitive societies that are not nomadic.



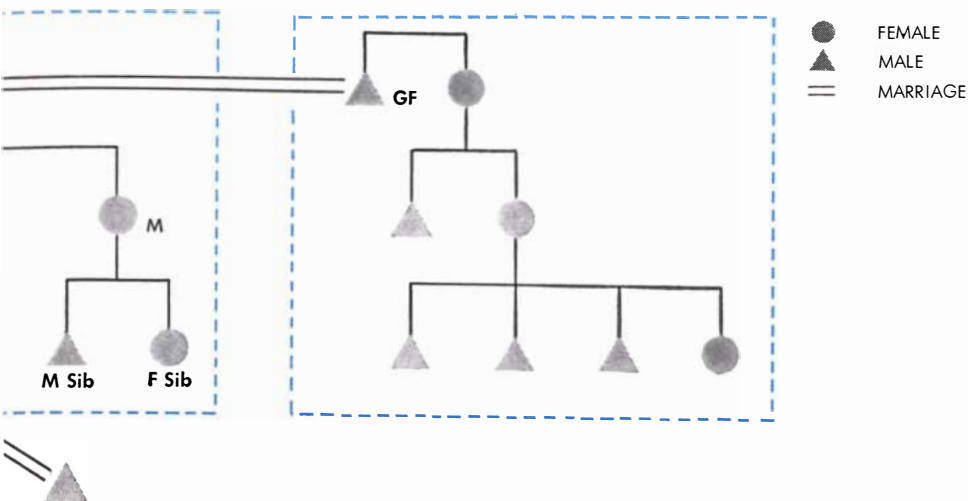
ASHANTI MATRILINEAL FAMILY is depicted in this family tree. The symbols are explained in the first key at right. The letters, which indicate the relations of each family member to the individual labeled "ego," are explained in the second key. Note that, according to the "classificatory" type of kinship terminology used

by the Ashanti, "ego's" aunt as well as his own female parent is called "mother"; his aunt's children as well as his own brothers and sisters are called "siblings." "Ego's" own domestic household is shown in the broken colored rectangle at the center of the chart. Below this rectangle is a smaller one, representing a possible fourth



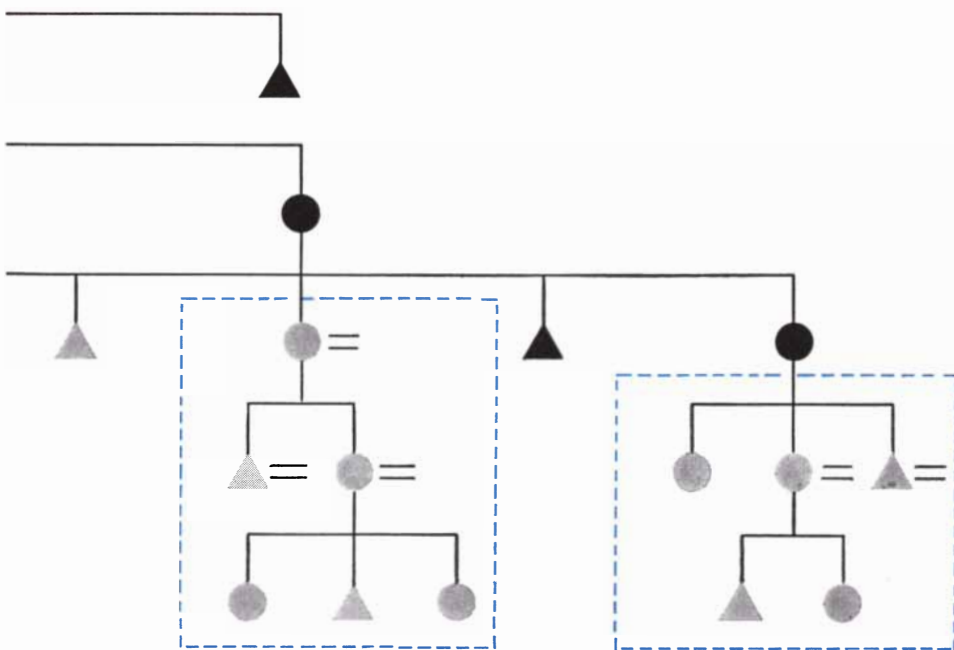
- LIVING FEMALE
- DECEASED FEMALE
- ▲ LIVING MALE
- ▲ DECEASED MALE
- = MARRIED MEMBERS

ASHANTI LINEAGE shown in this chart represents the common ancestry of six domestic families, traced through the female line (mothers and grandmothers, not fathers and grandfathers) to a single ancestress



generation in "ego's" family. The fourth generation, comprising his sister's children, will be his heirs. His own wife lives apart from him in another matrilineal household elsewhere in the village. His children are heirs not of himself but of his male affinal relations ("in-laws"), who share his wife's household. Also shown in this chart, in whole or part, are four households in which dwell spouses of other members of "ego's" family.

describe our kin—our uncles, aunts and cousins—beyond the immediate conjugal family fails to suggest the compelling ties that bind the kinship of peoples other than those of modern European and American civilization. Students of primitive kinship systems have found that they employ a terminology wholly unlike our own: the "classificatory" system, which groups relatives by status rather than sorting out their genetic interrelationships. It appears that all kinship systems obey certain universal principles governing the separation, inner unity and orderly sequence of generations. Viewed from the vantage point of such understanding, our family appears to be the much-curtailed form of a once far more elaborate and comprehensive organization.



Two "facts of life" necessarily provide the basis of every family: the fact of sexual intercourse is institutionalized in marriage; the fact of parturition is institutionalized in parenthood. Societies differ greatly, however, in which of these institutions they select as the more important. Our society selects marriage: the result is the conjugal family, centered upon a single marital relationship and the children it produces. Most human societies, however, rate parenthood above marriage. This results in the consanguineal family, centered upon a single line of descent.

Biologically our lineal inheritance derives equally from both sides of the family according to Mendelian law. Societies that prize lineage, however, restrict social inheritance either to the maternal or the paternal line. The social heritage—that is, property, citizenship, office, rank—passes either through the father or through the mother. "Patrilineal" descent (father to son) was the rule in ancient Rome, China and Israel, and occurs in many primitive societies. "Matrilineal" descent (mother's brother

(top). This "matrilineal" descent does not mean that Ashanti property and authority pass from mother to daughter; rather they descend from a woman's brother to her son.

to sister's son) is common in Asia, Africa, Oceania and aboriginal America.

One matrilineal society that flourishes today is the ancient, wealthy and artistic kingdom of Ashanti in Ghana, West Africa. While European mores have made some inroads among the Ashanti, back-country Ashanti villages still keep to their strictly matrilineal ways. Let us consider how such a society works.

First of all, let us note that a matrilineal society is not a matriarchal society: it is not ruled by women. So far as I know there is not, nor has there ever been, such a thing as a genuine matriarchal government. In every preliterate society men, not women, hold the political, legal and economic power; the women usually remain legal minors all their lives, subject to the authority of their menfolk. Primitive peoples usually understand quite well why men, not women, must be the rulers. The women, they say, are incapacitated for warfare

and the affairs of state by the necessity of bearing and rearing children. Many peoples, including the Ashanti, believe that women are magically dangerous to men during menstruation and after childbirth.

In describing the Ashanti kinship system I am going to use common English terms (like "aunt" and "cousin") rather than attempt to translate the native terminology. The typical Ashanti household consists of an old woman, her daughters, their children and one or two of her sons. The old woman, the daughters and the sons are all married, but where are their spouses? We can suppose that all of these people are on good terms with their husbands and wives; nevertheless they do not form part of the same household with them, because they do not belong to the same clan. The spouses all live nearby, in households belonging to their own clans. The legal head of the household is one of the old woman's sons; he inherited his role from his mother's brother, not his father; he will pass it on to his sister's son, not his own [see illustration at bottom of preceding two pages].

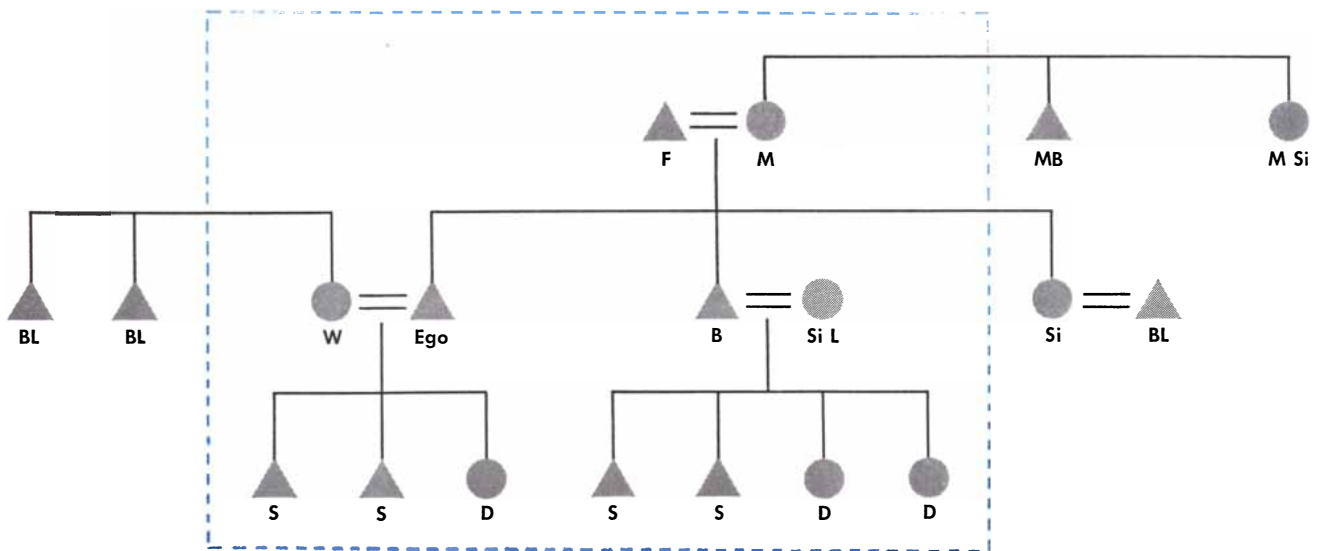
Among the Ashanti marriage is governed by strict moral, legal and religious rules. Yet it is clear that the Ashanti find the fact of descent much more important than the fact of marriage. That is why the households are formed by mothers and children rather than by husbands and wives. The lineage group to which the old woman and her children belong is united by the bond of common descent from an ancestress of perhaps the 10th

generation before that of the youngest members. Through this ancestress the group traces its descent from an even more remote mythological ancestress: the progenitor of their clan, one of the eight clans into which the Ashanti people is divided.

It is considered a sin and a crime for members of the same Ashanti lineage to have sexual relations; by this token they must look for spouses of independent descent, that is, of a different clan. Since husband and wife commonly reside in separate households, they must live near each other if they are to have a normal marital relationship. More than 80 per cent of all marriages occur within the village community. Usually, therefore, one or two lineages of each of the eight clans is found in a village of average size.

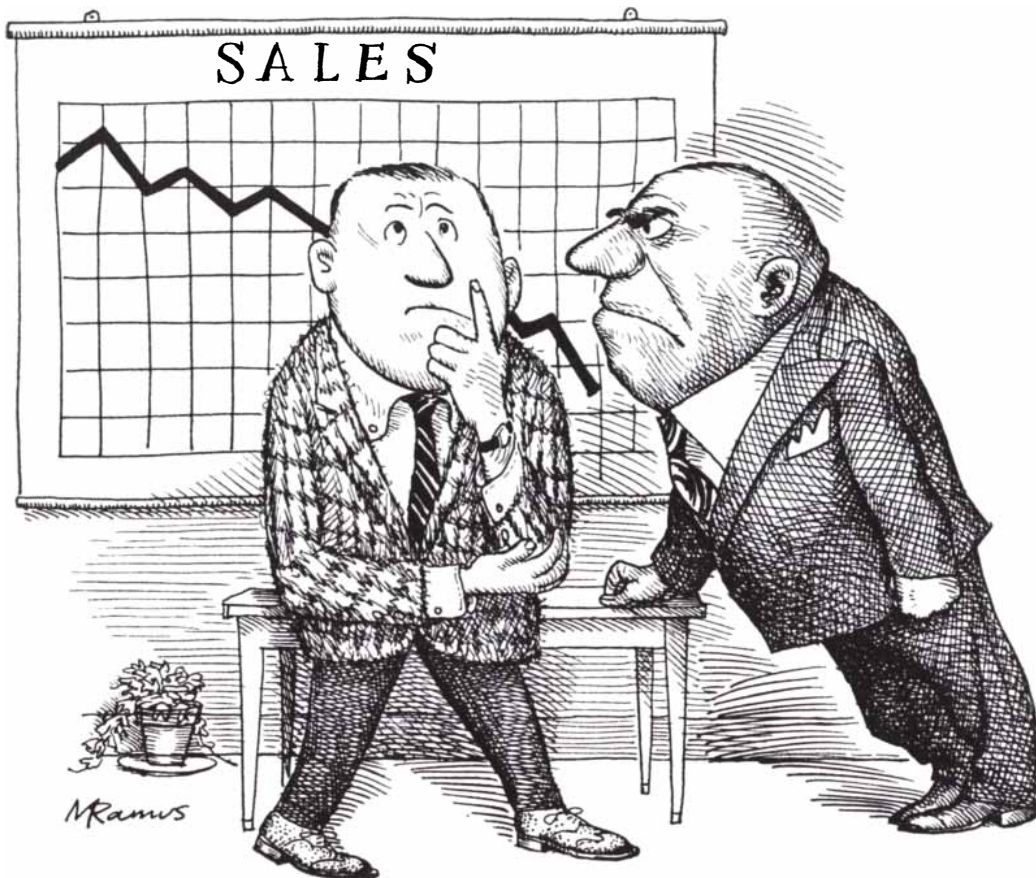
The Ashanti rule of matrilineal descent has implications that reach far beyond the domestic household. Every Ashanti is by birth a citizen of the chiefdom to which his maternal lineage belongs. A man or woman can build a house freely on any vacant site in this chiefdom, and can farm any piece of unclaimed soil in the lands that it owns. An individual has no such rights in any other chiefdom. By the rule of matrilineal descent, a man can will no property to his own children; they belong to another household and another clan: his wife's. A man's heirs and successors are his sisters' sons. On his death his property and any position of hereditary rank he may hold pass automatically to his

- B BROTHER
 - BL BROTHER-IN-LAW
 - D DAUGHTER
 - Ego SPEAKER
 - F FATHER
 - M MOTHER
 - MB MOTHER'S BROTHER
 - M Si MOTHER'S SISTER
 - S SON
 - Si SISTER
 - Si L SISTER-IN-LAW
 - W WIFE
-
- FEMALE
 - ▲ MALE
 - == MARRIAGE



TALLENSI PATRILINEAL FAMILY differs from the Ashanti family (see chart at bottom of preceding two pages) in that it is a community of fathers, sons and their wives, not one of mothers, their brothers and their children, all living apart from their

husbands and wives. It resembles the Ashanti family, however, in its use of classificatory terminology; e.g., "ego" addresses his brother's children, as well as his own, as "son" or "daughter," a common practice with peoples who live in large joint households.



The Perfect Solution

(nutritionally speaking)

“Cut out the brainstorming,” roared the harassed sales manager to ivy league adman. “*Ruffage* breakfast cereal needs a *real* sales hypo.”

Ivy league shrugged. “Okay, no dancing girls . . . wait! I’ve got a new wave length. Have you read about Pfizer *Lysine*? Terrific! It’s something called an amino acid. Gives cereal products the high protein quality of meat or eggs. That kind of health bonus could really get *Ruffage* off the launching pad!”

The manager squints. “Boy, I think you may have it. Get Pfizer on the phone.”

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

If you are considering amino acid or vitamin fortification of a food product (or, for that matter, if you need a food acidulant, antioxidant or preservative) get in touch with the Pfizer Chemical Sales Division. *For any problem which might be solved by a high quality organic chemical, think of Pfizer first.* Chas. Pfizer & Co., Inc., Chemical Sales Division, 630 Flushing Ave., Brooklyn 6, N. Y.



... sells more than 100 organic chemicals for food, medicinal and industrial uses.

Some bulk products of this Division are:

CITRIC, GLUCONIC, TARTARIC, OXALIC ACIDS AND SALTS • ANTIBIOTICS • PLASTICIZERS • VITAMIN A, C, B₁₂ STABLETS* AND OTHERS

*TRADEMARK

oldest nephew. If he wishes his own sons and daughters to benefit from his property, he must be content to make them gifts during his lifetime. They can accept his gifts only with the consent of his matrilineal heirs and of the elders in his lineage group. In the Ashanti tradition the individual comes under the authority of the mother's brother, not the father. It is the mother's brother whose consent is legally essential for a girl or boy to marry; he is also responsible for any costs that arise from divorce or other suits against them.

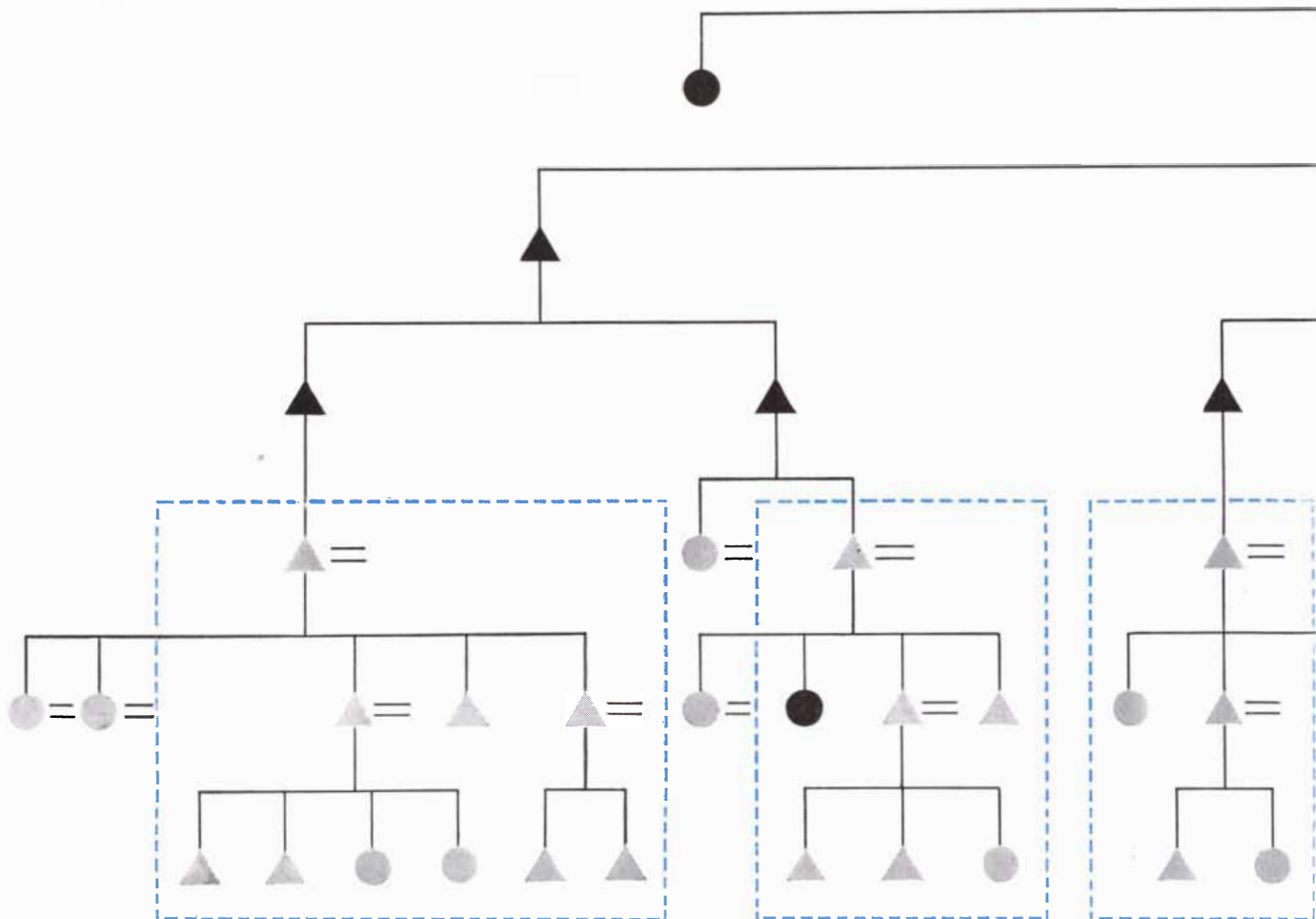
How do marriage and parenthood work out in such a system of kinship rules? It is undeniable that the Ashanti have delicate problems of marital adjustment. Both husband and wife must reach

a compromise between their primary loyalties to matrilineal kin and their attachment to each other and to their children. When a man marries, he acquires legal rights to his wife's marital fidelity and to domestic services such as the regular provision of his meals. If a wife commits adultery, her husband can claim damages from the other man and apologies and a gift of placation from the wife, even if, as often happens, he does not divorce her. He can and will insist on divorce if his wife neglects her household duties or refuses to sleep with him. The husband is in turn obliged to provide food, clothing and general care for his wife and children. If he fails in these duties, his wife can divorce him. In fact, divorce is very common among

the Ashanti. Usually it is free of acrimony, for it does not involve the splitting of a household.

What an Ashanti man does not acquire by marriage is rights over his wife's reproductive powers, that is, over the children she bears him. These belong to her lineage, as opposed to his. An Ashanti man cannot demand help from his sons, for example in farming or in the payment of a debt, as he can from his sisters' sons. He can punish his nephew, but not his sons. He can order his nieces to marry a man of his choice, but not his daughter.

At the opposite extreme from the Ashanti are the Tallensi, who live nearby in Ghana's remote northern uplands. The Tallensi kinship and marriage sys-



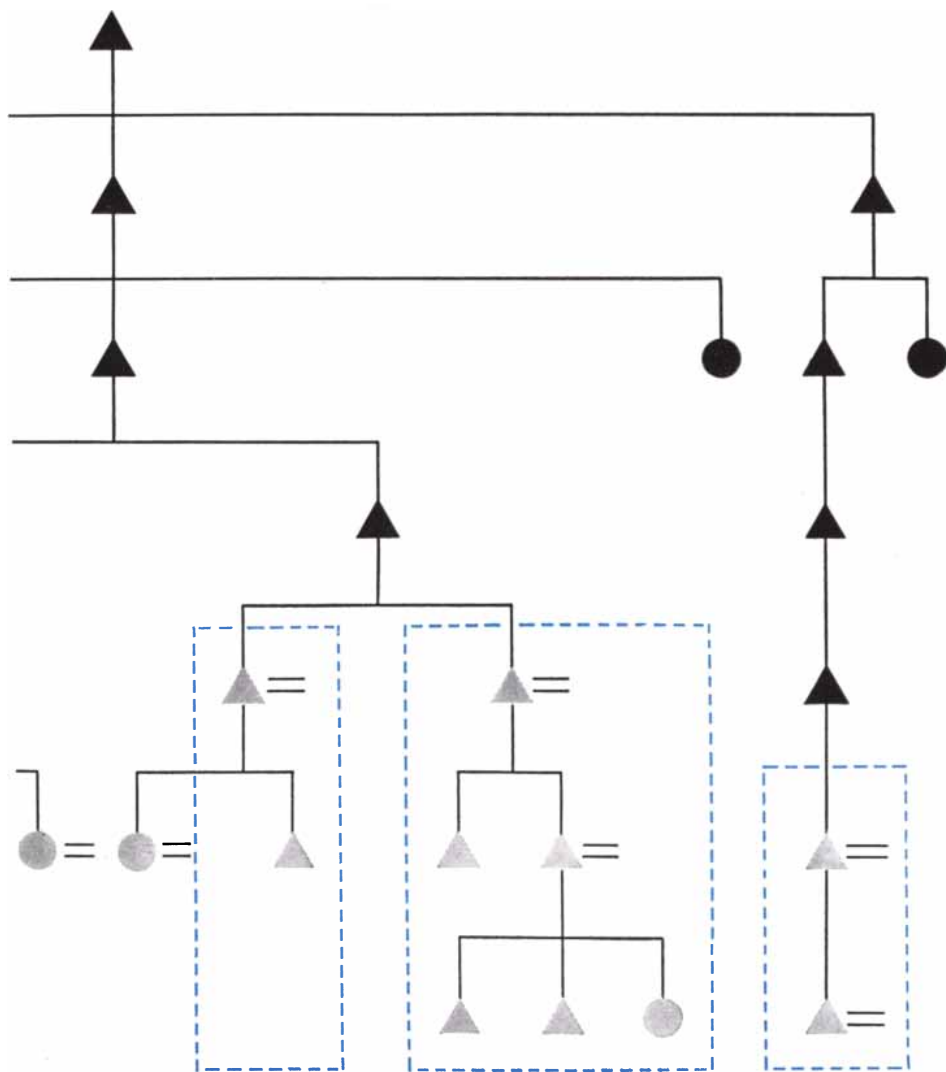
- LIVING FEMALE
- DECEASED FEMALE
- ▲ LIVING MALE
- ▲ DECEASED MALE
- == MARRIED MEMBERS

TALLENSI LINEAGE depicted here is shared in common by six domestic families. Unlike the Ashanti, the Tallensi lineage is traced in the male line: from father to son. This family tree includes six genera-

tem is the mirror image of that of the Ashanti. The Tallensi household is not matrilineal but patrilineal; it consists of a group of men, usually a man and his sons and grandsons, together with their wives and unmarried daughters. The men of this household and others in the immediate neighborhood all share the same patrilineal descent, which they can trace back in the male line to a single male ancestor [see illustration on these two pages]. Tallensi men share their land, are equally eligible for family offices and join in the worship of ancestral spirits. Like the Ashanti, the Tallensi are "exogamous"; their children must marry members of clans other than their own. Among the Tallensi, however, a woman joins her husband's household

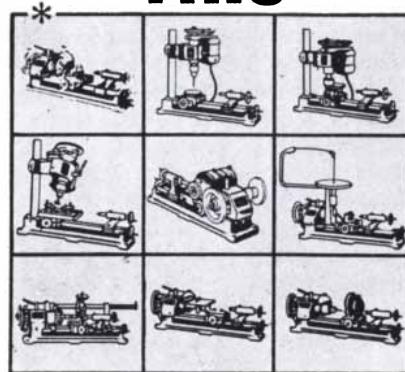
on marriage, because he has rights not only to her domestic services and marital fidelity, but also to her children. This is the crucial distinction between matrilineal and patrilineal systems.

Our Western way of reckoning kinship is neither matrilineal nor patrilineal. Rather, it is "bilateral" [see illustration at bottom of next two pages]. That is, we consider our mothers' kin to be as closely related to us as our fathers'. Nowadays we follow the same etiquette with both maternal and paternal relatives. Our terminology distinctly reflects the equality of our conjugal family system. Since we rate the conjugal (husband-wife) over the lineal (parent-child) bond, the paternal or maternal orienta-

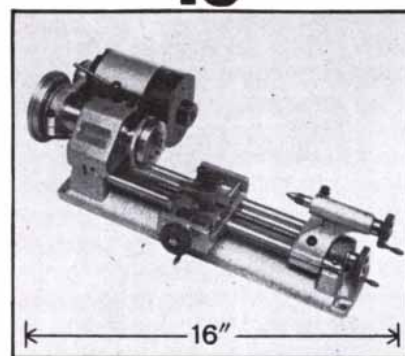


tions, all derived from a single male. In each generation the women marry into other households and their children do not continue their lineage but that of their husbands.

THIS



IS



UNIMAT

THE IDEAL MINIATURE MACHINE SHOP FOR RESEARCH LABS AND MODEL SHOPS

MULTI-FUNCTION PRECISION MACHINE TOOL OCCUPIES NO MORE SPACE THAN A TYPEWRITER! Engineers and Designers supplement their sketches and blueprints with machined-to-scale models anybody can "read". Technicians in research labs turn out machine work with amazingly small tolerances, down to .0004-of-an-inch! Manufacturers developing new products find UNIMAT indispensable in the mock-up shop. Hundreds † of efficiency-minded companies, hospitals and government agencies are now putting their UNIMATS to a thousand-and-one uses... it's the practical machine for making small parts! Let us tell you how they can serve you.

* **BASIC UNIMAT** includes motor, lathe and components for converting to drill press, tool and surface grinding machine, and polisher-grinder. Low-cost attachments: jig saw, threader, circular saw, indexer-divider. Plus complete range of machine accessories.

† **TO MENTION A FEW:** Atom Products Division of GE, U.S. Naval Research, Bell Telephone Laboratories, Westinghouse, Pratt & Whitney, Raytheon, NYU-Bellevue Medical Center, Smithsonian Institute, General Motors.

Write for illustrated literature and price list
AMERICAN-EDELSTAAL/UNIMAT DIVISION
 DEPT. DF, 350 BROADWAY, NEW YORK 13, N. Y.



SEPARATION OF GENERATIONS from one another, a universal feature of kinship systems which serves to maintain the authority of seniors over juniors, is represented in this series of photographs.

The photograph at left depicts the Tallensi custom of avoidance between a father (*center of photograph*) and his eldest son, who may not share his father's plate, although a younger son is shown

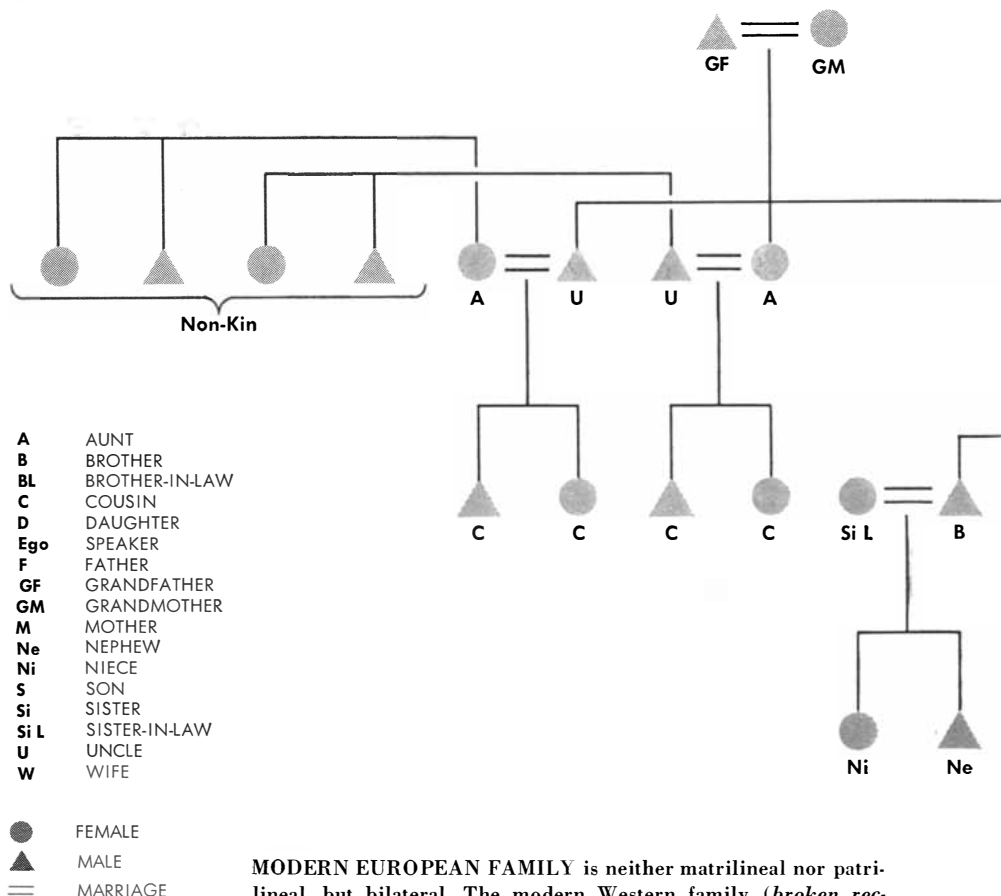
tion of the lineage becomes a matter of indifference. In naming our spouses' relatives we assimilate them to our own: a mother-in-law is a kind of mother, a brother-in-law is a kind of brother, and we treat them accordingly.

Our kinship terminology, like that of the Eskimos and a few other peoples, follows the so-called descriptive system. We have separate labels for each category of our kin, according to their generation, their sex and their linkage to us by descent or marriage. We distinguish our parents ("father" and "mother") from their male siblings ("uncles") and their female siblings ("aunts"). We have different appellations for our own siblings ("brother," "sister") and for our aunts' and uncles' children ("cousins").

Most primitive peoples use the entirely different labels of the classificatory system. This system often strikes Westerners as odd, although it is widespread among the peoples of mankind. Its principle is that in each generation all relatives of the same sex are addressed in the same way, no matter how remote the relationship. A sister and a female first- or second-cousin are all called "sister"; a father, an uncle and more distant male collaterals of their generation are called "father." A woman addresses her nieces and nephews, as well as her own offspring, as "my children." The nieces and nephews, as well as her own children, call her "mother." The Tallensi, the Swazi of South Africa and many other societies even use words for "father" with a feminine suffix added, to designate the sisters of all the men they address as "father." A Swazi calls his mother's brother a "male mother."

This terminology was recognized for the first time nearly a century ago by a great U. S. anthropologist, Lewis H. Morgan. His *Systems of Consanguinity and Affinity of the Human Family*, published in 1871, founded the modern study of kinship systems. Morgan and

his followers believed that classificatory terminology had survived from an extremely primitive stage of social organization, in which a group of sisters would mate promiscuously with a group of brothers and would rear the offspring in common.



MODERN EUROPEAN FAMILY is neither matrilineal nor patrilineal, but bilateral. The modern Western family (*broken rec-*



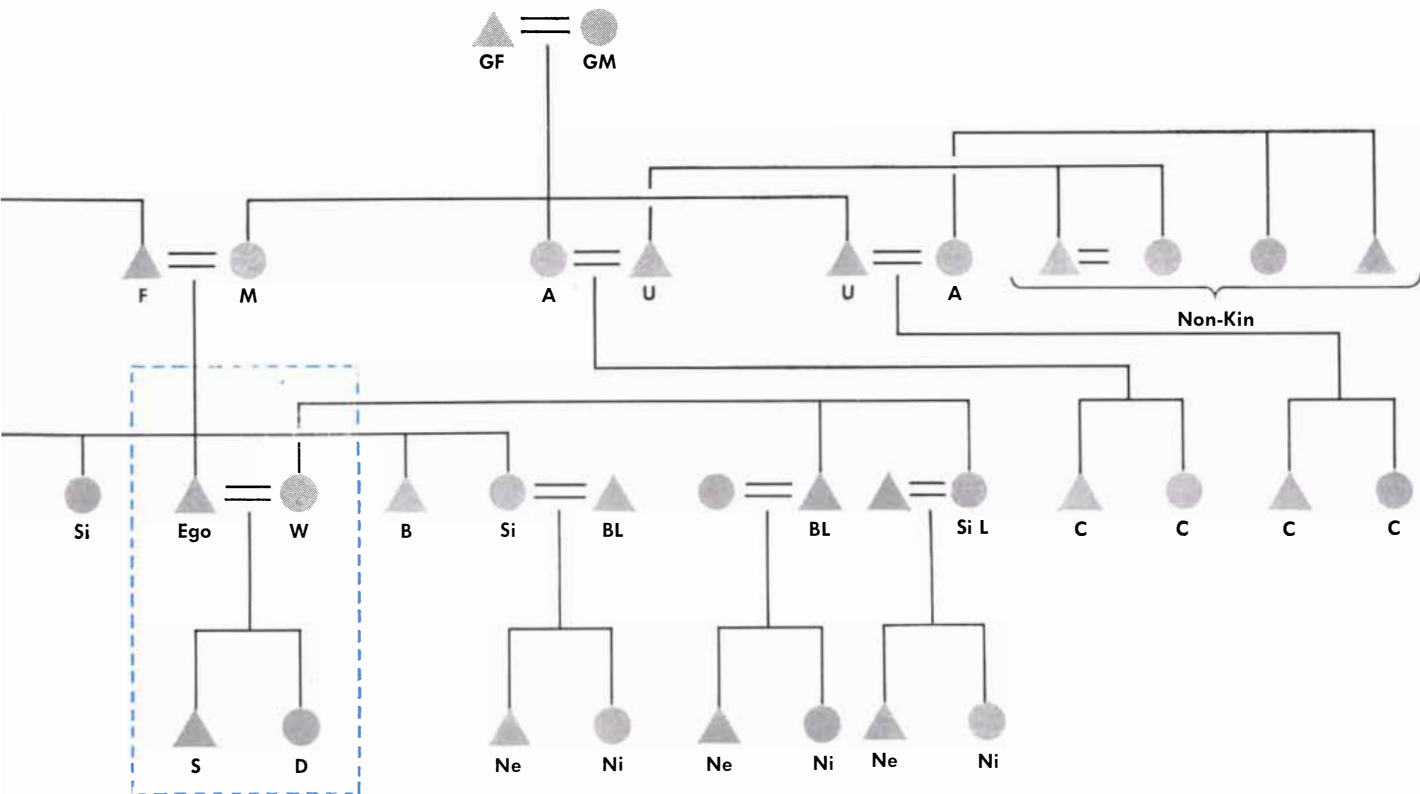
doing so. The photographs at center and on the page at right show a Tallensi custom that illustrates the succession of juniors to the authority of their seniors. An eldest son whose father has died

wears his father's tunic turned inside out. While his eldest sister clutches the garment, he marches around the homestead, then enters his father's cattle shed, thus canceling the avoidance taboo.

By now Morgan's theory of "group marriage" has been completely discredited. Modern anthropology has discovered far more cogent reasons for the existence of classificatory terminology. If a man calls all the male relatives of his generation "brother," it is not be-

cause at some remote period the promiscuity of the elder generation made it impossible to tell one's brother from one's cousin. The reason is that such generalized terminology expresses the deep sense of corporate unity in the extended family. A child in such a family

knows very well which of the women of the household is his physiological mother. Like children anywhere in the world, he will love his real mother as he loves none of her sisters or female cousins. Yet in the joint family those sisters and cousins share his mother's duties to him,



tangle) is smaller than the Ashanti or Tallensi and centered upon marriage, not lineage. Since neither maternal nor paternal lineage

has exclusive importance, we acknowledge relatives on both sides and give them similar names (e.g., "mother," "mother-in-law").

COMMAND DESTRUCT



The flight testing of second generation missiles—more versatile and powerful than their predecessors—requires a device for sure termination of any missile flight that might endanger the test range or surrounding area.

Ramo-Wooldridge engineers, under a United States Army Signal Corps contract, have successfully developed and delivered the first sub-miniature, completely transistorized radio "command destruct" receivers.

Specifically designed for missile flight safety operations, the receiver (AN/DRW-11) can actuate safety mechanisms or destruct devices. It has three command channels, each of which actuates a control relay.

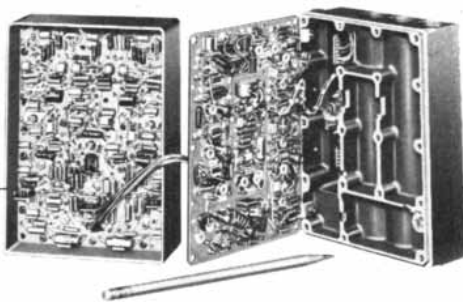
The "command destruct" receiver accepts frequency modulated signals in the UHF radio command band. It is designed to operate with closer radio frequency and command frequency channel spacing than has been used to date, thus making possible more efficient use of the available radio spectrum.

Compact and rugged, the radio receiver's modular construction permits rapid and complete accessibility to all components. One module houses the basic receiver. The second module contains the three command channels and relays. This integrated package occupies 115 cubic inches, and weighs 4 pounds. The receiver requires no pressurization and operates reliably under the adverse environmental conditions encountered in missile flight testing.

Engineers and scientists interested in being associated with some of the nation's most advanced research and development programs are invited to acquaint themselves with current opportunities at Ramo-Wooldridge. The areas of activity listed below are those in which R-W is now engaged and in which openings exist.

- Missile electronics systems**
- Advanced radio and wireline communications**
- Information processing systems**
- Electronic language translation**
- Anti-submarine warfare**
- Air navigation and traffic control**
- Analog and digital computers**
- Infrared systems**
- Electronic reconnaissance and countermeasures**
- Basic and applied physical research**

For a copy of our brochure, *An Introduction to Ramo-Wooldridge*, or other additional information write to Mr. Donald L. Pyke.



RAMO-WOOLDRIDGE

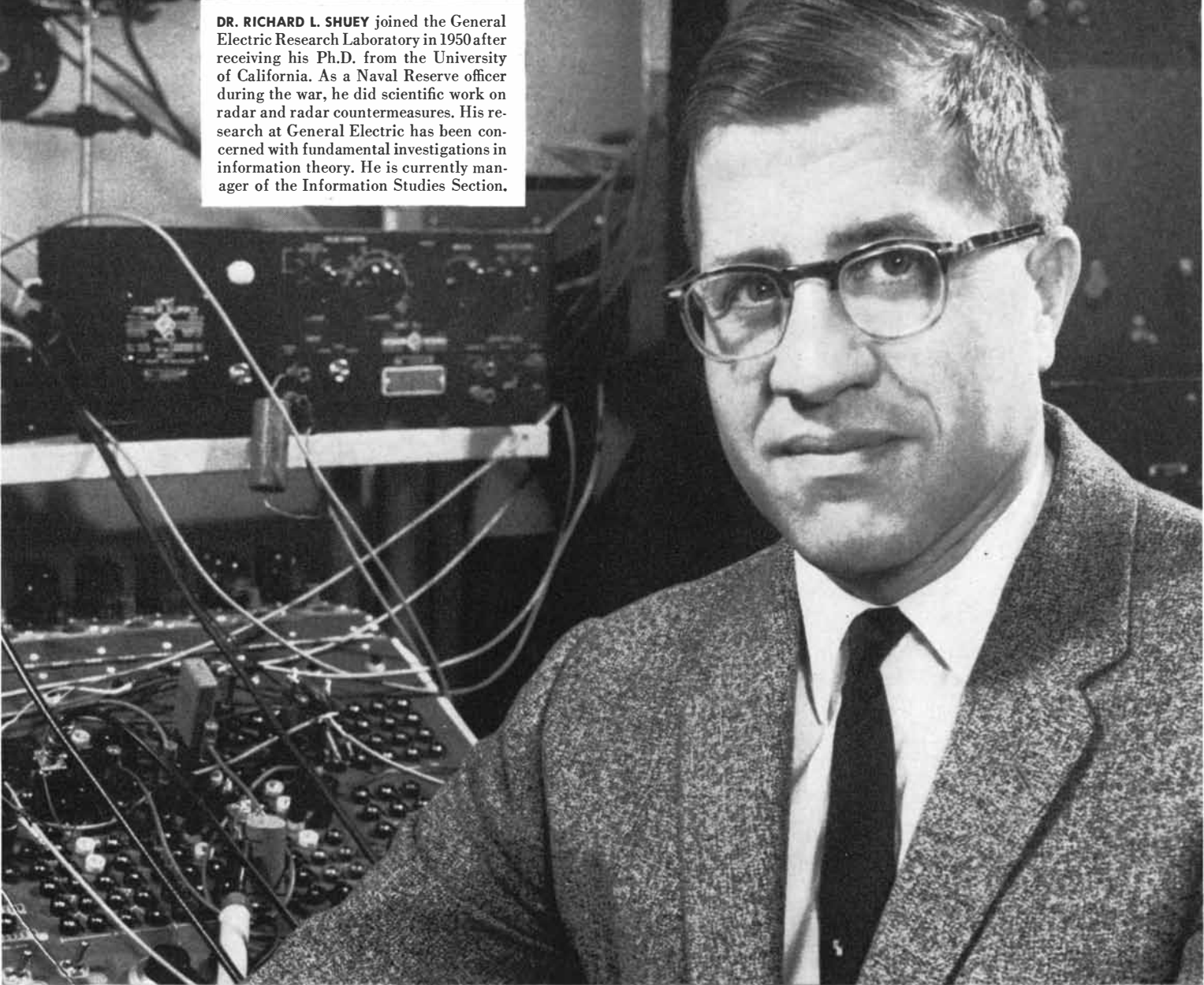
P. O. BOX 90534, AIRPORT STATION • LOS ANGELES 45, CALIFORNIA
a division of **Thompson Ramo Wooldridge Inc.**

and he must observe the same code of politeness with each of them. If his real mother should die, another of the women he calls "mother" will replace her. The classificatory terminology binds together groups that share status and responsibilities. To people like the Ashanti and Tallensi the word "mother" has a social rather than a biological significance: it defines one rank in a complex family system.

The need to define relationships is crucial in every society, and all kinship systems have evolved in response to this need. We are indebted to A. R. Radcliffe-Brown, the distinguished British anthropologist, for the most satisfactory statement of the underlying principles. The first of these establishes a clear demarcation between successive generations. The elders are not only physiological progenitors of their young; they also protect and nurture them throughout childhood and provide their first training in the crafts, customs and morals of the tribe. This all-important relationship requires not only love on the part of the parents but also respect on the part of the children. Parental authority is incompatible with complete intimacy. Most societies banish everything sexual from the parent-and-child relationship; the universal taboo on incest between parent and child epitomizes the cleavage between elder and younger generations. Many societies enforce certain "avoidances" that help to maintain social distance between generations. The Tallensi, for example, forbid an eldest son to eat from his father's dish [see illustrations at top of preceding two pages]. Some central African tribes carry avoidance to extremes. One tribe, the Nyakyusa, requires fathers and children to live in separate villages. In the matrilineal Ashanti society, on the other hand, it is the uncle to whom children show respect (or at least resentful submission). Ashanti fathers are not figures of authority to their children and need not keep aloof from them. Indeed, the father's lack of authority over his children is compensated for by warm bonds of trust and affection.

Radcliffe-Brown's second principle is the so-called sibling rule of unity and loyalty among the members of a single generation. The unity among siblings (meaning cousins as well as brothers and sisters) is the converse of the first principle of separation between each generation of siblings and the next. Internally, of course, each generation is differentiated by sex and order of birth. Yet the rule generally prevails that siblings

DR. RICHARD L. SHUEY joined the General Electric Research Laboratory in 1950 after receiving his Ph.D. from the University of California. As a Naval Reserve officer during the war, he did scientific work on radar and radar countermeasures. His research at General Electric has been concerned with fundamental investigations in information theory. He is currently manager of the Information Studies Section.



Will machines ever “think”?

General Electric's Dr. Richard L. Shuey seeks new insight into the problems of information processing

TODAY'S computing machines frequently are described as “fast morons” — they do what they are told, and they do it with extraordinary speed. But will tomorrow's machines be capable of judgment without human guidance? Dr. Richard L. Shuey of the General Electric Research Laboratory believes that they will — when future, more sophisticated machines are given the capability of *self-organization*. While it is unlikely that man-made machines will ever duplicate all aspects of human intelligence, they will develop *their own criteria for decision making*, and in most cases will program their own operations.

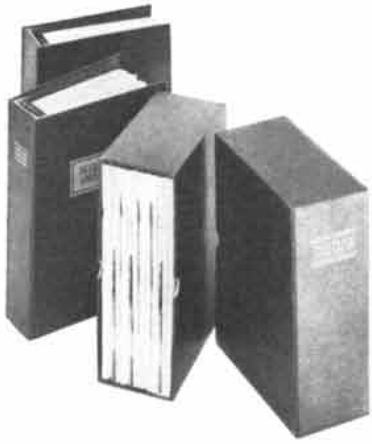
Dr. Shuey and his associates are attacking these problems by using and combining knowledge from several

areas of science. Mathematicians, electrical engineers, and physicists work side by side, and there is a growing interest in applying biological science to the theory of information processing.

The dramatic advances that are already being made in this area at General Electric typify the progress that can be made when scientists are provided the incentives, the tools, and the freedom to seek out new knowledge.

Progress Is Our Most Important Product

GENERAL  ELECTRIC



Preserve your copies of **SCIENTIFIC AMERICAN**

☞ A handsome and durable library file or binder in which to keep your copies of **SCIENTIFIC AMERICAN**.

☞ Both styles bound in dark green library fabric and stamped in gold leaf.

FILE (shown at right): Holds 12 issues. Single copies easily accessible. Price: \$2.35 (U.S.A. only).

BINDER (shown at left): Holds 6 issues. Copies open flat. Price: \$2.50 (U.S.A. only).

Address your order,
enclosing check or
money order, to:

Department F (File) or A (Binder)
SCIENTIFIC AMERICAN
415 Madison Avenue
New York 17, N. Y.

(New York City residents please add 3% Sales Tax)

PHYSICISTS— ENGINEERS RECOGNITION AND REWARD

... both come early
at **PERKIN-ELMER!**

It is Perkin-Elmer policy to offer important rewards in salary, security and satisfaction just as soon as it is possible. The mainstay of this progressive point of view is a non-regimented approach to creative imagination that offers gifted Engineers and Physicists the broad and unfettered freedom so necessary to the full development of individual abilities.

Active in the dawning Space Age, Perkin-Elmer programs include vital projects in the most advanced and complex areas of:

- **Reconnaissance Systems**
- **Infrared Systems**
- **Range Instrumentation**
- **Optical Research & Development**

Investigate these challenging positions today—by sending your resume to:

Mr. R. H. Byles, Dept. 915

Perkin-Elmer Corporation
NORWALK, CONNECTICUT

TO CREATE, MEASURE, CONTROL

100,000,000 C°

Is a complex THERMONUCLEAR problem now under investigation in **PROJECT MATTERHORN'S** new 30 million dollar laboratories at Princeton University's James Forrestal Research Center.

SENIOR POSITIONS OPEN:

Instrumentation

For an engineer or physicist skilled in sophisticated and diverse instrumentation development.

Electronics

For an engineer experienced in high power r.f. circuitry, induction heating or allied fields.

For further information, write
Raymond B. Starbuck

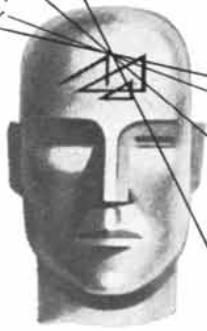
**PROJECT
MATTERHORN**
P.O. Box 451, Princeton, N. J.

share all things on equal terms. Frequently the sibling principle is generalized to include all tribesmen of the same generation. In East and West Africa this is institutionalized in the so-called age-grade system. The pastoral Masai, for example, initiate youths into their lowest "grade" of junior warriors every seven years, two successive grades forming a "generation set." Members of a set are classificatory brothers to each other and are classificatory fathers to the next set. Cattle-keeping and warfare are the tasks of the junior sets, while government is the prerogative of the senior sets.

The third principle of kinship, according to Radcliffe-Brown's scheme, accounts for the orderly succession of the distinct sibling groups in time: this is the rule of "filiation." Most societies, as we have seen, stress this rule more strongly than we do. Filiation is usually traced on strictly matrilineal or patrilineal lines. Occasionally the two modes are combined. In some African tribes the individual inherits land and political offices from his father, and livestock and religious-cult memberships from his mother. The bond of common filiation forms social groups that reach beyond the single household in time as well as space. These groups are often called clans. Frequently they are exogamous; as among the Ashanti and Tallensi, their members may not marry one another but must seek mates from other clans. This establishes "affinal" (in-law) relationships between clans and binds them into a still larger unit: the tribe.

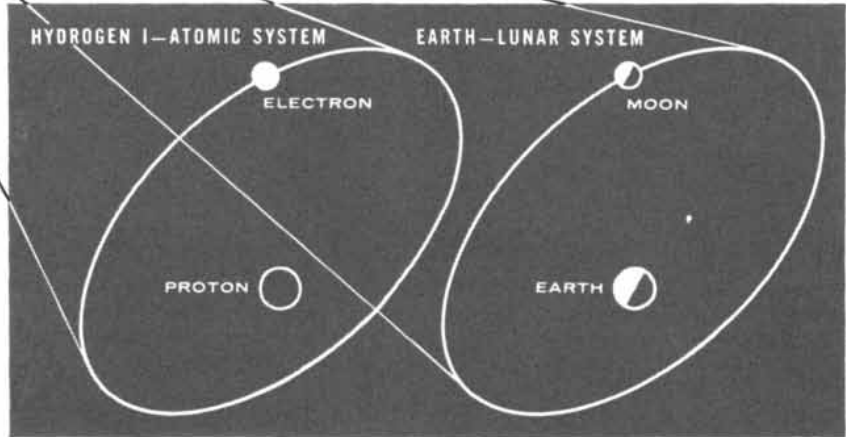
What happens to kinship-based societies when industry, a money economy and Western education impinge on them? Recent investigation shows an increasing breakdown of both patrilineal and matrilineal family systems under such conditions. In their place bilateral systems similar to our own become established. The reasons are obvious. Industry and commerce require the individual to earn wages and to enter legal contracts not as a member of a family but on his own. Western law and education emphasize the responsibilities of individual citizenship and parenthood, as opposed to group citizenship and collective responsibility of kinfolk to children. In his legal and economic roles the individual separates from his kin group. The family constituted by marriage becomes his primary concern. In Africa and elsewhere, as people become industrialized, we are witnessing processes of social evolution analogous to those that shaped the much more limited institution that we call the family.

$$P(k_1, k_2, \dots, k_m) = \frac{n!}{k_1! k_2! \dots k_m!} p_1^{k_1} p_2^{k_2} \dots p_m^{k_m}$$



BOLD MINDS

Is order and organization in MACROCOSM and MICROCOSM an underlying principle of the universe . . . or does a fundamental state of randomness prevail in the cosmos, as might be expressed by the multinomial formula at left?



THROUGHOUT HISTORY..... BOLD MINDS have sought to understand the forces at work in the universe, and as they developed working hypotheses, endeavored to turn all knowledge to their own purposes, devising philosophical and mechanical systems of their own.

As old hypotheses become inadequate or untenable, thinking men devise new ones. So the concept

of a "flat" world has changed to an oblate orbiting spheroid—mere speck in a vast and expanding universe; so "empty" formless space is regarded as a curved continuum occupied by random knots of turbulence (creating the new branch of mechanics—hydromagnetics).

Today new horizons of discovery and surmise arise before the speculative mind.

ENGINEERS AND SCIENTISTS AT REPUBLIC FEEL KINSHIP WITH ALL BOLD MINDS OF PAST AND PRESENT, AS THEY FACE THE EXHILARATING CHALLENGES OF CREATING VEHICLES TO FLY IN ENVIRONMENTS WHERE NEW APPROACHES IN THERMO/AERODYNAMICS MUST BE MADE... AS WELL AS APPROPRIATE PROPULSION AND ELECTRONIC SYSTEMS TO POWER AND GUIDE TRANSIT IN SPACE

Groups of Research, Development and Experimental Engineers and Scientists at Republic Aviation are now working on projects over the whole range of aeronautics and astronautics—from supersonic and hypersonic weapons systems, both manned and unmanned, to plasma propulsion and space electronics.

Imaginative professional men at many levels of experience are invited to inquire about opportunities indicated below:

ELECTRONICS

- Inertial Guidance & Navigation
- Digital Computer Development
- Systems Engineering
- Information Theory
- Telemetry SSB Technique
- Doppler Radar
- Countermeasures
- Radome & Antenna Design
- Microwave Circuitry & Components
- Receiver & Transmitter Design
- Airborne Navigational Systems
- Jamming & Anti-Jamming
- Miniaturization-Transistorization
- Ranging Systems
- Propagation Studies
- Ground Support Equipment

THERMO, AERODYNAMICS

- Theoretical Gasdynamics
- Hyper-Velocity Studies
- Astronautics Precision Trajectories
- Airplane/Missile Performance
- Air Load and Aeroelasticity
- Stability and Controls
- Flutter & Vibration
- Vehicle Dynamics & System Designs
- High Altitude Atmosphere Physics
- Re-entry Heat Transfer
- Hydromagnetics
- Ground Support Equipment

PLASMA PROPULSION

- Plasma Physics
- Gaseous Electronics
- Hyperionics and Shock Phenomena
- Hydromagnetics
- Physical Chemistry
- Combustion and Detonation
- Instrumentation
- High Power Pulse Electronics

NUCLEAR PROPULSION & RADIATION PHENOMENA

- Nuclear Weapons Effects
- Radiation Environment in Space
- Nuclear Power & Propulsion Applications
- Nuclear Radiation Laboratories



A new \$14,000,000 Research Center—to be completed this year—is part of Republic's far-ranging R&D programs aimed at major state-of-the-art breakthroughs in every flight regime & environment.



Send resume in complete confidence to:
Mr. George R. Hickman, ENGINEERING EMPLOYMENT MANAGER—DEPT. 8F

REPUBLIC AVIATION

FARMINGDALE, LONG ISLAND, NEW YORK

MATHEMATICAL GAMES

An inductive card game, and the answers to the "brain-teasers" in the May issue

by Martin Gardner

Most mathematical games, from ticktacktoe to chess, call for deductive reasoning on the part of players. In contrast, Eleusis, a remarkable new card game invented by Robert Abbott, a young New York writer, is an induction game. It should be of special interest to mathematicians and other scientists because of its striking analogy with scientific method and its exercise of precisely those psychological abilities in concept formation that seem to underlie the "hunches" of creative thinkers.

Eleusis is a game for three or more players. It makes use of the standard deck of playing cards. Players take turns at being the "dealer," who has no part in the actual play except to serve as a kind of umpire. He deals to the other players until one card remains. This is placed face-up in the center of the table as the first card of the "starter pile." To make sure that players receive equal hands, the dealer must remove a certain number of cards before dealing. For three players (including the dealer, who of course does not get a hand) he removes one card; for four players, no

cards; five players, three cards, and so on. The removed cards are set aside without being shown.

After the cards are dealt and the "starter card" is in place, the dealer makes up a secret rule that determines what cards can be played on the starter pile. It is this rule that corresponds to a law of science; the players may think of the dealer as Nature. The dealer writes his rule on a piece of paper, which he folds and puts aside. This is for later checking to make sure that the dealer does not upset Nature's uniformity by changing his rule. For each player the object of the game is to get rid of as many cards as possible. This can be done rapidly by any player who correctly guesses the secret rule.

An example of a very simple rule is: "If the top card of the starter pile is red, play a black card. If the top card is black, play a red card." Beginners should limit themselves to extremely simple rules of this type, then move on to more complicated rules as their ability to play improves. One of the most ingenious features of Eleusis is that the method of scoring (to be explained later) puts pressure on the dealer to choose a rule which not everyone will guess quickly, but which is simple enough so that one player is likely to guess it ahead of the

others and fairly early in the game. Here again we have a pleasant analogy. The basic laws of physics are difficult to detect, yet once they are discovered they usually turn out to be based on relatively simple equations.

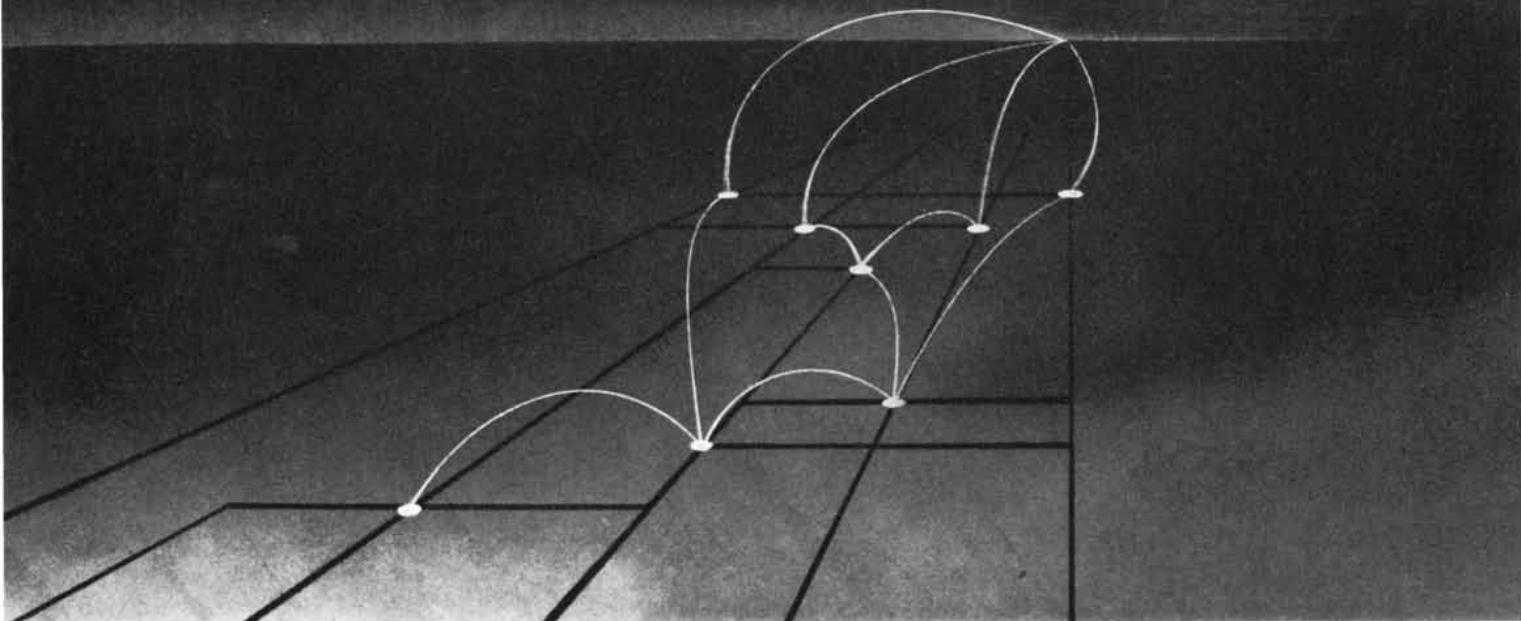
After the rule is written, the "first stage" of the game begins. The first player takes any card from his hand and places it face-up on the starter card. If the card conforms to the secret rule, the dealer says "Right" and the card remains on the starter pile. If it violates the rule, the dealer says "Wrong." The player then takes back the card, places it face-up in front of him, and the turn passes to the next player on the left. Each player must play one card from his hand at each turn. His "mistake cards" are left face-up in front of him and spread slightly so that they can be clearly identified. The correctly played cards which form the starter pile are also fanned along the table so that all the cards can be seen. A typical starter pile is shown in the illustration below.

Each player tries to analyze the cards in the starter pile to discover the rule governing their sequence. He then forms a hypothesis that he can test by playing what he thinks is a correct card, or by playing a card he suspects will be rejected. The first stage of the game ends when all the cards in the players' hands have been played.

The dealer's score is now figured. It is based on how far the leading player (the person with the fewest mistake cards) is ahead of the others. If there are two players (not counting the dealer), the dealer's score is the number of cards in the leading player's mistake pile subtracted from the number of cards in the other player's pile. For three players, multiply the leading player's mistake



A typical "starter pile" for the game of Eleusis. What is the secret rule that determines the order of the cards?



Report from IBM



Yorktown Research Center, New York

ORGANIZING A MAXIMAL-SPEED COMPUTER

In designing a computer suitable for extremely high information-processing rates, it becomes necessary to re-examine basic concepts of machine organization in the light of new devices, new programming techniques and new applications. This study is being conducted by a machine organization group at the IBM Yorktown Research Center.

Investigations into the principles of computers are leading to the design of a completely superconducting machine. Its computing speed and capacity will be so high that the finite velocity of propagation of electromagnetic signals becomes the limiting speed factor. Therefore, the design must not only provide for the unique properties of superconductors but must minimize the effects of information transmission delays. This will be accomplished by a machine organi-

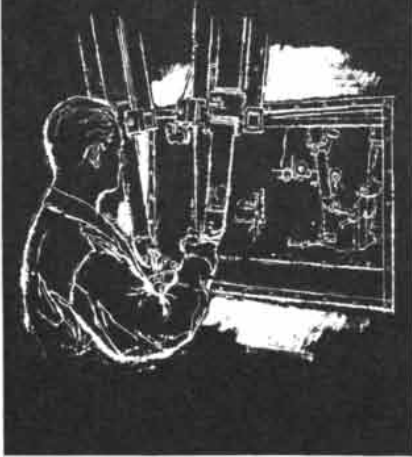
zation which causes information to be confined in packets as it is processed through the machine, and by the use of miniature circuits. In addition, the machine will provide the facility for simultaneous or parallel calculations of different parts of a problem. Furthermore, whereas most machines have been synchronous (in that information flow is controlled by traffic signals operated by a common clock), methods of completely asynchronous operation are now being investigated.

A machine such as this superconductor computer may well lead to important theoretical advances in many scientific fields. This study is part of a broad research program in computer organization extending the mathematical theories of computers and their application to information processing systems of all kinds.

IBM. RESEARCH

Investigate the many career opportunities available in exciting new fields at IBM.
International Business Machines Corporation, Dept. 659F, 590 Madison Avenue, New York 22, New York
© 1959 SCIENTIFIC AMERICAN, INC

FISSION PRODUCTS NOW AVAILABLE



For the first time, *kilocurie* quantities of long-lived radioactive fission products are available for your development work. The new Fission Products Pilot Plant at Oak Ridge National Laboratory makes it possible to distribute these isotopes at greatly-reduced prices:

- Cerium-144
- Cesium-137
- Promethium-147
- Strontium-90
- Technetium-99

As the nation's principal supplier of isotopes, the Laboratory offers more than 300 radioactive and stable isotope products. Requests are invited for information concerning compounds for source fabrication. Oxides, fluorides, chlorides, and plate sources are available. Whatever your needs, we are ready to help you. Write to: Isotopes Division, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee.



ISOTOPES DIVISION
Oak Ridge National Laboratory
Operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION



cards by two, then subtract from the total of mistake cards belonging to the other players. For four players, multiply by three and do the same. For five players, the multiplier is four; for six the multiplier is five, and so on. The suits and values of cards do not enter into the scoring.

For example, suppose there are three players and the dealer. The mistake cards number 10, five and three. Twice three is six, which is taken from 15 to give the dealer a score of 9. This is recorded and the game goes into its second and final stage, during which the mistake cards are played.

The mistake cards remain fanned face-up on the table in front of each player, but a player may rearrange his cards if he wishes. Plays are made in turn as before, each player taking any card and putting it on the starter pile. The dealer tells him if it is right or wrong. If it is wrong, he replaces the card among his mistake cards.

The second stage ends when one player gets rid of all his cards, or when the dealer sees that it is impossible for more cards to be accepted on the starter pile. The slip of paper is now opened and the rule read. This corresponds in a sense to the mathematician's final deductive proof of a theorem that was first suggested to him by an inductive guess based on a set of particular observations. Other scientists are of course denied this final verification and must rest content with establishing their hypotheses to a high degree of probability. If the scientist accepts the pragmatic epistemology of, say, William James and John Dewey, he will not believe in the existence of the folded sheet of paper. The successful operation of his hypothesis will be the only meaning of its "truth." Or he may agree with Bertrand Russell and others that the truth of his theory is its correspondence with an external structure, even though he has no way of seizing the structure and unfolding it.

Players are now scored in a manner similar to the way in which the dealer was scored. Each takes the number of cards he holds, multiplies by the number of players exclusive of himself and the dealer, then subtracts the product from the total number of cards held by the other players. If the result is a minus number, he is given a score of 0. A bonus of 6 goes to the player who went out. If no one went out, it goes to the player with the fewest cards, and if two or more tie, the bonus is divided between them. For example, if there are four players (excluding the dealer) who hold two, three, 10 and no cards, their

respective scores will be 7, 3, 0 and 21.

The deal passes to the left after each hand. The game continues until each person has been dealer twice; then the player with the highest score is the winner of the set.

If the rule is not applicable until two cards are on the starter pile, then the first card played is correct no matter what it is. If a rule involves numbers, the ace is 1, the jack 11, the queen 12 and the king 13. If it is permissible to "turn the corner" (continue in cyclic fashion: J-Q-K-A-2-3 . . .), the dealer must state this in his rule.

Rules should be avoided that restrict a player, on most of his turns, to less than a fifth of the cards in the deck. For example, the rule "Play a card with a value of one unit above the value of the top card" is not acceptable, because at each turn a player would be limited to only four cards out of the 52.

After writing down his rule, the dealer may, if he wishes, give a hint of it. He might say: "This rule involves the two top cards of the starter pile," or "This rule involves the suits." After the play begins, no further hints are permitted unless the play is very informal.

The following secret rules are typical, and are listed in order of increasing complexity.

1. Alternate even and odd cards.
2. The card played must have either the same suit or the same value as the card on top of the pile (as in the card game called Eights).
3. If the top two cards are of the same color, play a card from ace to 7. If they are of different colors, play a card from 7 to king.
4. If the second card from the top is red, play a card with a value equal to or higher than this card. If the second card is black, play a card of equal or lower value.

5. Divide the value of the top card by four. If the remainder is one, play a spade; if two, play a heart; if three, play a diamond; if zero, play a club.

If the players have some mathematical sophistication, the rules can of course be more advanced. The dealer, however, must always shrewdly estimate the skill of the players so that he can raise his score by choosing a rule that one player is likely to discover ahead of the others.

It is permissible to make up rules in which the players themselves are involved. (One thinks of the physicist whose apparatus influences what he is trying to observe, or the anthropologist whose investigation of a culture changes the culture.) For example, "If your last name has an odd number of letters, play



ENGINEERS GROW TALL AT LINK AVIATION

The growth of fine timber, like the development of a career, requires a stimulating environment. At Link's Palo Alto Research and Development Laboratory, engineers reach full professional stature because the atmosphere is right for unusual development and progress.

Link — one of the world's leading producers of analog computing equipment for diverse applications — is well-known for liberal benefit programs, salaries, and graduate-study tuition-payment programs provided for members of the technical staff.

And the environment of one of California's most charming communities makes Link's growing Palo Alto facility an ideal location for working and living.

Positions at intermediate and advanced levels are open now at Link-Palo Alto for exceptional men with experience in these fields:

- digital computers
- analog computers
- radar simulators
- optical systems
- electronic packaging
- electromechanical packaging
- automatic checkout equipment

For a stimulating growth environment, look to Link for unusual opportunity.

Contact Mr. A. C. Rutman
Link Aviation, Inc., P. O. Box 1318
Palo Alto, California



LINK AVIATION, INC. A subsidiary of
General Precision Equipment Corporation

NEW PRINTING analytical balance

by *Ainsworth*

Manufacturer of fine instruments since 1880.

This new electronic instrument automatically prints the weight... by simply pushing a button the operator obtains a permanent record of the weight, printed on a tape.



It is convenient and fast.

It eliminates the possibility of errors in reading, adding or transcription.

It adds, subtracts, subtotals, prints sample numbers, etc.

Balance and adding machine can also be used independently.

Printing range: 200.0000 grams to 000.0001 grams.

Sensitivity: 1/10 mg.

Write for Bulletin 159

WM. AINSWORTH & SONS, INC.
2151 LAWRENCE STREET • DENVER 5, COLORADO

a color other than the color of the top card; otherwise play the same color." It would be unfair, however, for a dealer not to tell the players when a rule of this tricky type is used.

The complete rules for Eleusis have been printed by the Association of American Playing Card Manufacturers, 420 Lexington Avenue, New York 17, N.Y., and will be sent by the Association to any reader who sends a four-cent stamp to cover the cost of mailing.

The cards in the illustration on page 160 have been played according to a simple rule not mentioned in this article. The reader may enjoy puzzling it out before it is explained next month. Note that the first seven cards follow a pattern of alternate colors. This often happens in a game as well as in the history of science. Players have in mind a condition that is not really part of the rule, but they stick by it until an experiment proves that the rule is simpler than they suspected or that their successes were merely accidental.

The answers to last month's problems and to the question of two months ago about the doughnut are as follows:

1.

The following analysis of the desert-crossing problem appeared in a recent issue of *Eureka*, a publication of mathematics students at the University of Cambridge. Five hundred miles will be called a "unit"; gasoline sufficient to take the truck 500 miles will be called a "load"; and a "trip" is a journey of the truck in either direction from one stopping point to the next.

Two loads will carry the truck a maximum distance of 1 and 1/3 units. This is done in four trips by first setting up a cache at a spot 1/3 unit from the start. The truck begins with a full load, goes to the cache, leaves 1/3 load, returns, picks up another full load, arrives at the cache and picks up the cache's 1/3 load. It now has a full load, sufficient to take it the remaining distance to one unit.

Three loads will carry the truck 1 and 1/3 plus 1/5 units in a total of nine trips. The first cache is 1/5 unit from the start. Three trips put 6/5 loads in the cache. The truck returns, picks up the remaining full load and arrives at the first cache with 4/5 load in its tank. This, together with the fuel in the cache, makes two full loads, sufficient to carry the truck the remaining 1 and 1/3 units, as explained in the preceding paragraph.

We are asked for the minimum amount of fuel required to take the truck

800 miles. Three loads will take it 766 and 2/3 miles (1 and 1/3 plus 1/5 units), so we need a third cache at a distance of 33 and 1/3 miles (1/15 unit) from the start. In five trips the truck can build up this cache so that when the truck reaches the cache at the end of the seventh trip, the combined fuel of truck and cache will be three loads. As we have seen, this is sufficient to take the truck the remaining distance of 766 and 2/3 miles. Seven trips are made between starting point and first cache, using 7/15 load of gasoline. The three loads of fuel that remain are just sufficient for the rest of the way, so the total amount of gasoline consumed will be 3 and 7/15, or a little more than 3.46 loads. Sixteen trips are required.

Proceeding along similar lines, four loads will take the truck a distance of 1 and 1/3 plus 1/5 plus 1/7 units, with three caches located at the boundaries of these distances. The sum of this infinite series diverges as the number of loads increases; therefore the truck can cross a desert of any width. If the desert is 1,000 miles across, seven caches, 64 trips and 7.673 loads of gasoline are required.

2.

If Smith has two children, at least one of which is a boy, we have three equally probable cases: BB, BG, GB. In only one case are both children boys, so the probability that Smith's other child is a boy is 1/3. Jones's situation is different. We are told that his older child is a girl, so there are only two equally probable cases: GG, GB. Therefore the probability that the other child is a girl is 1/2.

If this were not so, we would have a simple method of guessing with better than even odds whether a flipped coin, covered by someone's hand, is heads or tails. We would simply flip our own coin. If it came heads we could reason: At least one of the two coins is heads, therefore the probability that the concealed coin is tails is 2/3. This reasoning is incorrect because we know *which* coin is heads. On the other hand, if someone flips two coins and informs you that at least one came up heads (picking this coin at random and not on a prespecified basis of naming the shiniest coin, the coin on the left and so on), you can bet that the coin is tails and in the long run expect to win two out of three times.

3.

The key to Lord Dunsany's chess problem is the fact that the black queen

Solving Problems of Manned Space Flight - at Northrop

by *Welko E. Gasich*

Director of Weapon System Development Engineering, Norair Division of Northrop Corporation, Hawthorne, California



Man in space. To put him there and return him safely to earth, no scientific breakthroughs are needed. It is now a problem of engineering. Engineers must solve lunar space challenges that include reliability, radiation, and human environment problems. Man himself must be trained for the environmental problems associated with either boost-glide or ballistic recovery. These are the areas in which the scientist and the engineer at Northrop are working today.

The outstanding man may work in several product areas at Norair Division — aircraft, missiles, and space vehicles.

System engineers in Norair's Astronautics Department work on close orbit systems, lunar orbit systems, interplanetary space systems, and galactic space systems. Scientists work in various fields of technology associated with space flight. In astrodynamics, for example, their areas may include celestial mechanics and trajectory analysis. In astronavigation, the problems of inertial guidance, star

tracking, and horizon scanning are paramount. In astrophysics, the Norair scientist employs the disciplines of astronomy, magnetic field physics, and aerophysics. Space propulsion research and development finds applications of nuclear propulsion systems, ionic and plasma microthrust systems.

An incalculable aid for the Norair technician are the facilities of the Northrop Corporation and Norair's own recently completed four-million-dollar test laboratories. Norair's high-grade equipment will include hypersonic and shock tunnels.

Such outstanding facilities augment other Norair advanced design studies for the space age. Current among these are the Satellite Rendezvous Program and special projects that include space vehicles for reconnaissance applications—for civilian as well as military use. Recent projects for the U.S. Government—particularly in the field of operations analysis—have proved measurable contributions.

Northrop constantly translates

advanced technologies into simplified applications — creating answers to complex problems that assure a high degree of reliability at low cost. One recent example at the Norair Division is the N-156F supersonic fighter. Weighing half as much as comparable U.S. fighters, it uses only half the fuel — to deliver equivalent performance for free-world defense.

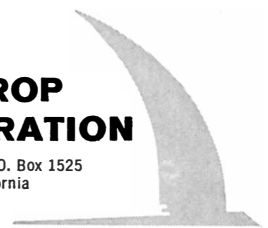
Current papers by Northrop scientists and engineers include:

Lightweight High-Performance Military Aircraft—W. E. Gasich; Problems Associated with Injecting, Orbiting, Recovering A Man from Space Flight—Ralph Hakes.

For copies of these papers and additional information about Northrop Corporation, write:

NORTHROP CORPORATION

Dept. K-1300-32, P.O. Box 1525
Beverly Hills, California

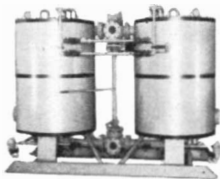


WHEN FURNACE ATMOSPHERES MUST BE DESERT-DRY



GAS GENERATOR MANUFACTURERS often include Lectrodryers when dry, controlled atmospheres are required. Thus, metallurgical furnace operations, sintering of carbides and similar processes proceed without damage by moisture.

Atmospheres in which research and production are carried on—whether room air or sealed gas chambers—can have similarly controlled dryness. Working with refrigeration and auxiliary equipment, Lectrodryers can automatically maintain dryness at dew-points as low as -110°F .



Lectrodryers come to you as self-contained units, ready to go to work. Lectrodryers are long on engineering—have built-in extra capacity which always seems to be needed; stay on the job year after year with remarkably little attention.

For help in obtaining desert-dryness for laboratory, pilot or production plant, tell us your troubles caused by unwanted moisture. Our engineers will suggest ways of solving them. Pittsburgh Lectrodryer Division, McGraw-Edison Company, 336 32nd Street, Pittsburgh 30, Pennsylvania.



Lectrodryer®

is not on a black square as she must be at the start of a game. This means that the black king and queen have moved, and this could have happened only if some black pawns have moved. Pawns cannot move backward, so we are forced to conclude that the black pawns reached their present positions from the other side of the board! With this in mind, it is easy to discover that the white knight on the right has an easy mate at Q3 (counting from the top of the board, which is really white's side), and reaches it in three moves. Black, however, delays the mate one move by playing his knight to KB6 (counting from bottom of board), then to K4, where it blocks the mate until it is taken by the white queen.

4.

Let n be the number of steps visible when the escalator is not moving, and let a unit of time be the time it takes Professor Slapenarski to walk down one step. If he walks down the down-moving escalator in 50 steps, then $n - 50$ steps have gone out of sight in 50 units of time. It takes him 125 steps to run up the same escalator, taking five steps to every one step before. In this trip, $125 - n$ steps have gone out of sight in $125/5$, or 25, units of time. Since the escalator can be presumed to run at constant speed, we have the following linear equation that readily yields a value for n of 100 steps:

$$\frac{n - 50}{50} = \frac{125 - n}{25}$$

5.

In long division, when two digits are brought down instead of one, there must be a zero in the quotient. This occurs twice, so we know at once that the quotient is $x080x$. When the divisor is multiplied by the quotient's last digit, the product is a four-digit number. The quotient's last digit must therefore be 9, because eight times the divisor is a three-digit number.

The divisor must be less than 125 because eight times 125 is 1,000, a four-digit number. We now can deduce that the quotient's first digit must be more than 7, for seven times a divisor less than 125 would give a product that would leave more than two digits after it was subtracted from the first four digits in the dividend. This first digit cannot be 9 (which gives a four-digit number when

AN INVITATION TO JOIN ORO

Pioneer In Operations Research

Operations Research is a young science, earning recognition rapidly as a significant aid to decision-making. It employs the services of mathematicians, physicists, economists, engineers, political scientists, psychologists, and others working on teams to synthesize all phases of a problem.

At ORO, a civilian and non-governmental organization, you will become one of a team assigned to vital military problems in the area of tactics, strategy, logistics, weapons systems analysis and communications.

No other Operations Research organization has the broad experience of ORO. Founded in 1948 by Dr. Ellis A. Johnson, pioneer of U. S. Opsearch, ORO's research findings have influenced decision-making on the highest military levels.

ORO's professional atmosphere encourages those with initiative and imagination to broaden their scientific capabilities. For example, staff members are taught to "program" their own material for the Univac computer so that they can use its services at any time they so desire.

ORO starting salaries are competitive with those of industry and other private research organizations. Promotions are based solely on merit. The "fringe" benefits offered are ahead of those given by many companies.

The cultural and historical features which attract visitors to Washington, D. C. are but a short drive from the pleasant Bethesda suburb in which ORO is located. Attractive homes and apartments are within walking distance and readily available in all price ranges. Schools are excellent.

For further information write:
Professional Appointments

OPERATIONS RESEARCH OFFICE

The Johns Hopkins University
6935 ARLINGTON ROAD
BETHESDA 14, MARYLAND

A Personal Invitation to ENGINEERS



from **ROBERT McCULLOCH**
President

"If you would like to be a member of a select corps of Engineers, working for an interesting, growing company... in one of the country's most stimulating areas... I invite you to write to Temco. Temco's growth is sound and planned, its products are diversified and challenging, our facilities are modern. Every benefit, for you professionally and in good living for you and your family, is here. Below are some of the areas in which jobs are open now."

ANTENNA DEVELOPMENT

Graduate Electronics Engineer or Physicist to perform analysis and design of antenna, microwave, and propagation systems for use in missile guidance and reconnaissance. Individual will be responsible for performing investigations in new types and concepts of transmitting and receiving antennas for both pulsed and CW signals, and the adaptations of these studies to current use in Electronic Development projects.

SENIOR FIELD SERVICE ENGINEER

Openings exist for a graduate Electronics Engineer with five years' experience in radar systems development, to be responsible for technical assistance and maintenance of Temco hardware in the field. Recent industry or military electronics experience with any of the following types of radar equipment is necessary. APS-20E, APS-45, FPS-20, FPS-8, FPS-6, MPS-11. The Field Engineer will coordinate the operation and application of the equipment to field uses with the Engineering Development sections.

Write **BILL G. HICKEY**
Supervisor Technical Employment
Room 306S, P. O. Box 6191



the divisor is multiplied by it), so it must be 8, making the full quotient 80809.

The divisor must be more than 123 because 80809 times 123 is a seven-digit number and our dividend has eight digits. The only number between 123 and 125 is 124. We can now reconstruct the entire problem as follows:

$$\begin{array}{r} 80809 \\ 124 \overline{)10020316} \\ \underline{992} \\ 1003 \\ \underline{992} \\ 1116 \\ \underline{1116} \\ 0 \end{array}$$

6.

Several procedures have been devised by which n persons can divide a cake in n pieces so that each is satisfied that he has at least $1/n$ of the cake. The following system has the merit of leaving no excess bits of cake.

Suppose there are five persons: A, B, C, D, E . A cuts off what he regards as $1/5$ of the cake and what he is content to keep as his share. B now has the privilege, if he thinks A 's slice is more than $1/5$, of reducing it to what he thinks is $1/5$ by cutting off a portion. Of course if he thinks it is $1/5$ or less, he does not touch it. C, D and E in turn now have the same privilege. The last person to touch the slice keeps it as his share. Anyone who thinks that this person got less than $1/5$ is naturally pleased because it means, in his eyes, that more than $4/5$ remains. The remainder of the cake, including any cut-off pieces, is now divided among the remaining four persons in the same manner, then among three. The final division is made by one person cutting and the other choosing. The procedure is clearly applicable to any number of persons.

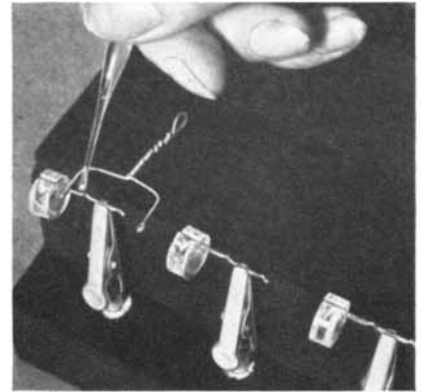
7.

The first sheet is folded as follows. Hold it face down so that when you look down on it the numbered squares are in this position:

$$\begin{array}{r} 2365 \\ \underline{1874} \end{array}$$

Fold the right half on the left so that 5 goes on 2, 6 on 3, 4 on 1 and 7 on 8. Fold the bottom half up so that 4 goes on 5 and 7 on 6. Now tuck 4 and 5 between 6 and 3, and fold 1 and 2 under the packet.

The second sheet is first folded in half the long way, the numbers outside, and



Eastman 910 Adhesive solves another production bottleneck

Universal Transistor Products Corp., Westbury, New York, makes a direct-reading precision radiation monitoring instrument, called a dosimeter.

Assembly of the pocket instrument requires careful attachment of the sensing element, an extremely delicate quartz fiber, to two pips on a fine aluminum wire.

This seemingly difficult operation is handled on a production-line basis with speed and simplicity by properly positioning the fiber, which is temporarily held in a Y-shaped support, and then cementing it to each pip with a drop of Eastman 910 Adhesive.

In less than one minute, the bond is formed.

Eastman 910 Adhesive is making possible faster, more economical assembly-line operations and new design approaches for many products. It is ideal where extreme speed of setting is important, or where design requirements involve joining small surfaces, complex mechanical fasteners or heat-sensitive elements.

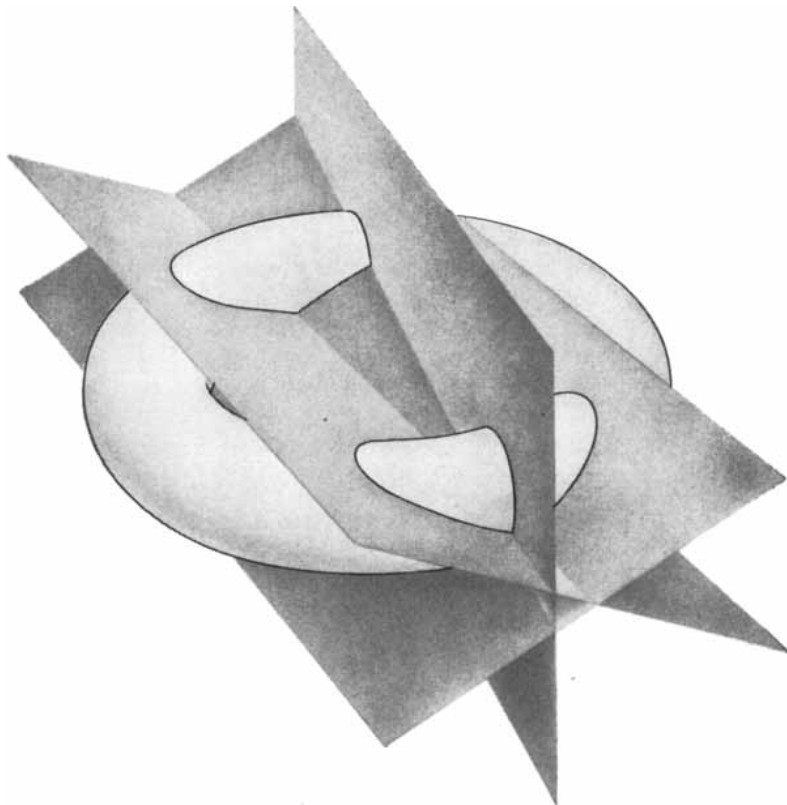
Eastman 910 Adhesive is simple to use. No mixing, heat or pressure is required. Upon spreading into a thin film between two surfaces, setting begins immediately. With most materials, strong bonds are made in minutes.

What production or design problem can this unique adhesive solve for you?



**Bonds Almost Instantly
... Without Heat,
Pressure or Catalyst**

For a trial quantity ($1/3$ -ounce) send five dollars to Armstrong Cork Company, Industrial Adhesives Division, 9106 Inland Road, Lancaster, Pa., or to Eastman Chemical Products, Inc., Chemicals Division, Dept. S-6, Kingsport, Tenn.



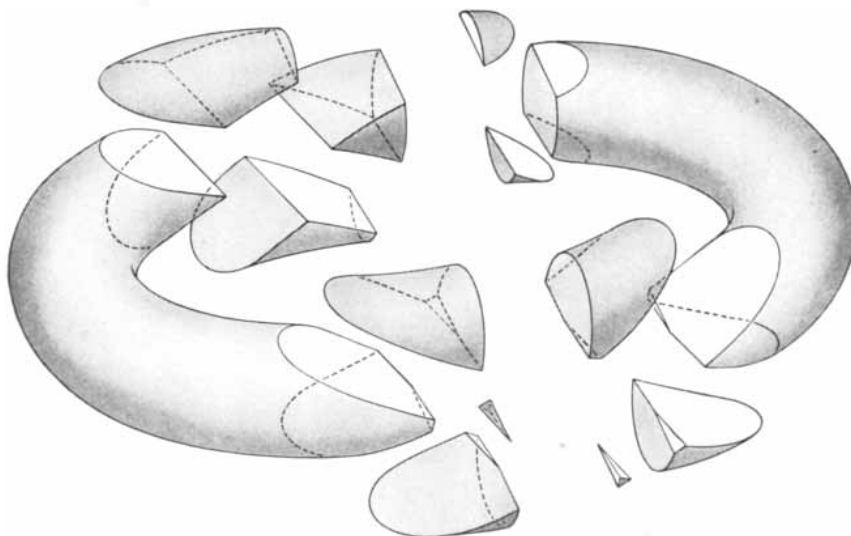
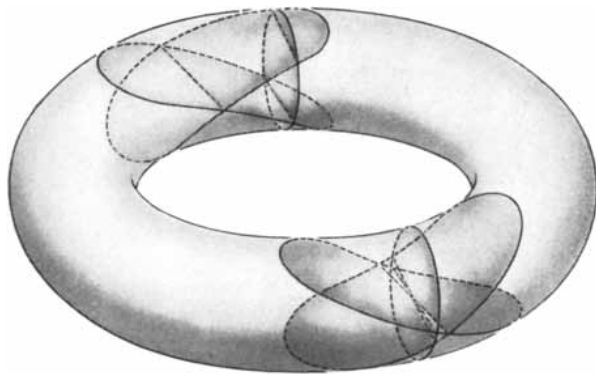
held so that 4536 is uppermost. Fold 4 on 5. The right end of the strip (squares 6 and 7) is pushed between 1 and 4, then bent around the folded edge of 4 so that 6 and 7 go between 8 and 5, and 3 and 2 go between 1 and 4.

8.

To determine the value of Brown's check, let x stand for the dollars and y for the cents. The problem can now be expressed by the following equation: $100y + x - 5 = 2(100x + y)$. This reduces to $98y - 199x = 5$, a Diophantine equation with an infinite number of integral solutions. Only one solution, however, meets the problem's condition that the value of y be less than 100. This solution is: $x = 31$ and $y = 63$, making Brown's check \$31.63.

9.

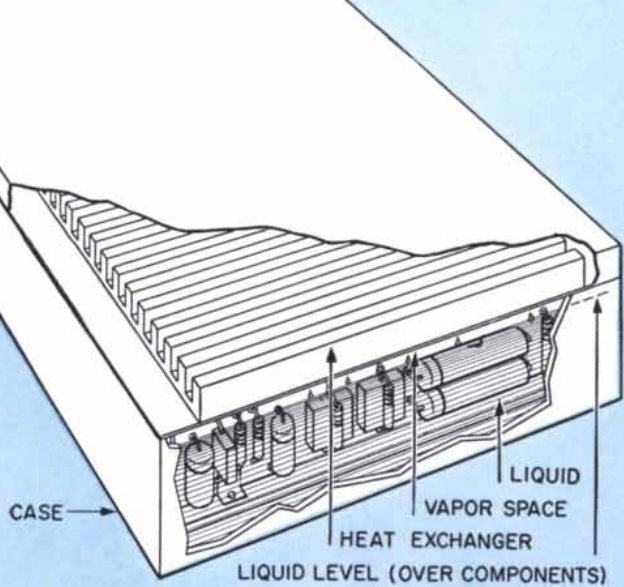
Regardless of how much wine is in one beaker and how much water is in the other, and regardless of how much liquid is transferred back and forth at each step (provided it is not all of the liquid in one beaker), it is impossible to reach a point at which the percentage of wine in each mixture is the same. This can be shown by a simple inductive argument. If beaker A contains a higher concentration of wine than beaker B, then a transfer from A to B will leave A with the higher concentration. Similarly a transfer from B to A—from a weaker to a stronger mixture—is sure to leave B weaker. Since every transfer is one of these two cases, it follows that beaker A must always contain a mixture with a higher percentage of wine than B. The only way to equalize the concentrations is by pouring all of one beaker into the other.



The illustration at left shows how a doughnut can be sliced into 13 pieces by three plane cuts. A large number of correspondents sent correct solutions, but a majority failed to find that elusive 13th piece. At the time of writing, the clearest diagrams showing a correct manner of cutting were drawn by the Reverend Joseph B. Tucker, Joseph Raab, William Ross and Stephen Barr. Barr also sent a rigorous proof that 13 was the maximum. The formula for the largest number of pieces that can be produced with n cuts seems to be:

$$\frac{n^3 + 3n^2 + 8n}{6}$$

How to slice a doughnut into 13 pieces with only three plane cuts



In Raytheon's "EV-GRAV" system, liquid refrigerant boils off the surfaces of the individual electronic components, rises as vapor, condenses on the heat exchanger, and drops as liquid to repeat the cycle.

"EV-GRAV" COOLING

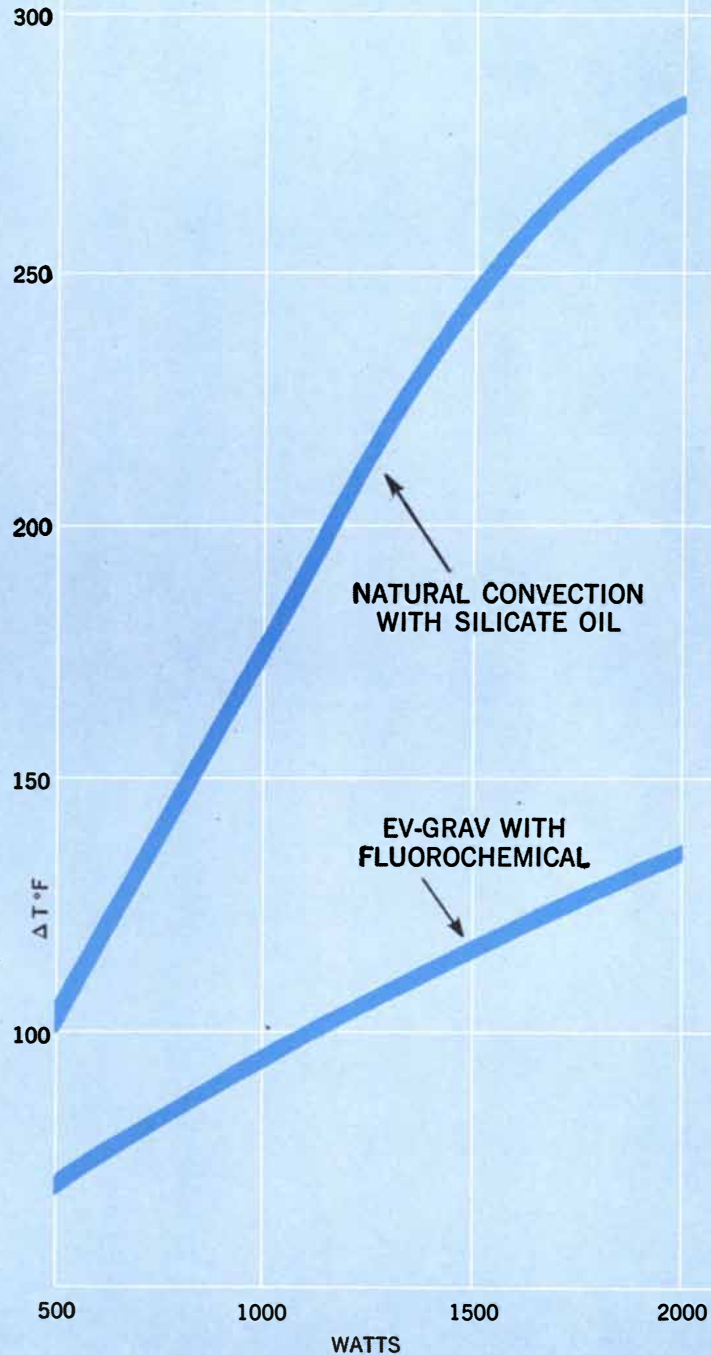
IN THE DESIGN OF HIGH HEAT-DENSITY ELECTRONIC EQUIPMENT

Performance requirements for electronic equipment in supersonic aircraft and missiles place particular emphasis on the need for more efficient heat transfer techniques.

The use of fluorochemical refrigerants in an "evaporative-gravity" cooling system is a novel method of removing heat from electronic components. The refrigerant boils at the surfaces of submerged heat-dissipating components and condenses on the surface of a heat exchanger at the top of the package.

This technique has proved more efficient than free convection in oil dielectrics or forced convection with gas dielectrics. The high dielectric strength of the fluorochemicals permits the achievement of higher density packaging.

Contributions such as this are typical of the Heat Transfer Group in Raytheon's Government Equipment Division . . . assisting design engineers in developing the complex weapons systems of tomorrow.



PROFESSIONAL ASSOCIATION WITH A FUTURE

Qualified engineers and physical scientists with BS or advanced degrees interested in systems, development, design or manufacturing engineering of complex electronic equipments are invited to write Donald H. Sweet, Government Equipment Division, Raytheon Manufacturing Company, Wayland, Massachusetts.

Engineering Laboratories: *Wayland, Maynard, Sudbury, Mass.; Santa Barbara, Calif.*
 Manufacturing Facilities: *Waltham, North Dighton, Mass.*



Excellence in Electronics

GOVERNMENT EQUIPMENT DIVISION



LAND



SEA



AEROSPACE



POLARIS FBM



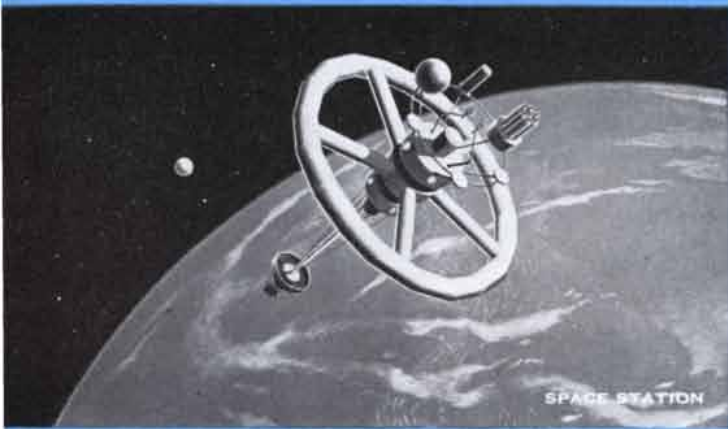
DISCOVERER SATELLITE



PROJECT ARGUS



Q-5. KINGFISHER



EXPANDING
THE FRONTIERS OF
SPACE
TECHNOLOGY

ADVANCED PROJECTS
AT LOCKHEED

DISCOVERER SATELLITE—Designed and built by Lockheed Missiles and Space Division, the first of a series of DISCOVERER satellite launchings was successfully placed in orbit on February 28. Later satellites in the series will carry live animals and their recovery attempted. Valuable data will be obtained on space environment and recovery techniques of major importance to the nation's space program. The DISCOVERER is an Advanced Research Projects Agency program under the direction of the Air Force Ballistic Missile Division, with Lockheed as systems manager.

POLARIS FBM—Lockheed is missile systems manager for the Navy POLARIS Fleet Ballistic Missile, under the cognizance of the Special Projects Office of the Bureau of Ordnance. Submarine-launched, the POLARIS will travel through three mediums in a single flight: water, air and outer space. With three-quarters of the earth's surface being water, practically no target in the world is outside its range. The solid-propellant POLARIS was *designed with the future in mind*—an approach that the Navy states has cut nearly two years from the original timetable.

Q-5, KINGFISHER—Developed for the Air Force, and currently being manufactured for the Army, the Kingfisher is designed to simulate enemy attacks to test the efficiency of our various defensive weapon systems. It is equipped with extensive instrumentation to register "kills" without itself being destroyed and can be recovered by parachute and landing spike to be used again, with marked savings in cost.

X-7—Lockheed's X-7 recoverable ramjet-engine test vehicle, developed for the Air Force, has established speed and altitude records for air-breathing vehicles and is also recoverable for re-use following flight.

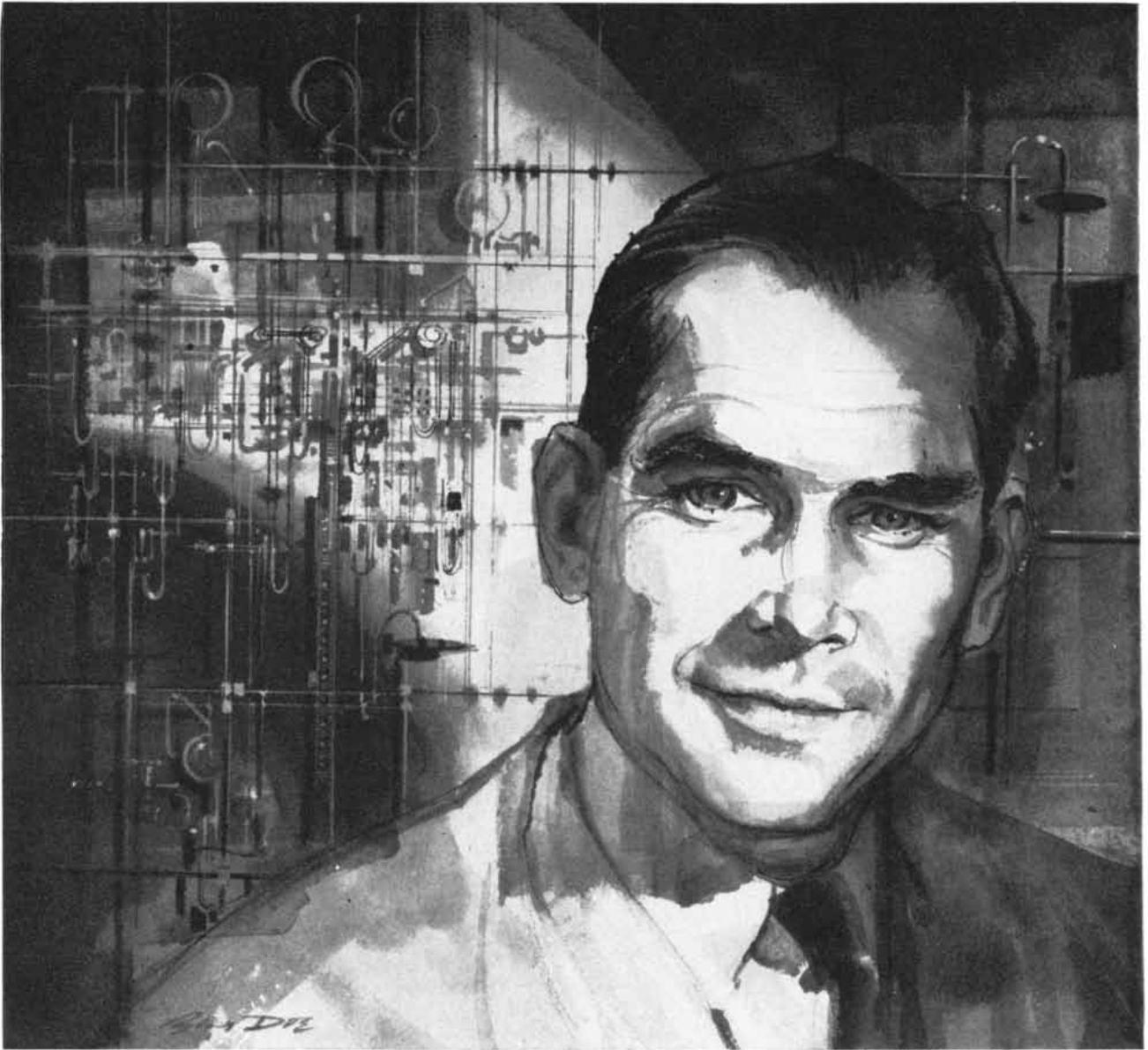
X-17—The nation's first successful reentry tests were conducted by the Air Force with the three-stage, Lockheed X-17 solid-propellant ballistic missile. The X-17 has pioneered many new techniques and the valuable experience gained from this program has facilitated development of other, inter-service projects, including the Navy POLARIS FBM. The Navy's history-making, 300-mile-high, Project Argus radiation explosions featured the X-17 as the vehicle.

SPACE STATION—An orbiting research facility, to serve as an advance base for space exploration, has been proposed in practical detail by Lockheed's research and development staff. The station would carry a 10-man crew. Prefabricated compartments for the rim of the wheel, the spokes, and the three hubs would be launched separately by means of ballistic missiles and guided into a cluster on the same orbit.

The successful completion of projects such as these requires a bold and imaginative approach to entirely new environments. Lockheed's programs reach far into the future. It is a rewarding future which scientists and engineers of outstanding talent and inquiring mind are invited to share. Write: Research and Development Staff, F-36, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship required.

Lockheed / **MISSILES AND SPACE DIVISION**

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA • CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO • HAWAII



W. P. Knight

Bill Knight is a rocket chemist. His field of interest is research on advanced solid and liquid propellants to meet the stringent requirements of today's military programs (and tomorrow's).

The continued success of the American missile program depends on men like Bill Knight.

But creation takes talent. The kind of talent that top-notch scientists and engineers can use to the utmost on

Aerojet's rapidly expanding programs in chemistry and other fields.

There are *many* projects at Aerojet that intrigue the scientific and engineering investigator. Your resume is invited. The address: AEROJET-GENERAL CORP., P. O. Box 296P, Azusa, California or P. O. Box 1947P, Sacramento, California. Attention: Director of Scientific and Engineering Personnel.



THE AMATEUR SCIENTIST

How to fit a diffusion cloud-chamber with a magnet and other accessories



Conducted by C. L. Stong

Amateurs who hanker to observe the decay of radioactive atoms and the behavior of subatomic particles often start out by making themselves a cloud chamber of the diffusion type. A simple diffusion chamber can be put together in less than five minutes from a glass jar with a screw cap, some alcohol of the rubbing variety and a small cake of dry ice. The jar is warmed, rinsed with

alcohol, promptly capped and upended on the dry ice. In a minute or so, depending on the size of the jar, a vapor trail about the thickness of a hair will suddenly appear near the bottom of the chamber. Other trails will then follow at intervals of about 30 seconds. Most of the trails mark the paths of the electrically charged particles in cosmic radiation. In effect the trails magnify the width of the paths more than a trillion times.

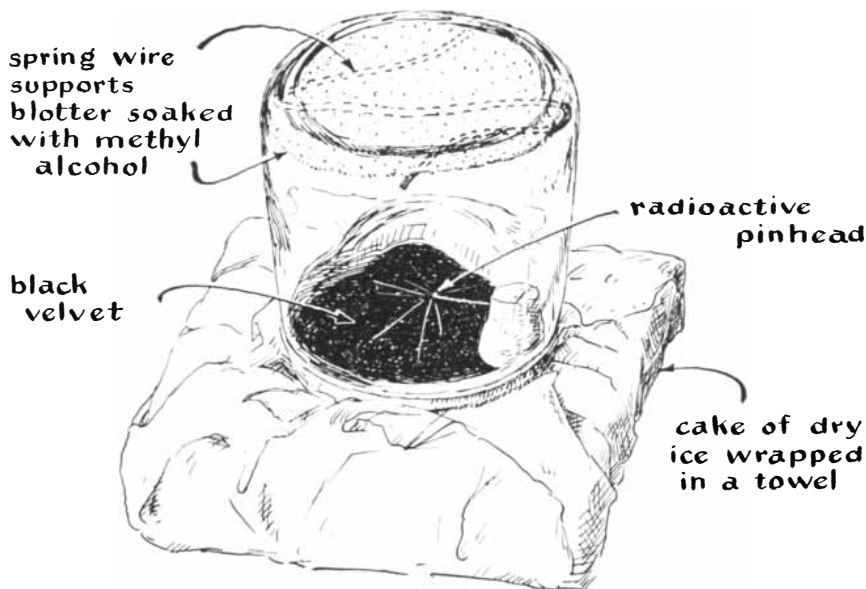
Although a chamber made in this way stages a fascinating show, it will not satisfy the serious amateur for long. The tracks are not easy to see in ordinary light, and old tracks spread into wisps of cloud that soon clutter the view.

Worse yet, the chamber stops working after a few minutes because condensation exhausts the alcohol vapor. To lengthen the operating period a pad saturated with alcohol may be fixed inside the glass top of the upended jar. Vapor evaporating from the pad will keep the chamber going for an hour or more.

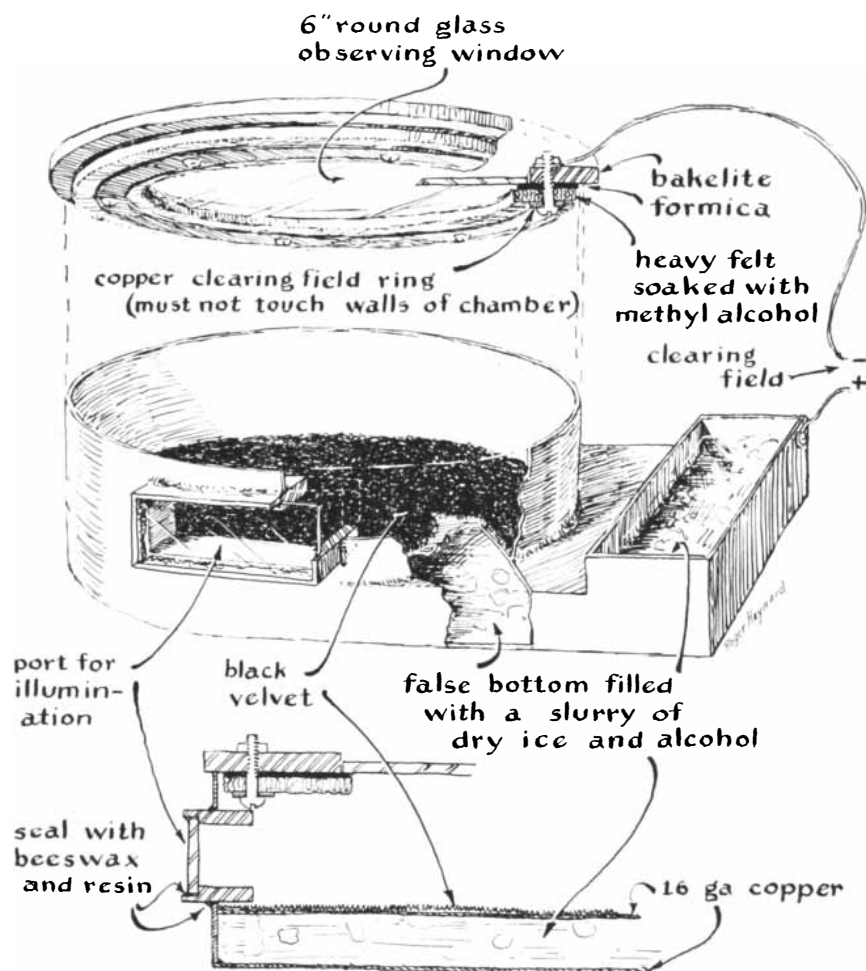
The tracks show up best when they are viewed in bright light and against a black background. A 35-millimeter slide-projector may be drafted as the light source; an effective background is provided by a scrap of black velvet fitted to the inside of the jar's screw cap. Old tracks can be cleared from the chamber by mounting a loop of wire just below



An amateur's photograph of the circular track of an electron in a magnetic field of 300 gauss



A diffusion cloud-chamber made with a glass jar



A diffusion cloud-chamber adapted for use with a magnetic field

the glass top and connecting it to the metal bottom through a voltage supply; when the voltage is turned on momentarily, the tracks disappear.

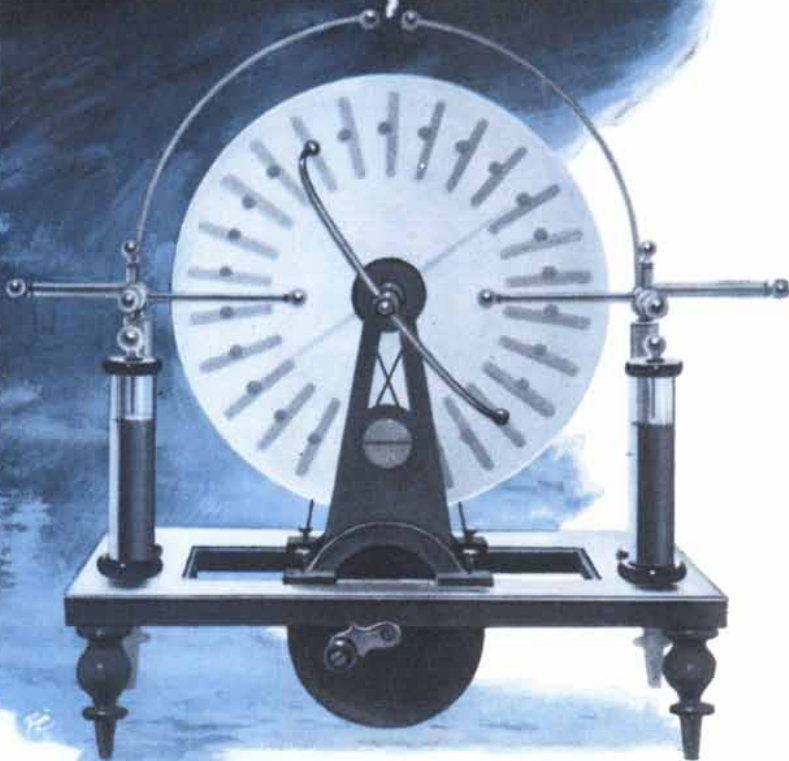
Other accessories may include a camera for photographing the tracks, mirrors set at angles to display the tracks in three dimensions, windows of flat glass to minimize optical distortion, and so on. The succession of improvements follow one another in such easy steps that a novice can find himself immersed in a full-blown hobby almost before he senses his involvement.

That is what happened to Gareth D. Shaw, a field engineer on duty in the Far East for the Bendix Aviation Corporation. His chamber is equipped with a full line of accessories for viewing and photographing tracks, plus other auxiliaries that enable him to identify particles and to determine their mass, charge, energy and velocity.

"All cloud chambers," writes Shaw, "are based on the fact that ions are created when charged particles move through a gas at high speed. Close encounters between the particle and an atom in its path dislodge an electron from the atom. The process forms two ions: the electron itself and the atom, now positive because it has lost a unit of negative charge. Either ion can disturb the delicate balance of electrical forces in a neighboring molecule of alcohol in the vapor state. On close approach to an ion the molecule acquires on the side facing the ion a charge that is opposite in sign to the charge of the ion. In consequence the molecule and the ion are mutually attracted. Other molecules in the vicinity react similarly. The ion thus acts as a center of condensation. When the temperature of the gas is below the dew point of the vapor, a droplet of alcohol quickly forms. A speeding particle leaves thousands of ions in its wake; the resulting droplets comprise the vapor trail.

"Two basic types of cloud chamber have been invented. They differ chiefly in the method used for cooling the gas below the dew point of the vapor. The first type, known as the expansion chamber, takes the form of a cylinder equipped with a close-fitting piston. When the piston is pulled down, the gas expands and its temperature drops. In the second type, the diffusion chamber, the gas is cooled by a refrigerant. When alcohol is used as the condensing vapor, a difference in temperature on the order of 150 degrees Fahrenheit is maintained between the top and bottom of the chamber. Alcohol evaporated near the top diffuses down through the air (or

what is charge?



Earth's attraction for a lightning bolt?

+ or -, which is up?

A resonant phenomenon?

A singularity in a field?

What is the nuclear "glue" for like charges?

A better comprehension of charge is important to Allison because energy conversion is our business and charge is one keystone for this conversion work. Thus we have a deep and continuing interest in electrons, protons, positrons, neutrons, neutrinos—charge in all its forms.

In its investigations, Allison calls upon the capabilities within General Motors Corporation and its Divisions, as well as the specialized talents of other individuals and organizations. By applying this systems engineering concept to new research projects, we increase the effectiveness with which we accomplish our mission—exploring the needs of advanced propulsion and weapons systems.

If you have advanced academic recognition and appropriate experience in the field of science and research, we would like to hear from you. Write R. C. Smith, Salaried Personnel, Dept. E-1.

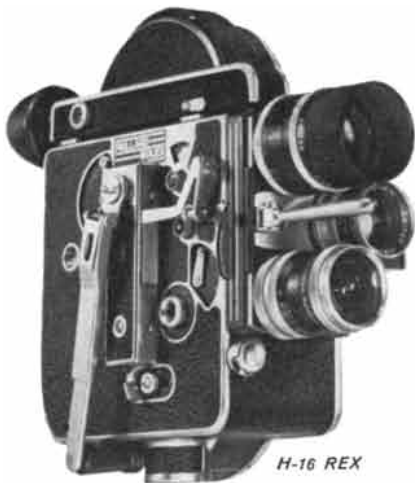
Energy conversion is our business



Division of General Motors,
Indianapolis, Indiana

NEW PRECISION

for your films



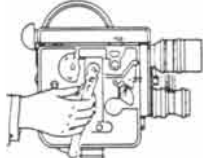
H-16 REX

NEW BOLEX H-16 REFLEX!

*New Variable Shutter Adds
Exposure Control to 16mm Movies*

CONTROL EXPOSURE more precisely than ever before—cut down glare . . . sharpen fast-action subjects . . . and wash out unwanted backgrounds. Makes possible perfect fades and lap dissolves.

SHOWN ON CAMERA is the **REXOFADER**, a fading device that automatically times fades for pre-set number of frames. Optional at \$37.50.



WITH THE BOLEX REFLEX SYSTEM, you view and focus through the shooting lens. No parallax, no figuring distance. Insures exact centering of subject in macrophotography—field scenes without a doubt about focus.

OTHER H-16 REX FEATURES: governed speeds from 12 to 64 fps, footage and frame indicators, time exposure setting, plus over 10 other professional extras as standard equipment. Priced from \$400.00 with Lytar 1" F/1.8 lens. Lenses shown are optional at extra cost. Available on convenient terms; write today for literature and the name of your Bolex dealer.

All prices include Federal Excise Tax where applicable.

BOLEX
PAILLARD Incorporated
100 Sixth Avenue, New York 13, N.Y.

other gas) into the cold region; hence the name diffusion chamber. The amount of alcohol that can be held in the vapor state by a gas depends directly on the temperature. The cooler air near the bottom of the diffusion chamber has a lower capacity for vapor than the warmer air at the top. Thus an unstable condition arises when alcohol vapor diffuses into the cold region of the chamber. Any small body—for example, a particle of dust—will trigger condensation. The chamber is sealed against the outside air, however, and all the dust in the chamber when it goes into operation is soon carried to the bottom by droplets. Thereafter ions constitute the most likely centers of condensation.

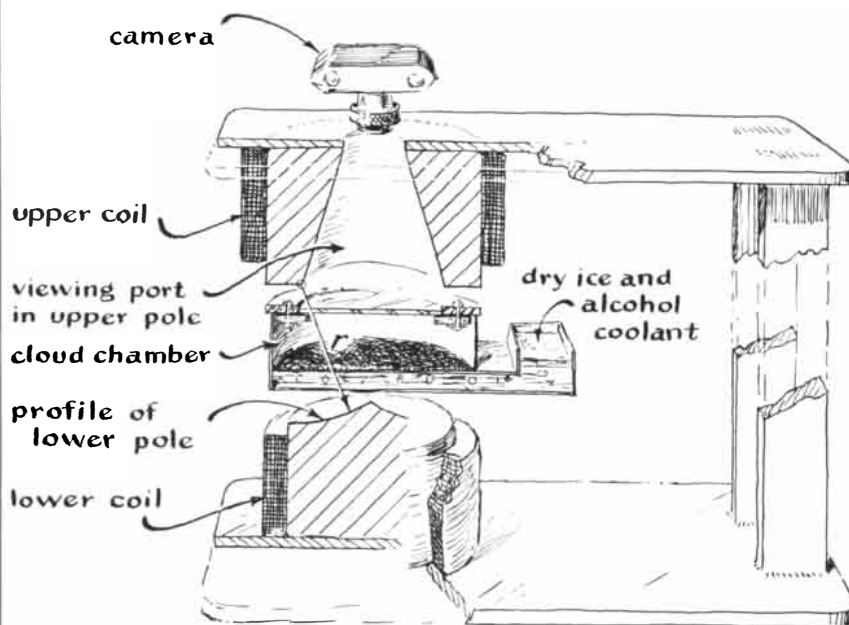
“Dry ice also encourages condensation outside the chamber. This is why it ‘smokes.’ Water vapor naturally present in the air condenses around particles of suspended dust. The resulting fog can be a source of annoyance, particularly when one is attempting to photograph tracks. In the case of a simple chamber, such as the one shown in the accompanying illustration [top of page 174], fog can be minimized by covering the exposed surfaces of the ice with a towel. Chambers of more sophisticated design, such as one cooled by a slurry of dry ice and alcohol [bottom of page 174], should be insulated by a jacket of material like that used to cover steam pipes.

“The experimenter is interested in the size and shape of the tracks because they provide clues to the identity of the responsible particles. It is therefore important to minimize convection currents

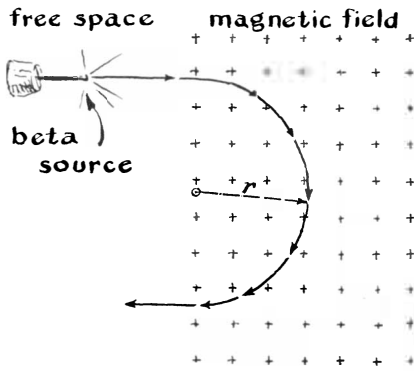
in the chamber by filtering as much heat from the light beam as possible. A small aquarium with flat sides makes a good filter. Most 35-mm. slide-projectors come equipped with heat filters and blowers. A pair of projectors may be needed to provide enough light for making photographs. Tracks show up best when viewed at an angle of about 130 degrees with respect to the light source.

“Photographs can be made inexpensively with a 35-mm. camera of $f/3.5$ aperture equipped with an auxiliary lens for close work. Lens openings range from $f/3.5$ to $f/8$ and shutter speeds from 1/10 to 1/100 second with film rated ASA 200. The photographs reproduced in this article were made with Kodak Tri-X film and developed in Kodak Microdol, a fine-grain developer. When the light source is relatively weak, a procedure known as ‘pushing the film’ is possible with this developer. The speed of the film is doubled by doubling the time in which the film is kept in the developer.

“Once the technique of operating the chamber has been mastered, the experimenter should consider adding a magnetic field to it. A chamber without a field is like a yardstick without inch marks—interesting but not very useful. When a charged particle moves at right angles to the direction of a magnetic field, it is acted upon by a force at right angles to both its direction and that of the field. If the field extends in the vertical direction, for example, and the particle moves from east to west, the particle is accelerated in the north-south



An electromagnet for a diffusion cloud-chamber



The path of an electron in a uniform field

direction. As a consequence a particle that enters a uniform field follows a circular path [see illustration above]. The radius and direction of the path depend on the sign and magnitude of the charge on the particle, on the mass and velocity of the particle and on the strength and direction of the field.

"A suitable electromagnet can be constructed inexpensively from scrap steel, available in most communities from local industries or scrap dealers. My magnet consisted of two pole-pieces and a yoke made of a pair of plates separated by two rectangular members [see illustration on opposite page]. The pole-pieces were approximately five inches long. The upper one was machined to a diameter of nine inches and the lower one to a diameter of seven inches. Both were made of soft-steel shafting. In the upper pole-piece was machined a conical hole, which tapered from two inches at the top to five inches at the bottom. The hole provides a clear path for viewing and photographing the tracks. The lower pole-face was shaped to produce a uniform distribution of magnetic flux through the sensitive region of the chamber. The face of this piece is in the form of a shallow, curved cone. The inner edge of the upper pole-face coincides with the center of curvature of the lower pole-face. The radius of curvature in the case of my magnet is four inches [r' in the illustration]. The pole-pieces are welded to the pair of soft-steel plates, each 3/8 inch thick, 10 inches wide and 18 inches long. The plates are welded in turn to the spacing members, also made of soft steel; each member is 1 1/2 inch thick, two inches wide and 14 inches long. The spacers provide an air gap of four inches between the pole-faces.

"Each of the two coils for energizing the magnet consists of 1,000 turns of No. 14 enameled copper magnet-wire, wound on wooden forms and wrapped with insulating tape. The coils require

Deluxe 4-inch DYNASCOPE®

Complete for only **\$89.95**
F.O.B. Hartford

Same model with **Dyn-O-Matic Electric Drive** only **\$109.95** F.O.B. Hartford

Compact, vibration-free Dyn-O-Matic drive assures smooth, effortless tracking. Self-actuating clutch engages and disengages automatically as you seek different objects. Synchronous 110/120 60 cycle motor. Unit fully enclosed.

Drive may be ordered separately for installation on any previous Dynascope.

ROUND TRIP TO OUTER SPACE!

Travel "first class" with close-up views and thrills that only a truly professional telescope can give you.

You'll have a front-row seat for thousands of brilliant nightly performances with this powerful advance designed Dynascope reflector. Its parabolic mirror and achromatic optics are incredibly precise, assuring perfect resolution and definition of all objects viewed. And you'll thrill at the ease with which you'll locate and hold objects because of the whisper smooth movements of the equatorial mount. Scores of experts attest to the superiority of these famous telescopes. Used by colleges, universities, clubs, and thousands of amateurs and professionals. Completely portable.

Discover an entirely new experience in magnified viewing, order today under our full-protection guarantee. You must be thrilled in every way with its performance and construction or your money refunded. Or write for details of our liberal Easy Payment Plan.

Includes All These Professional Features:

- EXQUISITE 4-INCH PARABOLIC PYREX MIRROR accurate to 1/8 wave. For famed Dynascope optical superiority.
- TRUE EQUATORIAL AND ALTIZUMUTH HEAVY-DUTY MOUNT with complete friction adjustments for any latitude, declination and ascension. Rugged cast-iron construction. Weighs over 12 lbs.
- ROTATING RINGS — Saddle has felt-lined rotating rings that permit tube to be quickly positioned for accessories or to bring eyepiece into more comfortable viewing position.
- 3 STANDARD 1 1/4" EYEPIECES: 18-mm Huygens, 9-mm Achromatic Ramsden, 7-mm Achromatic Ramsden for 65X, 130X and 167X.
- 4X ACHROMATIC CROSSHAIR FINDERSCOPE: Crosshair, usually found only in much more expensive scopes, assures greater accuracy, easier spotting. Coated achromatic lenses. Screw-type micrometer focus. Extra large field of view. Double-posted bracket with collimation adjustments.
- RACK AND PINION DOUBLE-DRAW EYEPIECE Holder for easy, exact adjustments. Accommodates any eyepiece, negative or positive.
- PROFESSIONAL-TYPE STEEL TRIPOD with fast-fold legs for easy portability. Designed to solve all stability problems. The result of hundreds of field tests and consultation with many authorities. Steadier support eliminates vibration. No canting, wobble or sideplay. Special position locks, prevent collapse. Completely portable. Sets up instantly on uneven terrain. Folds up quickly, without disassembly, for full portability.

CRITERION Manufacturing Co., Dept. DSA-10, 331 Church St., Hartford, Conn.

HAPPINESS ACCORDING TO THE GREEKS...

"The exercise of vital powers along lines of excellence, in a life affording them scope."

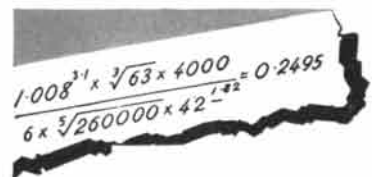
There are currently opportunities for electrical, mechanical, nuclear and optical engineers, as well as for physicists with experience in optical and microwave spectroscopy and in gas discharge processes, in the following areas:

- Atomic Frequency Standards
- Light Weight Doppler Radar
- Nuclear Reactor Design and Theory
- Stimulated Emission of Light Radiation

Send resume to:

TRG INCORPORATED

TECHNICAL RESEARCH GROUP
2 AERIAL WAY, SYOSSET, N. Y.



A 66-inch Slide-rule for your pocket



Slide Rule Open

The GARFIELD Calculator carries 66-inch spiral scales yet measures only ten inches fully extended and six inches when closed. Four to five figure accuracy can be relied on. It is indispensable to the scientist, research worker and student. Administrative staff and business men will find it of tremendous value for a host of estimating and checking calculations.

The GARFIELD Slide Rule solves multiplication, division, percentage calculation and gives 5 place logarithms.

You may use it for 30 days and if you are not satisfied repack and mail it back.

What our users say:

"It does all you claim—four or five figure accuracy without eyestrain or magnifiers. Half an hour's study is ample for its use." A.E.B. . . .

"I use the Calculator for all my slide rule work and need the extra digit which normal slide rules cannot give. I had to get one of my customers a GARFIELD Slide Rule last month, after using mine in his office." E. & G.H. Textile Manufacturers.



Slide Rule Closed

Send for yours now—Only \$19.95 postpaid.

Oliver Garfield Co., Inc., Dept. SA-69
108 E. 16th St., New York 3, N. Y.

ENGINEERS and SCIENTISTS

at Convair-Astronautics pursue space projects at a most advanced state of the art, requiring the highest degree of professional skill. Keystone of these many programs is the mighty

ATLAS ICBM

In this young missile age, Atlas already lists many unique achievements. A proven weapon, it is our only large, tested booster and the only known vehicle to steer itself into orbit. It will lift the first manned capsule into space, and most exploration programs of the future include Atlas in their planning.

PROJECT CENTAUR

. . . design, construction and testing of a high energy, upper stage rocket . . . is the newest Convair-Astronautics program released. Boosted by Atlas, Centaur will be able to place in orbit a satellite weighing several thousand pounds.

Positions are available now in design (electrical, electronic, mechanical, structural), systems design & analysis, propulsion, test laboratories, field test, engineering writing, computer programming, research engineering, and other specialties.

INTERVIEWS

are regularly conducted throughout the U.S. by our engineering representatives. So that advance interview arrangements may be made, please send your resume at once to Mr. G. N. McMillan, Engineering Personnel Administrator, Dept. 130-90

CONVAIR ASTRONAUTICS

Convair Division of

GENERAL DYNAMICS

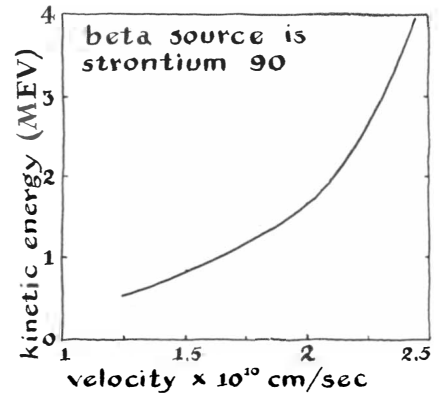
5536 Kearny Villa Road,
San Diego, California



some 60 pounds of wire. The forms were made approximately 1/16 inch larger than the pole-pieces so that the coils could be slipped over the poles easily during assembly. The lower coil rests on the yoke plate and requires no fastening. The upper one is supported by an aluminum ring bolted to the upper pole. The magnet is energized by a six-ampere direct current at 100 volts, and is designed for a maximum duty-cycle of 15 minutes. Extended operation at six amperes results in overheating. The magnet produces a field strength of 1,000 gauss in the sensitive region of the chamber. Motor-generators of the type used for arc welding are suitable for powering the unit and can occasionally be picked up on the surplus market for a few dollars. An inexpensive power supply can also be assembled from surplus rectifier-units of the silicon-disk type.

"The coils must be interconnected so that the current flows in the same direction through each. When they are properly connected, the north end of a magnetic-compass needle will point to one pole-face and the south end to the other. A resistor of 1,000 ohms rated at 20 watts should be connected across the input terminals of the coils to dissipate the energy generated by the collapse of the magnetic field when the magnet is turned off. Without this resistor serious arcing will occur at the switch contacts. If a voltmeter or other instrument is connected across the coils, it should be removed before turning off the magnet; otherwise the sharp rise in voltage that accompanies the collapse of the field will damage the meter.

"When the magnet is ready for operation, the field strength must be measured in the region to be occupied by the sensitive part of the chamber. The current through the coils is adjusted as accurately as possible to six amperes and a note is made of the voltage at this value of current. The field is then meas-

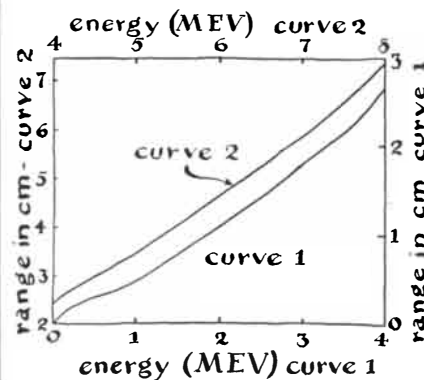


Energy-velocity graph of beta particles

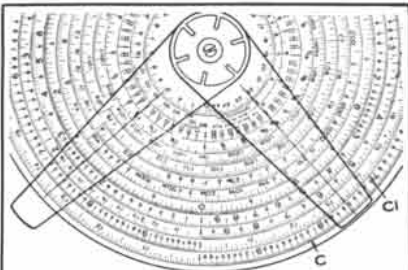
ured (in gauss) with a fluxmeter. This measurement is made only once, so a fluxmeter may be borrowed from a local electric-power firm or the physics laboratory of a nearby school. If desired, the magnet may be calibrated for a series of current values.

"The experimenter will be well repaid in terms of convenience for care taken in constructing the chamber. One good design, which is made principally of sheet metal, provides two compartments. The lower one holds the refrigerant (a slurry of crushed dry ice mixed with alcohol), and also serves as the base for the upper compartment [see illustration on page 174]. Sheet steel may be used, but copper is recommended at least for the surface between the compartments because of its effectiveness as a conductor of heat. The upper chamber is closed by a lid that consists of an assembly of concentric rings and a disk of clear glass. The ring assembly supports the glass and includes an insulated ring of copper that serves as one electrode for applying an electric field across the chamber to clear it of old tracks. The ring assembly also incorporates a felt pad from which alcohol evaporates when the chamber is in operation. As an alternative scheme the wall of the chamber may be lined with a strip of blotting paper arranged so that its lower edge rests in the pool of alcohol at the bottom of the chamber. Fluid is drawn through the paper by capillary attraction, evaporates, condenses and returns to the pool for recirculation. The chamber may be supported within the magnet on a flat platform of nonmagnetic sheet metal (such as aluminum) attached to the lower pole. A bracket to support the camera in line with the opening should also be provided.

"To prepare the chamber for operation, crush enough dry ice into pea-sized lumps to fill the lower container. Do not handle the ice with your bare hands—a



Energy-range graph of alpha particles



CALCULATIONS

Easily Solved on the BINARY CIRCULAR SLIDE RULE

In Arithmetic, Algebra and Trigonometry. Any number of factors can be handled in long and difficult calculations. The "C" scale of the BINARY rule is 25 inches long, with graduations 25% further apart than those of a 20-inch slide rule. The CI, A, K and Log scales are divided as closely as a 20" straight rule. The Log-Log scale extends from 1,0015 to 1,000,000. Gives trig functions from 0 to 90 degrees on back, with indicator reading. Engine divided scales in black, overlaid with yellow, on alternate scales on white coated aluminum. Permanently accurate. Dia. 8 1/2 inches. Price—\$10.25 in case. Approved at leading Univ. Used by largest firms in U.S.

ATLAS SLIDE RULE—Precision Made

The "Atlas" slide rule solves problems in Multiplication, Division and Proportion. Gives results with a maximum error of less than 1 in 35,000. Has two "C" scales. One is 25" long and the other is a spiral of 25 coils. Equivalent to a straight rule 50 ft. long. Reads answers to 5 places. ACCURATELY CENTERED. Used in largest U.S. Laboratories. Chemists, Physicists and Engineers have found this rule invaluable for its great accuracy. Dia. 8 1/2", same construction as "Binary". Trig functions from 0 to 90 degrees on back. Price—\$13.50 in case.

MIDGET CIRCULAR SLIDE RULE

Similar to Binary. Has C, CI, A, LL and Binary scales. C scale is 12" long. Precision made, accurately centered, remains accurate. Trig functions on back, with indicator. 3/4 million sold. Price—\$4. in case. 4" dia. Same construction as above rules (no yellow). Descriptive Literature free. Satisfaction Guaranteed. Sold at Bookstores & Engineering Equipment Stores. Or, Order direct. INSTRUCTION BOOK FREE.

GILSON SLIDE RULE CO.

Box 1237 SA, Stuart, Fla.
Slide Rule Makers since 1915

SPACE POWER SCIENTISTS

Supervisory and specialist positions currently available at the Flight Propulsion Laboratory Dept. of General Electric exist for men with advanced degrees and abilities oriented toward demonstrating the feasibility of plasma acceleration and ion propulsion, in terms of hardware development.

Specific experience areas should include one or more of the following—magnetogas dynamics, electromagnetic accelerators, electrostatic acceleration, plasma generation, plasma heat transfer and flow, ultra-high vacuum, surface ionization, high temperature thermodynamics, high temperature nozzles.

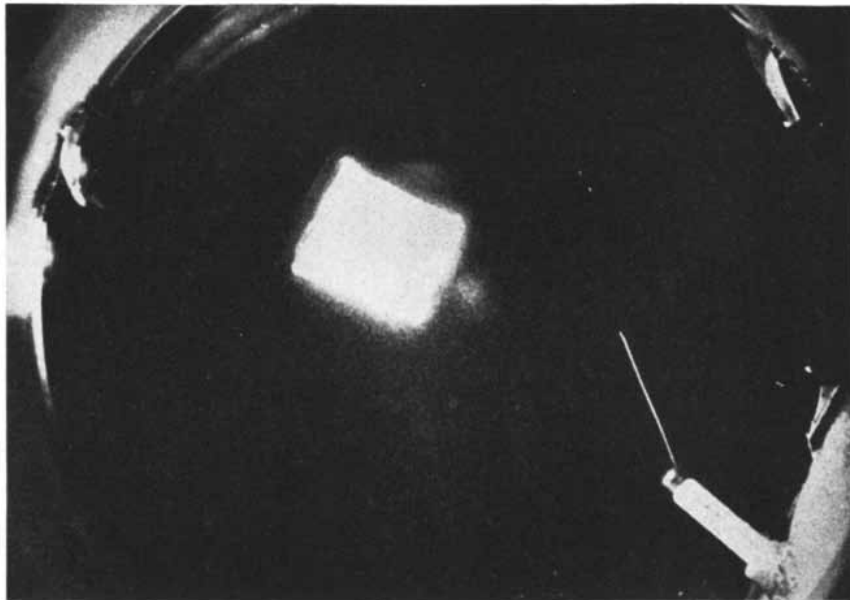
At your request, we should be happy to forward a reprint of a paper on the subject of ion propulsion by Mr. Edwards and Dr. Roschouch of the Laboratory staff. Presented at a recent A.S.M.E. meeting, the paper describes FPLD's ion rocket research model.

Please direct your inquiry
in confidence to Dr. Mark Peters,
Bldg. 100, Dept. 59-MF

FLIGHT PROPULSION DIVISION

GENERAL ELECTRIC

Cincinnati 15, Ohio



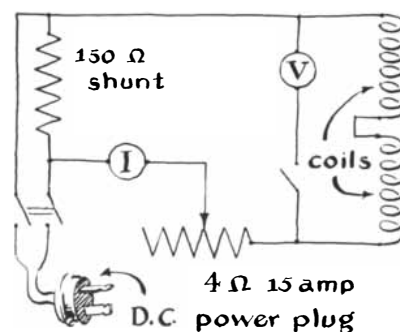
Vapor trail (lower right) of an alpha particle

frozen finger is quite as painful as a burned one. Alcohol is next added *slowly* to the ice. Violent bubbling may occur until the temperature of the container drops close to that of the ice. Additional ice may be added from time to time as required. Next saturate the pad with alcohol and pour about a tablespoonful of alcohol into the chamber. Place the assembly in the magnet and apply power to the coils.

"Some of the trails in the chamber will now be curved. If the upper pole of the magnet attracts the north end of a magnetic-compass needle (which indicates that the direction of the magnetic flux is from the lower to the upper pole), electrons will follow a counterclockwise path. Relatively light particles of low energy that carry a positive charge will curve clockwise. The direction in which some particles move can be determined by inspection. Energy expended in the creation of ions during flight causes the particle to lose speed; more time is thus available for the transfer of energy near the end of flight. The heavier ionization is seen as a thickening of the track. The direction of flight is known, of course, when particles originate in a radioactive material deliberately placed in the chamber. The identity of some particles can also be determined by inspection. Alpha rays make relatively short, thick tracks; electrons and protons, thin ones. Mesons are usually so energetic that their flight is not perceptibly affected by a field of 1,000 gauss. Consequently their tracks appear thin and straight.

"It is interesting to analyze photographs of tracks and to calculate the

speed, mass and energy of the responsible particles. The accompanying photograph [page 173], for example, shows the circular path of an electron ejected from a short stub of wire coated with radioactive material. Before the photograph was made, the current of the magnet was adjusted to generate a field strength at the chamber of 800 gauss. The momentum of the particle, expressed in units of 'magnetic rigidity,' is equal to the radius of its path multiplied by the field strength. The radius of this particular path is 3.09 centimeters. Thus the momentum of the particle is equal to 3.09×800 , or 2,472, gauss-centimeters. With this quantity known, the velocity of the particle can be learned by doing just a little more arithmetic. The quantity representing the magnetic rigidity is combined with the ratio of the electron's charge to its mass (1.7588×10^7 electromagnetic units per gram) and the velocity of light (3×10^{10} centimeters per second) according to the accompanying formula [see page 184]. In this



Circuit diagram for magnet coils

“To provide the necessary managerial guidance for command action required to insure an effective and technically compatible integrated air defense mission system...”

This is one of the functions of the MITRE Corporation. Its nucleus is a technical staff of scientists and engineers with established reputations in research, design, and development of large-scale, computer-based systems involving communications, radars, data processors, and weapons systems—operating in real-time.

Utilizing a multi-discipline approach, MITRE technical staff members develop these systems from design analysis through component selection or development, circuit design, prototype construction, and final environmental testing.

Within this system concept, engineers and scientists find a challenging environment in which to pursue independent research in:

- ADVANCED SYSTEMS ANALYSIS
- CIRCUIT DESIGN
- COMMUNICATIONS SYSTEMS
- DIGITAL COMPUTER SYSTEMS
- ENVIRONMENTAL TESTING
- INFRARED TECHNIQUES
- OPERATIONS RESEARCH
- SYSTEM DESIGN
- RADAR & RADAR DATA PROCESSING SYSTEMS
- ELECTRONIC COUNTER-COUNTERMEASURES

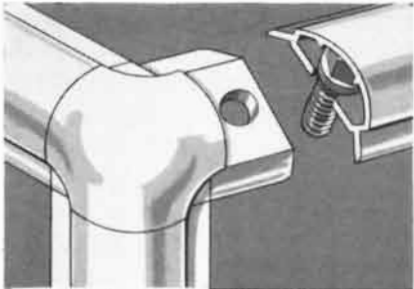
Conveniently located in suburban Boston, MITRE's modern research facilities include fully equipped electronics laboratories and two large-scale, high-speed digital computers—the IBM 704 and an experimental SAGE ANFSQ-7. These machines will soon be augmented by an IBM 7090 and a solid state SAGE computer.

The urgency of the MITRE task requires that our present staff nucleus be greatly expanded by highly qualified engineers and scientists anxious to add to their training and experience.

To arrange an immediate
confidential interview, please send resume to:
Dana N. Burdette, Personnel Director

THE
MITRE
CORPORATION

244 Wood Street — Lexington 73, Massachusetts



**FAST, SIMPLE,
ECONOMICAL
METHOD TO
CUSTOM BUILD
SCIENTIFIC
ENCLOSURES**

Widney DORLEC

*prefabricated cabinet
frame components
over 300 styles and
types in 3 radii*

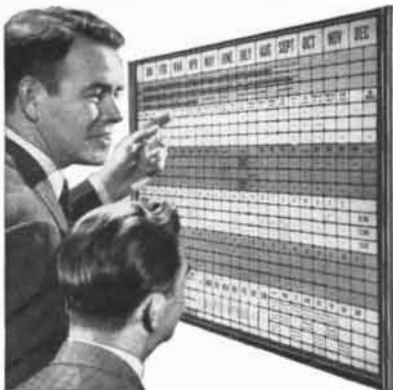


Design and assemble fully radiused cabinets to specific dimensions without machining. Prefabricated die cast duraluminum corners and extruded duraluminum sections. Unlimited versatility! Currently used by leading manufacturers and laboratories. The answer for any scientific, commercial or government application.



For literature, write Dept. YF429
BRITISH INDUSTRIES CORP.
Port Washington, L. I., N. Y.

How To Get Things Done Better And Faster



BOARDMASTER VISUAL CONTROL

- ☆ Gives Graphic Picture—Saves Time, Saves Money, Prevents Errors
- ☆ Simple to operate—Type or Write on Cards, Snap in Grooves
- ☆ Ideal for Production, Traffic, Inventory, Scheduling, Sales, Etc.
- ☆ Made of Metal. Compact and Attractive. Over 350,000 in Use

Full price **\$49.50** with cards

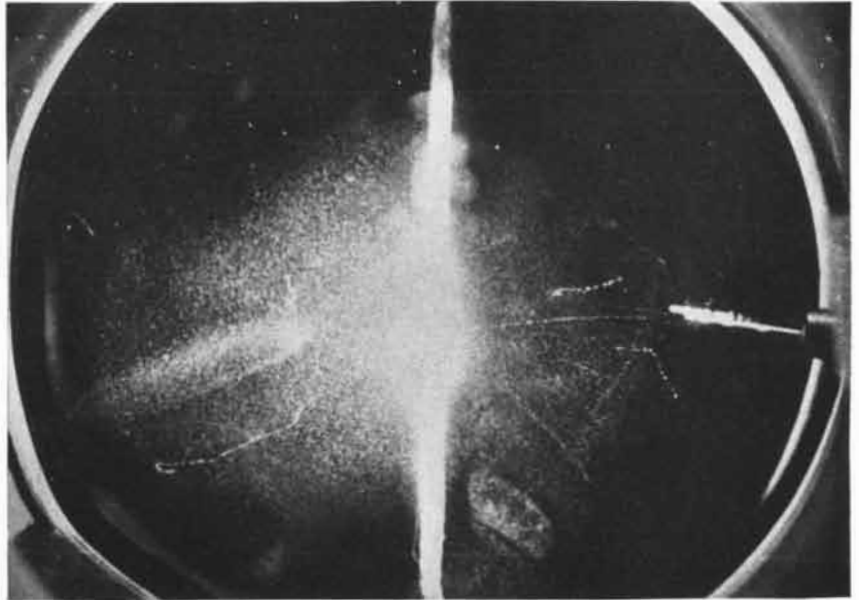
FREE

24-PAGE BOOKLET NO. C-400
Without Obligation

Write for Your Copy Today

GRAPHIC SYSTEMS

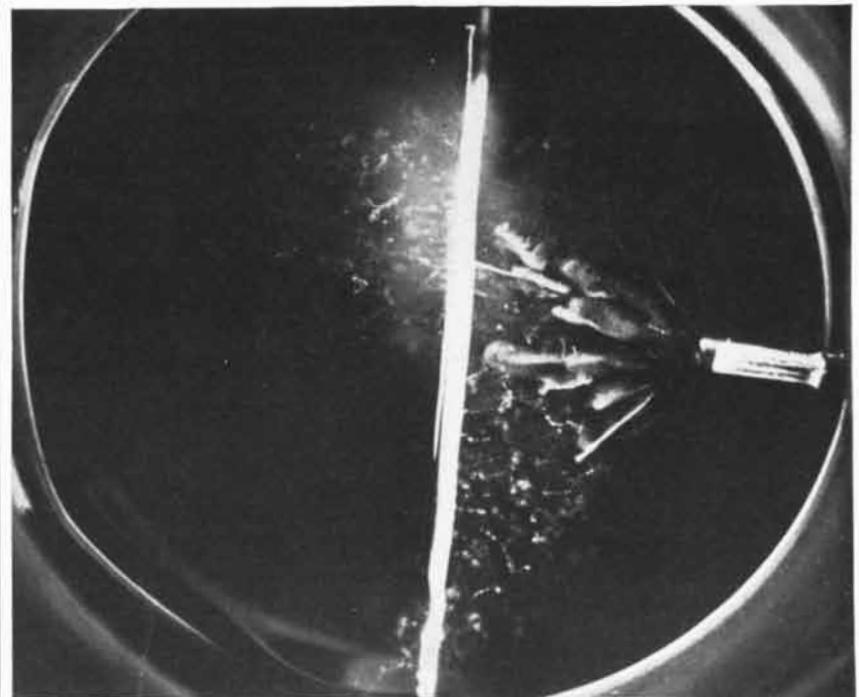
55 West 42nd Street • New York 36, N. Y.



Beta particles penetrate a wax barrier in the diffusion chamber

case the velocity turns out to be 2.47×10^{10} centimeters per second. This is equivalent to about 153,000 miles per second, or 82.4 per cent of the velocity of light. The energy of the particle is found (in millions of electron volts) by squaring the ratio of the velocity of the particle to that of light and inserting the result in the second formula. The energy of the electron in this example was .394 million electron volts.

“An interesting property of matter can be observed by calculating the velocity and energy of a substantial number of electrons and plotting the result as a graph [see illustration at top of page 178]. Note how the curve bends up sharply as the speed of the particle approaches the velocity of light. This is in accord with the theory of relativity, which states that matter gains mass with velocity, and that the mass becomes in-



Alpha particles (heavy trails) and electrons produced by X-rays leave tracks in chamber

RADIATION FUZING

final moment of proof in a missile system

There are hundreds of moments of proof in the lifespan of a missile system, but the final, and most dramatic, is that split-second when the radiation fuze fulfills the purpose of the mission. There may be no time for a "second shot".

The critical problems of high closing rates in air and space, of ground and submarine target discrimination and sensitivity, and of improved countermeasures in all areas, demand fuzing techniques which will not fail the technical integrity of the complete missile system. Such fuzes must be subminiaturized and ruggedized to provide absolute reliability and precision under re-entry and other extreme environmental conditions.

The Light Military Electronics Department has experience over a wide range of fuze projects such as mass production of mortar and bomb fuzes . . . COBRA and CORAL fuze development . . . a design

study for MAULER . . . advanced Infrared fuzes . . . and a dozen others. Analytical and Development engineering capabilities include:

MICROWAVE DEVICES * SCANNERS AND SEEKERS
OPTICS AND INFRARED TECHNIQUES
MOLECULAR AMPLIFIERS AND TECHNIQUES
TUBE AND TRANSISTOR CIRCUITRY
EXTREME ENVIRONMENT PRODUCT DESIGN
LOGIC CIRCUITRY * MAGNETIC DEVICES
SYSTEM ANALYSIS INCLUDING COUNTER-COUNTERMEASURES
EVALUATION

For brochure "RADIATION FUZING . . . Final Moment of Proof" or further information on any aspect of fuzing design and development, contact Manager - Missile Sales, Light Military Electronics Department . . . Dept. 11D.

LMED

GENERAL ELECTRIC

LIGHT MILITARY ELECTRONICS DEPARTMENT
FRENCH ROAD, UTICA, NEW YORK

A DEPARTMENT IN THE DEFENSE ELECTRONICS DIVISION

Send for free
illustrated brochure



**Get UNITRON's FREE
Observer's Guide and Catalog on
ASTRONOMICAL TELESCOPES**

**This valuable 38-page book
is yours for the asking!**

With artificial satellites already launched and space travel almost a reality, astronomy has become today's fastest growing hobby. Exploring the skies with a telescope is a relaxing diversion for father and son alike. UNITRON's handbook contains full-page illustrated articles on astronomy, observing, telescopes and accessories. It is of interest to both beginners and advanced amateurs.

Contents include—

- Observing the sun, moon, planets and wonders of the sky
- Constellation map
- Hints for observers
- Glossary of telescope terms
- How to choose a telescope
- Amateur clubs and research programs



UNITRON
INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
204-206 MILK STREET • BOSTON 9, MASS.

Please rush to me, free of charge, UNITRON's new Observer's Guide and Telescope Catalog 6-R

Name _____
Street _____
City _____ State _____

"BIG" LENSES

Our selection of diameters and focal lengths is the largest in the United States available for immediate delivery. Perfect magnesium fluoride coated and cemented achromatic telescope objectives. Aluminum tubing and cells available for lenses listed below. Send for complete list of other diameters and focal lengths.

We can supply ALUMINUM TUBING for the above lenses.

MOUNTED AIR SPACED OBJECTIVES

The finest American Made, hand-corrected air-spaced astronomical objectives; mounted in black anodized aluminum cells.

DIA.	F.L.	PRICE	PRICE
3 1/4"	48"	Coated \$32.00	Not Coated \$28.00
4 1/2"	62"	Coated \$69.00	Not Coated \$60.00

**6" DIA. AIR SPACED
ASTRONOMICAL
TELESCOPE OBJECTIVE**

Hard coated on 4 surfaces
f/10—60" focal length MOUNTED \$175.00
UNMOUNTED \$150.00
f/15—90" focal length MOUNTED \$175.00
UNMOUNTED \$150.00

The effective aperture of the above lenses is six inches. The black anodized aluminum mount fits into seven inch dia. aluminum tubing.

8 POWER ELBOW TELESCOPE 8x50

This M-17 telescope has a brilliant image 48 degree apparent field—325 feet at 1,000 yards. The telescope can be adjusted for focusing 15 feet to infinity. It has a 2" objective, focusing eyepiece 28mm focal length with an Amici erecting system. Turret mounted filters, clear, red, amber and neutral. Lamp housing to illuminate reticle for night-time use. Truly the biggest bargain you were ever offered. Original Government cost \$200. BARGAIN PRICE...\$13.50 Ppd.



ASTRONOMICAL TELESCOPE MIRRORS

Precision polished to 1/4 wave and aluminized. Mirror mount, rack and pinion, tubing available.

Dia.	F.L.	Postpaid
3 1/4"	42"	\$ 9.75
4 1/4"	45"	\$13.50
6"	60"	\$25.00

Free Catalogue "MILLIONS" of Lenses, etc.
We pay the POSTAGE—C.O.D.'s you pay postage—Satisfaction guaranteed or money refunded if returned within 10 days.



finite at the speed of light. This means that the kinetic energy of a particle, however small it may be, must also increase without limit as it approaches the speed of light, because kinetic energy is the product of mass and velocity.

"A similar graph can be drawn to show how the particle acquires mass with velocity. The mass of the electron at rest is known (it is 9.1×10^{-28} gram), and its velocity can be measured by means of the diffusion chamber. To find its mass at any velocity these values are inserted in Einstein's equation for relativistic mass [third formula on this page]. The rest is simple arithmetic.

"The curvature of alpha particles is difficult to detect with this apparatus because a magnetic field of 1,000 gauss exerts little influence on their relatively large mass (about 8,000 times that of the electron). The energy of alpha particles can be found by analysis of the tracks, however, because the length of the tracks depends on the rate at which the particles expend energy in ionizing atoms. Curves showing this relationship have been constructed from data acquired by observing numerous alpha-decay processes [see illustration at bottom of page 178]. To find the energy of an alpha particle, measure the length of its track in centimeters and refer to the curves. Care must be taken to enlarge the photographs accurately to full scale; errors in enlargement are preserved in the results.

"The classical formula for computing kinetic energy ($Ke = 1/2 m v^2$) may be used for computing the energy of alpha particles because their velocity is so low that the relativistic mass effect may be neglected. This formula expresses energy in terms of ergs. To convert ergs into electron volts multiply by 6.25×10^{11} . The length of the alpha track depicted in the second photograph [top of page 180] is 3.1 centimeters, which according to the graph corresponds to an energy of 4.65 mev. From this value the formula for velocity gives a speed of 1.496×10^9 centimeters per second, or about 9,000 miles per second.

"The diffusion chamber invites numerous other interesting experiments. Air can be replaced by other gases, for example. In general it will be found that the quality of the tracks drops in proportion as the molecular weight of the gas falls below that of the vapor. The accompanying photograph of a beta track [page 173] was made in an atmosphere of oxygen.

"Gamma rays and X-rays dislodge electrons throughout the gas; the resulting tracks are characteristically erratic

[see illustration at bottom of page 182]. In this case a particle source was included and appears at the right side of the picture together with a pattern of alpha tracks. The white strip across the center was made by a wax barrier, inserted to determine whether electrons could penetrate it. The broad, irregular masses in the vicinity of the alpha particles are wisps of cloud representing old tracks. These could have been cleared away by momentarily connecting a potential of from 45 to 90 volts across the electrodes of the chamber."

$$v_e = Hr \frac{e}{m_o} \sqrt{\frac{c^2 - v^2}{c^2}}$$

where:
 v_e = velocity of electron in centimeters per second
 Hr = magnetic rigidity in gauss-centimeters
 $\frac{e}{m_o}$ = ratio of electron's charge to mass (1.7588×10^7)
 c = velocity of light (3×10^{10} cm per sec)

$$T = 0.511 \left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} - 1 \right)$$

where:
 T = kinetic energy in millions of electron volts (with other quantities as previously defined)

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where:
 m = increased mass of particle in grams
 m_o = rest mass of particle (with other quantities as previously defined)

$$v_\alpha = \sqrt{\frac{2K}{m_o}}$$

where:
 v_α = velocity of alpha particle
 K = kinetic energy of alpha particle
 m_o = rest mass of alpha particle

Formulae to Determine Nature of Particles

BEYOND THE RIM



Today mankind is embarked on the most exciting voyage of discovery since Columbus sailed beyond the rim of the known world.

In a physical sense, it is a voyage that ranges from investigation of the infinitesimal components of matter to exploration of the vastness of the cosmos.

But at Sandia Laboratory it is a voyage of the mind—a voyage beyond the rim of our present comprehensions, to unlimited destinations.

At our laboratories in Albuquerque, N. M. and Livermore, California, we perform research and development pertaining to nuclear weapons and certain allied non-military projects for the Atomic Energy Commission. We need men with the knowledge, the experience, and the desire to venture beyond the rim in many fields of science and engineering. At present, we have challenging opportunities in these specific fields:

PHYSICS and MATHEMATICS—Scientists at PhD level for both fundamental and applied research. Both physicists and mathematicians are needed at our Albuquerque location, mathematicians only at Livermore.

EXPLOSIVES CHEMISTRY—Chemists or chemical engineers with advanced degrees and extensive experience in this field, at both Albuquerque and Livermore.

STATISTICS—Experienced statisticians with MS or PhD degrees and interest in statistical methods and quality control, particularly in statistical design of experiments. Required at Albuquerque only.

QUALITY CONTROL—Industrial, mechanical, and electrical engineers with experience in quality control methods development and training assignments, at Albuquerque only.

STRESS ANALYSIS—Experienced mechanical or aeronautical engineers, preferably with advanced degrees, at both Albuquerque and Livermore.

HUMAN ENGINEERING—Experienced personnel with advanced degrees in psychology plus engineering degrees, at Albuquerque only.

HEAT TRANSFER—Aeronautical or mechanical engineers with MS or PhD degrees for analytical and experimental research and development in

aerodynamic heating and heat transfer problems, at Albuquerque only.

ELECTRICAL or MECHANICAL ENGINEERING—experienced personnel with BS or MS degrees, at both Albuquerque and Livermore.

Sandia Laboratory offers many advanced and specialized facilities to further work of its scientists and engineers. Liberal employee benefits, including generous vacations and holidays, insurance and retirement plans, educational aid program, add to Sandia's attractiveness as a place to work. Albuquerque, a city of over 225,000 with a mild, dry climate and friendly Southwestern atmosphere, is a delightful place in which to live. Livermore, located in the San Francisco Bay area, offers suburban advantages close to metropolitan San Francisco.

IF YOU ARE INTERESTED in a career at Sandia, our illustrated brochure will tell you more about the opportunities we offer to advanced scientists and engineers. Write to Employment Section 569E at either Albuquerque, N. M., or Livermore, California.



7 ways to satisfy a scientific curiosity



Illustration:
Bohr's Radium
Atom

INSIDE THE LIVING CELL
Some Secrets of Life
By J. A. V. Butler

The noted British biochemist presents a lucid account of the makeup of cells, the marvelous mechanisms by which they function, and their manifold forms and roles in the living body. A brilliant discussion, aided by 44 illustrations, of man's progress toward understanding fundamental processes of his own nature and of life itself. **\$3.50**

CAN MAN BE MODIFIED?
By Jean Rostand

Can man, through science, raise himself to a species of superman? This breathtaking book by the distinguished French biologist synthesizes the advances of modern science toward controlling the heredity, chemistry, intelligence and even emotions of organisms, and speculates authoritatively on man's biological future. **\$3.00**

ELEPHANTS

By Richard Carrington

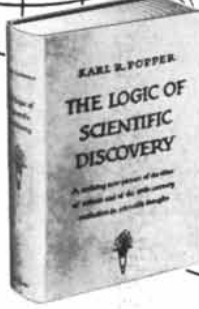
The complete story of the evolution, anatomy, temperament, habits and extraordinary personality of the great behemoth which has figured prominently in mythology, religion, literature, art, commerce and entertainment. An engagingly written book by the well-known naturalist and author of *A Guide to Earth History*. 81 illustrations. **\$5.00**

SIGMUND FREUD COLLECTED PAPERS

Edited by Anna Freud, Ernest Jones and James Strachey. Five Volumes, Boxed. Published for the first time in America—117 papers by the founder of psychoanalysis, offering his views on a fascinating range of subjects from sex to war, from religion to poetry. The authorized translation. *The set \$25.00. Special pre-publication offer extended* **\$19.95**

SOVIET SPACE SCIENCE

By Ari Shternfeld
Just published, this comprehensive new account of Russian theoretical and practical progress in the field of astronautics is written by a leading Soviet space scientist and now appears in English in the official U.S. Air Force translation. "Singularly free of propaganda... One of the best surveys of astronautics published in any country." *Willie Ley* **\$6.00**



Through your bookseller, or order direct from

Basic Books, Publishers
59 Fourth Avenue, New York 3, N. Y.

P-51

Please send me the books checked below for free examination. Within 7 days I will send you full payment, plus postage, or I will return them and owe nothing.

- Elephants, \$5.00
- Existence, \$7.50
- Inside The Living Cell, \$3.50
- Sigmund Freud—Collected Papers, \$19.95
- Logic of Scientific Discovery, \$7.50
- Soviet Space Science, \$6.00
- Can Man Be Modified?, \$3.00

Name.....

Address.....

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

SAVE POSTAGE! Check here if you are enclosing payment now and we will pay postage. Same return privilege guaranteed.

THE LOGIC OF SCIENTIFIC DISCOVERY

By Karl R. Popper

For the first time in English—a striking picture of the logical character of scientific discovery by the scholar who, according to the *Manchester Guardian*, has "introduced a greater number of important ideas into the philosophy of science than any other living philosopher." Translation by Dr. Popper himself. **\$7.50**

EXISTENCE

Ed. by Rollo May, Ernest Angel and H. F. Ellenberger

The first inclusive statement for American readers of the concepts and practice of Existential Analysis—presenting writings of Binswanger, Kuhn, Minkowski and Straus, the leading exponents of this new European approach to psychotherapy. "This book opens up a new dimension... the ultimate question of man's nature and the whole of his reality." *Paul Tillich* **\$7.50**

BASIC BOOKS PUBLISHERS



BOOKS

Koestler on Kepler and the history of man's picture of the universe

by I. Bernard Cohen

THE SLEEPWALKERS: A HISTORY OF MAN'S CHANGING VIEW OF THE UNIVERSE, by Arthur Koestler. The Macmillan Company (\$6.50).

In the index to the 600-odd pages of Arnold Toynbee's *A Study of History*, abridged version, the names of Copernicus, Galileo, Descartes and Newton do not occur." These words, with which the preface of *The Sleepwalkers* begins, exemplify both the tone and the purpose of Arthur Koestler's new book. He is concerned with "the gulf that still separates the Humanities from the Philosophy of Nature." Koestler prefers the latter expression to "Science," because it carries with it the "rich and universal associations" of the 17th century, the "days when Kepler wrote his *Harmony of the World* and Galileo his *Message from the Stars*." In fact, the greater part of Koestler's book deals with the 17th century, the age known now for the "Scientific Revolution" but then for the "New Philosophy," which had as its aim not a revolution in technology but the "understanding of nature." Koestler regards the 17th century nostalgically as an age that still had a place in it for the universal man, and that had not seen either the present fragmentation of knowledge or the erection of "academic and social barriers" between the "Sciences" and the "Humanities."

One result of this "cold war," according to Koestler, is that there exist histories of the sciences but "no comprehensive survey of man's changing vision of the universe which encloses him," a deficiency that Koestler believes his own efforts to have remedied. He has not written "a history of astronomy, though astronomy comes in where it is needed to bring the vision into sharper focus; and, though aimed at the general reader, it is not a book of 'popular science' but a personal and speculative account of a controversial subject."

Koestler asks the reader to keep in mind that despite the time limit he has imposed—to begin with the Babylonians and to end with Newton—the subject was still so vast that to keep it "within manageable limits" he "could attempt only an outline." The result is thus "sketchy in parts, detailed in others, because selection and emphasis of the material was guided by my interest in certain specific questions, which are the *leitmotifs* of the book." These are two in number. First there are "the twin threads of Science and Religion, starting with the undistinguishable unity of the mystic and the savant in the Pythagorean Brotherhood." These threads run through history together, "falling apart and reuniting again, now tied up in knots, now running on parallel courses, and ending in the polite and deadly 'divided house of faith and reason' of our day." Koestler believes that a "study of the evolution of cosmic awareness in the past may help to find out whether a new departure is at least conceivable, and on what lines." Such a statement strongly suggests, as the text confirms, that what Koestler objects to is not merely the fragmentation of science but fragmented science itself, which has failed to achieve for man the goals that the 17th-century natural philosophers held to be the fruits of their inquiries.

The second *leitmotif* is the "psychological process of discovery," which Koestler conceives "as the most concise manifestation of man's creative faculty." He is equally concerned with "that converse process" which blinds man "towards truths which, once perceived by a seer, become so heartbreakingly obvious." Koestler calls this negative aspect of discovery a "blackout shutter" and observes its presence in scientific men of the highest genius: Aristotle, Ptolemy, Galileo, Kepler. It is suggested that a study of the greatest scientific men of the past shows that "while part of their spirit was asking for more light, another part had been crying out for more darkness." Koestler believes that to understand science one must be concerned with the character and personality of

scientists, since "all cosmological systems . . . reflect the unconscious prejudices, the philosophical or even the political bias of their authors." Whether the subject be physics or physiology, "no branch of Science, ancient or modern, can boast freedom from metaphysical bias of one kind or another." This is Koestler's explanation for the fact that the evolution of science follows a bewildering series of zigzags rather than a simple and logical linear progression. And so we are led to Koestler's main theme: "The history of cosmic theories, in particular, may without exaggeration be called a history of collective obsessions and controlled schizophrenias; and the manner in which some of the most important individual discoveries were arrived at reminds one more of a sleepwalker's performance than an electronic brain's."

That it should be Arthur Koestler who has chosen this particular assignment may be an occasion for some surprise. His reputation, at least in this country, was made by the novel *Darkness at Noon*, in which he explored the psychological reasons for the confessions of old-line Bolsheviks in the Russian trials of the 1930s. Five years ago, however, Koestler decided to give up political matters for science. This decision was not quite as odd as it might seem; in pre-Hitler Germany Koestler had been science editor of the Ullstein chain of newspapers, and he had started his career as a science student in Vienna.

That his present writing on science should concentrate so much on the psychological aspects of scientific discovery is in keeping with Koestler's psychological approach to political problems. His *Insight and Outlook* dealt with questions similar in meaning but not in kind to those considered in *The Sleepwalkers*. His portrayal of conflicting attitudes in *The Yogi and the Commissar* may help to prepare the reader for his present reflections on the mysticism of the early cosmologists, as opposed to the hard-boiled positivism of modern science.

It will be apparent to anyone who picks up this book that Koestler has done

a solid job of research. He provides a wealth of quotations from original source-material and buttresses them with references to some of the major results of historical scholarship. The very bulk of the book may deter some readers; it should be said at once that the narrative is fascinating and the style engaging and urbane. The author's personal prejudices and predilections will variously delight, enrage, stimulate, repel, attract, astound and titivate the scientist, the historian and the general reader. The book is stuffed with all kinds of recon-dite information about the lives of the early scientists and their contributions to the science of the universe. At the same time Koestler propagates old errors and adds new ones of his own; in general he presents a highly biased and/or inaccurate view of the nature and growth of science, and a distorted account of some of the major episodes in the history of astronomy.

Koestler is most successful in his discussion of Johannes Kepler, to whom about half *The Sleepwalkers* is devoted. One almost has the feeling that what began as a biography of Kepler ended up as a history of cosmology only by virtue of having Copernicus, Tycho Brahe and Galileo appear so that Kepler might be made a more sympathetic figure; and that a wholly inadequate account of ancient and medieval cosmology was added only to point up the originality of Kepler's contributions. Koestler claims that his own scholarly contribution lies mainly in the sections dealing with Kepler, "whose works, diaries and correspondence have so far not been accessible to the English reader; nor does a serious English biography exist." This is true, and it may be added that the only two major studies of Kepler's astronomy are all but inaccessible even to scientists and historians. Indeed, they were not consulted by Koestler.

Kepler makes an ideal subject for Koestler. Because one of Kepler's main concerns was the influence of the stars on the lives of men, he kept meticulous records of both the great and the minute events of his own life. How many biographers could begin, as Koestler does: "Johannes Kepler, Keppler, Khepler, Kheppler or Keplerus was conceived on 16 May, A.D. 1571, at 4:37 a.m., and was born on 27 December at 2:30 p.m., after a pregnancy lasting 224 days, 9 hours and 53 minutes. The five different ways of spelling his name are all his own, and so are the figures relating to conception, pregnancy and birth, recorded in a horoscope which he cast for himself." Koestler remarks: "The contrast between

his carelessness about his name and his extreme precision about dates reflects, from the very outset, a mind to whom all ultimate reality, the essence of religion, of truth and beauty, was contained in the language of numbers."

Guided by Kepler's self-portrait, Koestler sketches for us the early years and education of a man who described himself as "born destined to spend much time on difficult tasks from which others shrunk." Quite early he became a Copernican, at a time when very few scientists had read that author's difficult exposition of a sun-centered system of the universe. But Kepler began his career more as an astrologer than a defender of Copernicus. His first job as teacher was marked by a prediction: From the stars he foresaw a very cold winter and an invasion by the Turks! Luckily for him he proved to be right about both. Although he knew that much of astrology was quackery, he remained convinced to his death that the stars and planets determine the fate of man.

Soon Kepler produced his first major work, the full title of which is: *A Fore-runner to Cosmological Treatises, containing the Cosmic Mystery of the admirable proportions between the Heavenly Orbits and the true and proper reasons for their Numbers, Magnitudes, and Periodic Motions*. Kepler believed he had discovered why there are only six planets, and why they are placed as they are in the Copernican system. This discovery he considered to be a divine revelation, he being only the instrument directed by God's will and plan. Kepler's discovery relates numbers and geometry: six planets and five regular solids. He conceived that within the sphere containing Saturn's orbit there is inscribed a cube, within which is inscribed another sphere containing the orbit of Jupiter. Within the sphere of Jupiter is a tetrahedron containing the sphere of Mars; within the sphere of Mars is a dodecahedron containing the sphere of the earth; within the sphere of the earth is an icosahedron containing the sphere of Venus; within the sphere of Venus is an octahedron containing the sphere of Mercury. Given a certain thickness for the surface of each sphere, the distances in fact come out right. For the young Copernican, steeped in the Pythagorean ideal and convinced that everywhere in nature there are harmonies of number and shape, it was a significant stroke. To the end of his life Kepler considered it a more important discovery than the celebrated laws that bear his name.

It was Kepler's good fortune (he held

it to be an act of divine Providence) that his book brought his skills in computation to the attention of Tycho Brahe. This Danish astronomer (for some reason Koestler insists on Frenchifying his name to "Tycho de Brahe") had reformed astronomy by making continuous rather than occasional observations of the planets, and by creating new instruments that made it possible to determine the planetary positions within less than eight minutes of arc. To appreciate what this figure means, one must recall that Copernicus had said that if he could ever predict the planetary positions within 10 minutes of arc, he would be as happy as Pythagoras was when he discovered his theorem. To Tycho, whose reforms made an exact science of astronomy, whose system of the world briefly became a rival of Ptolemy's and Copernicus's, and whose observations provided Kepler with the materials for his own deep discoveries, Koestler devotes an unilluminating pair of short chapters.

Using Tycho's observations of Mars, Kepler found his first two laws; these he published in his *New Astronomy*, which he described as "a physics of the sky, derived from investigations of the motions of the star Mars." Kepler's first law states that the planets move around the sun in elliptical orbits, one focus of the ellipse being occupied by the sun. His second law states that along this orbit each planet moves in such a manner that a line drawn from the sun to the planet sweeps out equal areas in equal times. Our modern assignment of the words "first" and "second" here suggests a logical progression: Is it not obvious that to determine the speed with which a planet moves along its orbit, and to compute the area swept out by a line drawn from sun to planet, there must be a prior determination of the shape of the orbit? But it is just this point that provides Koestler with a chief illustration of his central thesis. For the fact of the matter is that in this instance (though it is not unique in the development of science) the logical order of the discovery is just the reverse of the chronological order.

Kepler's *New Astronomy* gives us almost every stage in the development of his ideas—even calculations based on suppositions he later knew to be false. To the exhausted reader he says (in Chapter 16): "If thou art bored with this wearisome method of calculation, take pity on me who had to go through at least seventy repetitions of it, at a very great loss of time." By Chapter 19 he is at last willing to give up all the variations he had introduced into older

hypotheses, and to approach his "goal according to my own ideas"; at last the reader could proceed to Kepler's own hypotheses. But 13 chapters later Kepler is still showing the consequences of physical assumptions, chiefly that some kind of *anima motrix* emanates from the sun, diminishes according to the inverse proportion of the distance and is active only in the plane of the planet's motion. In this way Kepler found the "second" law, knowing it was based on errors which he said "like a miracle . . . cancel out in the most precise manner." On this score Koestler remarks: "The correct result is even more miraculous than Kepler realized, for his explanation of the reasons *why* his errors cancel out was once again mistaken, and he got, in fact, so hopelessly confused that the argument is practically impossible to follow—as he himself admitted. And yet, by three incorrect steps and their even more incorrect defense, Kepler stumbled on the correct law. It is perhaps the most amazing sleepwalking performance in the history of science—except for the manner in which he found his First Law." In the course of this new adventure Kepler turned to an egg-shaped planetary orbit and repudiated the previously announced second law; he said that he regretted that the orbit was not "a perfect ellipse [for then] all the answers could be found in Archimedes's and Apollonius's work." Then by chance he suddenly found a clue to the fact that the orbit was indeed elliptical. He tells us: "I felt as if I had been awakened from a sleep." But search as he might ("until I went nearly mad"), he could never find "a reason why the planet preferred an elliptical orbit."

From antiquity up to the time of Kepler's book everyone was agreed that planetary motions were either circles or some combination of circles. No one was able to understand why a planet should move along an ellipse until Newton showed that this orbit was a consequence of a central force of gravitation dependent on the inverse square of the distance. It is not surprising that Kepler's contemporaries (including Galileo) never accepted elliptical orbits, if indeed they had ever heard of them. Koestler cannot forgive Galileo his treatment of Kepler. "In his works," says Koestler, Galileo "rarely mentions Kepler's name, and mostly with intent to refute him. Kepler's three Laws, his discoveries in optics, and the Keplerian telescope, are ignored by Galileo, who firmly defended to the end of his life circles and epicycles as the only conceivable form of heavenly motion." This statement is re-



LINCOLN LABORATORY

continues to augment its staff.

We invite inquiries from persons
with superior qualifications.

A brochure is available which is

generally descriptive of

Lincoln Laboratory programs

in the following areas:

AICBM SYSTEMS STUDIES

NEW RADAR TECHNIQUES

RADIO PHYSICS

SOLID STATE Physics, Chemistry, and Metallurgy

COMMUNICATIONS:

Techniques

Psychology

Theory

**INFORMATION PROCESSING,
DIGITAL COMPUTER TECHNOLOGY**

Research and Development

M. I. T. LINCOLN LABORATORY

BOX 18

LEXINGTON 73, MASSACHUSETTS



Causality

THE PLACE OF THE
CAUSAL PRINCIPLE
IN MODERN SCIENCE

By **MARIO BUNGE**. This searching essay on determinism places special emphasis on causal determinism — causality — and shows how the causal principle actually works in various departments of modern science. The analysis shows that the causal principle is neither a panacea nor a superstition, but a philosophical hypothesis employed in science (in competition with other principles of determinism) that is essentially critical and self-correcting. 39 line cuts. \$7.50

Theoretical Elasticity

By **CARL E. PEARSON**. A compact and complete discussion and summary of modern theoretical results and methods in elasticity — presented in a form which does not require extensive mathematical experience, including a particularly thorough treatment of thermoelasticity, elastic wave motion, and non-linear elasticity. \$6.00

The Common Sense of Science

By **J. BRONOWSKI**. "Bronowski, who is an able mathematician, an imaginative director of practical research, a gifted man of letters . . . is uncommonly well equipped to treat the broad theme of his essay, to give it unity and clarity."
—*Scientific American* \$2.00

Learning and Instinct in Animals

By **W. H. THORPE**. "The factual information which this book brings together, and the syntheses which it attempts, make it required reading for anyone interested in the problem of learning." —*Quarterly Review of Biology* \$10.00

Ask your bookseller



HARVARD
UNIVERSITY PRESS
Cambridge 38, Mass.

peated a number of times with variations. Yet according to Koestler's own presentation even to find the first two laws within Kepler's *New Astronomy* is a heroic exercise. Moreover, the reader who has found them will quickly discover that they are based on false and untenable assumptions. Koestler writes: "The ellipse had nothing to recommend it in the eyes of God and man; Kepler betrayed his bad conscience when he compared it to a cartload of dung which he had to bring into the system as a price for ridding it of a vaster amount of dung. The Second Law he regarded as a mere calculating device, and constantly repudiated it in favour of a faulty approximation; the Third as a necessary link in the system of harmonies, and nothing more." If this is so, it is hardly surprising that Galileo did not accept Kepler's laws, even if he had succeeded in finding them within Kepler's prolix and confused presentation.

Koestler emphasizes the fact that Kepler was the first man to base astronomy on physics, even that he was the first man to make astronomy a causal physical science. But Koestler denies the reader equal insight into the relationship between Galileo's Copernican astronomy and Galileo's new science of dynamics. So the link between the work of Kepler and Galileo on the one hand and of Newton on the other is only half-presented. Koestler altogether gives Galileo a hard time. Kepler is "disarming"; according to Koestler, no one who met him "in the flesh or by correspondence could seriously dislike him." Galileo, in contrast, is characterized by "arrogance minus humility"; he is a man held in "aversion"; he is "ambiguous" and "subtle"; he confounds "freedom of thought" with "sophistry, evasion, and plain dishonesty." Galileo is condemned by Koestler on the ground that at the age of 70 he was frightened in the prison of the Inquisition, from which he was released (according to a report of the time) "more dead than alive." Koestler ascribes Galileo's "panic" to "psychological causes." Says Koestler: "It was the unavoidable reaction of one who thought himself capable of outwitting all and making a fool of the Pope himself, on suddenly discovering that he has been 'found out.'" But there is no reason whatever to believe that Galileo intended to make a fool of the Pope. I would submit that Galileo's panic (if he felt it at all) in a prison with that particular history needs no "psychological" explanation. That Koestler, who so sensitively described the thoughts of the prisoner Rubashov in *Darkness at Noon*, should

find it necessary to invoke such an explanation is rather odd.

Why is it that Koestler can find no sympathy for Galileo, even in the trial room of the Inquisition? Koestler writes that although he has from early childhood retained "vivid impressions" of the "wholesale roasting alive of heretics by the Spanish Inquisition" (which is neither relevant nor exactly true), he finds "the personality of Galileo equally unattractive, mainly on the grounds of his behaviour towards Kepler." This absurd bias makes a travesty of the concluding portion of Koestler's book by forcing him to ignore or to belittle Galileo's profound contribution to physics and astronomy. All this because Galileo did not immediately answer Kepler's letters or accept his laws! Furthermore, Koestler makes it plain that his bias is not based "on affection for either party in the conflict" between Galileo and the Roman Church, but on his own personal "resentment that the conflict did occur at all." For Koestler the conflict was only in the nature of "a clash of individual temperaments," and not "a fatal collision between opposite philosophies of existence." Because of his belief in the "unitary source of the mystical and scientific modes of experience" and "the disastrous results of their separation," Koestler treats Galileo as the villain of his book.

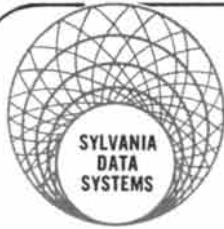
The presentation of Copernicus is equally unsympathetic; the section devoted to his work is entitled "The Timid Canon." Koestler calls him "a stuffy pedant," lacking "the sleepwalking intuition of the original genius." Having "got hold of a good idea," Copernicus "expanded it into a bad system." I find myself wondering how different Koestler's book might have been if he had brought to bear on Copernicus the insight with which he portrayed the old Bolshevik Rubashov. Surely the reader would have been fascinated and rewarded by a thoughtful consideration of the mind of a man who stood at the threshold of the world of modern science and yet was not free of the shackles of his medieval heritage, who presented a new system of the world and yet knew that there was no physics to account for it.

Since Koestler presents Copernicus without understanding, it is hardly surprising that his account of the pre-Copernican period is a collection of platitudes. Indeed, he almost completely ignores astronomical and cosmological thought from Ptolemy to Copernicus, which has been considerably illuminated by recent scholarship. Because he finds Ptolemy "profoundly distasteful," Ptolemy's conceptions are reduced to "the

work of a pedant with much patience and little originality, doggedly piling 'orb in orb.' A handful of pages contemptuously dismiss the greatest achievement of ancient astronomy because of what is held to be an unforgivable failure to adopt the heliocentric system proposed by Aristarchus, a position in which Koestler finds it necessary to ignore the fact that Aristarchus's heliocentric astronomy was never worked out by its author but was only a suggestion whose implications were never—and could not possibly have been—realized. To go back farther in time, Koestler's presentation of the world of the Babylonians and the Egyptians reads as if it had been written decades ago, before serious investigation had made any dent in our ignorance of their respective astronomical systems. One must conclude that any statement in the book that does not refer to Kepler's life or writing must be taken with a grain of salt.

Koestler's epilogue contains the moral of his tale. It requires the whole salt-cellar. He declares that the divorce of science from religion—the freeing of science from its "mystical ballast"—enabled it to "sail ahead at breathtaking speed to its conquest of new lands beyond every dream." The price paid for this rapid advance was that "it carried the species to the brink of physical self-destruction, and into an equally unprecedented spiritual impasse. Sailing without ballast, reality gradually dissolved between the physicist's hands; matter itself evaporated from the materialist's universe." This evil is imputed in the first instance to the villain of the book, Galileo, because it was he who "banished the qualities which are the very essence of the sensual world—colour and sound, heat, odour, and taste—from the realm of physics to that of subjective illusion." In the end the very "hard atoms of matter" have gone "up in fireworks; the concepts of substance, force, of effects determined by causes, and ultimately the very framework of space and time turned out to be as illusory as the 'tastes, odours and colours' which Galileo had treated so contemptuously." Says Koestler: "Compared to the modern physicist's picture of the world, the Ptolemaic universe of epicycles and crystal spheres was a model of sanity."

Koestler tries to make out that 20th-century physics is just like the pre-Keplerian cosmology. The fact that quantum mechanics works is for him irrelevant; it reminds him only of "Urban VIII's famous argument which Galileo treated with scorn: that a hypothesis which works must not necessarily have any-



SECOND IN A SERIES

The Role of Mathematics in the Security of Nations...

A Problem that is challenging creative minds at Sylvania's Data Systems Operations

Throughout the pages of recorded history, mathematics has guarded man against the forces of nature and human enemies. For example, one of the earliest applications of applied mathematics was the nilometer used by the priests of ancient



Egypt to record the rising waters of the Nile. This simple device warned the populace of devastating floods. 5,500 years later mathematics still stands between man and destruction from a far graver danger—enemy ICBMs.

At Sylvania's Data Systems Operations, advanced research and development programs are under way to expand use of this common language of science and thereby extend man's capabilities across broad technological areas. Indica-

tive of the significant programs now under way are the data processing phase of BMEWS, the USAF's Ballistic Missile Early Warning System, and MOBIDIC, first large-scale, mobile digital computer designed and developed for the U. S. Army Signal Corps.

Sylvania's interest is in senior men of extremely high professional capabilities, who have the initiative to formulate their own research approaches and provide

the leadership required to make major advances in computer programming. These men should have a minimum of 5 years' experience, possess an advanced degree (PhD preferred), and be able to project their thinking beyond present technological constrictions. There are immediate positions for:

- SENIOR MATHEMATICIAN
- SENIOR COMPUTER PROGRAMMER—Real-Time Systems
- SENIOR COMPUTER PROGRAMMER—Research

Please send resume to J. B. Dewing

DATA SYSTEMS OPERATIONS



189 B Street — Needham 94, Massachusetts

OXFORD
Scientific Texts

**Conduction of Heat
in Solids**

Second Edition

By H. S. CARSLAW and J. C. JAEGER. This standard work has been entirely reset and expanded into the most complete account possible of soluble problems and exact solutions in the subject. New chapters deal with melting and freezing, integral transforms, and numerical methods, and discussion of many subjects has been extended. 63 text figures. \$13.45

**Coordinate Geometry
with
Vectors and Tensors**

By E. A. MAXWELL. This textbook combines a traditional course on three-dimensional coordinate geometry with vectors, rather detailed treatment of tensors, and work on the general quadric that introduces some techniques of matrix algebra. Text figures. \$4.00

**A History of
Technology**

Edited by CHARLES SINGER, E. J. HOLMYARD, A. R. HALL, and TREVOR I. WILLIAMS. Now complete in five volumes, this set deals with the subject from the Old Stone Age to the later nineteenth century. Each volume is copiously illustrated with half-tone plates and text figures.

Volume I
*From Early Times to the Fall of
Ancient Empires*

Volume II
*The Mediterranean Civilizations
and the Middle Ages*

Volume III
*From the Renaissance to the Industrial
Revolution*

Volume IV
*The Industrial Revolution c. 1750
to c. 1850*

Volume V
*The Late Nineteenth Century c.
1850 to c. 1900*

Each volume \$26.90

At all bookstores

OXFORD UNIVERSITY PRESS

thing to do with reality for there may be alternative explanations of how the Lord Almighty produces the phenomena in question."

Koestler thus comes to the depressing conclusion of his reflections. Modern science—and here Koestler departs from cosmology to deal entirely with physics—is a "modern version of scholasticism." Koestler condemns the men of science for their reaction to what he calls "the phenomena of 'extra-sensory perception'" even as he bemoans the "rigorous banishment of the word 'purpose'" from the vocabulary of science. Science is divorced from faith, with the result that "neither faith nor science is able to satisfy man's intellectual cravings." Science, since the days of the villainous Galileo, has allegedly "claimed to be a substitute for, or the legitimate successor of, religion; thus its failure to provide the basic answers produced not only intellectual frustration but spiritual starvation." If only science could regain "its mystical inspiration," if only a new Kepler would arise to confute Heisenberg and Schrödinger, then the world might be better in some way. In the absence of a Kepler, Koestler concludes with the hope that the "muddle of inspiration and delusion, of visionary insight and dogmatic blindness, of millennial obsessions and disciplined double-think, which this narrative has tried to retrace, may serve as a cautionary tale against the hubris of science—or rather of the philosophical outlook based on it."

For me the most melancholy aspect of Koestler's conclusion is that it bears so little relation to the book which it serves as an epilogue. Five years of contemplation of the peculiar qualities of Kepler's mind, of the work of his predecessors and successors in the development of cosmology, have resulted only in an empty lament over 20th-century physics. So little has Koestler learned from his researches that the epilogue is actually based to a considerable degree on his earlier writings, borrowed, as he says, "without quotation marks."

Fortunately for the reader, Koestler is frank about his prejudices. And he has done his bit to correct the old-fashioned notion that science progresses only by orderly, logical steps. Science is an activity of human beings, and human beings do not always behave exactly the way history expects them to. There is no doubt that the scientific activity of man has wellsprings that we do not fully understand. When all is said and done, Koestler's eloquence in describing just how disorderly and illogical the progress

of science can be may even outweigh his deficiencies as a historian.

Short Reviews

ARCHAEOLOGY AND THE OLD TESTAMENT, by James B. Pritchard. Princeton University Press (\$5). **THE ANCIENT NEAR EAST**, edited by James B. Pritchard. Princeton University Press (\$6). These two fine books by a foremost student of Old Testament literature and Biblical archaeology are prime examples of intelligent popularization. The first volume is an engrossing nontechnical account of how history as written in the Bible has been "changed, enlarged or substantiated" by the past century of archaeological work. Our understanding of this rich segment of man's cultural and religious heritage has been broadened not only by the finds in Palestine but also by discoveries—documents and monuments—in the "peripheral lands" of Mesopotamia, Egypt, Syria and Anatolia. Pritchard's text, supported by admirable illustrations, describes the excavations in modern Israel and Jordan, Baal and the religion of Canaan, the information gained about Assyria (Israel's enemy) from the digging in modern Iraq, myth in the ancient Near East, the laws and culture of Egypt and Babylon. The second book is an excellent anthology of texts and pictures drawn from two large volumes edited by Pritchard (one of them, *The Ancient Near East in Pictures*, was reviewed in these columns a few years ago), which are standard treatises on their subject. The texts include excerpts from the Gilgamesh Epic, the Descent of Ishtar to the Nether World, the Telepinus Myth, poems about Baal and Anath, the Code of Hammurabi, the Instruction of Amenem-Opet, the Hymn to the Aton, Egyptian love songs, the inscription on the Moabite Stone, the Gezer Calendar, Assyrian, Egyptian and Babylonian documents describing military expeditions and sieges.

PSYCHOTHERAPEUTIC DRUGS, by Ashton L. Welsh. Charles C. Thomas (\$4.75). The use of tranquilizers or ataractic drugs has soared in the last few years. In sales volume they are second, according to some reports, only to antibiotics and vitamins. The rising market for peace-of-mind pills, apart from being a most interesting social phenomenon, has broad and serious medical implications. What good are these various psychotherapeutic agents? What basis is there for the extensive claims made on

P
H
O
N
I
X
P
H
O
N
I
X
P
H
O
N
I
X

At the crossroads of opportunity for men with vision in Electronic Engineering.

**GOODYEAR
AIRCRAFT
CORPORATION**

ELECTRONIC LABORATORY

**WE HAVE OPENINGS IN OUR
MODERN LABORATORIES FOR
ADVANCED ENGINEERS AND
SCIENTISTS IN ELECTRONIC
RESEARCH AND DEVELOPMENT**

Long range research and development projects.

Graduate studies available under company financed evening courses.

LEISURE LIVING AT ITS BEST
"IN THE VALLEY OF THE SUN"

Send resume to: A. E. Manning

Engineering and Scientific Personnel

GOODYEAR AIRCRAFT

LITCHFIELD PARK
PHOENIX, ARIZONA

Similar opportunities available in our
Akron, Ohio, Laboratory

**JET
PROPULSION
ENGINES**

Edited

by *O. E. LANCASTER*

Volume 12 in the distinguished *High Speed Aerodynamics and Jet Propulsion* series, this definitive volume covers the historical development of jet propulsion, and the basic principles of turbojets, turboprops, ramjets, intermittent jets, solid and liquid propellant rockets, ram rockets, jet driven rotors, and atomic energy in jet propulsion. 818 pages, with over 400 line drawings. \$20.00

At your bookstore, or



*Princeton
University Press
Princeton, New Jersey*

their behalf by drug manufacturers? What are the known side effects of the continued use of such medicaments? The author of this book, a dermatologist and syphilologist on the staff of the University of Cincinnati, undertakes to answer these questions on the basis not only of his own clinical experience but also of data gathered from an extensive search of the medical literature. His monograph considers the five major groups of tranquilizers: the phenothiazines, the Rauwolfia alkaloids and their fractions, the substituted propanediols, the diphenylmethane derivatives, and the ureides and amides. The evidence is quite clear that the use of these drugs may involve many disagreeable and even dangerous toxic effects and side reactions, that all too often they are indiscriminately prescribed and taken. A very useful book, which all doctors ought to be required to read.

OF STARS AND MEN, by Harlow Shapley. The Beacon Press (\$3.50). As man learns more about the universe the evidence mounts that he himself is incidental. In this sensitive and brilliant little book Shapley describes four "adjustments" in man's evolving thought about his relations to the total material universe. At first he and his small stamping ground were the whole world. Then, when he began to climb the hills to see what was on the other side, the horizon receded and a strange vagueness supplanted his notion of a snug and fixed domain. In time he became aware of the daily movements of the sun and the stars, and of the wandering planets. The earth, it appeared, was a sphere, turning on its track with the other heavenly bodies. Yet it was still thought to be the chosen central sphere of the universe, with man the crown of all living forms. In the 16th century the heliocentric concept supplanted the geocentric and forced a second adjustment; the earth had to yield its central position. But man could still cling to the treasured notion that he was the apple of the cosmic eye. A third change came with the realization that the sun is an ordinary star, a mere trifle in a huge galaxy of stars, and that the galaxy itself is one of millions. Thus human pride and self-assurance were eroded, though vanity continued to assert itself in the belief that man was unique even if his abode was not. Now, however, a fourth adjustment is required. Scientific workers have come up with pretty convincing evidence that whenever "the physics, chemistry and climates are right on a planet's surface,

1-2-3-4..

AND MANY MORE good reasons why Scientists, Researchers, Physicists, Engineers and Chemists should read this extraordinary book.

IT IS THE ONLY BOOK



that describes how Creation developed from seeds of energy and produced the cosmos with its multitude of galaxies, each with their millions of stars, suns and planets.

IT IS THE ONLY BOOK



that describes how it all began with the integration of energy into masses that became electrons, molecules, matter, suns and galaxies.

IT IS THE ONLY BOOK



that defines the source and character of Nature's forces and how they react to grow the universe. The Universe did not appear suddenly in space some six or so billion years ago as many believe, because Nature does not operate that way. Everything must grow. It must start from primordial energy, which develops electrons, atoms, molecules, viruses, cells, seeds and substances.



The
CYBERNETICS
of Creation

supplies a logically coordinated mental picture of Nature's forces, and enables the reader to really understand Creation as well as the fundamentals and inter-actions of all branches of science. Any researcher or student of physics, chemistry, or electricity can save years of time in his education.

Included FREE to those who order now . . . the priceless Chart of Nuclides with its descriptive pamphlet; produced at the Knolls Atomic Power Laboratory of General Electric Company. To own what you surely will consider your most valuable book send coupon below.

Please send me on approval copies @ \$5.95 of Cybernetics of Creation with the chart of Nuclides.

Name.....

Address.....

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

TECHNIBOOK, INC.
P.O. Box 2 • Newport Beach • Calif.

life will emerge, persist and evolve." This fact, coupled with certain observational facts of astronomy, forces us, says Shapley, to the realization that other planets very likely accompany some of the thousands of millions of stars that radiate energy capable of supporting life. Increasing knowledge has therefore not only dissolved the "subjective miraculous" and pierced deep into the "mystery of life," but has laid the basis for reasoned confidence in the theory that life is abundant and widely distributed throughout the universe. Asks Shapley: "What should be the human response" to this awesome circumstance? Frank Ramsay once commented on the physical universe in these words: "I don't feel the least humble before the vastness of the heavens. The stars may be large, but they cannot think or love; and these are qualities which impress me far more than size does." Our perspective is now changed. It is no longer a question of our competing with huge masses of incandescent gas and concluding comfortably and reasonably that they are mere outsize inanimate blobs, not worth a single living cell. Instead, we ourselves are "conceivably peripheral," not to be taken too seriously even among the animals and plants on our local planet, to say nothing of the possibilities of the richly endowed metagalaxy. Our philosophies and our religions must adapt themselves to this new view of the cosmos. And yet Shapley does not break entirely with Ramsay's view. He pleads for humility and hope, if not high confidence. There is much to learn, much to strive for, much we can accomplish through reason and imagination. If we are not alone, not even a chosen people, at least we can try to be equals among equals. Shapley's essay meanders and is uneven; its conjectures will not appeal to many cosmologists. But it is humane, courageous and fascinating writing.

THE FOLKLORE OF BIRDS, by Edward A. Armstrong (30 shillings); **CLIMATE AND THE BRITISH SCENE**, by Gordon Manley (25 shillings); **MOUNTAIN FLOWERS**, by John Raven and Max Walters (25 shillings); **THE WORLD OF THE SOIL**, by Sir E. John Russell (25 shillings). Collins. The New Naturalist Series in which these books appear is the best natural-history series being published today. In 10 years more than 40 volumes have appeared, many of them distinguished, and all of them solid contributions to biological literature for the general reader. Because the series is primarily concerned with the wildlife of Britain, only a few of the books have

been published in the U. S.; among these are Alister Hardy's superlative *The Open Sea*, reviewed in these columns three years ago. This neglect is regrettable because the scientific content of the books, their clarity of presentation and the high quality of the illustrations (in black-and-white and in color) would assure them an appreciative audience in the U. S. despite the focus of attention on the British scene. The volumes listed above confirm the point. Armstrong's book traces to their origins in early cultures the magico-religious beliefs concerning a number of familiar birds: the swan, the raven, the owl, the robin and the wren. The history, from their beginnings in the "foggie dark sea of Antiquity," of various traditions and beliefs, of fables about weather-prophet birds, of such customs as breaking the wishbone, makes an engrossing tale, which is supported by a mass of data drawn from archaeology, anthropology, psychology, religious history and ornithology. Manley's subject is British weather in its infinite variety: Chaucer's "sweet April showers," London fogs, the famous English spring, the wild storms over the Channel, the smog over Liverpool, the redoubtable Scotch mist, the rain that falls and falls on Ireland, the wind-swept heights of the Pennines, the scant sunshine on Ben Nevis (about 750 hours a year). The volume by Raven and Walters is the first ever published on the wild flowers of British mountains. It is a true labor of love, the result of a collaboration between an amateur and a professional botanist (the amateur being an authority on Greek philosophy and a fellow of King's College, Cambridge) who have hunted flowers in the hills of Scotland, Wales, Ireland and the Lake District. While British mountain flowers do not provide so gorgeous a display as those of the Alps, they include many species of rare and gentle beauty that are lovingly described and discussed in this attractive volume. John Russell's monograph deals with how the soil was formed and how completed by organic matter; the living conditions for soil inhabitants; visible and invisible soil inhabitants from microorganisms to worms, slugs, snails, fungi and arthropods; man's control of the soil; the soil and the landscape; soil analysis and soil surveys. Discoveries made by soil scientists, chemists, physicists, biologists and geologists are very skillfully brought together in this authoritative and readable work by the former director of the Rothamsted Experimental Station, where much fruitful research has been performed on this complex and still lit-

tle-known department of natural history. Many fine photographs.

AMERICAN VOTING BEHAVIOR, edited by Eugene Burdick and Arthur J. Brodbeck. The Free Press (\$7.50). Why do people vote the way they vote? The editors of this heavy volume have collected essays by various students of voting behavior who report the latest researches in the field. The articles are not impressive. There are the usual weighty, long-winded demonstrations of the obvious: voters are prejudiced, irrational, neurotic, conformist, timid, stupid, suggestible; some persons vote like their fathers, some rebel and vote the opposite of their fathers; many voters simply don't care; some believe what they read but many never read; some are politically hypnotized by television—and so on and on. The statistical data are inconsequential; the writing is jargon-laden and pretentious. Among the few interesting pieces is Brodbeck's clever comparison of certain features of electioneering with psychotherapy. But on the whole this is just another bowl of thick social-science porridge, concocted of the trivial and the trite.

PROJECT SHERWOOD: THE U. S. PROGRAM IN CONTROLLED FUSION, by Amasa S. Bishop (\$5.75); **U. S. RESEARCH REACTOR OPERATION AND USE**, edited by Joel W. Chastain, Jr. (\$7.50); **RADIATION BIOLOGY AND MEDICINE**, edited by Walter D. Claus (\$11.50); **URANIUM ORE PROCESSING**, edited by John W. Clegg and Dennis D. Foley (\$7.50); **THORIUM PRODUCTION TECHNOLOGY**, by F. L. Cuthbert (\$6.50); **SOLID FUEL REACTORS**, by Joseph R. Dietrich and Walter H. Zinn (\$10.75); **PHYSICAL METALLURGY OF URANIUM**, by A. N. Holden (\$5.75); **BOILING WATER REACTORS**, by Andrew W. Kramer (\$8.50); **FLUID FUEL REACTORS**, edited by James A. Lane, H. G. MacPherson and Frank Maslan (\$11.50); **THE TRANSURANIUM ELEMENTS**, by Glenn T. Seaborg (\$7.50); **SODIUM GRAPHITE REACTORS**, by Chauncey Starr and Robert W. Dickinson (\$6.50); **THE SHIPPINGPORT PRESSURIZED WATER REACTOR**, written by Personnel of the Naval Reactors Branch in the Atomic Energy Commission, of the Westinghouse Electric Corporation and of the Duquesne Light Company (\$9.50). These volumes, prepared under the supervision of the Atomic Energy Commission, were presented in complete sets to the delegates to the Second International Conference on the Peaceful Uses of Atomic Energy, held at Geneva in September of

IR



THERE IS ROOM FOR YOU IN CROSLEY'S INFRARED SYSTEMS

One of the largest and fastest growing Infrared Systems departments in the country has Supervisory and Staff positions available for engineers and physicists.

Areas of interest include long range programs to significantly advance the state-of-the-art in:

- Airborne Defensive Systems
- Airborne Early Warning
- AICBM Detection
- Reconnaissance and Surveillance
- Tracking and Track-While-Scan Systems
- Passive Ranging
- Anti-submarine Warfare

MR. JAMES T. DALE

Director — Scientific and Technical Personnel

Avco/Crosley

1329-N ARLINGTON STREET, CINCINNATI 25, OHIO

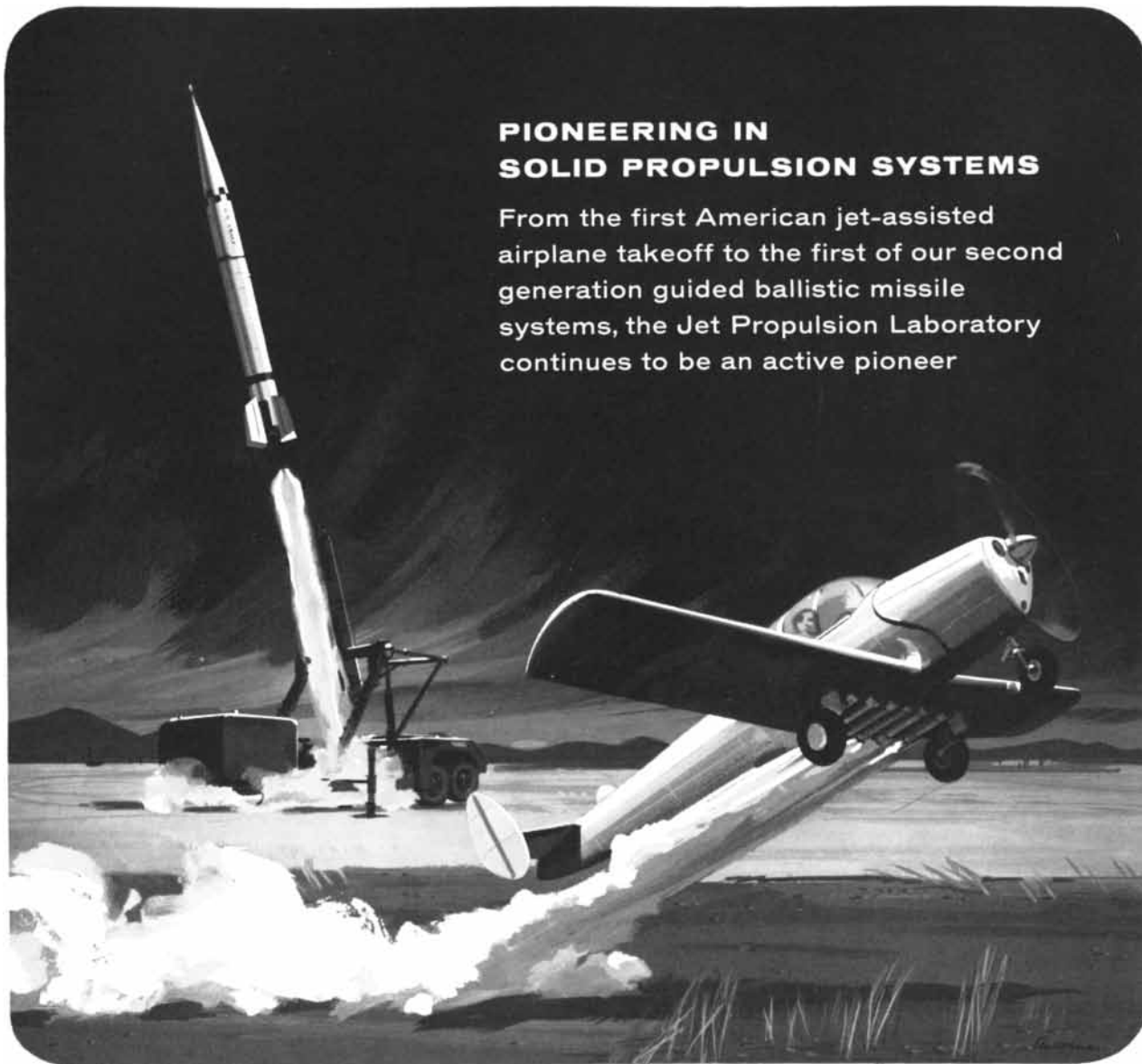
Professional Teamwork

In the fields of reconnaissance and surveillance the effective utilization of infrared requires the concentrated effort of both scientists and engineers.

At AVCO/Crosley a number of exciting developments are underway to extend the state-of-the-art in practical applications of basic Infrared technology. Current fields of interest include reconnaissance systems, tracking devices, and ranging equipment. Illustrated above is one type of Infrared Track and Ranging Unit developed at Crosley.

AVCO/Crosley engineers are answering the problem of space conquest through the design of systems which include, among other devices, new concepts of infrared detection equipment.

NOTABLE ACHIEVEMENTS AT JPL...



PIONEERING IN SOLID PROPULSION SYSTEMS

From the first American jet-assisted airplane takeoff to the first of our second generation guided ballistic missile systems, the Jet Propulsion Laboratory continues to be an active pioneer

In August 1941, America's first jet-assisted airplane takeoff was accomplished with an Ercoupe monoplane, using JPL developed solid propellant rockets. Scientists at JPL shortly discovered that a powdered perchlorate oxidizer, mixed with a liquefied plastic fuel binder, could be cast directly in plastic-lined light-weight motor cases. Thus a safe and cheap method was now available for preparing large internal-burning

composite propellant charges. This basic process became the foundation for the modern solid propellant industry.

In 1954, U. S. Army Ordnance requested JPL to develop a compact, rugged long-range guided missile weapon system that could be transported, aimed and fired as simply as a cannon. Within five years, JPL perfected the **Sergeant**, the first of America's second-generation guided ballistic missiles. In

January 1958, clusters of small-scale **Sergeants** helped launch America's first earth satellite, the JPL built **Explorer**, which provided vital space environment information.

Now under the direction of the National Aeronautics and Space Administration, the experienced JPL research and development team continues to apply solid propellant vehicles for space exploration.



CALIFORNIA INSTITUTE OF TECHNOLOGY **JET PROPULSION LABORATORY**

A Research Facility of the National Aeronautics and Space Administration
PASADENA, CALIFORNIA

OPPORTUNITIES NOW
OPEN IN THESE FIELDS

APPLIED MATHEMATICIANS · PHYSICISTS · SYSTEMS ANALYSTS · CHEMISTS · IBM-704 PROGRAMMERS
ELECTRONIC, MECHANICAL, CHEMICAL, PROPULSION, INSTRUMENTATION, MICROWAVE, AERONAUTICAL AND STRUCTURAL ENGINEERS

last year. The 12 books offer a comprehensive review of atomic-energy technology in the last three years. Bishop's monograph gives a clear account of work done in the U. S. on thermonuclear reactions. Glossaries and excellent illustrations help to make this book understandable to the average reader. The other volumes in the series are addressed to specialists. A valuable and impressive record.

THE BIRDS OF ALASKA, by Iran Gabrielson and Frederick C. Lincoln. The Stackpole Company (\$15). A massive natural-history compendium of some 900 closely printed pages describing the various species of birds of Alaska, their range, haunts and habits. The information is drawn from the files of the Wildlife Management Institute, from other literature (which is listed in an extensive bibliography) and from the observations of the senior author, who has made many field trips over the entire Alaskan territory, studying and collecting birds and gathering data on bird life from Eskimos, Aleuts and travelers in the Arctic. The book is illustrated by color plates of average quality; they cover only a small fraction of Alaskan birds, which is disappointing in a volume otherwise so complete.

FOUNDATIONS OF MATHEMATICS, by Carl H. Denbow and Victor Goedicke. Harper and Brothers (\$6). A better-than-average textbook for the one-year course of college mathematics, which offers a brief survey not only of the usual bread-and-butter subjects but also of the philosophy of mathematics and of advanced topics of special interest such as group theory, the algebra of logic, and infinite sets. The authors have made no profound discoveries in pedagogy nor toppled any sacred monuments, but they sometimes have a nice fresh way of presenting old ideas and problems so as to make them clearer than usual and even exciting.

PERSPECTIVES IN VIROLOGY, edited by Morris Pollard. John Wiley & Sons, Inc. (\$7). Twenty specialists report on recent progress in various fields of virological research. Some of the papers are exceptionally stimulating in suggesting new lines of research on the relation of viruses to cancer and other diseases. To counterbalance the accepted notion that all viruses are destructive to their hosts, René Dubos in a delightfully conceived scientific and historical paper entitled "Tulipomania and the Benevolent Virus" indulges himself in the "fantasy" that

certain viruses are "now and then helpful" to other living organisms.

JET PROPULSION ENGINES, edited by O. E. Lancaster. Princeton University Press (\$20). The latest volume in the High Speed Aerodynamics and Jet Propulsion series considers the principles and problems encountered in combining components to form a complete jet engine. The subjects covered include the history of rocket propulsion, basic principles of jet propulsion, the turbojet engine, the turboprop engine, the ramjet engine, intermittent jets, solid-propellant rockets, the ram rocket, jet rotors, atomic energy in jet propulsion.

Notes

THE PRINCIPLES OF SCIENCE: A TREATISE ON LOGIC AND SCIENTIFIC METHOD, by W. Stanley Jevons. Dover Publications, Inc. (\$2.98). A paperback reissue of Jevons's celebrated work, first published in 1874. A new introduction by Ernest Nagel considers how much of this dissertation on the method and logic of the physical sciences is still of value to the scientist and philosopher. Despite many limitations, the *Principles*, says Nagel, "remains a richly instructive book."

THE MEANING OF MEANING, by C. K. Ogden and I. A. Richards. Harcourt, Brace and Company (\$2.25). The well-known Ogden and Richards study of the influence of logic upon thought and of the science of symbolism is now issued in a paper-bound edition.

SEA SHELLS OF TROPICAL WEST AMERICA, by A. Myra Keen. Stanford University Press (\$12.50). A descriptive listing of 1,650 species of marine mollusks from southern California to Colombia. Notes on geographic distribution, extensive bibliography, 1,500 illustrations, including 10 pages of color plates.

AUTOMATIC PROCESS CONTROL, by Donald P. Eckman. John Wiley & Sons, Inc. (\$9). A study of automatic control with particular emphasis on process control. For engineers.

THE MENTALITY OF APES, by Wolfgang Köhler. Vintage Books (\$1.25). Köhler's important book on animal psychology is issued in an inexpensive reprint.

A CENTURY OF MOUNTAINEERING, by Arnold Lunn. The Macmillan Company

How would you answer these questions for someone outside your field (your family, for instance):

**What is smog made of?
Why do people "see" flying saucers?
How can tornadoes spread disease?
How will our "vertical frontier" affect future space travel?**

BETWEEN EARTH and SPACE

By Clyde Orr, Jr.

Author of *Fine Particle Measurement*

A real find... this beautifully written, timely book answers these and hundreds of other questions in clear, non-technical language. Professor Orr conducts a fascinating journey through our atmosphere explaining what it means to us in terms of climate and weather, supersonic flight, gaseous and radioactive poisons and satellite exploration. A "thoroughly delightful book," declares the *Chicago Sunday Tribune*, "O, that more scientists would write so interestingly." Illustrated \$4.95

Send for your 10-day approval copy!

THE MACMILLAN COMPANY, Dept. SA-2
60 Fifth Avenue, New York 11, N. Y.

Please send me..... copies of Orr: **BETWEEN EARTH and SPACE** @ \$4.95. It is understood I may return the book(s) within 10 days and owe nothing. Otherwise you may bill me. **SAVE**—enclose payment and we pay the delivery charge.

Name

Address

CityZone....State.....

Signature

Price subject to change without notice.



SPANISH (American or European) • **FRENCH**
ITALIAN • **GERMAN** • **RUSSIAN** • **JAPANESE**
ICELANDIC • **MODERN GREEK**
—any of 34 languages available AT HOME

With LINGUAPHONE The World's Standard Conversational Method—You Start to SPEAK another language TOMORROW or IT COSTS YOU NOTHING! In just 20 minutes a day, you and your family can learn another language while relaxed AT HOME—the same easy, natural way you learned to speak English long before you went to school. Only LINGUAPHONE brings 8 to 12 of the world's best native language teachers into your home. You hear both men and women converse about up-to-date, everyday matters in their native tongue. YOU listen—YOU understand—YOU SPEAK correctly as they do. It's like living in another land. That's why Linguaphone is used 'round the world by scientists, educators, governments and business firms. Over a million home-study students of all ages have learned to speak another language this ideal, conversational way. Send today for Free booklet that fully describes the Conversational Method; also details on how you may obtain a COMPLETE Course-unit in the language you choose on FREE TRIAL. Linguaphone Institute, T-3069 Radio City, N. Y. 20.

LINGUAPHONE INSTITUTE
T-3069 Radio City, New York 20, N. Y.
Please send me: FREE Book.
 Details on FREE Trial. No obligation, of course.
My language interest is.....
Name

Address

CityZone....State.....

World's Standard Conversational Method For Over Half a Century

(\$6.75). A most attractively illustrated memoir by a noted mountaineer celebrating the 100th anniversary of the famous Alpine Club, and recalling great climbing feats and climbers and the many controversies of mountaineering.

PLANNING OF EXPERIMENTS, by D. R. Cox. John Wiley & Sons, Inc. (\$7.50). An account of the ideas underlying modern work on the statistical aspects of experimental design.

THE VERTEBRATE STORY, by Alfred S. Romer. The University of Chicago Press (\$7). A radical revision of Romer's noted work *Man and the Vertebrates*, first published in 1933 and last revised in 1941.

OUR BIBLE AND THE ANCIENT MANUSCRIPTS, by Sir Frederic Kenyon. Harper and Brothers (\$6.95). A. W. Adams, an Oxford scholar, has completely revised this classical account, first published in 1895, of how the Scriptures have come to us, bringing it abreast of the most recent advances in knowledge by including the latest textual and archaeological discoveries. Forty-nine full-page plates. An engrossing book.

THE FACE OF THE SUN, by H. W. Newton. Penguin Books (85 cents). This compact Pelican furnishes an account of our knowledge of the surface of the sun, in particular the sunspots and their associated phenomena, from the time of Galileo to the International Geophysical Year.

THE ABC OF RELATIVITY, by Bertrand Russell. George Allen & Unwin Ltd. (15 shillings). This very attractive, characteristically lucid primer first appeared in 1925 but has long been out of print. It is now reissued with numerous revisions by Felix Pirani.

ATTIC RED-FIGURED VASES, by Gisela M. A. Richter. Yale University Press (\$5). Revised edition of a fine handbook on the activity of the Attic potteries.

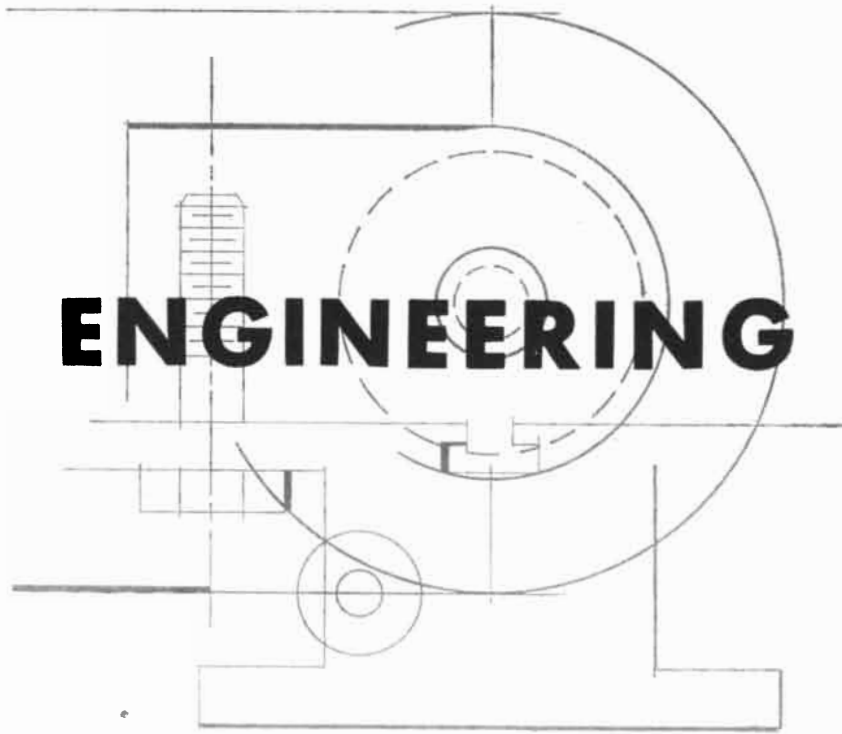
LANDSCAPES OF ALASKA, edited by Howel Williams. University of California Press (\$5). An elegant, attractively illustrated book that describes in non-technical language the geologic evolution of this vast and extraordinarily scenic land, whose features include the highest peak on the continent, desolate tundra, vast glaciers, fiords and enormous mountain ranges.

ACOUSTIC ASSOCIATES, INC.....	40	DATASYNC, A DIVISION OF BERNDT-BACH, INC.....	85
Agency: Freedman & Ross, Inc.		Agency: Van der Boom, Hunt, McNaughton, Inc.	
AERO SERVICE CORPORATION.....	42	DAYSTROM SYSTEMS DIVISION OF DAYSTROM, INC.....	113
Agency: The Aitkin-Kynett Co., Inc.		Agency: The Phillips-Ramsey Company	
AEROJET-GENERAL CORPORATION, A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY.....	172	DU PONT DE NEMOURS, E. I., & CO., INC., POLYCHEMICALS DEPARTMENT	104
Agency: D'Arcy Advertising Company		19, 101, 102, 103, 104	
AERONCA MANUFACTURING CORPORATION.....	11	Agency: Batten, Barton, Durstine & Osborn, Inc.	
Agency: Penn and Haniaker, Inc.		EASTMAN CHEMICAL PRODUCTS, INC., SUBSIDIARY OF EASTMAN KODAK COMPANY.....	49
AINSWORTH, WM., & SONS, INC.....	164	Agency: Fred Wittner Company	
Agency: Walter L. Schump, Advertising		EASTMAN CHEMICAL PRODUCTS, INC., SUBSIDIARY OF EASTMAN KODAK COMPANY, CHEMICALS DIV.....	167
ALLEN-BRADLEY COMPANY.....	139	Agency: Fred Wittner Company	
Agency: The Fensholt Advertising Agency, Inc.		EASTMAN KODAK COMPANY.....	75
ALLIED CHEMICAL CORPORATION.....	130, 131	Agency: The Rumrill Company Inc.	
Agency: Benton & Bowles, Inc.		EDMUND SCIENTIFIC CO.....	179
ALPHA CORPORATION, A COLLINS RADIO SUBSIDIARY.....	10	Agency: Walter S. Chittick Company	
Agency: Don L. Baster, Inc.		ELECTRONIC ASSOCIATES, INC.....	1
AMERICAN BOSCH ARMA CORPORATION, ARMA DIVISION.....	5	Agency: Gaynor & Ducas, Inc.	
Agency: Doyle, Kitchen & McCormick, Inc.		ERCO, DIVISION OF ACF INDUSTRIES, INC.....	43
AMERICAN EDELSTAAL, INC., UNIMAT DIV.....	153	Agency: Conti Advertising Agency, Inc.	
Agency: Harold J. Siesel Company		FIRST NATIONAL CITY TRUST COMPANY.....	36
AMPEX CORPORATION, INSTRUMENTATION DIVISION.....	33	Agency: Mogul Lewin Williams & Saylor, Inc.	
Agency: McCann-Erickson, Inc.		GARFIELD, OLIVER, CO., INC.....	177
ARGONNE NATIONAL LABORATORY.....	201	Agency: Daniel & Charles, Inc.	
Agency: Grant-Jacoby Studios, Inc.		GENERAL ATOMIC DIVISION OF GENERAL DYNAMICS CORPORATION.....	121
AVCO CORPORATION.....	6, 7	Agency: Barnes Chase Company	
Agency: Benton & Bowles, Inc.		GENERAL DYNAMICS CORPORATION.....	Back Cover
AVCO CORPORATION, CROSLLEY DIVISION.....	195	Agency: D'Arcy Advertising Company	
Agency: Robert Acomb, Inc.		GENERAL ELECTRIC COMPANY.....	157
BASIC BOOKS, PUBLISHERS.....	186	Agency: Batten, Barton, Durstine & Osborn, Inc.	
Agency: Wunderman, Ricotta & Kline, Inc.		GENERAL ELECTRIC CO., FLIGHT PROPULSION DIVISION.....	180
BAUSCH & LOMB OPTICAL CO.....	14	Agency: Deutsch & Shea, Inc.	
Agency: Wolff Associates, Inc.		GENERAL ELECTRIC CO., LIGHT MILITARY ELECTRONICS DEPARTMENT.....	183
BECKMAN INSTRUMENTS, INC., SCIENTIFIC AND PROCESS INSTRUMENTS DIVISION.....	87	Agency: De Garmo Incorporated	
Agency: Charles Bowes Advertising, Inc.		GENERAL MOTORS CORPORATION, ALLISON DIVISION.....	175
BELL TELEPHONE LABORATORIES.....	29	Agency: Kudner Agency, Inc.	
Agency: N. W. Ayer & Son, Incorporated		GILSON SLIDE RULE CO.....	180
BENDIX AVIATION CORPORATION.....	50	GOODYEAR AIRCRAFT CORPORATION, A SUBSIDIARY OF THE GOODYEAR TIRE & RUBBER CO.....	193
Agency: MacManus, John & Adams, Inc.		GRAPHIC SYSTEMS.....	182
BENDIX COMPUTER DIVISION OF BENDIX AVIATION CORPORATION.....	99	Agency: Diener & Dorskind Incorporated	
Agency: Shaw Advertising, Inc.		GRUMMAN AIRCRAFT ENGINEERING CORPORATION.....	20, 21
BRITISH INDUSTRIES CORPORATION.....	182	Agency: Fuller & Smith & Ross Inc.	
Agency: The Zlowe Company Inc.		GURLEY, W. & L. E.....	44
CARBORUNDUM COMPANY, THE.....	122, 123	Agency: Fred Wittner Company	
Agency: G. M. Basford Company		HARVARD UNIVERSITY PRESS.....	190
CELANESE CORPORATION OF AMERICA, CHEMICAL DIVISION.....	114, 117	Agency: Franklin Spier, Inc.	
Agency: Ellington & Company, Inc.		HAYDON, A. W., COMPANY, THE.....	85
CENTURY ELECTRONICS & INSTRUMENTS, INC.....	125	Agency: Cory Snow, Inc.	
Agency: Advertising Engineers		HERCULES POWDER COMPANY, INCORPORATED.....	80
COLLINS RADIO COMPANY.....	Inside Back Cover	Agency: Fuller & Smith & Ross Inc.	
Agency: W. D. Lyon Company (Incorporated)		HEWLETT-PACKARD COMPANY.....	51
CONSOLIDATED ELECTRODYNAMICS CORPORATION.....	128, 129	Agency: L. C. Cole Company-Inc.	
Agency: Hixson & Jorgensen, Inc., Advertising		HOOVER CHEMICAL CORPORATION, DUREZ PLASTICS DIVISION.....	35
Agency: Klau-Van Pietersom-Dunlap, Inc.		Agency: The Rumrill Company Inc.	
CONVAIR-ASTRONAUTICS, DIVISION OF GENERAL DYNAMICS CORPORATION.....	178	INTERNATIONAL BUSINESS MACHINES CORPORATION.....	81, 161
Agency: Barnes Chase Company		Agency: Benton & Bowles, Inc.	
COOPER-BESSEMER CORPORATION, THE.....	45		
Agency: The Griswold-Eshleman Co.			
CORNELL AERONAUTICAL LABORATORY, INC. OF CORNELL UNIVERSITY.....	204		
Agency: Barber & Drullard Inc.			
CORNING GLASS WORKS.....	84		
Agency: The Rumrill Company Inc.			
CRITERION MANUFACTURING CO.....	177		
Agency: Equity Advertising Agency, Inc.			

INDEX OF ADVERTISERS

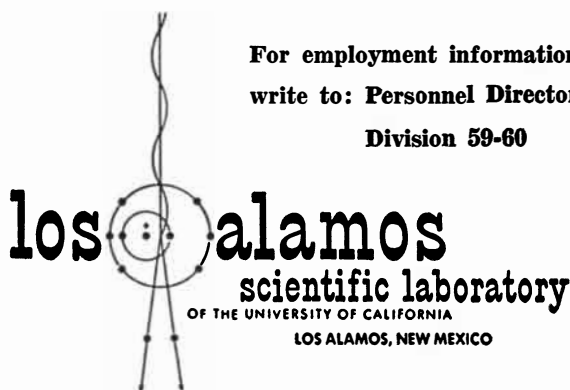
JUNE, 1959

INTERNATIONAL NICKEL COMPANY, INC., THE Agency: Marschalk and Pratt Div. of McCann-Erickson, Inc.	22	MINNESOTA MINING AND MANUFACTURING COMPANY, MAGNETIC PRODUCTS DIVISION Agency: MacManus, John & Adams, Inc.	26	RAYTHEON COMPANY..... 15 Agency: Donahue & Coe, Inc.
INTERNATIONAL TELEPHONE & TELEGRAPH CORPORATION Agency: J. M. Mathes Incorporated	38, 39	MITRE CORPORATION, THE..... 181 Agency: Deutsch & Shea, Inc.		RAYTHEON COMPANY, GOVERNMENT EQUIPMENT DIVISION..... 169 Agency: Donahue & Coe, Inc.
JAEGERS, A..... 184 Agency: Carol Advertising Agency		NATIONAL COMPANY, INC..... 25 Agency: Burton Browne Advertising		REPUBLIC AVIATION CORPORATION..... 159 Agency: Deutsch & Shea, Inc.
JANITROL AIRCRAFT DIVISION, SURFACE COMBUSTION CORPORATION..... 4 Agency: Oilborne Industrial Advertising, Inc.		NORTHROP CORPORATION..... 165 Agency: Erwin Wasey, Ruthrauff & Ryan, Inc.		SANDIA CORPORATION..... 185 Agency: Ward Hicks Advertising
JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY..... 196 Agency: Stebbins & Cochran		NORTON COMPANY, REFRACTORIES DIVISION Agency: James Thomas Chirurg Company		SAVE THE CHILDREN FEDERATION..... 97 Agency: Monroe F. Dreher, Inc.
JOHNS-MANVILLE CORP., ASBESTOS FIBRE DIVISION Agency: J. Walter Thompson Company	8	NORTONICS, A DIVISION OF NORTHROP CORPORATION Agency: Erwin Wasey, Ruthrauff & Ryan, Inc.		SERVO CORPORATION OF AMERICA..... 17 Agency: Smith, Winters Mabuchi, Inc.
KENNAMETAL INC..... 28 Agency: Ketchum, MacLeod & Grove, Inc.		NUCLEAR-CHICAGO CORPORATION..... 48 Agency: Don Colvin & Company, Inc.		SHELL CHEMICAL CORPORATION Inside Front Cover Agency: J. Walter Thompson Company
KLING PHOTO CORPORATION, ARRIFLEX DIVISION Agency: Advertising Aides	44	OAK RIDGE NATIONAL LABORATORIES—ISOTOPES DIVISION (UNION CARBIDE CORPORATION) Agency: J. M. Mathes Incorporated		SIGMA INSTRUMENTS, INC..... 77 Agency: Culver Advertising, Inc.
LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION..... 115 Agency: J. M. Mathes, Incorporated		OPERATIONS RESEARCH OFFICE, THE JOHNS HOPKINS UNIVERSITY..... 166 Agency: M. Belmont Ver Standig, Inc.		SINGER MANUFACTURING COMPANY, THE, MILITARY PRODUCTS DIVISION..... 34 Agency: O. S. Tyson and Company, Inc.
LINDSAY CHEMICAL DIVISION, AMERICAN POTASH & CHEMICAL CORPORATION..... 24 Agency: C. Franklin Brown, Inc.		OXFORD UNIVERSITY PRESS, INC..... 192 Agency: Denhard & Stewart, Inc.		SOLAR AIRCRAFT COMPANY..... 83 Agency: The Phillips-Ramsey Company
LINGUAPHONE INSTITUTE..... 197 Agency: The Kaplan Agency, Inc., Div. of Mogul Lewin Williams & Saylor, Inc.		PAILLARD INCORPORATED..... 176 Agency: Fuller & Smith & Ross Inc.		SYLVANIA ELECTRIC PRODUCTS, INC., SYLVANIA ELECTRONIC SYSTEMS DIVISION Agency: J. Walter Thompson Company
LINK AVIATION, INC., A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION Agency: Gaynor & Ducas, Inc.	163	PERKIN-ELMER CORPORATION..... 158 Agency: G. M. Basford Company		SYLVANIA ELECTRIC PRODUCTS, INC., SEMI-CONDUCTOR DIVISION..... 41 Agency: J. Walter Thompson Company
LITTLE, ARTHUR D., INC..... 16 Agency: Henry A. London, Advertising, Inc.		PFIZER, CHAS. & CO., INC., CHEMICAL SALES DIVISION..... 151 Agency: MacManus, John & Adams, Inc.		SYLVANIA ELECTRONIC SYSTEMS, A DIVISION OF SYLVANIA ELECTRIC PRODUCTS, INC..... 191 Agency: Deutsch & Shea, Inc.
LOCKHEED MISSILES AND SPACE DIVISION, LOCKHEED AIRCRAFT CORPORATION Agency: Hal Stebbins, Inc.	170, 171	PHILCO CORPORATION, GOVERNMENT & INDUSTRIAL DIVISION..... 31 Agency: Maxwell Associates, Inc.		SYSTEM DEVELOPMENT CORPORATION..... 202, 203 Agency: Stromberger, LaVene, McKenzie: Advertising
LOS ALAMOS SCIENTIFIC LABORATORY OF THE UNIVERSITY OF CALIFORNIA..... 200 Agency: Ward Hicks Advertising		PHILLIPS CHEMICAL COMPANY, A SUBSIDIARY OF PHILLIPS PETROLEUM COMPANY Agency: Lambert & Feasley, Inc.		TECHNIBOOK, INC..... 193
MACMILLAN COMPANY, THE..... 197 Agency: J. M. Hickerson Inc.		PITTSBURGH ELECTRODRYER DIVISION, McGRAW-EDISON COMPANY..... 166 Agency: The Griswold-Eshleman Co.		TECHNICAL RESEARCH GROUP..... 177 Agency: Aiken Advertising Agency, Inc.
MAGNAVOX COMPANY, THE..... 127 Agency: Chamberlin-Junk Advertising, Inc.		PRINCETON UNIVERSITY, JAMES FORRESTAL RESEARCH CENTER..... 158 Agency: Hobar Corp. Advertising		TEMCO AIRCRAFT CORPORATION..... 167 Agency: Rogers & Smith Advertising Agents, Inc.
MALAYAN TIN BUREAU, THE..... 100 Agency: Gray & Rogers		PRINCETON UNIVERSITY PRESS..... 193 Agency: Franklin Spier, Inc.		THOMPSON, H. I., FIBER GLASS CO..... 44 Agency: Van der Boom, Hunt, McNaughton, Inc.
MARCHANT CALCULATORS, DIVISION OF SMITH-CORONA MARCHANT INC..... 137 Agency: Foote, Cone & Belding		QUESTAR..... 82		THOMPSON RAMO WOOLDRIDGE, INC., TAPCO GROUP..... 140, 141 Agency: Meldrum & Fewsmith, Inc.
M I T LINCOLN LABORATORY..... 189 Agency: Randolph Associates		RCA SERVICE COMPANY, A DIVISION OF RADIO CORPORATION OF AMERICA..... 142 Agency: Al Paul Lefton Company, Inc.		TRANSITRON ELECTRONIC CORPORATION..... 12 Agency: The Bresnick Company, Inc.
MELPAR, INC., A SUBSIDIARY OF WESTINGHOUSE AIR BRAKE COMPANY..... 37 Agency: Larrabee Associates Advertising		RADIO CORPORATION OF AMERICA, DEFENSE ELECTRONIC PRODUCTS..... 79 Agency: Al Paul Lefton Company, Inc.		UNION CARBIDE CORPORATION, LINDE DIVISION Agency: J. M. Mathes Incorporated
MINNEAPOLIS-HONEYWELL..... 144, 145 Agency: The Aitkin-Kynett Co., Inc.		RAMO-WOOLDRIDGE, A DIVISION OF THOMPSON RAMO WOOLDRIDGE INC..... 156 Agency: The McCarty Co.		UNION CARBIDE CORPORATION, OAK RIDGE NATIONAL LABORATORIES—ISOTOPES DIVISION Agency: J. M. Mathes Incorporated
MINNEAPOLIS-HONEYWELL, DATAMATIC DIVISION..... 88, 89 Agency: Batten, Barton, Durstine & Osborn, Inc.		RAND CORPORATION, THE..... 2 Agency: Fletcher Richards, Calkins & Holden, Inc.		UNITED STATES GRAPHITE COMPANY, THE, DIVISION OF THE WICKES CORPORATION Agency: Price, Tanner & Willox, Inc.
		RANSBURG ELECTRO-COATING CORP..... 78 Agency: H. L. Ross, Advertising		UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO..... 184 Agency: Larcom Randall Advertising, Inc.
				VARI-TYPER CORPORATION..... 86 Agency: Bruce Angus Advertising Agency
				VEECO VACUUM CORP..... 76 Agency: Duncan-Brooks, Inc.
				WALLACE & TIERNAN INCORPORATED..... 30 Agency: Branstater Associates, Inc.
				WESTINGHOUSE ELECTRIC CORPORATION, DEFENSE PRODUCTS GROUP..... 46, 47 Agency: Ketchum, MacLeod & Grove, Inc.
				WESTINGHOUSE ELECTRIC CORPORATION, SEMICONDUCTOR DEPARTMENT..... 18 Agency: McCann-Erickson, Incorporated
				WHITE, S. S., DENTAL MFG. CO., INDUSTRIAL DIVISION..... 114 Agency: W. L. Towne Company, Inc.



At Los Alamos, the many-faceted field of engineering offers inspiration to skilled, imaginative professionals. Fascinating design and development projects in chemical, metallurgical, electrical and mechanical engineering are a vital part of the Laboratory's diversified research program. And engineering is just one of the many scientific activities in which far-seeing men and women find a challenge at the Laboratory of the future.

**For employment information,
write to: Personnel Director
Division 59-60**



BIBLIOGRAPHY

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

ROCKET ASTRONOMY

HIGH ALTITUDE ROCKET RESEARCH. Homer E. Newell, Jr. Academic Press, Inc., 1953.

PHYSICS AND MEDICINE OF THE UPPER ATMOSPHERE. Edited by Clayton S. White and Otis O. Benson, Jr. University of New Mexico Press, 1952.

ROCKET EXPLORATION OF THE UPPER ATMOSPHERE. Special Supplement (Vol. I) to *The Journal of Atmospheric and Terrestrial Physics*. Edited by R. L. F. Boyd and M. J. Seaton. Pergamon Press, Ltd., 1954.

ROCKET OBSERVATIONS OF THE IONOSPHERE. Herbert Friedman in *Proceedings of the IRE*, Vol. 47, No. 2, pages 272-279; February, 1959.

THE SUN AND ITS INFLUENCE. AN INTRODUCTION TO THE STUDY OF SOLAR-TERRESTRIAL RELATIONS. M. A. Ellison. Routledge and Kegan Paul, Ltd., 1955.

AN ANCIENT GREEK COMPUTER

DER ASTROLABOS VON ANTIKYTHERA. P. Rediadis in *Das Athener Nationalmuseum*, Vol. 1, pages 43-51, plates IX, X; 1908.

SUR L'INSTRUMENT EN CUIVRE DONT LES FRAGMENTS SE TROUVENT AU MUSÉE ARCHÉOLOGIQUE D'ATHÈNES ET QUI FUT RETIRÉ DU FOND DE LA MER D'ANTICYTHÈRE EN 1902. J. Théofanidis in *Praktika tes Akademias Athenon*, Vol. 9, pages 140-153; 1934.

ART SALVAGED FROM THE SEA. George Karo in *Archaeology*, Vol. I, No. 4, pages 179-185; December, 1948.

THE ASTROLABE OF THE NEEDLE-MAKER OF ISFAHAN. Robert T. Gunther in *The Astrolabes of the World*, Vol. I, pages 118-120; Oxford University Press, 1932.

GREEK ASTROLABES. Robert T. Gunther in *The Astrolabes of the World*, Vol. I, pages 53-59; Oxford University Press, 1932.

HEAVENLY CLOCKWORK. THE GREAT ASTRONOMICAL CLOCKS OF MEDIEVAL CHINA. Joseph Needham, Wang Ling and Derek J. de Solla Price. Cambridge University Press, 1959.

PRECISION INSTRUMENTS TO 1500. Derek J. Price in *A History of Technology*,



mathematical investigations in nuclear sciences

Problems carried to completion on Argonne's computers have contributed to the design of nuclear reactors, the design of the 12.5 Bev Zero Gradient Synchrotron, the theory of nuclear structure and reactions, and to basic chemical and biological theory. These computations are made possible by investigations into the mathematical foundations of basic theories, and examinations of new techniques in applied mathematics and numerical analysis. Computer and automation research at Argonne have contributed to the experimental sciences through the design and operation of large scale data recording and data reduction systems.

In order to serve the mathematical needs of its scientists and engineers, Argonne operates an analogue computer, PACE; an IBM 704; and GEORGE, a digital computer designed and constructed at the Laboratory.

Argonne
NATIONAL LABORATORY
Operated by the University of Chicago under a contract with the United States Atomic Energy Commission

PROFESSIONAL PLACEMENT
P.O. BOX 299-N5
LEMONT, ILLINOIS

STAFF POSITIONS AVAILABLE FOR QUALIFIED *Physical Metallurgists, Chemical Engineers, Physicists, Mechanical Engineers, Metallurgical Engineers, Chemists, Electrical Engineers, Mathematicians, Technical Writers*

edited by Charles Singer, E. J. Holmyard, A. R. Hall and Trevor I. Williams, Vol. III, pages 582-619; Clarendon Press, 1957.

LOVE IN INFANT MONKEYS

THE DEVELOPMENT OF AFFECTIONAL RESPONSES IN INFANT MONKEYS. Harry F. Harlow and Robert R. Zimmermann in *Proceedings of the American Philosophical Society*, Vol. 102, pages 501-509; 1958.

THE NATURE OF LOVE. Harry F. Harlow in *American Psychologist*, Vol. 12, No. 13, pages 673-685; 1958.

BEER

THE ART AND SCIENCE OF BREWING. C. A. Kloss. Stuart and Richards, 1949.

BEER HAS A HISTORY. Frank A. King. Hutchinson's Scientific and Technical Publications, 1947.

THE BIOCHEMISTRY OF BREWING. I. A. Preece. Oliver & Boyd, 1954.

BREWING: SCIENCE AND PRACTICE. H. Lloyd Hind. Chapman & Hall, Ltd. 1938.

SELF-REPRODUCING MACHINES

ARTIFICIAL LIVING PLANTS. Edward F. Moore in *Scientific American*, Vol. 195, No. 4, pages 118-127; October, 1956.

COMPUTABILITY AND λ -DEFINABILITY. A. M. Turing in *The Journal of Symbolic Logic*, Vol. II, No. 4, pages 153-163; December, 1937.

THE GENERAL AND LOGICAL THEORY OF AUTOMATA. John von Neumann in *Cerebral Mechanisms in Behavior*, edited by Lloyd A. Jeffress, pages 1-41; John Wiley & Sons, Inc., 1951.

MAN VIEWED AS A MACHINE. John G. Kemeny in *Scientific American*, Vol. 192, No. 4, pages 58-67; April, 1955.

THE ORIGINS OF LIFE. J. B. S. Haldane in *New Biology*, No. 16, pages 12-27; April, 1954.

JUNCTION-DIODE AMPLIFIERS

LOW-NOISE IN SOLID-STATE PARAMETRIC AMPLIFIERS AT MICROWAVE FREQUENCIES. W. E. Danielson in *Journal of Applied Physics*, Vol. 30, No. 1, pages 8-15; January, 1959.

THE PARAMETRIC AMPLIFIER. F. S. Harris in *CQ*, Vol. 14, No. 11, pages 74-75; November, 1958.

THE POTENTIAL OF SEMICONDUCTOR DIODES IN HIGH-FREQUENCY COMMUNICATIONS. A. Uhlir, Jr. in *Proceed-*

Fellow Engineers and Scientists:

My company has asked me to tell you of the unusual opportunities in operations research at System Development Corporation. These range from positions for engineers and scientists who would like to develop their skills working in a team under an experienced leader to opportunities for those who are looking for positions of leadership. I hope that the following account of our work will lead you to inquire for further information.

Briefly, SDC's business is automated decision-making systems. More fully, we develop large scale, computer-based information processing systems in which the computer is used as an on-line, centralized control element for a system operating in real-time. At this stage of the art these systems are semi-automatic, the man-machine type in which man shares the repetitive control function with the computer. Our work is concept-oriented, rather than hardware-oriented, and deals with problems of over-all system design, data processing development, and man-machine system training.

The most fully developed large-scale semi-automatic system is the SAGE (Semi-Automatic Ground Environment) Air Defense System. We have a major responsibility in the development of SAGE. Our experience and unique team skills have led to diversification of our activities; we now have important contracts for other major military and government systems vital to our country. The demand for our services is reflected in our growth from 70 to more than 2,700 employees since 1955, and the intriguing possibilities of automated decision-making are only beginning to be realized.

In this brief message, I can only suggest the variety of operations research problems at SDC. Perhaps the most important point is that this variety is limited only by the imagination and initiative of our scientists.

Some examples of areas of work are: (1) allocation of decision-making functions between man and machine for optimal system performance; (2) measures of system capacity and system performance; (3) exploration and evaluation of design changes by operational gaming; (4) quality control and testing of operational computer programs; (5) allocation of computer capacity among several system functions; (6) scheduling and costing of production of operational computer programs; (7) optimal assignment of mixed weapons to targets.

SDC recognizes the importance of a well planned research program for the vitality and future of the company, and we are carefully organized to carry out such a program. The following are some areas our operations research people are involved in: (1) simulation and operational gaming techniques in problems of control systems; (2) information retrieval and theory of information processing; (3) medical data processing; (4) universal language for computer programming; (5) logistics. We have unusual facilities for research at SDC—these include one of the largest computer facilities in the world and outstanding simulation laboratories.

We have given considerable thought to organizing the activities at SDC to provide for professional development and self-expression. Operations research professionals are carefully assigned so that their individual talents are matched with company needs. These assignments are reviewed regularly to make sure that developing talents are directed into new company opportunities. We regard the publication of research articles and participation in professional societies as activities important to the company. We encourage new ideas and provide the time and means to explore them.

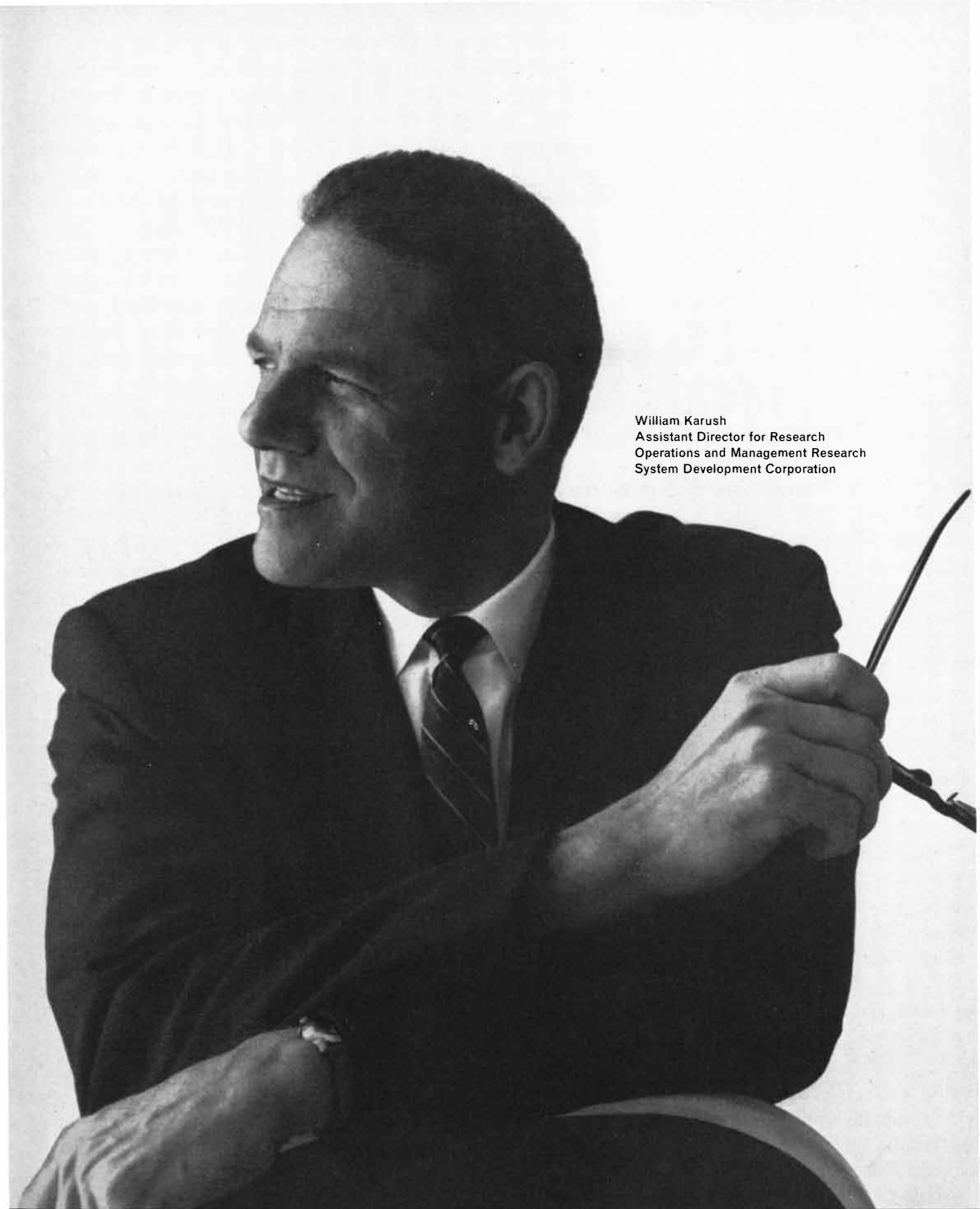
SDC is one of the leaders in a field which will have a remarkable technological and scientific development. It is a new and vigorous company with a bright future. I encourage you to join us.

Please write Mr. R. W. Frost at the address below if you wish to pursue this invitation.

William L. Kaush

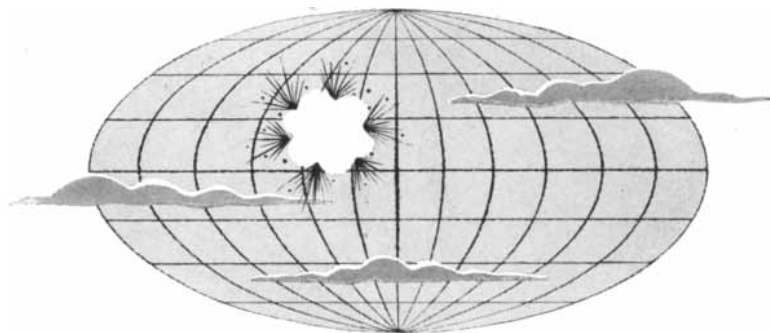
11-105A





William Karush
Assistant Director for Research
Operations and Management Research
System Development Corporation

FUTURE LIMITED WARFARE

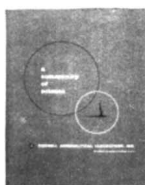


SUBJECT OF A SEARCH FOR NEW KNOWLEDGE AT CORNELL AERONAUTICAL LABORATORY

The free world's ability to quickly stamp out a limited war can mean the avoidance of a catastrophic total conflagration. Its accomplishment calls for new concepts in the areas of quick destruction, wide dispersal of relatively small forces, highly creative use of camouflage, great mobility of troops and weapons, the development of small, highly flexible missiles, as well as anti-missile weapons and the ability to capitalize on the cover afforded by night and bad weather. Today an important segment of C.A.L.'s technical know-how is devoted to these tasks. Current studies include Close-Support Weapons Systems, Tactical Air Weapons Studies, Combat Zone Air Defense, Reconnaissance and Surveillance, Combat Control Systems and Combat Area Mobility. C.A.L.'s searching look into the battlegrounds of the future includes more than a dozen research and development projects inherent in the problems of limited warfare. They are problems that offer attractive opportunities for engineers and scientists. If you are interested in becoming a member of one of our small, closely knit research teams working on far-reaching scientific and technological programs, write today for a free copy of our factual, illustrated employment prospectus entitled "A Community of Science."



CORNELL AERONAUTICAL LABORATORY, INC.
of Cornell University
Buffalo 21, N.Y.



**FREE
REPORT**

J. S. Ruch L.W.
CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo 21, New York

Please send me a copy of "A Community of Science"

Name

Street

City Zone State

Please include employment information.

ings of the IRE, Vol. 46, No. 6, pages 1,099-1,115; June, 1958.

WORM AUTOBIOGRAPHIES

THE MECHANISM OF PROBOSCIS MOVEMENT IN ARENICOLA. G. P. Wells in *The Quarterly Journal of Microscopical Science*, Vol. 95, Part 2 (Third Series, No. 30) pages 251-269; June, 1954.

THE SOURCES OF ANIMAL BEHAVIOUR. G. P. Wells. An Inaugural Lecture Delivered at University College London, 5 May 1955. Published for the College by H. K. Lewis & Co., Ltd., 1955.

SPONTANEOUS ACTIVITY CYCLES IN POLYCHAETE WORMS. G. P. Wells in *Symposia of the Society for Experimental Biology*, No. IV, pages 127-140; 1950.

PRIMITIVE KINSHIP

AFRICAN SYSTEMS OF KINSHIP AND MARRIAGE. Edited by A. R. Radcliffe-Brown and Daryll Forde. Oxford University Press, 1950.

CUSTOM AND CONFLICT IN AFRICA. Max Gluckman. Basil Blackwell, 1955.

THE FATHER IN PRIMITIVE PSYCHOLOGY. Bronislaw Malinowski. Kegan Paul, Trench, Trubner & Co. Ltd., 1927.

SOCIAL ORGANIZATION. Robert H. Lowie. Rinehart & Company, 1948.

STRUCTURE AND FUNCTION IN PRIMITIVE SOCIETY. A. R. Radcliffe-Brown. Cohen & West Ltd., 1954.

WE, THE TIKOPIA. Raymond Firth. American Book Company, 1936.

THE WEB OF KINSHIP AMONG THE TALENSI. Meyer Fortes. Oxford University Press, 1949.

MATHEMATICAL GAMES

EXPERIENCE AND PREDICTION. Hans Reichenbach. University of Chicago Press, 1938.

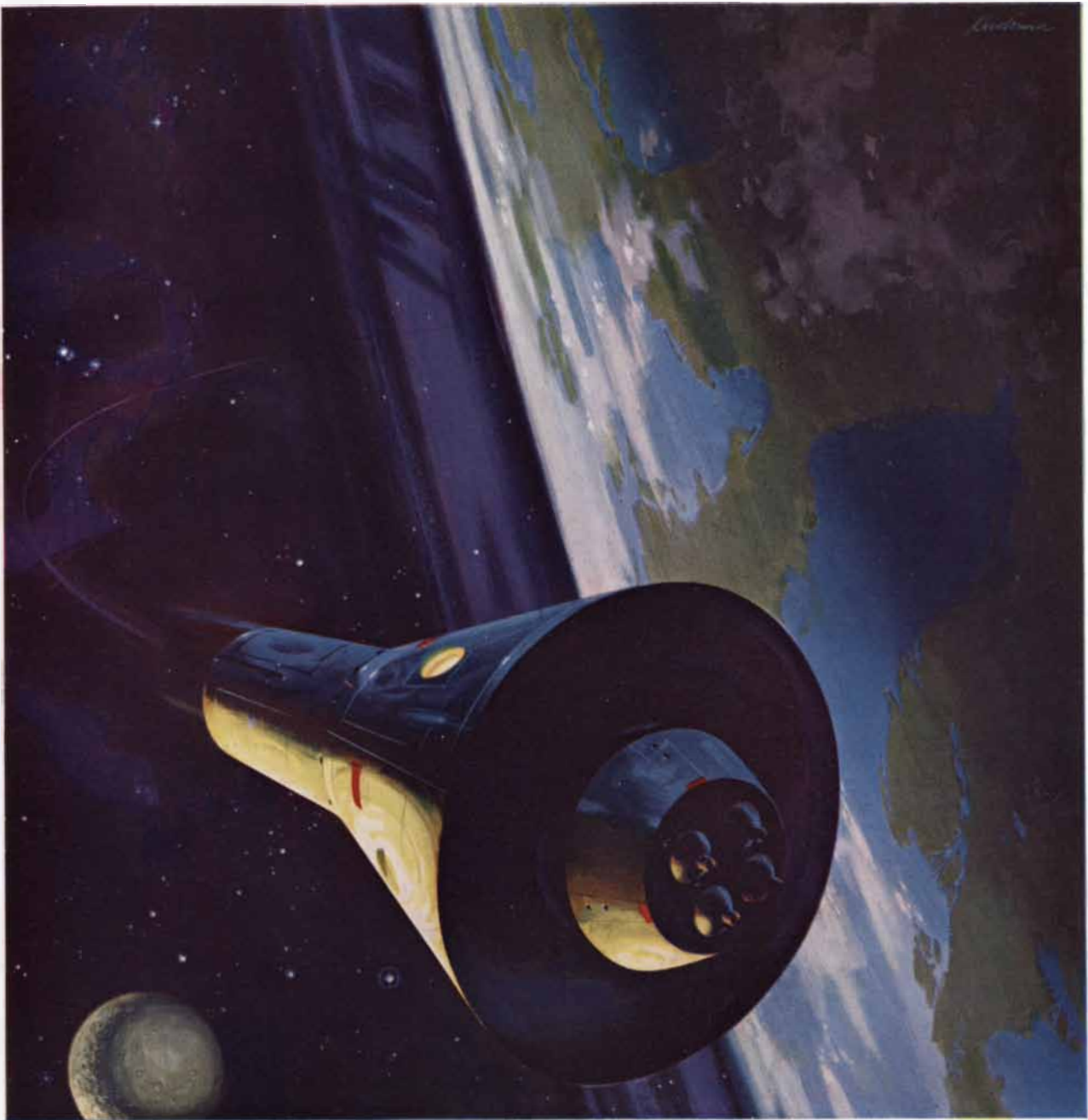
JOHN DEWEY. Bertrand Russell in *A History of Western Philosophy*, pages 819-827. Simon and Schuster, Inc., 1945.

THE MEANING OF TRUTH. A SEQUEL TO "PRAGMATISM." William James. Longmans, Green, and Co., 1909.

THE AMATEUR SCIENTIST

INTRODUCTORY NUCLEAR PHYSICS. David Halliday. John Wiley & Sons, Inc., 1955.

LECTURE SERIES IN NUCLEAR PHYSICS. E. M. McMillan *et al.* Government Printing Office, 1947.



complete instrumentation
for NASA's
Project Mercury

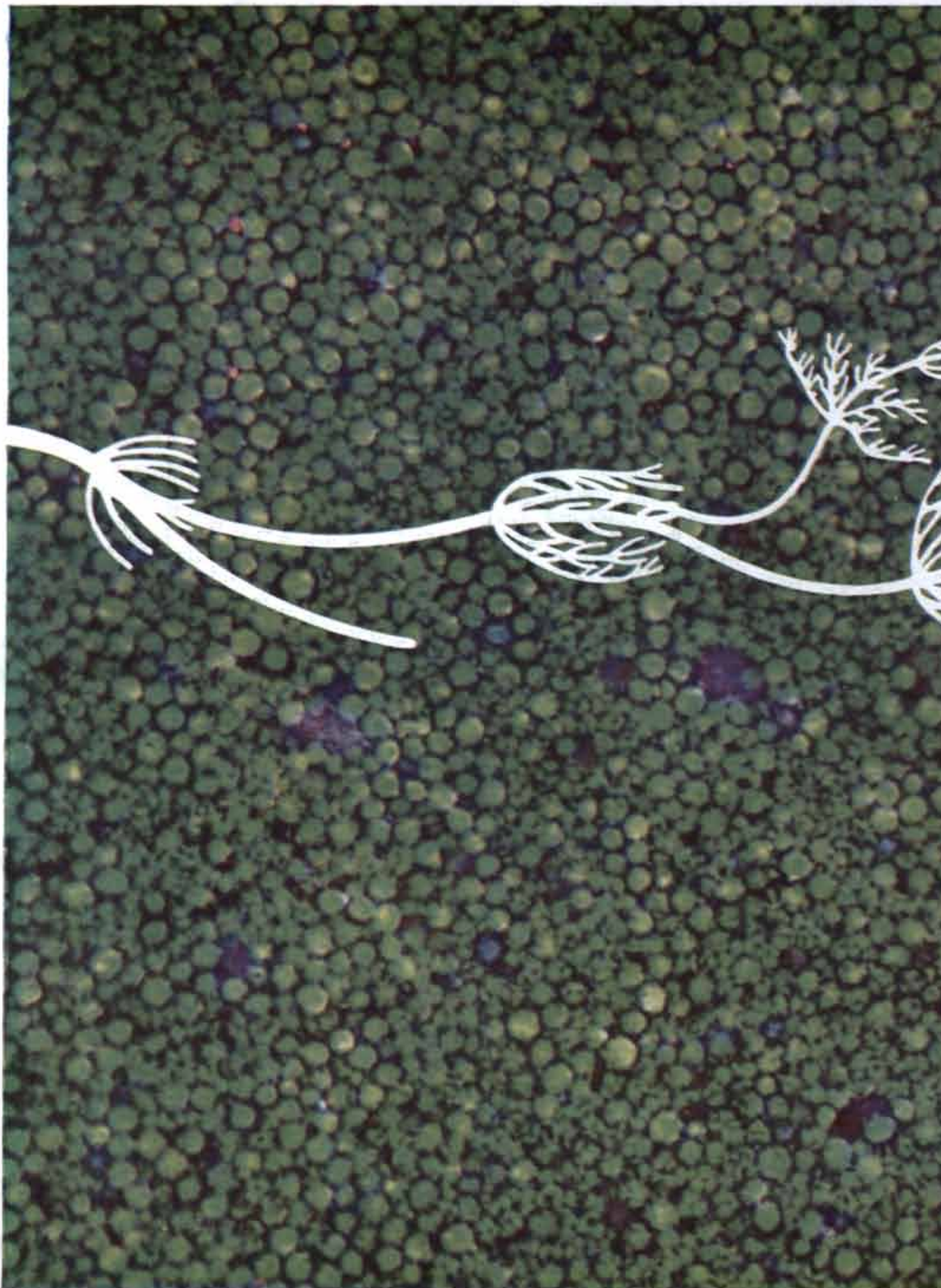
COLLINS ELECTRONICS

The reality of McDonnell's manned satellite will be a great milestone in NASA's exploration of space. Collins Radio Company is extremely proud to participate in Project Mercury by supplying the complete electronic system. This consists of orbital radio voice communication, a command system for radio control, a telemetry data system, a Minitrack beacon system, a transponder beacon system for precision tracking, and a rescue radio voice and beacon system. Other Collins space electronic projects include the communication-navigation system for the X-15, moon relay communication studies, and satellite tracking facilities.



COLLINS RADIO COMPANY • CEDAR RAPIDS, IOWA • DALLAS, TEXAS • BURBANK, CALIFORNIA

GENERAL DYNAMICS



Problems of Survival: World population—1,094 million in 1850; 1,550 million in 1900; 2,500 million in 1950.

© 1959 SCIENTIFIC AMERICA