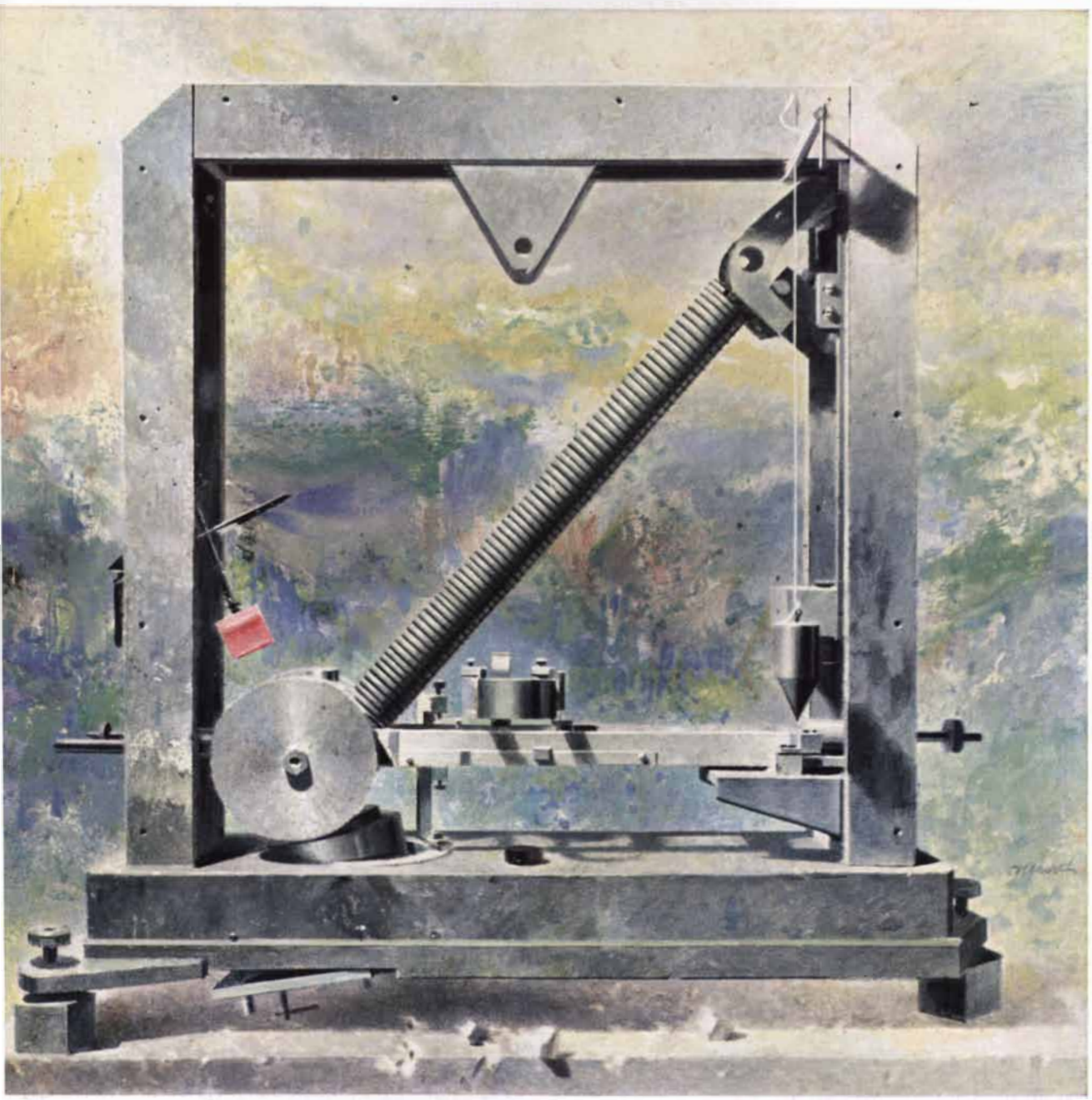
# SCIENTIFIC AMERICAN

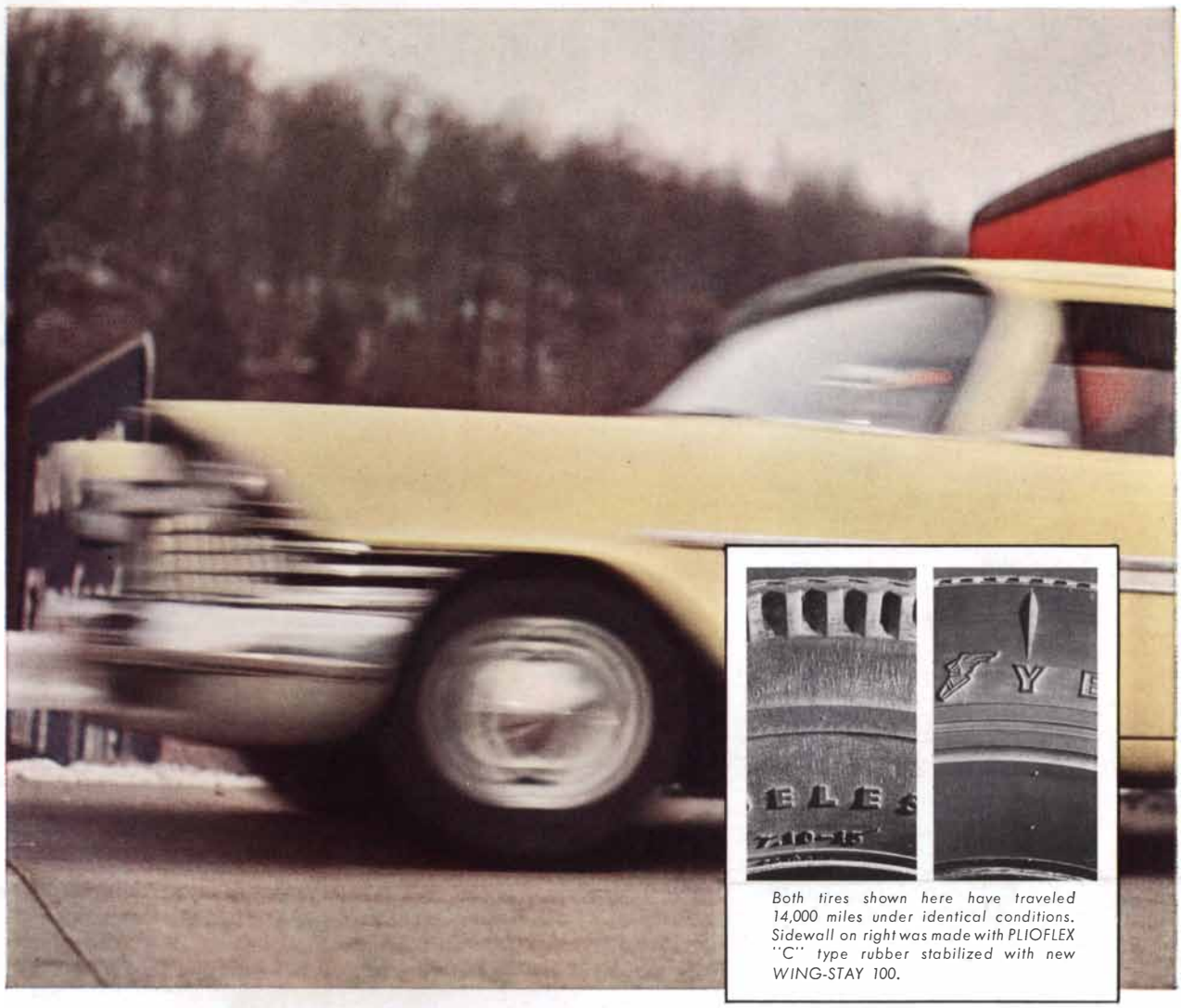




LONG EARTHQUAKE WAVES

*FIFTY CENTS*

*March 1959*



Both tires shown here have traveled 14,000 miles under identical conditions. Sidewall on right was made with PLIOFLEX "C" type rubber stabilized with new WING-STAY 100.

# Now—rubber that keeps its age a secret

**Whirling around** a test track—or spinning through traffic—tires *age* with wear. The effects of this aging process show up most often in the sidewalls, where small cracks appear. Not only do they mar the looks of the tire, they rob it of strength and cut into its service life.

**What causes cracking?** Two things, mainly—atmospheric oxygen and ozone. To combat them, antioxidants have been developed. So have antiozonants. *But not until now* has a truly effective *combination* of antioxidant and antiozonant been perfected. And that's WING-STAY 100 by Goodyear.

**The superior protection of Wing-Stay 100** can be yours in four new PLIOFLEX rubbers. Dynamic aging resistance thus becomes another key advantage of PLIOFLEX 1500C, 1710C, 1712C, and 1714C – along with assured processability, high uniformity and excellent physical characteristics.

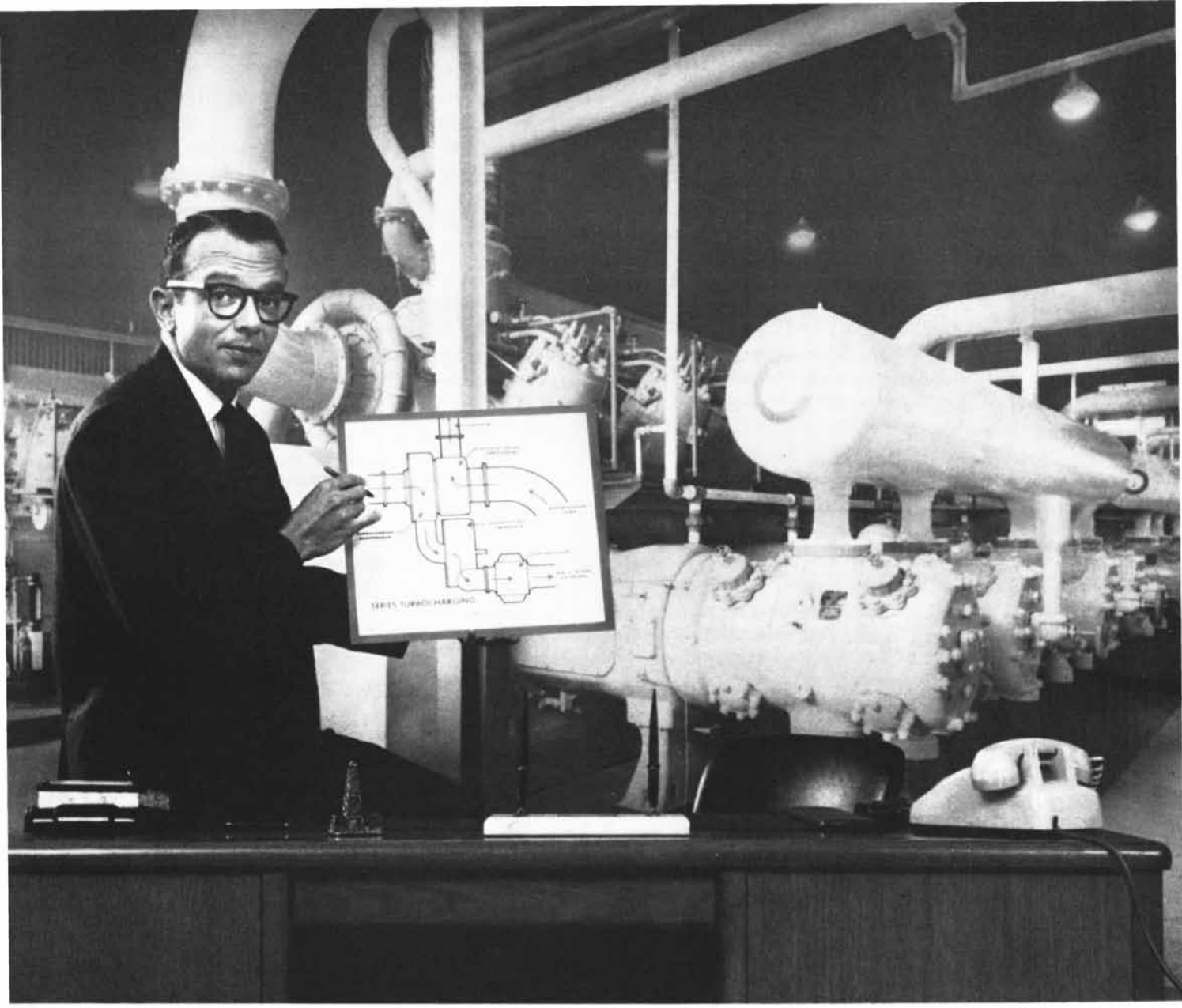
**For more information** and complete technical service on PLIOFLEX "C" type rubbers—plus other rubber chemicals and a full line of synthetic rubbers—write:

Goodyear, Chemical Division, Dept. C-9457,
Akron 16, Ohio


GOODYEAR

CHEMICAL DIVISION

Wing-Stay, Plioflex—T. M.'s The Goodyear Tire & Rubber Company, Akron, Ohio



Donald L. Reed, *Manager Gas Engine Compressor Sales, The Cooper-Bessemer Corporation, explains . . .*

# How we now make engines do 40% more work

The diagram shows a recent major development in feeding air to the power cylinders of Cooper-Bessemer's big engine-driven compressor units. This unique "*series turbocharging*" overcomes many former supercharging limitations and successfully boosts air supply for better combustion, more effective scavenging of exhaust gases, greater efficiency and increased power!

As a result, gas transmission, petroleum and chemical companies are getting 40% *more* power with these new V-angle compressor units than with predecessors of the same bore, stroke and speed. Or, for a given job, this means less fuel consumption and much lower costs for housing, foundations, piping and year-in, year-out operation.

Find out what cost-saving advancements Cooper-Bessemer can apply to *your* needs in power and compression facilities. Call our nearest office.

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

*SUBSIDIARIES:* Cooper-Bessemer of Canada, Ltd. . . . Edmonton • Calgary Toronto • Halifax

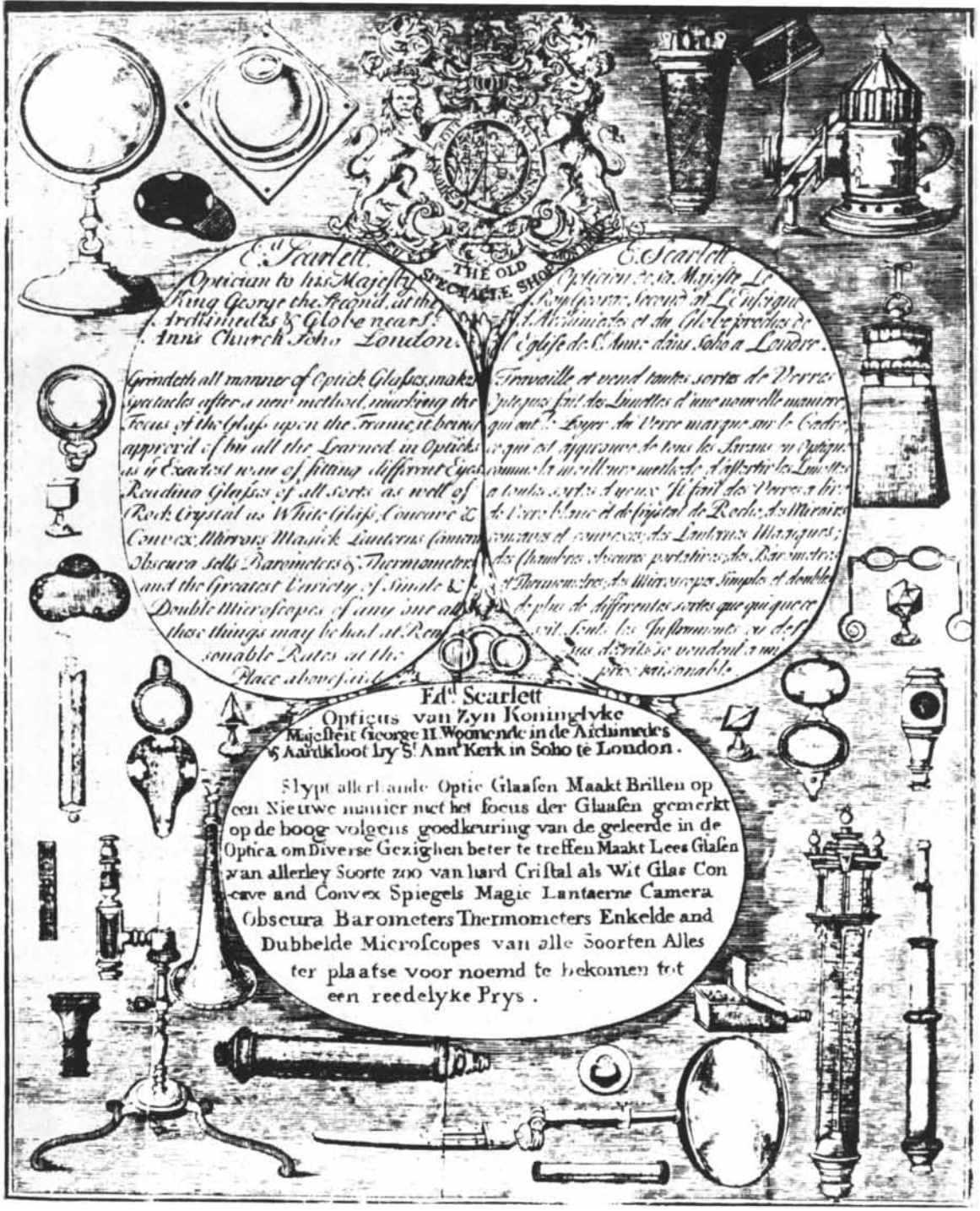
Cooper-Bessemer International Corporation...NewYork • Caracas • Mexico City

C-B Southern, Inc. . . . Houston

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

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



Established 1845 **SCIENTIFIC AMERICAN** March, 1959 Volume 200 Number 3

ARTICLES



DEPARTMENTS





PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK 17, N. Y.  SECOND CLASS POSTAGE PAID AT NEW YORK, N. Y., AND AT ADDITIONAL MAILING OFFICES. SUBSCRIPTION RATE IN THE U. S. $5 PER YEAR.

## THE COVER

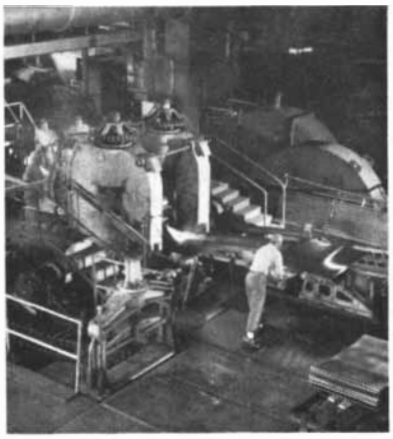
The painting on the cover depicts a seismometer used in the Lamont Geological Observatory of Columbia University to detect earthquake waves of great length (*see page 131*). The seismometer is essentially a mass suspended in such a way that when the earth shakes the mass tends to remain stationary. The apparent movement of the mass can then be used to record the vibrations of the earth. In this seismometer the mass is the round object at lower left. The mass is mounted at the end of an arm which is free to move vertically, and is supported by the spring which runs diagonally across the frame of the apparatus. When the frame is shaken by the earth, the mass oscillates vertically with a period of the order of 30 seconds. Thus the system detects only the vertical component of very long earthquake waves.

## THE ILLUSTRATIONS

Cover painting by Walter Murch

| Page | Source |
|---|---|
| 40-45 | Irving Geis |
| 46 | State University of Iowa |
| 47 | United Press Photo |
| 49-50 | H. B. D. Kettlewell |
| 51-53 | Eric Mose |
| 55 | Bunji Tagawa |
| 56-58 | Emi Kasai |
| 72 | Emi Kasai |
| 73 | Radiation Laboratory, University of California |
| 74-80 | James Egleson |
| 82 | Argonne National Laboratory |
| 87-88 | James D. Ebert |
| 90-96 | John Langley Howard |
| 100 | Joya Hairs |
| 101 | Guatemalan Bureau of Cartography |
| 102-108 | Bunji Tagawa |
| 110-113 | University of Oklahoma |
| 117-126 | Bruno Bettelheim |
| 131-140 | Irving Geis |
| 146 | Alex Semenoick |
| 148-152 | Alex Semenoick |
| 155-166 | Roger Hayward |


**Raw Material**—Zirconium tetrachloride is delivered to Mallory-Sharon's sponge plant in 6-ton rubber containers.



**Rolling** sheet bar into finished sheets. Both titanium and zirconium are available in a wide range of mill shapes.

*Who's*

# FULLY INTEGRATED

## *for special metals production*

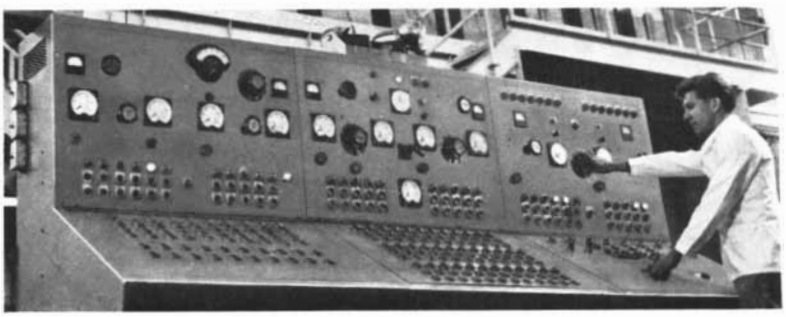
Titanium and zirconium have progressed, in a few short years, from limited application to practical special-purpose metals.

In the forefront of this development since its beginning, Mallory-Sharon now offers the *only completely integrated production facilities* in the industry.

From raw materials, through sponge production, vacuum melting, and rolling of mill products, we carefully control quality and physical properties at every step.

Backing-up these physical facilities is an outstanding "special metals team"—research and development, technical staff, and application engineers.

When you have a technical problem involving titanium, zirconium or other special metals, come to "headquarters". You'll find a Mallory-Sharon service engineer can be most helpful on properties and applications. And he can provide you with a wealth of information on machining, forming and welding of titanium and its alloys for special purposes.



**Vacuum Melting**—photo shows remote control panel for vacuum double melting furnaces at Niles, Ohio.

**Zirconium Chunklets** produced at Ashtabula, Ohio, plant are used to produce ingots for forging or rolling.

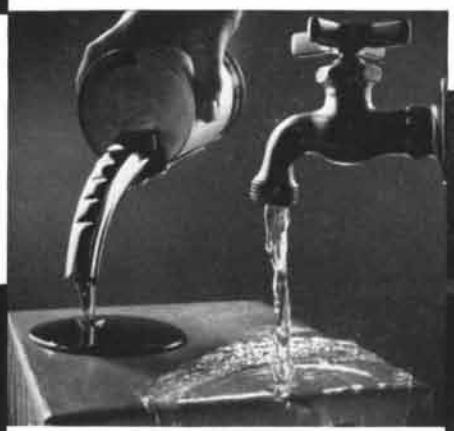
**MALLORY** MS **SHARON**

MALLORY-SHARON METALS CORPORATION · NILES, OHIO

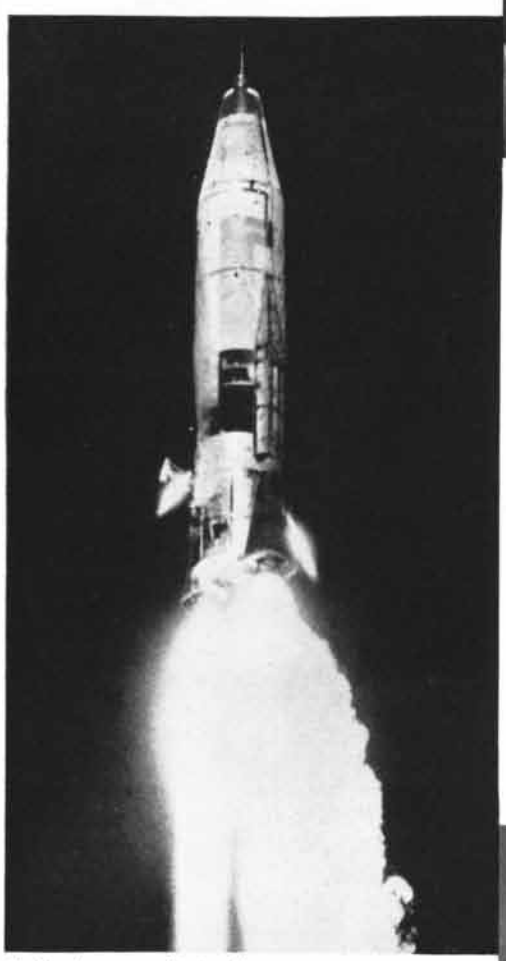
*Integrated producer of Titanium · Zirconium · Special Metals*

3M COMPANY CHEMICALS

THE RAW MATERIALS OF PROGRESS



Protective coatings for papers, textiles, leathers



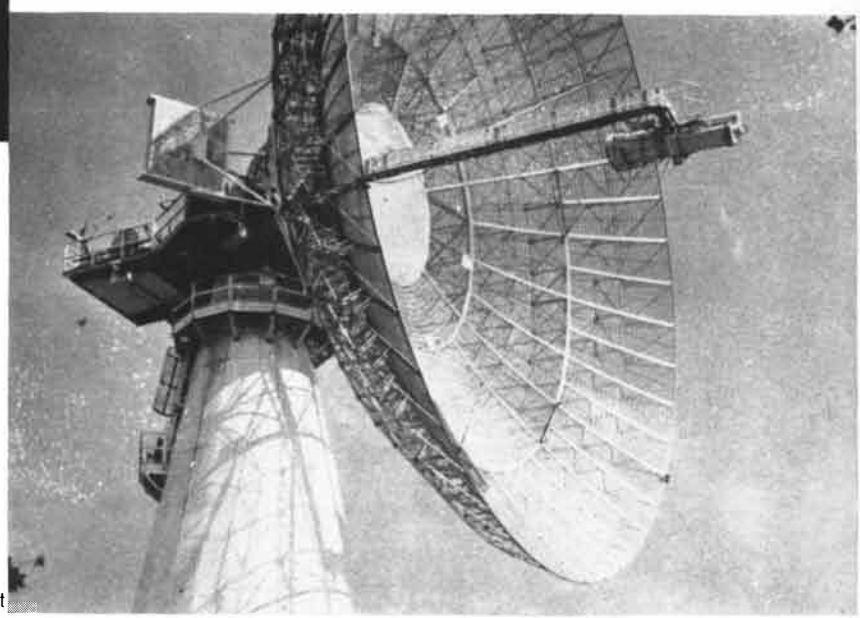
Plastics for spacecraft, aircraft

# 3M CHEMISTRY INVITES

Set off, if you will, on a voyage of discovery in the realm of your own imagination. The versatility and variety of 3M Chemical Products invite you to explore their potential in your field.

In such diverse areas as electronics, aeronautics, automotive, textiles, plating, leather, plastics and packaging, 3M Chemicals are helping to push processing and product development far beyond previously accepted limits. They solve problems of chemical, thermal and dimensional stability, combat contamination and corrosion, add exceptional flexibility, longevity, strength and functional improvements to many products.

Each of the 3M Chemicals in the list at the right offers superiorities that invite imaginative use. Explore them—write for detailed data now.



Inert fluids for electronic equipment

Friction particles and binders for brake and clutch facings

# YOU TO TOUR YOUR OWN IMAGINATION

**Plastics and Elastomers:** KEL-F® and fluorochemical polymers offering great chemical and thermal stability, high solvent resistance and outstanding electrical properties.

**Friction Particles and Binders** for brake liners, clutch facings.

**Textile Finishes:** "SCOTCHGARD" Brand finishes for textiles, which repel oil as well as water. **Tanning Chemicals** for leather.

**Protective Size** for papers and packaging: "SCOTCHGARD" Brand oil and water-repellent sizes for papers, containerboard.

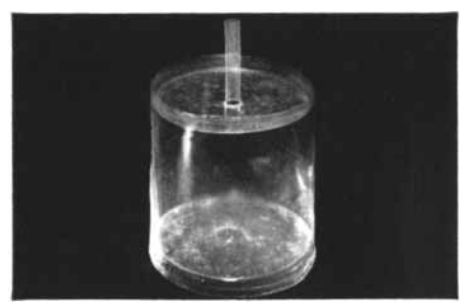
**Corrosion Control Materials** including plastics, carbon impregnates, primers and coating resins.

**Acids and Alkanes:** KEL-F® oils, waxes and greases for use as lubricants, fluids, sealants; fluorocarbon chemicals and polymers with a broad spectrum of use, including "do-nothing" chemicals from the fluorochemical family, which now serve as insulating and coolant fluids.

**Inorganic Oxides and Acids** serving in steel pickling, chemical processing, or in paint, plastics or rubber industries.

For literature, write on company letterhead, specifying product interest, to 3M Chemical Division, Dept. WH-39, St. Paul 6, Minnesota.

**Cools Tube.** 3M Fluorochemical Inert Fluid FC 75 was chosen by RCA as the best low-temperature coolant for this high-power transmitting tube. FC 75 permitted design of tube for operation at temperatures below 32°F with essentially the same power output as that obtained with water cooling at temperatures above 32°F.



**Resists Chemical and Thermal Shock:** Expellent bladders for the missiles field, made of tubing formulated of KEL-F® halofluorocarbon polymers, have zero moisture absorption, are so inert and temperature resistant that they survive liquid oxygen and both red and white fuming nitric acid for indefinite periods.

**3M CHEMICAL DIVISION, MANUFACTURERS OF: Acids • Resins • Elastomers • Plastics • Oils, Waxes and Greases • Dispersion Coatings • Functional Fluorochemicals • Inert Liquids and Surfactants**

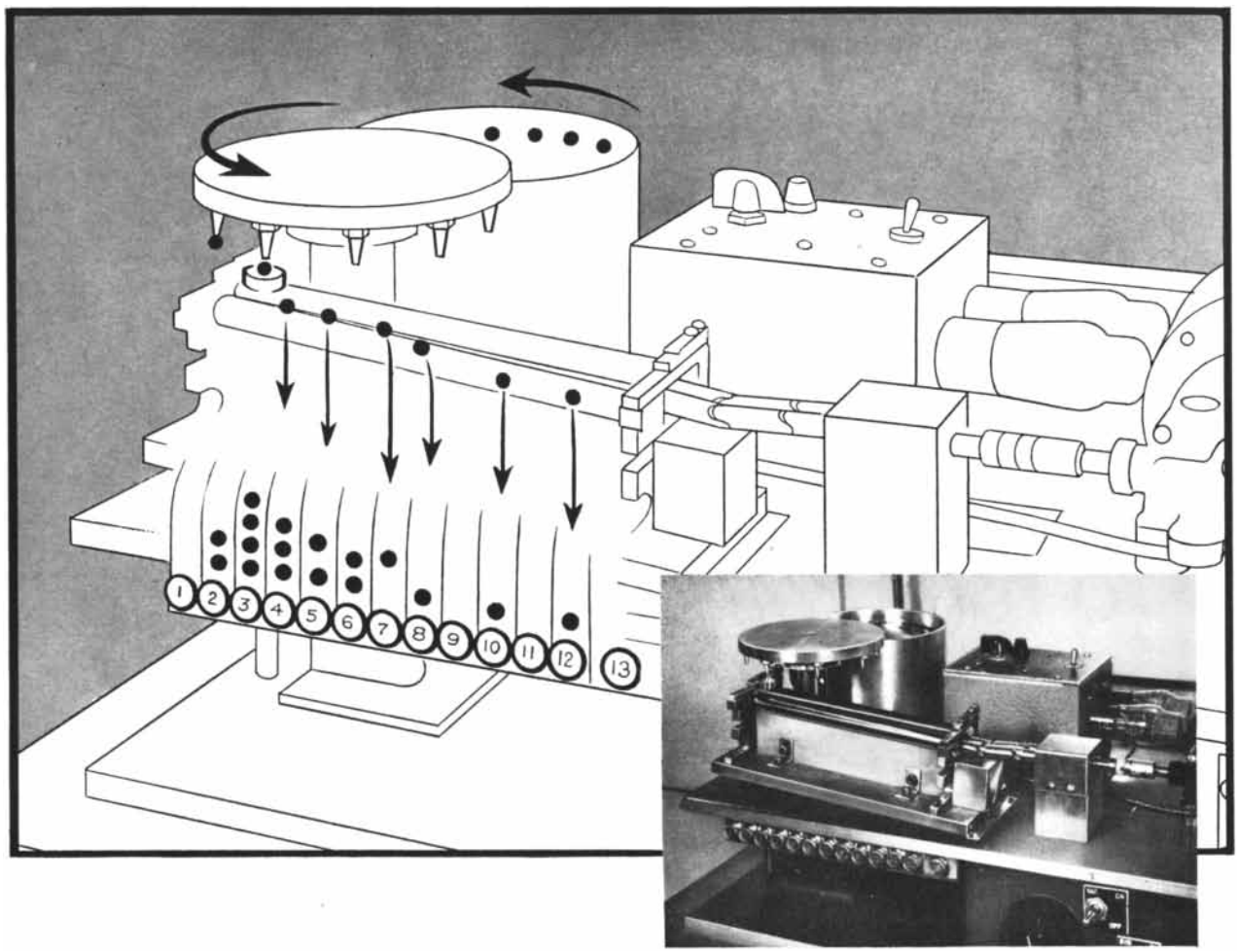
**CHEMICAL DIVISION**

**MINNESOTA MINING AND MANUFACTURING COMPANY**

**. . . WHERE RESEARCH IS THE KEY TO TOMORROW**

3M COMPANY

## TECHNOLOGICAL LEADERSHIP IN SEMICONDUCTORS




# How semiconductor dice are "loaded" for better transistors

The silicon or germanium die is the heart of the transistor. Precise thickness is vital to the transistor's performance and must be measured within a few ten thousandths. At Sylvania this is accomplished by combining the roller micrometer principle with an ingenious and exclusive unit-feed mechanism developed by Sylvania engineers.

For the circuit designer, this seemingly simple refinement makes important contributions to a better, more uniform transistor. It eliminates damage and contamination of the dice, both difficult to avoid in now obsolete hand-tweezer feeding.

At Sylvania, technological achievements like the automatic unit-feed mechanism are in progress every day. Always, the objective is to produce the best possible transistor at the lowest possible cost.

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
Semiconductor Division
1740 Broadway, New York 19, N. Y

LIGHTING • TELEVISION • RADIO • ELECTRONICS • PHOTOGRAPHY • CHEMISTRY-METALLURGY

# Foxboro makes a better instrument . . . or Foxboro doesn't make it!

Final calibration of a Stabilflo control valve. Development of this Foxboro product, with its wide-range V-port design, contributed new exactness to automatic process control.

FOXBORO
REG. U.S. PAT. OFF.

**Creative Design and Manufacture of Instruments and Instrument Systems for Measurement and Control of Process Variables. The Foxboro Company, Foxboro, Mass., U. S. A.**

# Voice of defense in the North

## Philco Microwave supports Nike control network across Alaska

Unaffected by the most severe winter storms . . . unhampered by rugged terrain . . . impervious to electronic jamming . . . Philco Microwave has been selected by the U.S. Army Signal Office to link Nike sites on the Alaskan Defense perimeter.

Advanced Philco CLR-9 microwave equipment assures extremely reliable electronic communication between these isolated guided missile outposts. Because it provides a completely reliable, uninterrupted communications system in this frozen land, Philco Microwave has become America's "voice of defense in the North."

At Philco, the world of tomorrow is *now*. To meet the challenge of advanced electronics research and engineering, Philco is pioneering advanced communications systems such as that developed for the Alaskan Nike sites. And, at Philco, engineering opportunities are also expanding—in the development of advanced communications systems, weapons systems and data processing.

Wherever you look at Philco; in guided missiles; in advanced navigation; in infra-red and radar technologies; as well as in communications systems . . . being "out front" is a habit.

In the wonder world of advanced electronics, look to the leader. Look ahead . . . and you'll choose Philco.

**PHILCO**

GOVERNMENT & INDUSTRIAL DIVISION

**4700 Wissahickon Ave., Philadelphia 44, Penna.**

# LETTERS

Sirs:

In his lengthy review of my book "Brighter than a Thousand Suns" [SCIENTIFIC AMERICAN, December, 1958] Robert R. Wilson makes the surprising statement that I have "never interviewed" one of my main subjects, Robert Oppenheimer. I interviewed Dr. Oppenheimer in his directorial office in Princeton in April, 1956, on appointment. I am sure there must be some kind of secretarial record of my visit to the Institute for Advanced Study. Dr. Oppenheimer knew the subject of the book I was preparing and after a more general discussion about the 13th century our conversation moved to more recent times and problems. However, I had been asked by a common editorial acquaintance not to touch upon the "Chevalier affair" because Dr. Oppenheimer did not want to talk about it.

I have no doubt that the reviewer acted in good faith when he made his inexact statement. He had to rely on other people's testimony as much as I. I interviewed over a period of two years almost a hundred persons in seven countries in order to piece this extraordinary story together. I can assure Professor Wilson most emphatically that not a single fact in my book stems from my "own vivid imagination," as he seems to believe, and that I have tried to check every single fact as thoroughly as possible. What the reviewer calls "inaccura-

**Scientific American,** March, 1959; Vol. 200, No. 3. 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.

**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.

**Subscription rates** for U.S.A. and possessions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $11; 3 years, $15. All other countries: 1 year, $8; 2 years, $14; 3 years, $18.

cies" are the "accuracies" of somebody else, who remembered and evaluated the facts differently. If I have not always been able to name the source of certain statements and information, this has been because I had to assure all the people I interviewed that I would be discreet whenever they said to me: "Better don't say who told you that."

It would indeed be of great importance if the men who made the atomic bomb would soon write their memoirs or publish their diaries. But I doubt that this can be done successfully as long as they have to pull their punches out of professional courtesy. As an "outsider," who was able to write down what he heard without being afraid of any "reprisals" by some colleagues he had criticized, I may after all have sketched a realistic picture of some value to future historians. Corrections will be made and should be made—that is the way history is written—but I doubt that Professor Wilson, who confesses to his "defensive bias," to his "indignation" and to his "emotional" response caused by my book, has been very helpful.

In "overdestroying" my book with this "H-bomb review" Professor Wilson has unfortunately also knocked down some standards of quiet scientific reasoning. Instead of pin-pointing mistakes he offers mainly damning generalizations without offering further proof. I hope that Hans A. Bethe is closer to a real evaluation of my work when he states in his pretty critical review of it: "On the whole the presentation is fair in contrast to some previous attempts at writing the same history. It gives a good picture of the psychological development of the scientists as well as of the scientific and political events."

ROBERT JUNGK

London, England

Sirs:

My apologies to Mr. Jungk for the incorrect statement about his lack of an interview with Robert Oppenheimer. I am happy to accept Jungk's word for the interview without recourse to any secretarial record. More than ever am I mystified that he could then so thoroughly have missed the essence of Oppenheimer's personality. Could it be that one interview was still on the scant side for the purpose of a biography?

The harshness in my review to which Mr. Jungk objects came about in part because of my disappointment in the book after having had my admiration

Coating of a TFE-fluorocarbon resin is used on filler barrel of the Parker 61 pen, a product of The Parker Pen Co., Janesville, Wisconsin

# THE INSIDE STORY: How a finish put an end to an inky problem

The inner barrel of the new Parker Pen is dipped into ink and fills by capillary action. Puzzling to the designers at first was how to make it easy to clean the wet barrel. *Solution:* A coating of the TFE resin sheds the ink so well, that it is not necessary to wipe the cell case.

Unless special techniques are used, nothing sticks with any strength to a TFE-fluorocarbon resin surface. Moreover, TFE resins resist heat to 500°F., are unaffected by almost all chemicals, and have lower coefficients of friction than any other solid material.

Special techniques can however be used to bond TFE resins. Sheets of TFE resins are often applied via these techniques to hoppers, conveyors and chemical vats. The exposed surfaces of the resins remain slippery and "anti-adhesive".

We've just issued a 20-page illustrated booklet entitled "TEFLON TFE-Fluorocarbon Resins in Mechanical Applications", packed with facts on uses of TFE resins. Send for your copy today. **E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room T-393, Du Pont Building, Wilmington 98, Delaware.**

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

DU PONT REG. U.S. PAT. OFF.

TEFLON®

TFE-FLUOROCARBON RESINS

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY

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

thoroughly aroused by his well-written early chapters. Jungk, as he points out, is in the excellent position of being an "outsider." Furthermore, his perceptivity in understanding scientists is remarkable; it seems more the pity that his account was marred by so many errors of fact. The "accuracies of somebody else" may be acceptable for a Hollywood columnist but are not appropriate for the serious subjects he has attempted to analyze. I very much hope that he continues to lend his obvious talent for analysis and good writing to the study of relationships between science, scientists and civilization, but I also hope that next time he divests himself of preconceived biases and spends that extra effort so necessary in preparing any reliable account.


ROBERT R. WILSON

Cornell University
Ithaca, N.Y.


Sirs:

Sanford Rosenthal's clinical experience in Peru ["Wound Shock"; SCIENTIFIC AMERICAN, December, 1958] confirms what has been known for many years, *i.e.*, there is a large loss of sodium chloride and water into burned tissues, and that giving such patients large volumes of salt solution by mouth, or parenterally when they cannot swallow, is good practice. The reader, however, will get the impression that this therapy is also appropriate and effective for shock due to wounds in general. Dr. Rosenthal should be aware of the well-documented reports from many clinicians that this therapy, which has been used in literally thousands of cases of wound shock of all varieties, simply does not work. It does not cure the shock of severe wounds, including extensive burns, such as those treated by Dr. Rosenthal himself in Peru. It is not the answer to the problem of wound shock, because the vast majority of patients who have been treated for, but have died of, wound shock have died in spite of full replacement of fluid and electrolyte deficits, when present. Nor is the successful treatment of tourniquet injury in rats or mice with salt solution applicable to other species, such as the dog, in which it has failed. The pathology of wound shock is far more complex than Dr. Rosenthal's description of the pathology of burns indicates. To be sure Dr. Rosenthal excludes bacterial activity from his consideration of the problem of wound shock, but unfortunately it is rare that one encounters


# MECHANIZATION

TI-designed fully automatic wafer sorter. Silicon wafers for TI diodes or rectifiers are vibration fed to pick-up stations where they are vacuum gripped by upper contacts of test arms. During transit to drop chutes, lower contacts are applied, polarity checked, test circuits adjusted, and tests performed . . . at a rate of more than 4000 per hour.

Greater reliability, faster delivery and lower unit costs for users of TI diodes and rectifiers result from mechanized production and testing facilities such as the silicon wafer evaluator shown here. Designed and built by the TI Semiconductor-Components division, this machine automatically tests and evaluates each wafer that later becomes the heart of a TI diode or rectifier.

Only advanced facilities can produce advanced components.

The wafer evaluator automatically adjusts its own test conditions to correspond to each wafer being checked, measures the critical electrical parameters, and then guides it into an appropriate vial. These tests, performed before assembly at a rate of more than 4000 per hour, insure the performance of every TI diode and rectifier wafer.

Continuous improvements in production technology at TI provide engineers the world over with precise reliable devices of practical economy and make possible new areas of semiconductor application.

THE WORLD'S LARGEST SEMICONDUCTOR PLANT

TEXAS INSTRUMENTS
INCORPORATED
SEMICONDUCTOR-COMPONENTS DIVISION
DALLAS, TEXAS

wounds which are wholly free of bacteria. Even a burn in man, if not in mice, is a good deal more than a loss of salt and water. It is also a destruction of tissue, and if more than the superficial layers of the skin have been destroyed, infection by ubiquitous bacteria is an unavoidable complication.


JACOB FINE, M.D.

Harvard Medical School
Boston, Mass.


Sirs:

At the beginning of our work on shock, inadequately controlled and standardized experiments had led to widely differing conclusions on the merits of saline-solution therapy, such as those expressed by Dr. Fine. By standardized experiments on large numbers of small laboratory animals we were able to overcome these difficulties and to show that large volumes of saline were necessary to produce survival (see Sanford Rosenthal and R. C. Millican, *Pharmacological Reviews*, Vol. 6, page 489, 1954). Since no properly controlled studies in man had been carried out with large volumes of saline, the Peru Project was undertaken. Our results in man as well as animals speak for themselves. The fact is that in over 80 severely burned adults (11 with over 50 per cent of the body burned) not one died during the shock period. The Peru Project was the first well-controlled clinical evaluation of large amounts of saline in burn shock, and I am unaware of any similar study in wound shock in man.

Dogs present technical difficulties for the study of therapy of shock and the published results have been quite inconstant. There are, however, experiments on dogs in which saline solutions have been effective as well as others to the contrary (see the above review).

We agree with Dr. Fine that much has to be learned about the causes of shock. Our publications have repeatedly pointed out that fluid and electrolyte disturbances were not the sole causes. We have shown that they are important factors, the correction of which can often prevent death. And we have shown that saline solutions are as effective as plasma in most cases of shock, if they are given in large enough amounts, by mouth or by injection.


SANFORD M. ROSENTHAL, M.D.

National Institutes of Health
Bethesda, Md.

# Keys to better catalysis

*. . . NORTON Ceramic Catalyst Carriers*

In modern chemical and petrochemical process reactions, very often the choice of proper catalyst carriers is as critical a factor as selection of the catalysts themselves. And time and again, NORTON Ceramic Catalyst Carriers have proved the *best* choice both for efficiency and economy.

It's more than just a question of a quality product. There's a personal equation involved — the Norton Man. He brings to chemical engineers the benefits of NORTON COMPANY'S years of experience in the chemical and petrochemical fields as well as the end products of its advanced manufacturing and quality control methods. He *understands* the problems involved. And, backed by NORTON COMPANY'S extensive research and engineering facilities, he's well qualified to help in their solution.

Whatever the feedstock or thermal conditions involved . . . whether reaction is in the gaseous or liquid phase . . . whether the carrier is to be coated or impregnated with the active agent, he's ready to suggest the specific NORTON product that will do the job best. He also knows that *every* NORTON Carrier gives chemical processors the assurance of highest uniformity. From lot to lot — in any quantity — size, weight, porosity, pore diameter and purity are held to close tolerances that assure precise duplication of results.

Take advantage of the service the Norton Man represents. Let him help you to meet catalyst carrier specifications exactly. It's the simple practical way to insure maximum catalyst activity and life . . . to keep catalyst costs low . . . to get optimum yield from your process. Write NORTON COMPANY, Refractories Division, 542 New Bond Street, Worcester 6, Mass.

**WIDE RANGE OF TYPES AS FOLLOWS**

| **Shapes** | **Materials** |
|---|---|
| Spheres | Alumina |
| Rings | Silicon Carbide |
| Pellets | Fused Magnesia |
| Granules | Zirconia |
| Powders | Silica, Zircon |
| | Magnesia — alumina |
| | Spinel, etc. |

**Porosity** — from 10% to 50%

**Surface Area** — from less than 1 to 70 $m^2$/gram*

*BET Method

NORTON
REFRACTORIES
*Engineered... Rx ...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

DOW **NEW PLASTICS** *inspire new product designs*

**The news columns have been filled recently with rapid-fire developments in thermoplastic materials . . . materials that hold promise for the improvement of hundreds of products, both old and new. As these stories break, you'll notice a high percentage of them featuring a Dow material. Take Zerlon* 150. A few weeks ago Dow introduced this weather resistant, optically clear plastic with an exciting new range of cost-saving properties. Several other news-makers in the complete Dow line are discussed on these pages.**

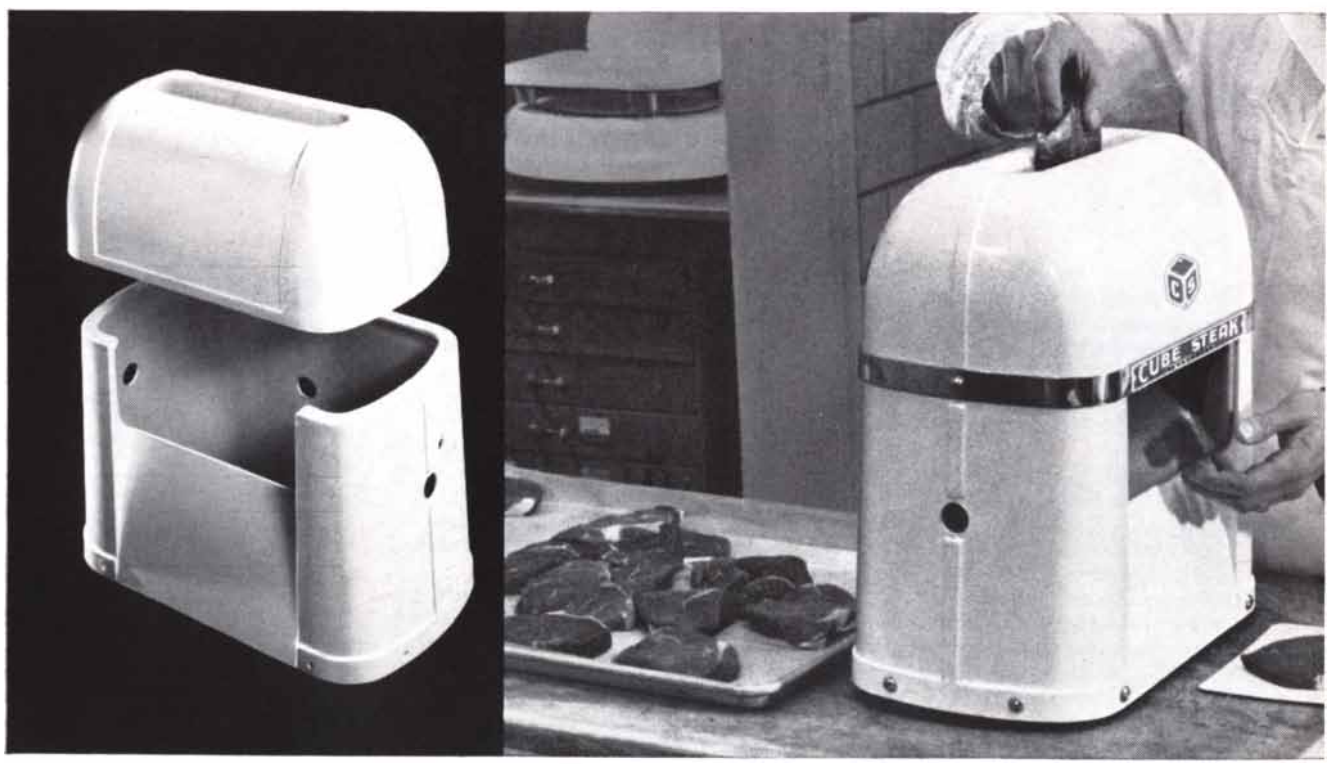
*Trademark

# "AGELESS" STYRON 480 GIVEN LIFETIME GUARANTEE IN NEW SUPERMARKET TOOL

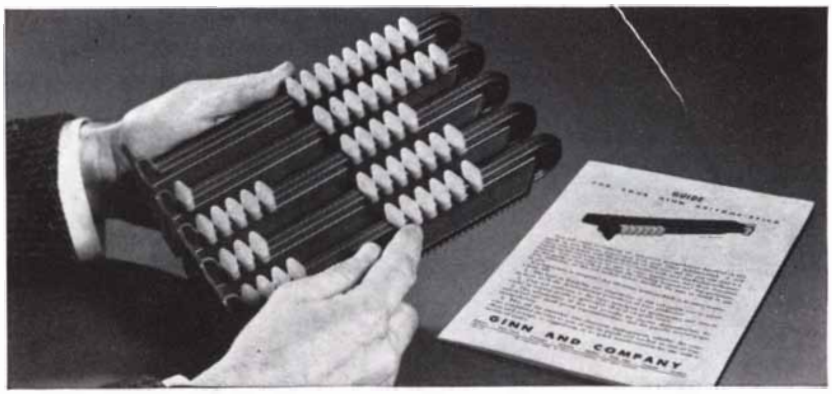
The housing of this new Cube Steak Tenderator is guaranteed for the life of the machine. This is a generous guarantee to make on equipment in rough and tumble supermarket service, but the manufacturer isn't worried . . . he knows the housing is made of Styron® 480. This versatile thermoplastic was chosen because it's durable and highly resistant to meat juices, has super high impact strength, an easy-to-clean surface.

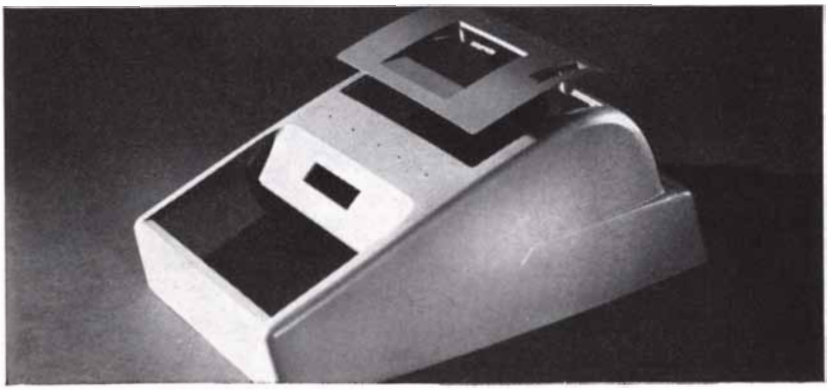
The excellent aging characteristics of Styron 480 were also an important consideration. In fact, the lifetime guarantee could not have been made without them. Fabrication was simplified and production costs substantially reduced by switching to plastic.

The housing made of Styron 480 is an excellent example of how Dow plastics help make good products better. An increasing number of manufacturers are selecting from the extensive Dow line of eight basic thermoplastics and dozens of specialized formulations. And you get extras from Dow you can't buy on a cost-per-pound basis: technical service, marketing assistance and a color styling service that's second to none.




**THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN**



## Ready for the sales countdown . . .

***with this abacus made of Styron 475***

A prominent publishing house markets this attractive, highly useful educational tool. It's made of polyethylene and Styron 475, a high impact Dow plastic with excellent dimensional stability, design flexibility and moldability to spare. This abacus was developed for the publisher by a custom molder who offers integrated design, engineering and production services. It's another example of how creative engineering utilizes the many benefits of Dow plastics in new product designs.

***. . . and this adding machine housing molded of Styron 440***

Outstanding impact strength, design versatility and a wide range of colors make Styron 440 an obvious choice for this application. The housing is easy to keep clean and its high resistance to heat prevents distortion when the machine is displayed in direct sunlight. Styron 440 also eliminated the extra fabrication and finishing operations that were necessary with the material previously used in the housing. The surface is smooth and polished when removed from the mold.

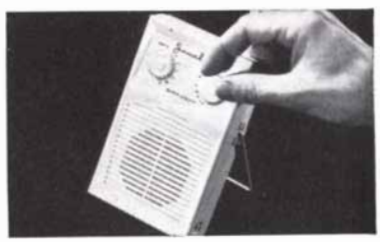
## 4 MORE PRODUCTS

***fashioned from America's first family of thermoplastics***

**ETHOCEL.** "The aristocrat of plastics," Ethocel® provides exceptionally high impact strength for this compact transit. Its superior dimensional stability helps keep the lens positioned in the one right place.

**TYRIL.** Characteristics such as beauty, strength and resistance to perspiration make Tyril® the ideal choice for this pen and pencil set. Tyril also provides excellent moldability for intricate details such as threaded sections.

**STYRON 440.** This new speaker housing for auditorium walls utilizes many of the properties of versatile Styron 440: Excellent large-area molding characteristics, a surface that requires no finishing.

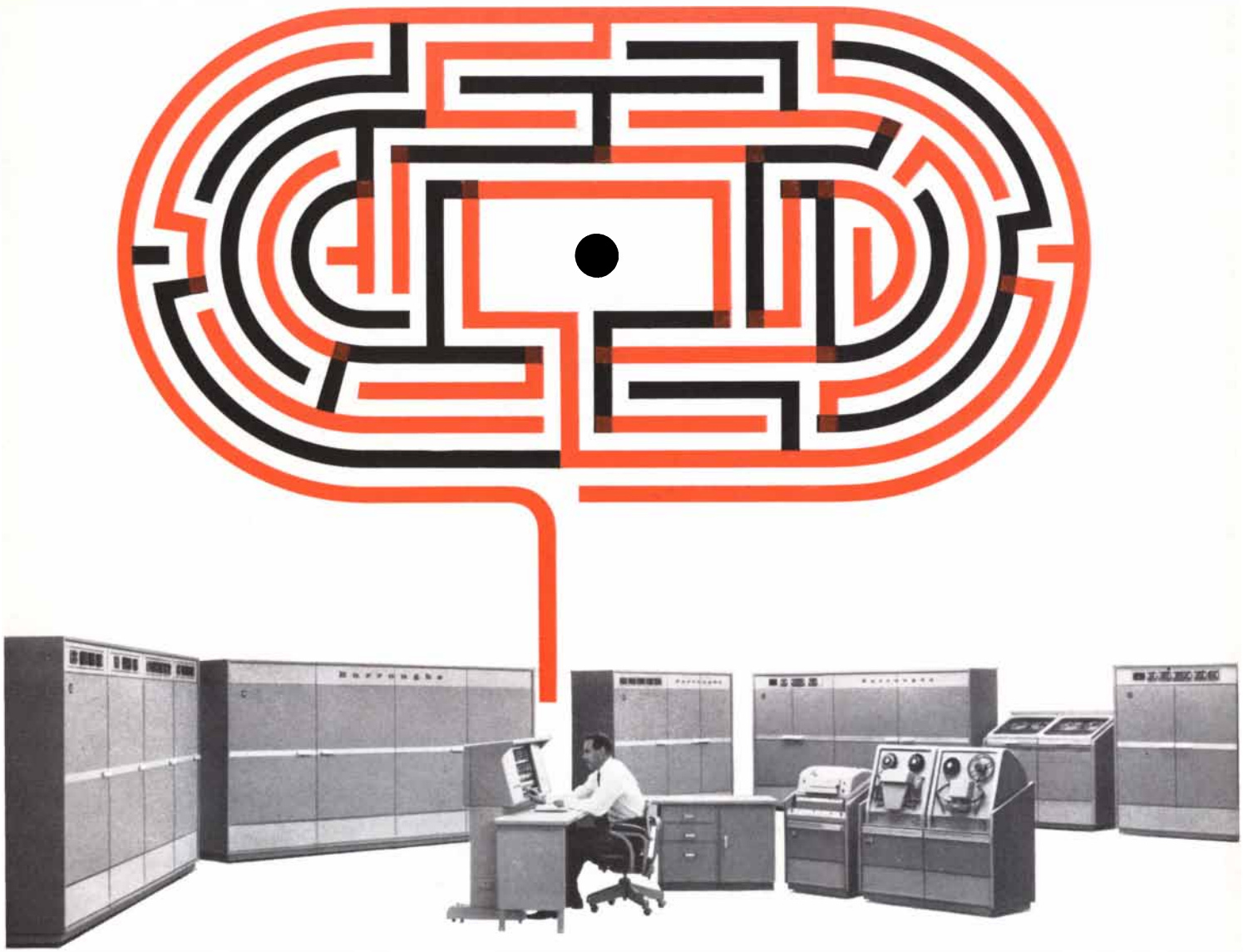


**TYRIL.** This transistor radio housing made of Tyril has toughness, dimensional stability and a wide range of colors. Excellent electrical properties are other benefits of this outstanding Dow thermoplastic.

**FOR MORE INFORMATION** about the versatile Dow plastics and the product designs discussed on these two pages, write to us today. THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Department 1510EQ3.

Industrial Molding Materials • Packaging Materials • Paint and Coating Materials • Building Products

DOW



*solving today's problems today: Burroughs 220 Computer*

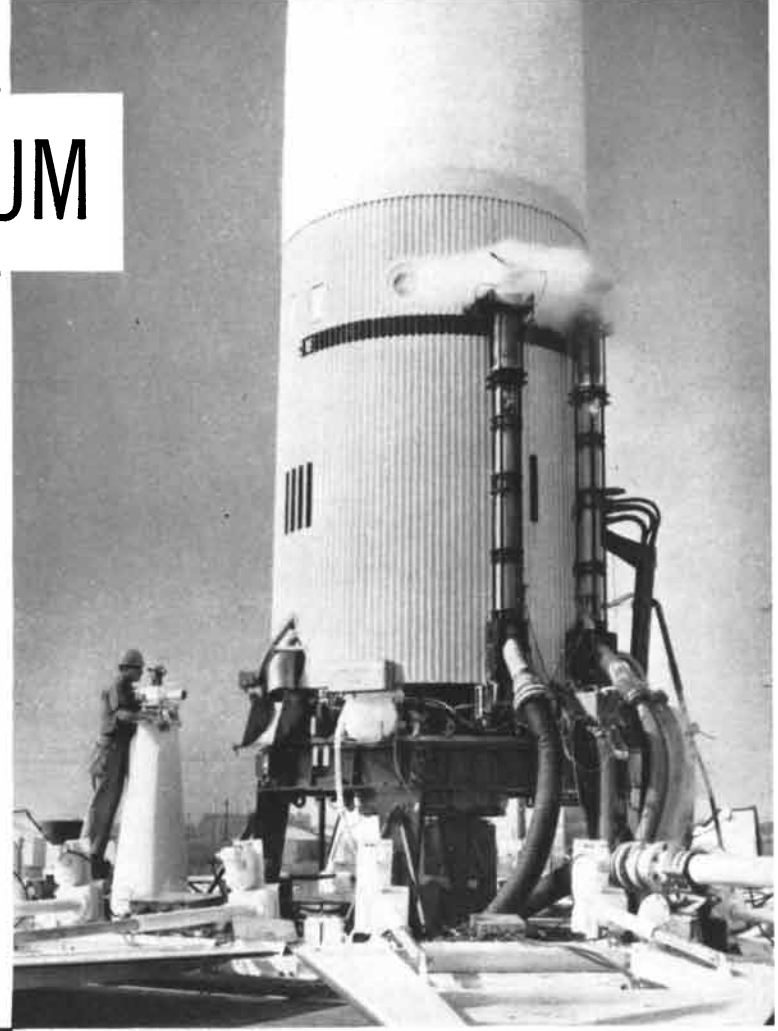
In scientific computation and business data processing, the new Burroughs 220 is delivering tangible results today. Linking a powerful digital computer to equally powerful input-output subsystems, the 220 offers balanced performance at the lowest application cost. Its expandable core memory, built-in floating decimal arithmetic, vast Datafile magnetic tape capacity and the multiple-card processing ability of Cardatron make this the most powerful system available in the medium price field. The 220 is just one part of a complete line of advanced Burroughs electronic data processing equipment... now in production... now at work in hundreds of installations... supported by an outstanding team of computer specialists. Write today for 220 brochure, ElectroData Division, Pasadena, California.

**Burroughs Corporation**

*"NEW DIMENSIONS/in electronics and data processing systems"*

# THE P-E SPECTRUM

*news of advanced systems and instruments from Perkin-Elmer*



NEW FAMILY OF AUTO-THEODOLITES "SQUARES-UP" MISSILE GYRO CONTROLS BEFORE LAUNCHING

A new family of theodolites, sensitive to a fraction of a second of arc, or approximately the angle subtended by a dime a mile away, is helping to obtain the high order of accuracy demanded in long range missiles.

Shown in use here is a short range theodolite, one of two used to align Ford Instrument Company's inertial guidance system on the Army Jupiter.

These precise electronic-optical systems, developed by Perkin-Elmer, monitor the inertial guidance systems of missiles up to the moment of launch by continuous observation of the azimuth angle formed by the missile gyro platform, the theodolite and a known reference mark. Automatic correction signals, as required, are transmitted to the missile's gyro platform via a closed loop system between the theodolite and the missile. P-E theodolites provide working distances ranging from 0 to 1500 feet.

These theodolites are another example of Perkin-Elmer's ability to combine electronics and optics into high-accuracy systems.

LOW-COST INSTRUMENT ATTRACTS NEW USERS FOR INFRARED, SURVEY SHOWS

Since Perkin-Elmer introduced the first low-cost infrared spectrophotometer two years ago, infrared has become as basic a tool in the laboratory as the analytical balance. A recent survey of 150 representative purchasers of the P-E INFRACORD® spectrophotometer reveals that over half are first-time users of this powerful analytical technique.

A typical INFRACORD user, Endo Laboratories Inc., of Richmond Hill, New York, employs the instrument to check both pharmaceutical raw materials and final product. These quality-control tests take a fraction of the time previously required for conventional wet methods. For example, the conventional method of assaying Endo's Coumadin Sodium or Percodan, an analgesic preparation — complicated mixtures of narcotic alkaloids, sedatives and other drugs — in some cases took almost three days. With the INFRACORD, Endo chemists make a positive determination in 25 to 30 minutes. In raw material checks, the instrument provides a permanent record of its analyses for comparison with spectra of standard purity materials.

The INFRACORD is another example of P-E's more than fifteen years of infrared experience and development.

For information on Perkin-Elmer and the products it makes for a wide range of growing industrial, scientific and defense markets, write Perkin-Elmer Corporation, 915f Main Ave., Norwalk, Connecticut.

**Perkin-Elmer** *Corporation*

NORWALK, CONNECTICUT

ANALYTICAL INSTRUMENTS • MILITARY SYSTEMS
• PRECISION ELECTRONIC COMPONENTS

# 50 AND 100 YEARS AGO

## SCIENTIFIC AMERICAN

MARCH, 1909: "Twice lately have the Wright brothers given exhibitions before royalty. A few weeks ago King Alphonso XIII of Spain visited them. Last week King Edward of Great Britain also paid them a visit. On this occasion Wilbur Wright made a flight of seven minutes, in which he performed difficult evolutions with great precision. Mr. Wright has started the construction of a half dozen aeroplanes in England, in addition to the 14 already nearing completion in France. Several of his pupils at Pau have made successful flights alone."

"At the meeting of the Aeronautic Society on March 10 Mr. Elmer A. Sperry gave an extremely interesting talk upon a new form of gyroscope which he calls active, to distinguish it from the ordinary or passive type. A gyroscope of the active type has several hundred times the energy of the passive type. Mr. Sperry said he has found that the kinetic energy put into the outer ring to move it in one direction could practically all be recovered from the inner or precessional ring that moved at right angles to it. In making the gyroscope active, he connects these two rings through gears so that they react upon each other."

"Prof. Muensterberg's 'machine for detecting lies,' technically known as a galvanic psychometer, has attracted much attention, despite the caustic comments with which it has been received in scientific circles. Many interesting results have been obtained with it by Dr. Veraguth of Zürich. A noise, a light, a touch, reading of an exciting novel, mental calculation or the recollection of some exciting incident, all produced—at the end of a few seconds, which may be called the latent period—a marked increase of the current."

"Drs. Soubris and Cronson, with the aeronaut Decugris, have made a balloon ascension for the purpose of studying the cause of 'balloon sickness,' which has been ascribed both to deficiency of oxy-

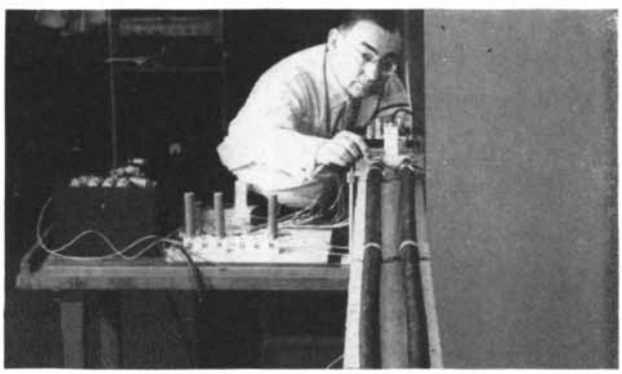
# THEY PROBE THE FUTURE OF DEEP-SEA TELEPHONY

"Dry Land Ocean," under construction at Bell Laboratories, simulates ocean floor conditions, is used to test changes in cable loss. Sample cables are housed in pipes which contain salt water under deep-sea pressure. The completed trough is roofed in and is filled with water which maintains the pipes at 37° F., the temperature of the ocean floor.

Deep in the ocean, a submarine telephone cable system is extremely hard to get at for adjustment or repair. This makes it vitally important to find out what can happen to such a system *before* it is installed.

Bell Laboratories engineers do this by means of tests which simulate ocean floor conditions on dry land. Among many factors they test for are the effects of immense pressures on amplifier housings and their water-resistant seals. They also test for agents which work very slowly, yet can cause serious destruction over the years—chemical action, marine borers and several species of bacteria which strangely thrive under great pressures.

Through this and other work, Bell Telephone Laboratories engineers are learning how to create better deep-sea telephone systems to connect America to the rest of the world.



Highly precise instruments developed by Bell Laboratories engineers are used to detect infinitesimal changes in cable loss—to an accuracy of ten millionths of a decibel.

Seawater and sediment in bottle characterize ocean floor. Test sample of insulation on coiled wire is checked for bacterial attack by conductance and capacitance tests.

**BELL TELEPHONE LABORATORIES**
WORLD CENTER OF COMMUNICATIONS
RESEARCH AND DEVELOPMENT

gen and to deficiency of carbon dioxide in the blood; Agazotti going so far as to recommend, for inhalation at great altitudes, a mixture of 13 per cent of oxygen and 87 per cent of carbon dioxide. Dr. Soubris experienced six distinct attacks, of which three were relieved by Agazotti's mixture, and the others were cured far more completely by pure oxygen, which therefore appears preferable for inhalation."

"The steamer *Mauretania* is reducing the time of the transatlantic passage on each succeeding trip. On March 2 she established a new record for the eastbound passage of four days, 20 hours and two minutes."

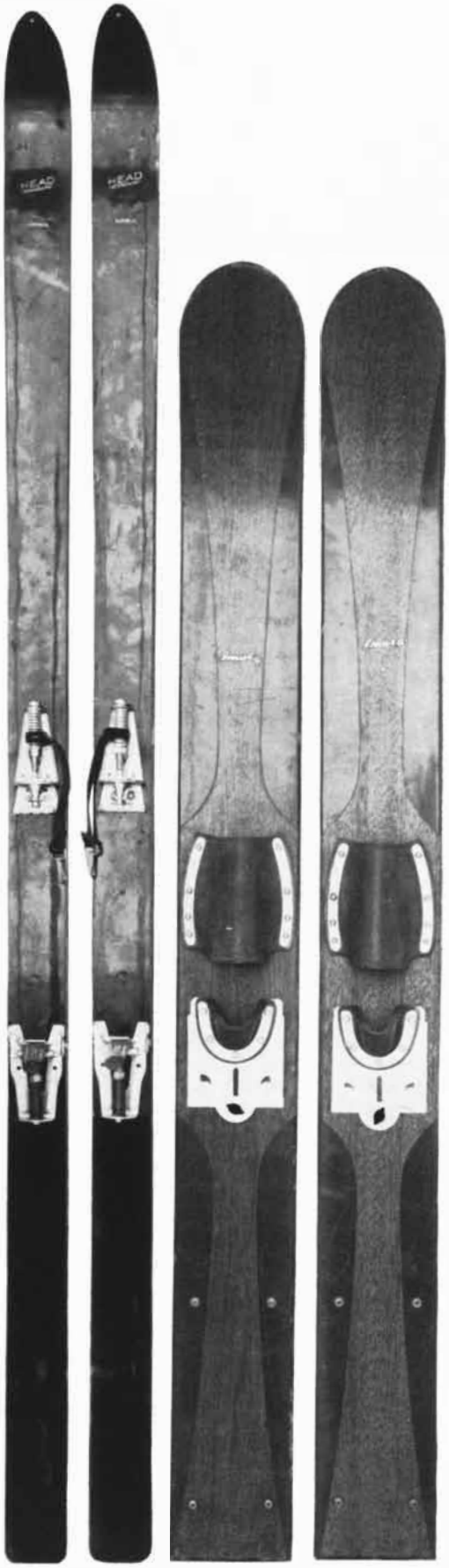
## SCIENTIFIC AMERICAN

MARCH, 1859: "Mankind has been wonderfully ingenious from its infancy in the concoction of edible varieties. Who would relish a stew of red ants in Burmah, a half-hatched egg in China, monkey cutlets and parrot pies at Rio de Janeiro, bats in Malabar, polecats and prairie wolves in North America? Yet there can be little doubt that these are unwarrantable prejudices. Dr. Shaw enjoyed lion; Mr. Darwin had a passion for puma."

"Athens, once the school and center of the world's civilization in arts and sciences, has lately been illumined with gas by English mechanics; and Constantinople, once the focus of Eastern learning, is now seeking light from the same source. The city of the Sultan promises at an early date to be illumined with a stream of light from Christendom."

"By recent accounts from Europe we learn that Mr. Henley has been sent out to Newfoundland to try and galvanize some life into the Atlantic cable at this end. He might as well try to resuscitate a dead whale. A banquet was recently given to Professor William Thomson, in Glasgow, in honor of his abilities and the services which he rendered without fee or reward in laying the Atlantic cable. The only signals of reliable character ever sent through it were transmitted by his instruments, which are simple signaling galvanometers."

"Not many years ago all the fashionable world of London flocked to Albemarle Street to see young Humphrey




# ENGINEERS MOVE FORWARD FAST AT LINK

Talented engineers who are *looking* forward to careers with genuine opportunity will find that they can keep *moving* forward at Link Aviation.

Located in Binghamton, in the heart of Upstate New York's all-season vacationland, Link's activities are steadily expanding. New positions exist for men with productive experience in several fields:

- *Staff scientists*, for advanced work on analog computers, airborne instrumentation, industrial controls and precision measurements
- *Mechanical engineers*, for electronic and electro-mechanical packaging
- *Design engineers*, for work on analog computers, systems, and components
- *Senior optics development engineers*
- *Applied mathematicians*

Link Aviation, Inc., is engaged in projects whose scope far exceeds its long-standing reputation for flight-simulation equipment. Engineers are stimulated by this diversity. And they like the recognition given them, in such forms as excellent salaries, exceptional insurance and retirement plans, and tuition-free advanced university courses.

If you want to progress in this direction contact us at once.

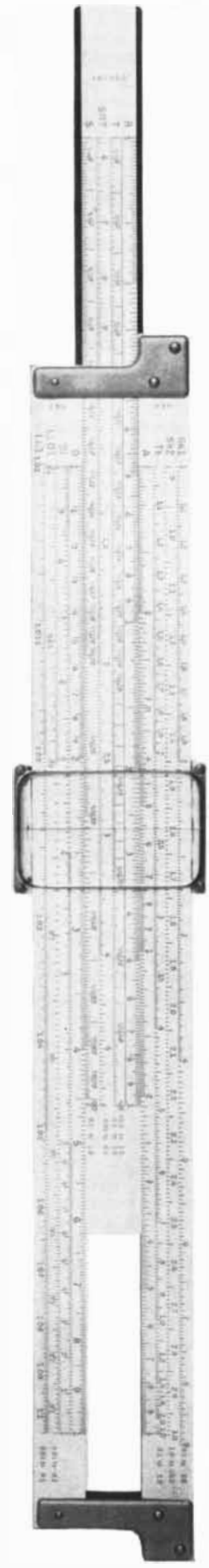
Write to: Mr. A. L. Wieland,
Link Aviation, Inc.,
Binghamton, New York

LINK

GENERAL PRECISION EQUIPMENT CORPORATION GPE

**LINK AVIATION, INC.**

A subsidiary of General Precision Equipment Corporation



Davy produce metals from earth. M. Deville, of Paris, under the patronage of the present Emperor, has now separated the metallic base of clay to such an extent that it is an article of commerce. Aluminium is now used for jewelry, especially bracelets, pins and combs; in cabinet-making it is excellent for inlaid work; its lightness renders it extremely convenient for pencil-holders, thimbles, seals, small statues, medallions, vases and the like; for spectacles also, as it does not blacken the skin like silver."

"The mysterious Frenchman, Monsieur F. Belly, announces in the Paris journals that his organization of the Nicaragua Canal Company is completed; that the money necessary is secured; that the vessel has been freighted to carry out the engineering material, and that this vessel, with himself, some of the engineers and clerks—sixty persons in all—will sail from Havre for Greytown in three weeks. We have no doubt that this energetic personage will get his stomach full of this job before he has been in Greytown three weeks."

"The breech-loading rifled cannon in England, which has recently sent shot crashing through their iron floating batteries as if they were pasteboard, is the invention of Mr. R. Armstrong, of Newcastle, England. The interior is steel, this is surrounded by wrought iron twisted in a spiral form like the stub and twist barrels of fowling pieces. Its strength is so great that it easily projects an 18-pounder elongated shot, and yet weighs no more than an ordinary 9-pounder."

"Humboldt answers 2,500 letters annually, and these form only a portion of the number he receives."

"We sometimes give Uncle John Bull a thrust under the ribs for his conservative tendencies, but of late years he has far surpassed us in political progress, commercial and social reforms. He has driven our steamships from the Atlantic Ocean, and we think he will distance us shortly in weight and measure reforms."

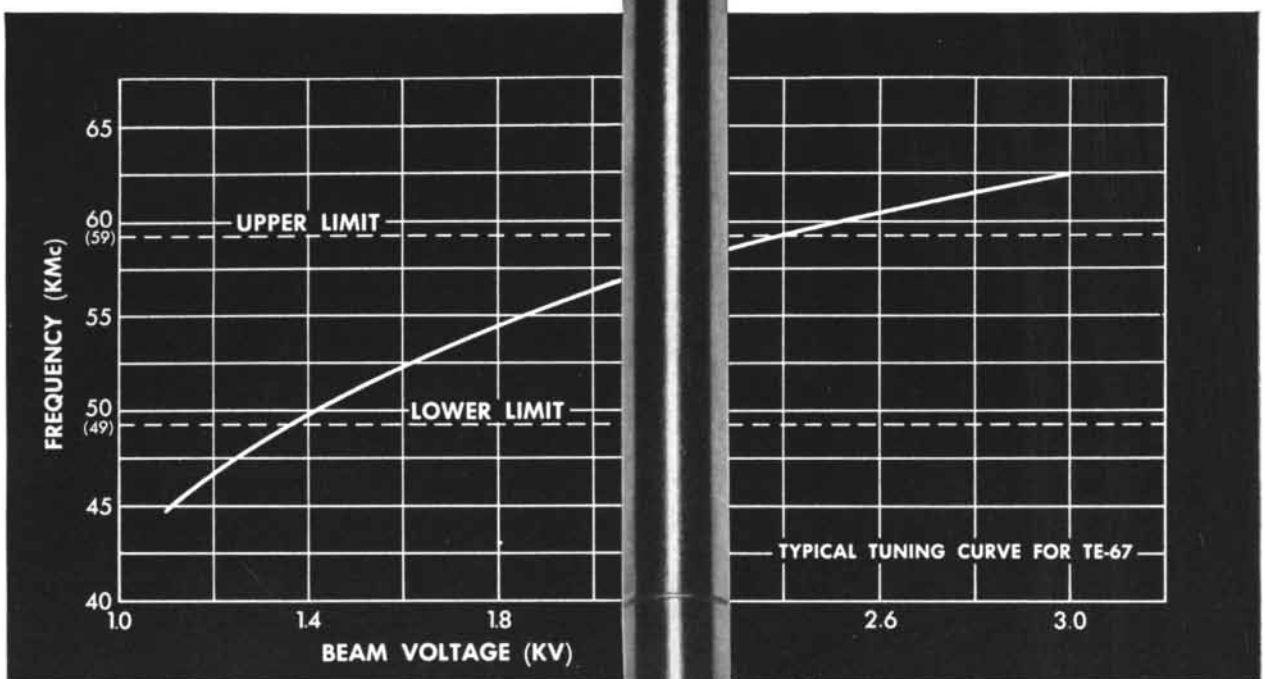
"The African expedition under Dr. Livingstone, by the last accounts, was proceeding up the Zambesi River, and had dug some very good coal on its banks for their steamboat."

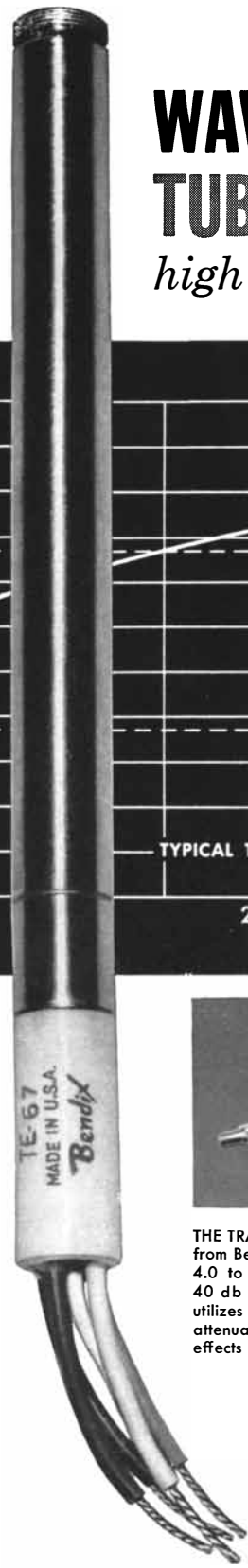
"By the report of the Registrar-General for 1858 we learn that London has a population of 2,876,000, and it is now the largest city by far in the whole world. In 1801 its population was only 958,000."

*New Bendix®*

# BACKWARD-WAVE OSCILLATOR TUBE

*for extremely high frequencies*




An exclusive Bendix Red Bank product, the Type TE-67 Backward-Wave Oscillator Tube generates microwave energy at extremely high frequencies never before available.

This new tube provides a wide range of usable frequencies for applications in: advanced types of multichannel telephone and television systems, high definition short-range radar, highly directive communications, microwave spectroscopy and other fields where low power, voltage-tuned millimeter wavelength radio frequency energy is required. As the backward-wave tube is voltage tuned, frequency is automatically changed by varying the voltage input. No mechanical tuning adjustment is required.

For more detailed information on the tubes described here, write to: RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

**ELECTRICAL DATA**

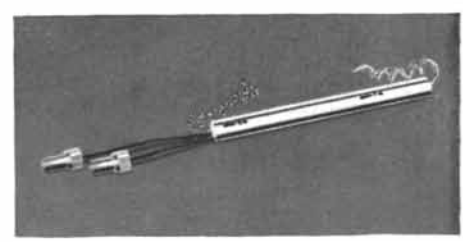
| | |
|---|---|
| Frequency Range | 49kmc—59kmc |
| Anode Voltage | 1000—3000 volts |
| Power Output | 5mw average |
| Beam Current | 5ma |
| Magnetic Field | 1300 gauss (minimum) |
| Heater Voltage | 6.3±10% |

**MECHANICAL DATA**

| | |
|---|---|
| Output Flange | Special adapter to RG-98/U |
| Maximum Diameter | 0.625″ |
| Length | 8″ |
| Mounting Position | Any |
| Weight | 5 oz.* |

*Without magnet (tube only). Magnets are available.

**Also available:** Type TE-66 with frequency range of 61 kmc to 71 kmc.
Type TE-75 with frequency range of 33 kmc to 50 kmc

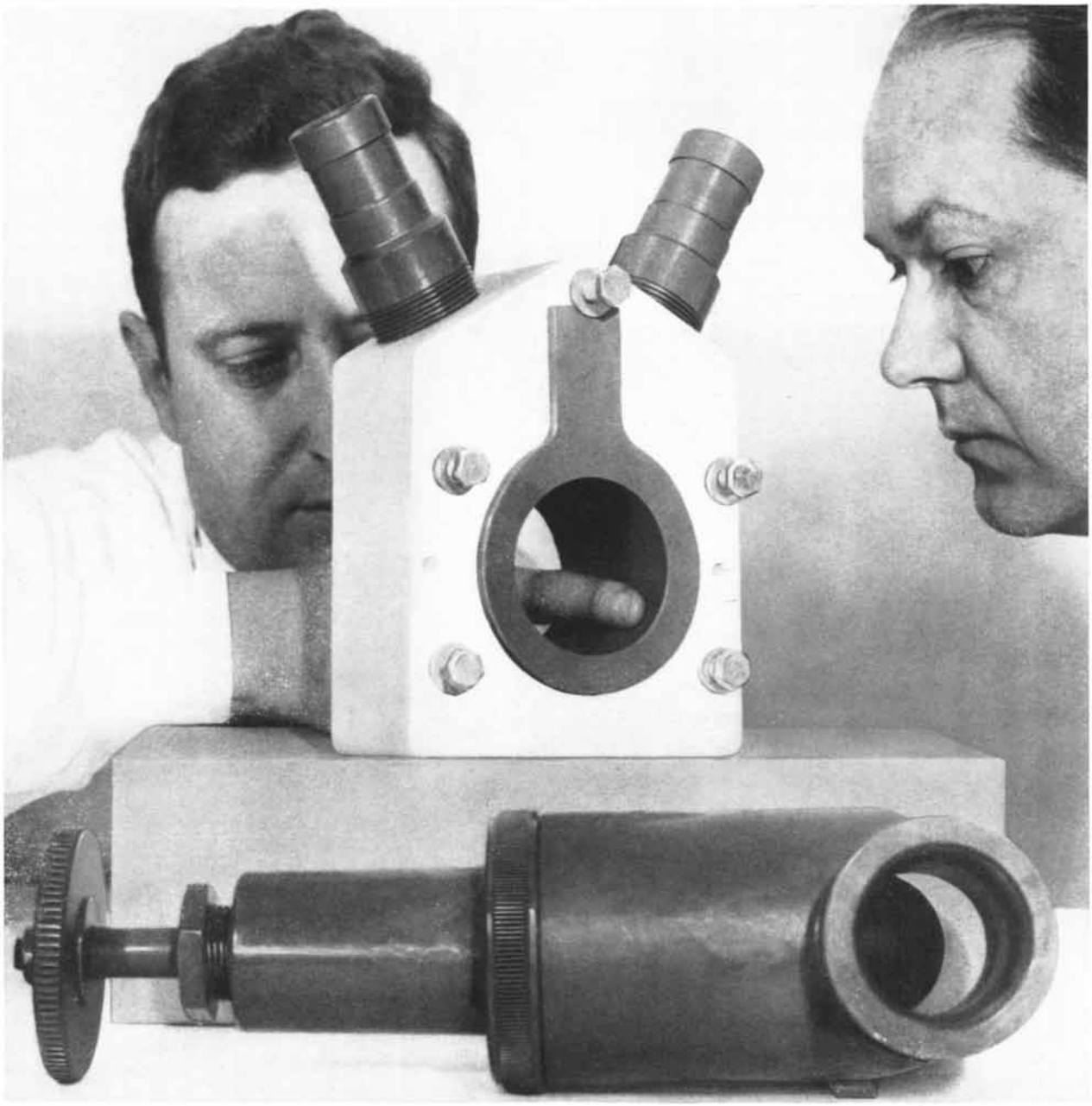


**THE TRAVELING-WAVE AMPLIFIER TUBE, also available from Bendix Red Bank, is designed for operation in the 4.0 to 8.0 kmc frequency range with approximately 40 db gain and 200 milliwatts output power. The tube utilizes a helical slow-wave structure with coupled helix attenuator section. The mechanical design minimizes the effects of vibration upon the tube operation.**

West Coast Sales & Service: 117 E. Providencia Ave., Burbank, Calif. • Export Sales & Service: Bendix International Division, 205 E. 42nd St., New York 17, N. Y. Canadian Distributor: Computing Devices of Canada, Ltd., P.O. Box 508, Ottawa 4, Ontario

Red Bank Division

Bendix AVIATION CORPORATION



# If you handle corrosive, abrasive, or contaminable fluids, these two new design ideas will mean a lot to you!

They are the Vanton sealless plastic pump (shown here disassembled), and the Flex-Plug throttlable plastic gate valve. Both are made by the Vanton Pump and Equipment Division of Cooper Alloy Corporation.

The Vanton pump is widely used in chemical processing, food, plating, products finishing, pharmaceutical, and similar processing industries. It eliminates problems of leakage, corrosion, contamination, and maintenance associated with shaft seals (standard on most pumps)—by eliminating the shaft seals!

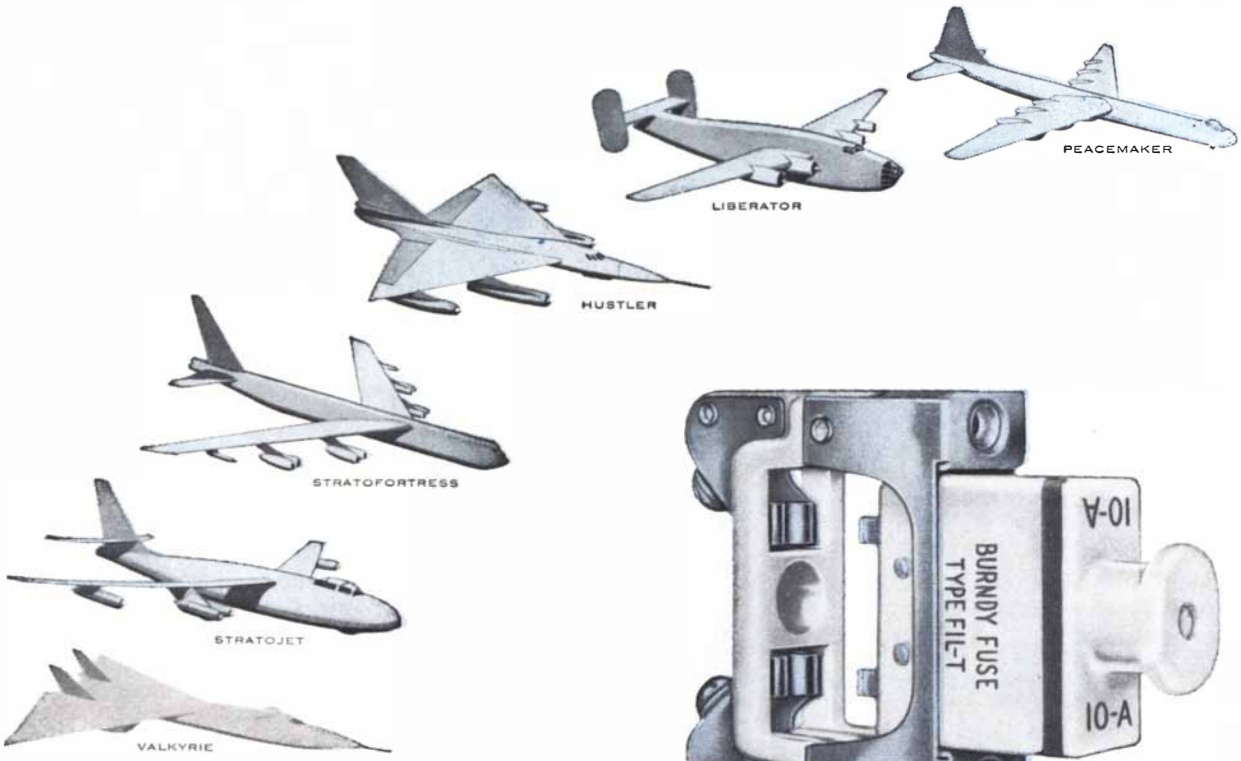
Design of plastic Flex-Plug valves is equally ingenious. When wide open, valve provides unobstructed, no-pressure-drop flow; when throttled, it provides close flow control of a globe valve. Both these new designs are typical of Cooper Alloy's fresh thinking in the creation of top-quality, top-performance products for industry.

Vanton Pump and Equipment Division

**COOPER ALLOY**

Corporation • Hillside, New Jersey

**STAINLESS STEEL** VALVES, FITTINGS, CASTINGS • **PLASTIC** PUMPS, VALVES, FITTINGS



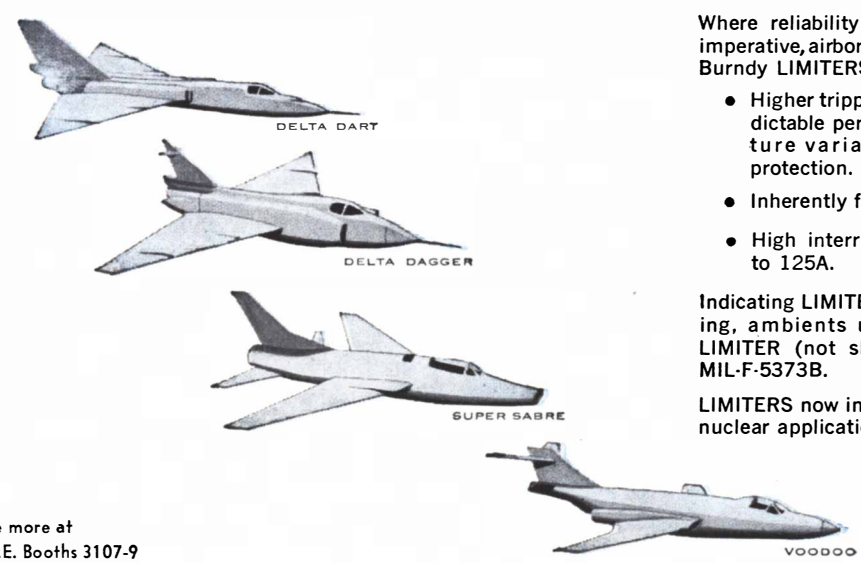




**THEN, NOW and TOMORROW—**

*for the toughest jobs in electrical circuit protection!*

# BURNDY LIMITERS




Where reliability under extreme service conditions is imperative, airborne electrical systems are protected by Burndy LIMITERS. Here's why —

- Higher tripping temperature provides uniform, predictable performance in spite of ambient temperature variation...pinpoints the moment for protection.
- Inherently fail-safe. No mechanical parts.
- High interrupting capacity—in ratings from ¼A to 125A.

Indicating LIMITER (above) for dead front panel mounting, ambients up to 300°F, and visible indicating LIMITER (not shown) conform to MIL-F-5372B and MIL-F-5373B.

LIMITERS now in development for 600°F operation and nuclear applications.

See more at
I.R.E. Booths 3107-9

58-28

OMATON DIVISION **BURNDY** NORWALK, CONNECT.; TORONTO, CANADA; IN EUROPE: ANTWERP, BELGIUM

# THE AUTHORS

JAMES A. VAN ALLEN ("Radiation Belts around the Earth") heads the physics department at the State University of Iowa. A native Iowan, he received his doctorate from the State University in 1939. During World War II he served as a Navy ordnance and gunnery officer and helped to develop the radio proximity fuze. Later he supervised the development and scientific use of the Aerobee rocket and balloon-launched rockets ("rockoons"). For the past 12 years his group at the University has been studying cosmic rays at high altitudes; Van Allen directed the cosmic-ray instrumentation of the satellite and space-probe program of the International Geophysical Year.

H. B. D. KETTLEWELL ("Darwin's Missing Evidence") visited Brazil last year to retrace the routes traveled by Charles Darwin in 1832. He has recently participated in the production of two Darwin centenary films, "Evolution in Progress" and "Darwin and the Insect Adaptations of Brazil." Educated at the Charterhouse School and the University of Cambridge (Gonville and Caius College), Kettlewell qualified as a physician at St. Bartholomew's Hospital, London, in 1933, then practiced medicine for 15 years. He has, however, been a lepidopterist since childhood. Long convinced that the genetics of evolution could be seen at work among moths, Kettlewell quit medical practice in 1948 in order to prove his point. As Nuffield Research Fellow in genetics at the University of Oxford he has pursued his quarry in the Belgian Congo, Uganda, the southern Sudan, Kenya, Portuguese East Africa, South Africa, Namaqualand, Norway, Corsica and Canada as well as Great Britain.

IRVINE H. PAGE, F. MERLIN BUMPUS and HANS J. SCHWARZ ("Angiotensin") worked together on the first synthesis of this blood-pressure hormone. Page, the senior author, is director of research at the Cleveland Clinic Foundation. He received his M.D. from the Cornell University Medical College in 1926, and after completing his internship served for three years as director of the chemical division of the Kaiser Wilhelm Institute in Munich. Later he worked at the Hospital of the Rockefeller Institute in New York and directed the Lilly Clinic and Laboratory

# Controls Company of America

*(what's our line?)*


*how can we work for you?*

**We can supply single controls or complete systems — with design integrated to your product or process. If you have a control problem, our creative engineering service may help you solve it.**

Controls Company of America has a "controlling" interest in the products of American industry. CC control systems figure in the aircraft, guided missile, electronics, air conditioning, automotive, refrigeration and appliance industries. The story behind our growth is one of total engineering — in which we tackle *all* controlling factors to produce complete systems or single units perfectly mated to the products they control. Write today and put these unequalled resources to work for you.

*Creative Controls for Industry*

## CONTROLS COMPANY OF AMERICA

EXECUTIVE OFFICES: SCHILLER PARK, ILLINOIS

HEATING AND AIR CONDITIONING CONTROLS DIV. MILWAUKEE, WIS.

APPLIANCE AND AUTOMOTIVE CONTROLS DIV. SCHILLER PARK, ILL.

REDMOND COMPANY, INC. OWOSSO, MICHIGAN

MILWAUKEE VALVE COMPANY MILWAUKEE, WIS.

HETHERINGTON, INC., FOLCROFT, PENN. • 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., NIJMEGEN, HOLLAND • CONTROLS COMPANY OF AMERICA (ARGENTINA) SRL, BUENOS AIRES.

for Clinical Research, where he shared in the discovery of another important blood substance: serotonin [see "Serotonin," by Irvine H. Page; SCIENTIFIC AMERICAN, December, 1957]. Bumpus, a Kentuckian, graduated from Purdue University. He received a Ph.D. in biochemistry from the University of Wisconsin in 1949; since then he has worked with Page at the Cleveland Clinic. Schwarz, the third author, was born in Switzerland. After acquiring a Ph.D. in chemistry from the University of Basel in 1951, he spent two years in Ottawa as a fellow of Canada's National Research Council, then joined Page's staff. He is now a biochemist at the Sandoz Chemical Works, Inc. in Hanover, N.J.

S. B. TREIMAN ("The Weak Interactions") is a theoretical physicist at Princeton University. A Chicagoan, he "drifted to mathematics in high school and, on bum advice, started college as a chemical engineer." This career was interrupted by World War II and service as a Navy radar technician. "I switched to physics after the war," he reports, "for no strong reason except that during a whole year in the Philippines my only reading material besides detective stories (of which I read at least 100) was, of all things, a popular exposition of relativity, atomic physics and all the other wonders of nature —badly written as I later learned but fascinating at the time." Treiman took his undergraduate and graduate degree at the University of Chicago, then joined the Princeton staff, where he is now an associate professor.

JAMES D. EBERT ("The First Heartbeats") studied chemical and physical biology at Washington and Jefferson College, graduating in 1942. He then went into the Navy, where he served as a gunnery officer. At the end of the war the sinking of his destroyer left him with a Purple Heart medal and a bed in the Naval Hospital at Bethesda, Md. There he became intensely interested in skin grafting and tissue specificity. "I decided that I would like to learn much more about these problems," he says. "I have spent the last 10 years doing just that." Ebert worked for his Ph.D. at Johns Hopkins University under B. H. Willier, who urged him to study the early development of tissue-specific molecules and immune reactions, especially in the embryonic heart. Recently he has been using animal viruses as research tools in this work. He has taught at the Massachusetts Institute of Technology and Indiana University, and is presently head

of the Carnegie Institution of Washington's Department of Embryology, located in Baltimore.

STEPHAN F. BORHEGYI ("Underwater Archaeology in the Maya Highlands") recently became director of the Milwaukee Public Museum. A Hungarian, he received a Ph.D. in anthropology from Péter Pázmány University in Budapest in 1946, after wartime service as a mounted artillery officer in the Hungarian Army and, upon the fall of Admiral Horthy's regime, as a fighter in the anti-Nazi underground. Borhegyi taught classical archaeology in Budapest for two years, then journeyed to the U. S. on a Wenner-Gren fellowship. Before taking his present post, Borhegyi studied Spanish-American communities in the U. S. Southwest, taught at San Carlos University in Guatemala City and directed the Stovall Museum of Science and History at the University of Oklahoma.

BRUNO BETTELHEIM ("Joey: A 'Mechanical Boy'") is professor of educational psychology and principal of the Sonia Shankman Orthogenic School at the University of Chicago. After receiving his Ph.D. from the University of Vienna in 1938 he spent a year in the concentration camps at Dachau and Buchenwald, an experience on which he based his paper "Individual and Mass Behavior in Extreme Situations," which General Eisenhower made compulsory reading for all U. S. military-government officers. Bettelheim has headed the Orthogenic School since 1944.

JACK E. OLIVER ("Long Earthquake Waves") comes from Massillon, Ohio. In 1941 he entered Columbia University with a scholarship which, he says, acknowledged his prowess in football "as well as other modest accomplishments." In 1946 Oliver returned to Columbia from a two-year hitch with the Pacific Fleet. Unable to decide between careers in civil engineering and physics, he called first on the adviser in civil engineering. "He happened to be out of his office," Oliver writes. "The physics adviser was in, however, so I proceeded to obtain a Bachelor's degree in physics in 1947 and later an M.A. Being in need of financial assistance, I found employment with what was then a small group in geophysics under Maurice Ewing. This sort of physics appealed to me and I obtained a Ph.D. under Ewing in 1953. The group eventually grew into the Lamont Geological Observatory and at present I am in charge of the program in earthquake seismology there."

# GMIdeas *for tomorrow minded industrial men*

These four GMIdeas have possibilities in many fields. If you recognize among them even the hint of an opportunity for your company, write for more information. It could very well be your first step toward your next big business success.

**INDUSTRIAL GROUP**

Chemical Division • Mechanical Division • Oilseeds Division • Special Commodities Division

General Mills

Oilseeds Division

Special Commodities Division

Chemical Division

Mechanical Division

GMIdea/No. 731 for creative chemists

## New Versamid-Based "Concrete From a Can" Makes Tough Resurfacing Jobs Easy

What a beating this highway department garage floor takes from tractor lugs, tire chains, chemicals, salt, grease and the weight of multi-ton vehicles. But no matter how severe the damage, patching and resurfacing the concrete is simple, quick, inexpensive—thanks to a new topping material made possible with our Versamid polyamide resin. This new "wonder product" is formulated with a Versamid-epoxy blend and ordinary sand. It trowels like concrete, feathers smoothly, adheres even to uncured and wet concrete—in layers as thin as 1/16-inch. And the bond is stronger than the internal strength of the concrete itself. Other money-saving topping and patching applications include highways, airfield runways, industrial flooring and non-skid approaches to bridges.

now turn the page for 3 more GMIdeas

GET MORE FACTS about opportunities with Versamids. Write GMIdea man H. T. Von Oehsen, Kankakee, Ill.

**CHEMICAL DIVISION**

General Mills

*General Mills does not make these new patching materials—only the Versamid polyamide resin that makes them possible.*

GMIdea/No. 732 for defense industries

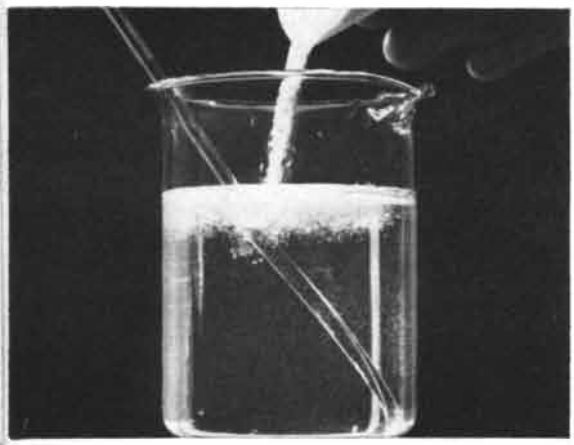
# A General Mills "Pilot" Commands the Mace Missile

From launching pad to target, a complex inertial guidance computer—developed and manufactured by General Mills—helps keep the Mace missile within its precise flight path. Along the way, this airborne electronic unit continuously computes the missile's actual position, compares this information with the programmed position and signals necessary corrections to other components in the inertial guidance system. We have the experienced people and facilities to take an idea—or to create that idea—and to build it into a complete system or sub-system for military or industrial application. During the past 18 years we've made many contributions important to America's sea, land and air strength. Research promises still greater contributions.

For new booklet describing our capabilities, write GMIdea man Lloyd Pearson, 1620 Central Ave., Minneapolis 13, Minn.

**MECHANICAL DIVISION**

General Mills



*1% Guartec being added to tap water*

*Same solution (as at left) ready for use*

GMIdea/No. 733 for product development people

# Need a Thickener In Your Product or Process? Investigate Guartec

All our guar gums, Guartec, Galactasol and Supercol, are manufactured so that they disperse quickly and completely; producing solutions with viscosities that can be controlled to meet specific industrial requirements. But, in hot or cold water, our gums are more than viscosity builders. In aqueous systems—acidic, basic or neutral—they are also suspending agents, stabilizers, film formers, water sealers, flotation reagents and selective flocculants. Edible grades are excellent thickeners and stabilizers in foods. These natural hydrocolloids are produced in U. S. and Pakistan plants. Our *Products Control Label* on every bag certifies controlled dispersability, viscosity, stability.

For more information about water soluble guar gums, phone, wire or write GMIdea man Fred Pugh, Minneapolis 26, Minn.

**SPECIAL COMMODITIES DIVISION**

General Mills

**GMI***dea*/ No. 734 for paint manufacturers

# Thanks to Safflower Oil—These Walls Will Still Be Color Fresh When She's a Big Girl

New paint vehicles—based on Safflower Oil from General Mills—make possible decorative coatings, even delicately tinted short and long oil alkyds, that retain their fresh, true color years longer than ordinary paints. Safflower Oil is non-yellowing, naturally light in color. It bleaches and refines still lighter—almost water white. And, because it is high in iodine value, it dries quickly, leaving a durable, flexible film. In many formulations, this versatile oil replaces and outperforms soybean and linseed oils. Enterprising manufacturers of exterior paints may provide professionals with specially tailored coatings formulated with Safflower Oil to make good paints better. Other uses for this unusually high unsaturated fatty acid are in foods, cosmetics, pharmaceuticals. Research hints at still other uses yet to come.

Do you see a new opportunity with Safflower Oil? Get the facts. Write GMIdea man Walter Flumerfelt, Minneapolis 26, Minn. **OILSEEDS DIVISION**

General Mills

*for other far reaching ideas yet to come, keep looking to*

**INDUSTRIAL GROUP**

Chemical Division • Mechanical Division • Oilseeds Division • Special Commodities Division

General Mills

## Galileo...on learning

"Philosophy is written in that great book which ever lies before our eyes—I mean the universe—but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in the mathematical language, and the symbols are triangles, circles, and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth." —*Il Saggiatore, 1610*

*THE RAND CORPORATION, SANTA MONICA, CALIFORNIA*

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

Established 1845 SCIENTIFIC AMERICAN March, 1959 Volume 200 Number 3

# Radiation Belts around the Earth

*Instruments borne aloft by artificial satellites and lunar probes indicate that our planet is encircled by two zones of high-energy particles, against which space travelers will have to be shielded*

by James A. Van Allen

So far, the most interesting and least expected result of man's exploration of the immediate vicinity of the earth is the discovery that our planet is ringed by a region—to be exact, two regions—of high-energy radiation extending many thousands of miles into space. The discovery is of course troubling to astronauts; somehow the human body will have to be shielded from this radiation, even on a rapid transit through the region. But geophysicists, astrophysicists, solar astronomers and cosmic-ray physicists are enthralled by the fresh implications of these findings. The configuration of the region and the radiation it contains bespeak a major physical phenomenon involving cosmic rays and solar corpuscles in the vicinity of the earth. This enormous reservoir of charged particles plays a still-unexplained role as middleman in the interaction of earth and sun which is reflected in magnetic storms, in the airglow and in the beautiful displays of the aurora.

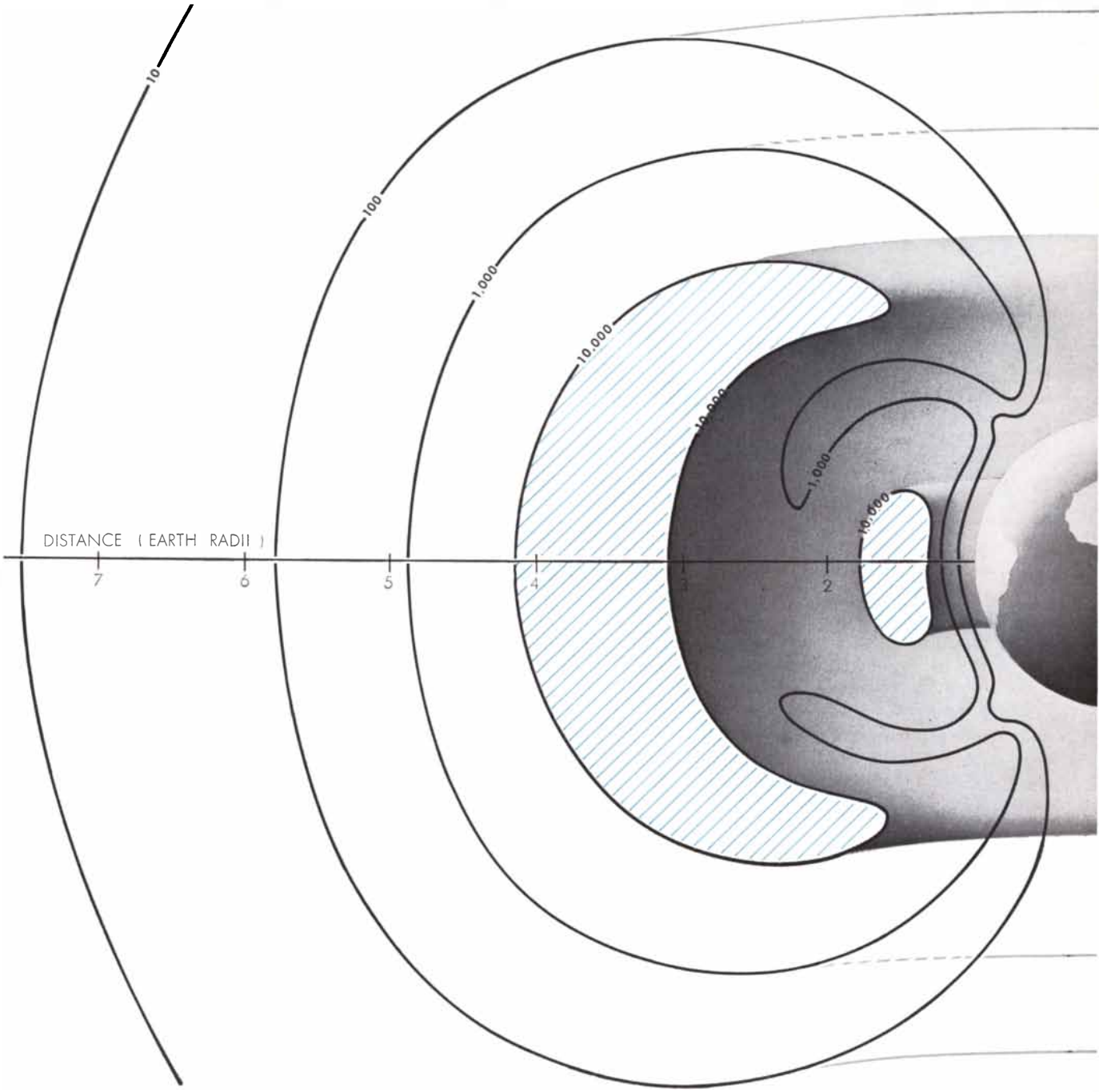
The story of the investigation goes back to 1952 and 1953, before any of us could think realistically about the use of earth satellites to explore the environment of the earth. Parties from our laboratory at the State University of Iowa spent the summers of those years aboard Coast Guard and naval vessels, cruising along a 1,500-mile line from the waters of Baffin Bay, near the magnetic pole in the far northwestern corner of Greenland, southward to the North Atlantic off the coast of Newfoundland. Along the way we launched a series of rocket-carrying balloons—"rockoons." (The balloon lifts a small rocket to an altitude of 12 to 15 miles, whence the rocket carries a modest payload of instruments to a height of 60 to 70 miles.) Our objective was to develop a profile of the cosmic-ray intensities at high altitudes and latitudes, and thus to learn the nature of the low-energy cosmic rays which at lower altitudes and latitudes are deflected by the earth's magnetic field or absorbed in the atmosphere.

Most of the readings radioed down from the rockets were in accord with plausible expectations. Two rockoons sent aloft in 1953, however, provided us with a puzzle. Launched near Newfoundland by Melvin Gottlieb and Leslie Meredith, they encountered a zone of radiation beginning at an altitude of 30 miles that was far stronger than we had expected. At first we were uneasy about the proper operation of our instruments. But critical examination of the data convinced us that we had unquestionably encountered something new in the upper atmosphere.

Significantly these measurements were made in the northern auroral zone. In this zone, which forms a ring some 23 degrees south of the north geomagnetic pole, the incidence of visible auroras reaches its maximum. Since rockets fired north and south of the zone had revealed nothing unusual, we speculated that the strong radiation played some part in the aurora. Showers of particles from the sun, it was thought, come plunging into the atmosphere along magnetic lines of force and set off these displays [see "Aurora and Airglow," by C. T. Elvey and Franklin E. Roach; SCIENTIFIC AMERICAN, September, 1955]. But the theory underlying this explanation did not explain satisfactorily why the aurora and the high-intensity radiation we had detected should occur in the auroral zone and not in the vicinity of the geomagnetic pole itself. Nor could it account for the high energies required to carry the solar particles through the atmosphere to such relatively low altitudes.

The mystery deepened when we found in later studies that the radiation persists almost continuously in the zone above 30 miles, irrespective of visible auroral displays and other known high-altitude disturbances. More discriminating detectors established that the radiation contains large numbers of electrons. Our original observations had detected X-rays only; now it turned out that the X-rays had been generated by the impact of electrons on the skin of the instrument package (as if it had been the "target" in an X-ray tube) and on the sparse atoms of the upper atmosphere itself. Sydney Chapman and Gordon Little at the University of Alaska suggested that such a process might well account for the attenuation of radio signals in the lower ionosphere of the auroral zones.

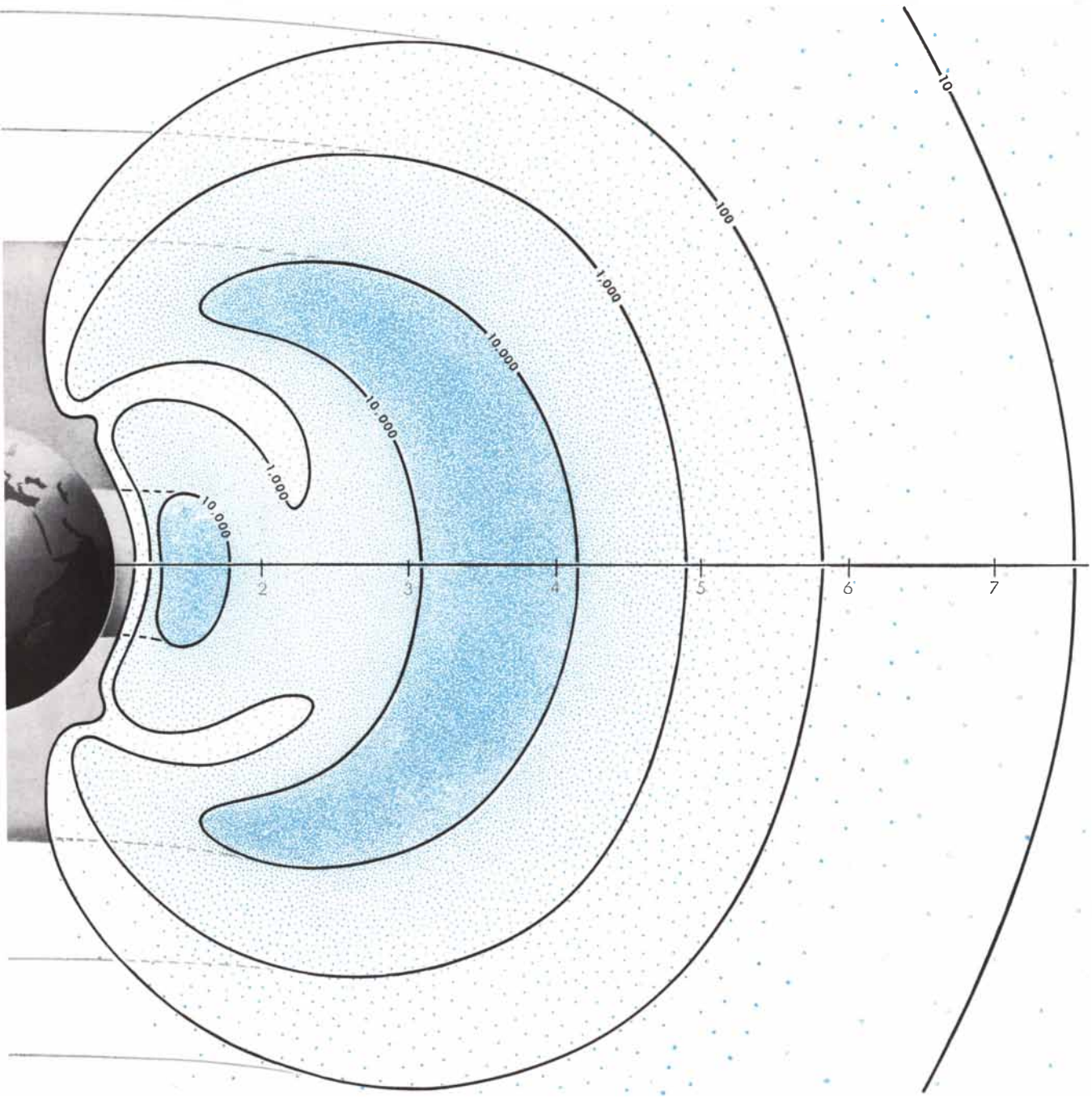
The International Geophysical Year gave us our first opportunity to investigate the "auroral soft radiation" on a more comprehensive scale. During the




**STRUCTURE OF RADIATION BELTS revealed by contours of radiation intensity (*black lines*) is shown schematically by shading (*left*); dots (*right*) suggest distribution of particles in the two belts. Contour numbers give counts per second; horizontal scale**

summer and fall of 1957 Laurence Cahill and I launched a number of rockoons off the coast of Greenland and also got off one successful flight in Antarctica. The latter flight established that the radiation exists in the southern as well as the northern auroral zone. In February, 1958, Carl McIlwain fired a series of two-stage rockets through visible auroras above Fort Churchill in Canada, and discovered that the radiation includes energetic protons (hydrogen nuclei) as well as electrons.

Meanwhile all of us had been pushing a new development that greatly expanded the possibilities for high-altitude research. During the summer of 1955 the President and other Government authorities were finally persuaded that it might be feasible to place artificial satellites in orbit, and authorized an I. G. Y. project for this purpose. In January, 1956, a long-standing group of high-altitude experimentalists, called the Rocket and Satellite Research Panel, held a symposium to consider how the satellites could be most fruitfully employed. At that meeting our group proposed two projects. One was to put a satellite into an orbit nearly pole-to-pole to survey the auroral radiation in both the north and south auroral zones. Such orbits, however, did not appear to be

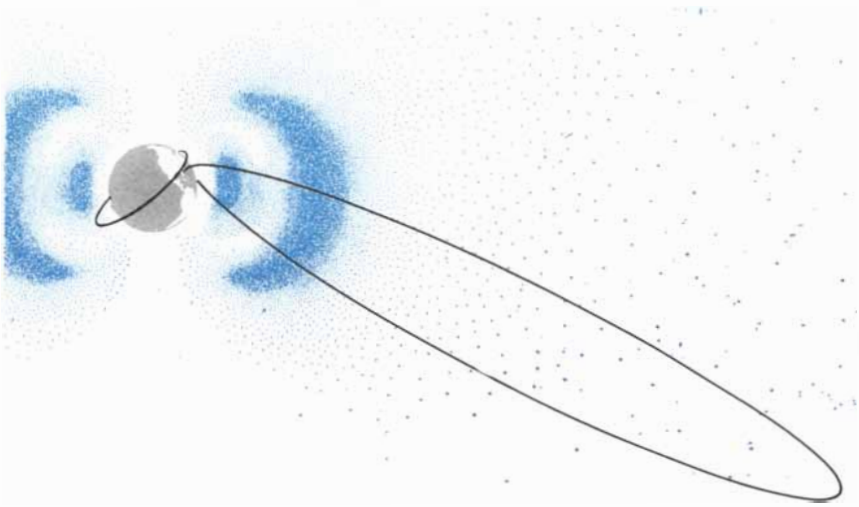



shows distance in earth radii (about 4,000 miles) from the center of the earth. Particles in the inner belt may originate with the radioactive decay of neutrons liberated in the upper atmosphere by cosmic rays; those in the outer belt probably originate in the sun.

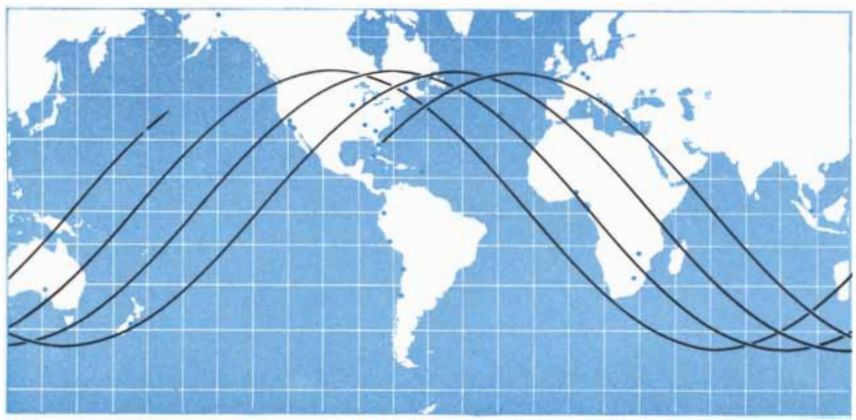
technically feasible in the immediate future. For the time being we were forced to abandon the use of a satellite to probe farther into the auroral soft radiation. We also suggested that a satellite orbiting over the lower latitudes of the earth might usefully be employed in a comprehensive survey of cosmic-ray intensities over those regions. This project was adopted, and we were authorized to prepare suitable experimental apparatus [see "The Artificial Satellite as a Research Instrument," by James A. Van Allen; SCIENTIFIC AMERICAN, November, 1956]. It was planned to place this apparatus on one of the early Vanguard vehicles.

The difficulties and failures of the Vanguard are now history. Sputnik I stimulated some high government officials to accept a proposal that a number of us had been urging for more than a year: to use the proven Jupiter C rocket as a satellite-launching vehicle. As a result on January 31, 1958, Explorer I went into orbit carrying our simple cosmic-ray detector and a radio to broadcast its readings.

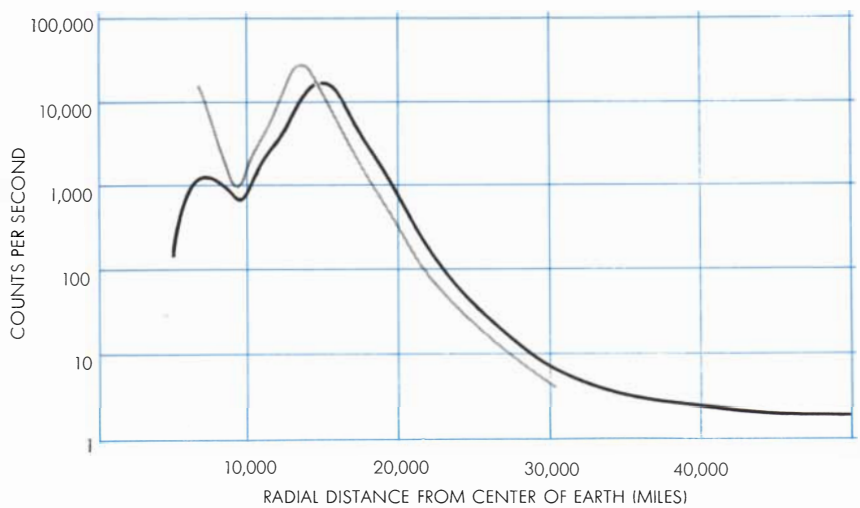
In the first reports from stations located in the U. S. the intensity of radiation increased with altitude along the expected curve. Several weeks later, however, we began to get tapes from stations in



EXPLORER IV AND PIONEER III gave the first detailed picture of the radiation belts. The Explorer IV satellite (*short ellipse*) monitored radiation levels for nearly two months at altitudes up to 1,300 miles. The Pioneer III lunar probe (*long ellipse*) provided data out to 65,000 miles. Its orbit is shown distorted because of the earth's rotation during flight.



EXPLORER IV ORBIT covered the entire region 51 degrees north and south of the equator; the black curve shows a small part of its trace on the earth's surface. More than 25 observation stations (*colored dots*) recorded data from several thousand of the satellite's passes.



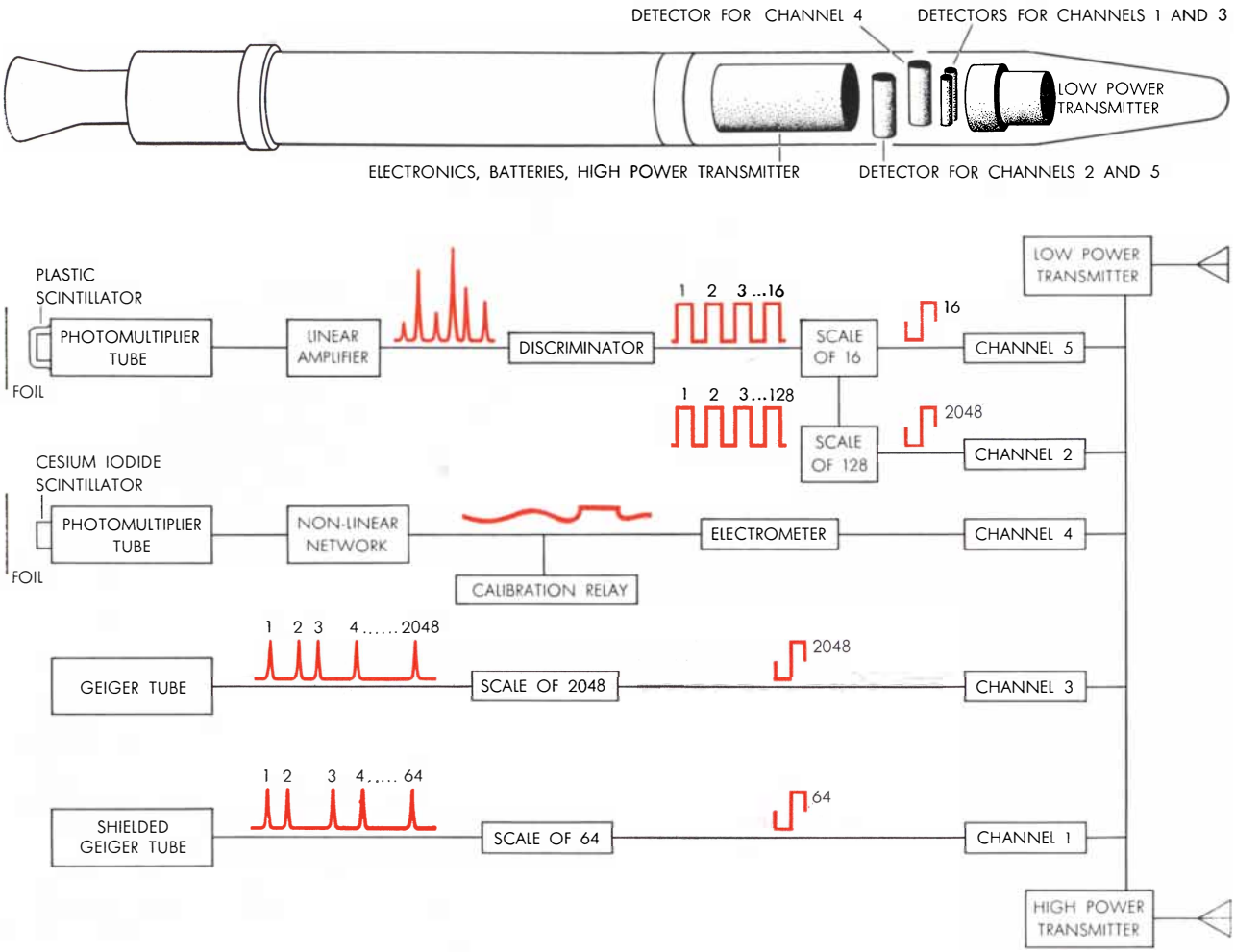

PIONEER III DATA gave the first confirmation of two distinct rings of particles. Counting rates on both the outbound (*black curve*) and the inbound (*gray curve*) legs of the flight showed two peaks. The two curves differ because they cover different sections of the belts.

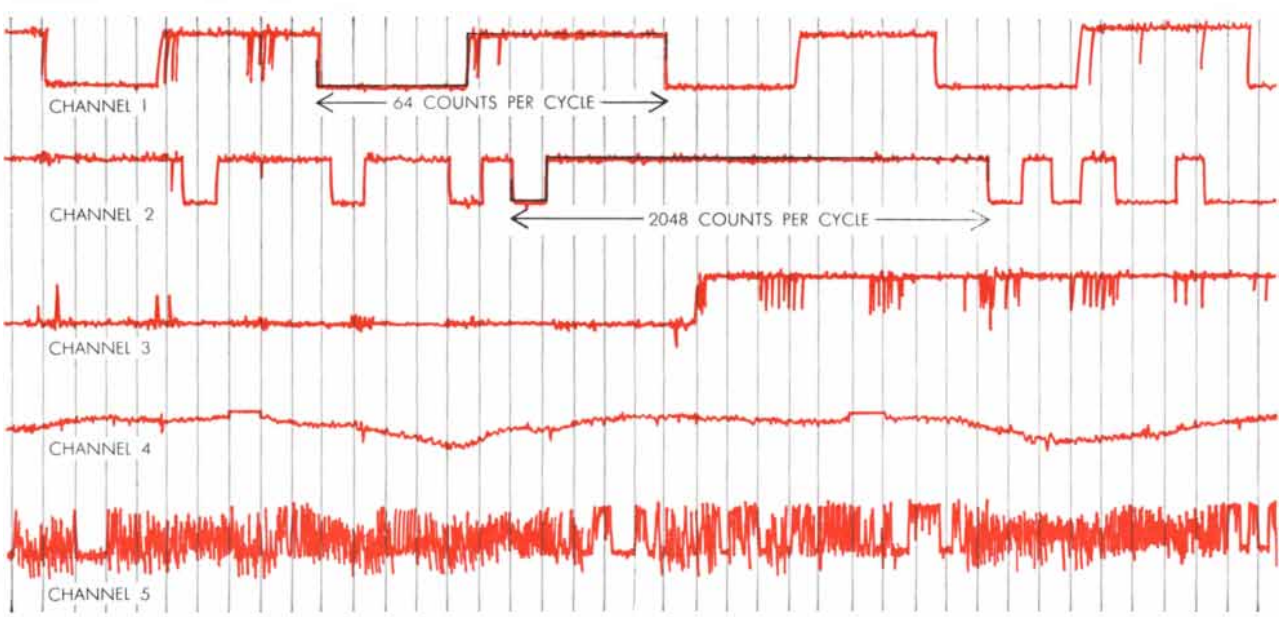
South America and South Africa which gave us counting rates for much higher altitudes, due to the eccentricity of the satellite's orbit. These records brought us a new surprise. At high altitudes over the equatorial region the apparent counting rate was very low; in some passes it dropped to zero for several minutes. Yet at lower altitudes the rate had quite "reasonable" values—from 30 to 50 counts a second. Again we were uneasy about the trustworthiness of the instruments. The only alternative seemed to be that cosmic rays do not strike the uppermost layers of the atmosphere over the tropics, and we were quite unable to accept this conclusion.

Our uneasiness was increased by the incompleteness of our early data. The Explorer I apparatus broadcast its observations continuously, but its signals could be picked up only intermittently, when the satellite came within range of a ground station. Our original apparatus, designed and developed by George Ludwig for the Vanguard satellites, included a magnetic-tape recorder which could store its observations for a complete orbit around the earth and then report them in a "burst" on radio command from the ground.

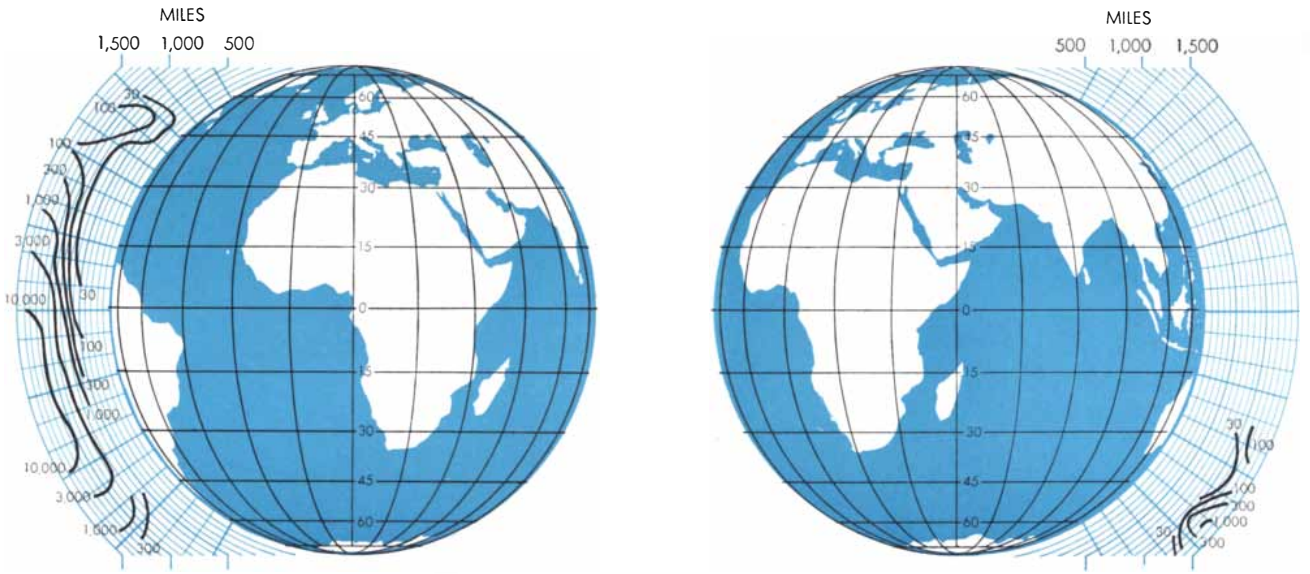
By early February, working with the Jet Propulsion Laboratory, we had converted this apparatus for use in the Explorer II satellite. The first attempt to get it into orbit failed. A second rocket placed Explorer III, carrying identical apparatus, in orbit on March 26. This satellite fully confirmed the anomalous results of Explorer I. At altitudes of 200 to 300 miles the counting rate was low. When the satellite went out to 500 to 600 miles, the apparent rate ascended rapidly and then dropped almost to zero. One day, as we were puzzling over the first tapes from Explorer III, McIlwain suggested the first plausible explanation for their peculiar readings. He had just been calibrating his rocket instruments, and called our attention to something that we all knew but had temporarily forgotten: A sufficiently high level of radiation can jam the counter and send the apparent counting rate to zero. We had discovered an enormously high level of radiation, not a lack of it. As Ernest Ray, a member of our group, inaccurately but graphically exclaimed: "Space is radioactive!"

During the next two months Explorer III produced a large number of playback records, every one of which showed the same effect. At low altitudes the counting rate was reasonably attributable to




**EXPLORER IV INSTRUMENTS** were designed to give a detailed picture of the nature and intensity of the radiation. Plastic scintillator counted only charged particles above certain energies; two different scaling factors adapted it to both high and low counting rates. Cesium-iodide scintillator measured the total energy input rather than individual particles. Shielded and unshielded Geiger tubes could be compared to estimate the penetrability of the radiation. Radio signals suggested by the red curves in upper drawing were recorded by ground stations and later played through a multichannel oscillograph to yield records like that shown below.




**TWO SETS OF CONTOURS from readings on opposite sides of the earth (*left and center*) show the northern and southern "horns" of radiation, which point toward the auroral zones; the contour numbers show radiation intensity in counts per second. The "tipped"**

cosmic rays. At higher altitudes—the precise height depended on both latitude and longitude—the count increased to very high values. Up to the points at which the counter jammed, it showed counting rates more than 1,000 times the theoretical expectation for cosmic rays. From the rate of increase and the length of the periods of jamming we judged that the maximum count probably went to several times this level. Since the radiation appeared to resemble the auroral soft radiation, we would not have been surprised to find it in the auroral zone or along the magnetic lines of force that connect these zones. But in the equatorial latitudes these lines of force lie much farther out in space than the altitudes attained by the satellites.

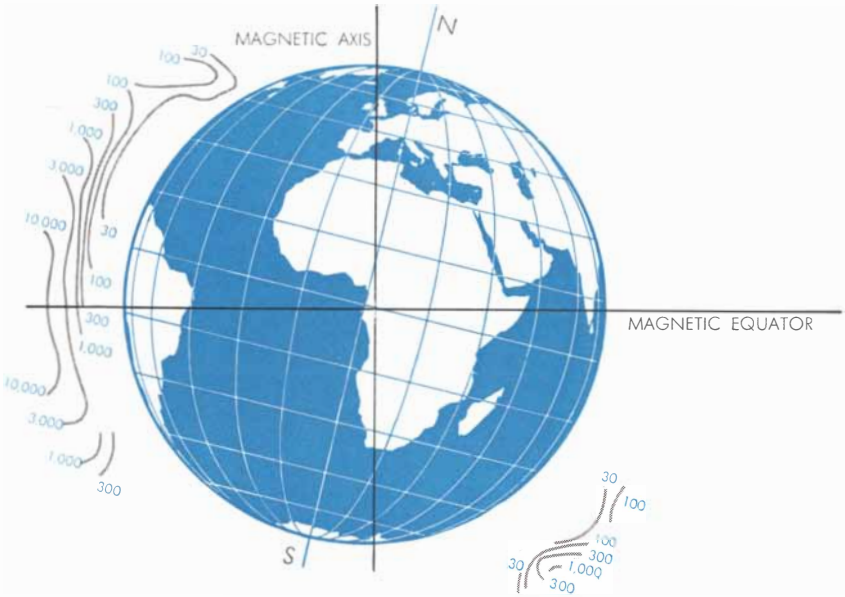
On May 1 of last year we were able to report with confidence to the National Academy of Sciences and the American Physical Society that Explorers I and III had discovered a major new phenomenon: a very great intensity of radiation above altitudes of some 500 miles over the entire region of their traverse, some 34 degrees north and south of the equator. At the same time we advanced the idea that the radiation consists of charged particles—presumably protons and electrons—trapped in the magnetic field of the earth.

We could rule out uncharged particles and gamma and X-rays because they would not be confined by the magnetic field, and so would be observed at lower altitudes. The possibility that the earth's magnetic field might act as a trap for charged particles was first suggested by the Norwegian physicist Carl Störmer in a classical series of papers beginning some 50 years ago, and there was a considerable body of evidence for the existence of low-energy charged particles throughout our solar system and specifically in the vicinity of the earth. But there had been no indication that these particles would possess the high energies we had detected.

From Störmer's theoretical discussion and our own observations we evolved a rough picture of the trapping mechanism. When a fast-moving charged particle is injected into the earth's magnetic field, it describes a corkscrew-shaped trajectory, the center line of which lies along a magnetic line of force. The turns of the helical path are quite open over the equator but become tighter as the particle reaches the stronger magnetic field toward the poles [*see illustration at bottom of opposite page*]. At the lower end of its trajectory the particle goes into a flat spiral and then winds back along a similar path to the other hemisphere, making the transit from one hemisphere to the other in a second or so. During this time its line of travel shifts slightly, so that the particle drifts slowly around the earth as it corkscrews from hemisphere to hemisphere. An electron drifts from west to east; a proton, in the opposite direction. At each end of its path the particle descends into regions of higher atmospheric density; collisions with the atoms of atmospheric gases cause it gradually to change its trajectory and to lose energy. After a period of days or weeks the particle is lost into the lower atmosphere.

There was obviously an urgent scientific need to extend these observations with equipment of greater dynamic range and discrimination. In April of 1958 we persuaded several Federal agencies to support further satellite flights of our radiation equipment as an adjunct to the I. G. Y. program, and we received the enthusiastic support of the National Academy of Sciences for the continuation of our work. We also persuaded the Army Ballistic Missile Agency and the Cape Canaveral Air Force Base to try to place the satellite in an orbit more steeply inclined to the equator; at an inclination of about 50 degrees to the equator it would cover a much greater area of earth and skim the edges of both auroral zones.

Working night and day, we set out at once to build new apparatus of a more discriminating nature. We retained the Geiger tube, which we had used in previous satellites, as a basic "simple-minded" detector. To be ready for the highest intensities of radiation, however, we used a much smaller tube that would yield a lower count in a given flux of radiation, and we hooked it into a circuit that would scale down its count by a much larger factor. To obtain a better idea of the penetrability of the radiation




**drawing at right shows the essential symmetry of the radiation around the earth's magnetic axis. The structure of the radiation zone was built up from hundreds of observed points.**

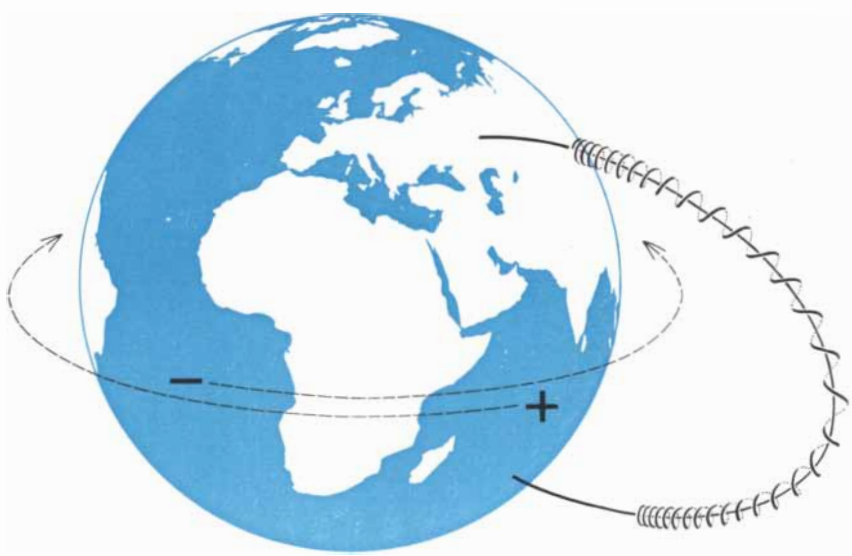
we shielded a similar Geiger tube with a millimeter of lead. As a more discriminating particle detector we adopted a plastic scintillator and photomultiplier tube to respond to electrons with an energy of more than 650,000 electron volts and to protons of more than 10 million electron volts. Finally we glued a thin cesium-iodide crystal to the window of another photomultiplier tube; the light emitted by the crystal when it was irradiated would measure the over-all input of energy rather than the arrival of individual particles. To keep out light when the crystal faced the sun, we shielded it with thin, opaque nickel foil. A special amplifier gave this detector a large dynamic range extending from about .1 erg per second to 100,000 ergs per second.

Explorer IV carried this apparatus into orbit on July 26, and sent down data for almost two months. Magnetic tapes from some 25 observing stations flowed in steadily from late July to late September; altogether we obtained some 3,600 recorded passes of the satellite. A typical pass was readable for several minutes; some of the best were readable for up to 20 minutes, a large fraction of the time required for the satellite to make a turn around the earth. We are still analyzing this mass of data, but the preliminary results have already proved to be enlightening.

The readings have confirmed our earlier estimates of the maximum levels of radiation. Moreover, we have extended our observations to more than 50 degrees north and south of the equator and have been able to plot the intensity of the radiation at various latitudes and longitudes for altitudes up to 1,300 miles. The intensity contours follow the shape of the earth in the equatorial region, but as they approach high northern and southern latitudes they swing outward, then inward and sharply outward again to form "horns" reaching down toward the earth near the auroral zones [*see illustrations at the top of these two pages*]. The entire picture so far is completely consistent with the magnetic-trapping theory.

It was clear from the contours that Explorers I, III and IV penetrated only the lower portion of the radiation belt. As early as last spring we began to make hypothetical extensions of the observed contours out to a distance of several thousand miles. One of these speculative diagrams showed a single, doughnut-shaped belt of radiation with a ridge around the northern and southern edges of its inner circumference, corresponding to the horns of the contours. Another showed two belts—an outer region with a banana-shaped cross section that extended from the northern to the southern auroral zone and an inner belt over the equator with a bean-shaped cross section [*see illustration on pages 40 and 41*]. The latter diagram seemed to fit the contours better. In our seminars and after-hour discussions McIlwain held out for the two-belt theory. The rest of us tended to agree with him but preferred to stay with the single "doughnut" because of its simplicity.

To take the question out of the realm of speculation we had to secure measurements through the entire region of radiation. In May, therefore, I arranged to have one of our radiation detectors carried aboard the lunar probes planned for the fall of 1958. On October




**TRAPPED PARTICLES spiral rapidly back and forth along a corkscrew-shaped path whose center is a magnetic line of force. At the same time they drift slowly around the earth (*broken arrows*). Electrons (*negative*) and protons (*positive*) drift in opposite directions.**

11, 12 and 13 Pioneer I, the first lunar probe, carried our instruments nearly 70,000 miles out from the earth. Though its readings were spotty, they confirmed our belief that the radiation extended outward for many thousands of miles, with its maximum intensity no more than 10,000 miles above the earth.

The next attempted moon shot, Pioneer II, was a fizzle. Pioneer III, however, went off beautifully on December 6. Although this rocket was intended to reach the vicinity of the moon, we were almost as pleased when it failed to do so, for it gave us excellent data on both the upward and downward legs of its flight, cutting through the radiation region for 65,000 miles in two places.

The observations on both legs showed a double peak in intensity [*see illustration at bottom of page 42*], establishing that there are indeed two belts rather than one. The inner belt reaches its peak at about 2,000 miles from the earth, the outer one at about 10,000 miles. Beyond 10,000 miles the radiation intensity diminishes steadily; it disappears almost completely beyond 40,000 miles. The maximum intensity of radiation in each belt is about 25,000 counts per second, equivalent to some 40,000 particles per square centimeter per second.

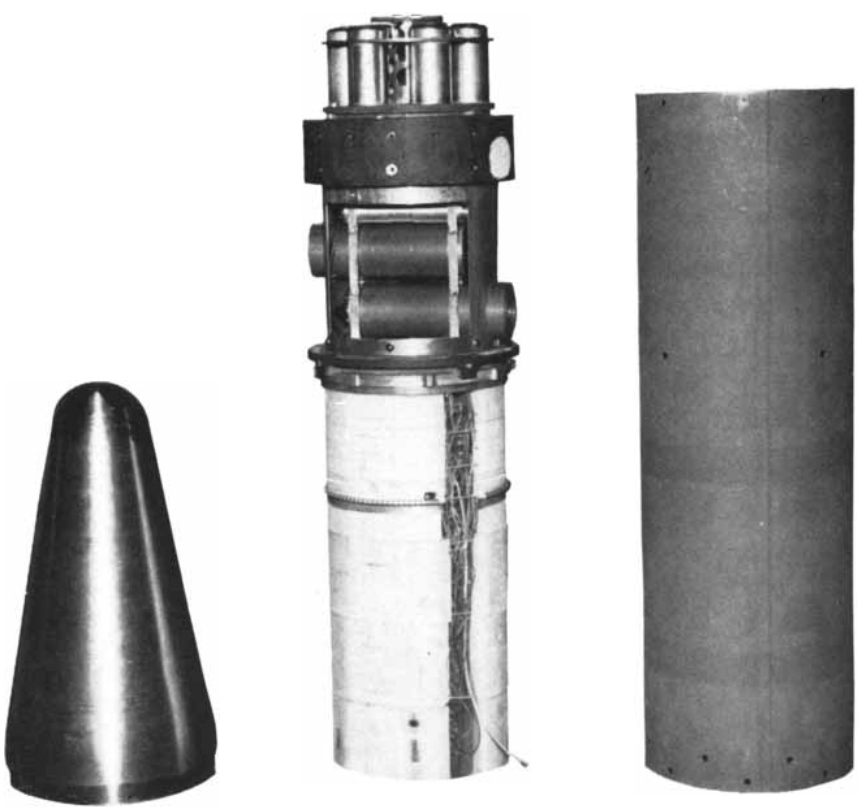
Most of us believe that this great reservoir of particles originates largely in the sun. The particles are somehow injected into the earth's magnetic field, where they are deflected into corkscrew trajectories around lines of force and trapped. In this theoretical scheme the radiation belts resemble a sort of leaky bucket, constantly refilled from the sun and draining away into the atmosphere. A particularly large influx of solar particles causes the bucket to "slop over," mainly in the auroral zone, generating visible auroras, magnetic storms and related disturbances. The normal leakage may be responsible for the airglow which faintly illuminates the night sky and may also account for some of the unexplained high temperatures which have been observed in the upper atmosphere.

This solar-origin theory, while attractive, presents two problems, neither of which is yet solved. In the first place the energy of many of the particles we have observed is far greater than the presumed energy of solar corpuscles. The kinetic energy of solar corpuscles has not been measured directly, but the time-lag between a solar outburst and the consequent magnetic disturbances on earth indicates that the particles are slow-moving and thus of relatively low energy. It may be that the earth's magnetic field traps only a high-energy fraction of the particles. Alternatively, some unknown magnetohydrodynamic effect of the earth's field may accelerate the sluggish particles to higher velocities. Some such process in our galaxy has been suggested as responsible for the great energies of cosmic rays. The second problem in the solar-origin theory is that it is difficult to explain how charged particles can get into the earth's magnetic field in the first place. We believe that neither problem is unsolvable.

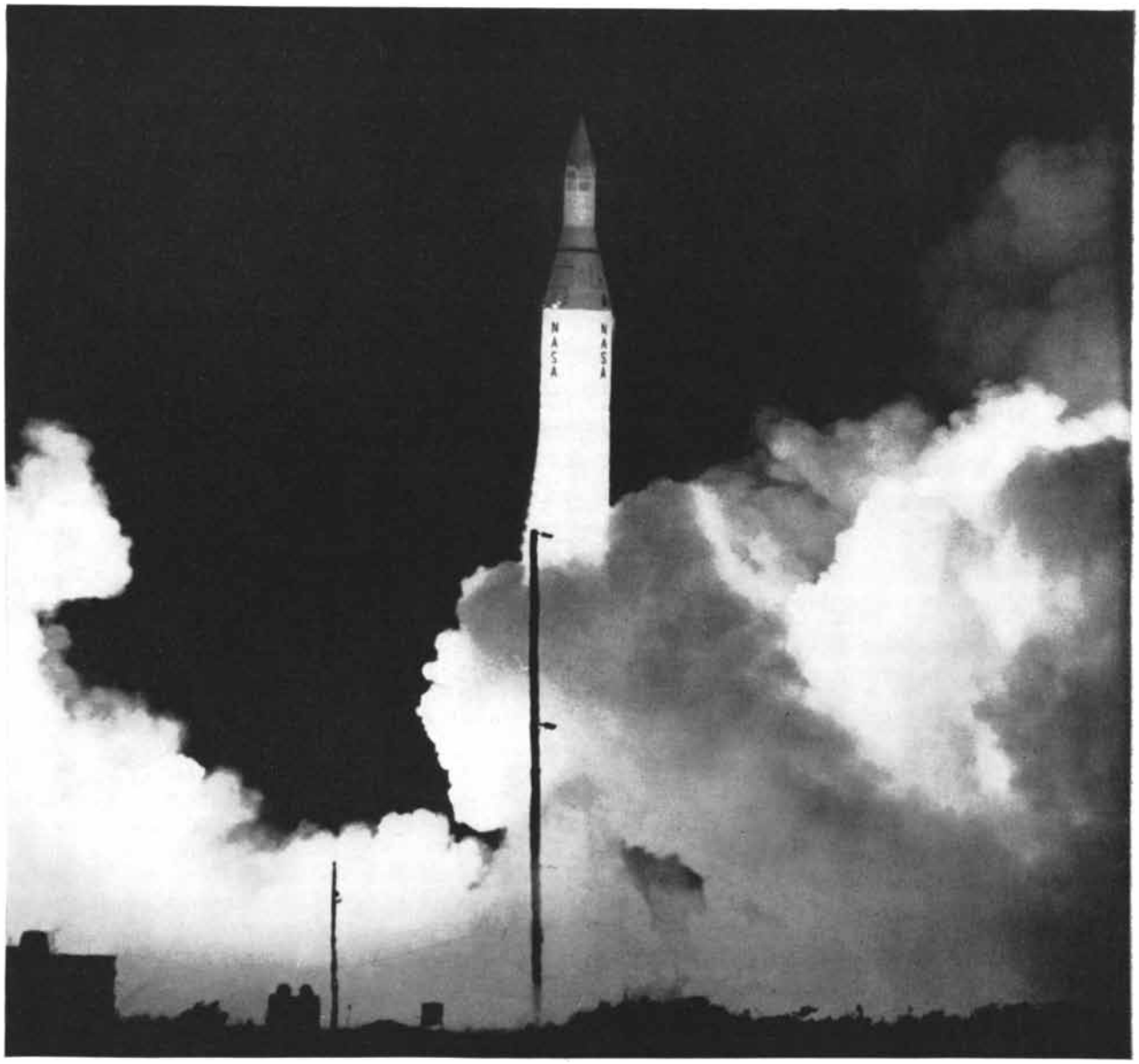
Nicholas Christofilos of the University of California and the Soviet physicist S. N. Vernov have suggested an entirely different theory of how the radiation originates. They note that neutrons are released in large numbers in the earth's upper atmosphere by the impact of cosmic rays. These neutrons, being uncharged, can travel through the magnetic field without deflection. In due course some of them decay there into electrons and protons, which are trapped.

Our group agrees that particle-injection of this sort is going on, and at a rate which can be easily calculated; but we feel for a number of reasons that it cannot be the main source of radiation-belt particles. If we are right in supposing that the radiation belts provide the "reservoir" for the aurora, the neutron hypothesis cannot account for more than one 10,000th of the auroral energy output. Even if the association between the radiation belts and the aurora turns out to be fortuitous, preliminary indications both from our work and from the Russian experience with Sputnik III suggest that most of the particles in the radiation belt have much lower energies than those of particles that would be produced by neutron decay. A full knowledge of the energy distribution of the particles will aid greatly in clarifying their origin.

Neither theory explains why there should be two belts rather than one. It is tempting to combine the two theories and suppose that the inner belt originates with "internal injection"—*i.e.*, neutron-decay products—and the outer one with "external injection" of solar corpuscles. The two-belt configuration may of course be a transitory phenomenon, though the data from Explorer IV and Pioneer III indicate that the separate belts persisted in essentially the same form for at least five months. We should bear in mind, however, that 1958 was a year of great solar activity. Three years



**HEAD OF EXPLORER IV** includes nose cone (*left*), instrument "payload" (*center*) and protective shell (*right*). Payload includes four detectors, two radio transmitters, batteries and associated electronic circuity. The outer shell is approximately six inches in diameter.




**FOUR-STAGE ROCKET launched the Pioneer III moon probe on December 6, 1958. Though the flight failed to reach the moon, its outbound leg gave a continuous record of radiation out to 65,000 miles; the inbound leg gave data between 30,000 and 10,000 miles.**

from now we may well find a much lower over-all intensity and perhaps a different structure altogether.

In addition to these possible long-term changes, there may be short-term fluctuations in the belts. While we feel sure that the influx and leakage of particles must balance in the long run, a major solar outbreak may temporarily increase the intensity of the radiation many-fold. If we were to detect such fluctuations and were to find that they coincide with solar outbursts on the one hand and with terrestrial magnetic disturbances on the other, we would have a plain lead to the origin of the particles. Before long we hope to launch a satellite that will monitor radiation levels for at least a year.

Our measurements show that the maximum radiation level as of 1958 is equivalent to between 10 and 100 roentgens per hour, depending on the still-undetermined proportion of protons to electrons. Since a human being exposed for two days to even 10 roentgens would have only an even chance of survival, the radiation belts obviously present an obstacle to space flight. Unless some practical way can be found to shield space-travelers against the effects of the radiation, manned space rockets can best take off through the radiation-free zone over the poles. A "space station" must orbit below 400 miles or beyond 30,000 miles from the earth. We are now planning a satellite flight that will test the efficacy of various methods of shielding.

The hazard to space-travelers may not end even when they have passed the terrestrial radiation belts. According to present knowledge the other planets of our solar system may have magnetic fields comparable to the earth's and thus may possess radiation belts of their own. The moon, however, probably has no belt, because its magnetic field appears to be feeble. Lunar probes should give us more definite information on this point before long.

# Darwin's Missing Evidence

*In his time certain species of moths were light in color. Today in many areas these species are largely dark. If he had noticed the change occurring, he would have observed evolution in action*

by H. B. D. Kettlewell

Charles Darwin's *Origin of Species*, the centenary of which we celebrate in 1959, was the fruit of 26 years of laborious accumulation of facts from nature. Others before Darwin had believed in evolution, but he alone produced a cataclysm of data in support of it. Yet there were two fundamental gaps in his chain of evidence. First, Darwin had no knowledge of the mechanism of heredity. Second, he had no visible example of evolution at work in nature.

It is a curious fact that both of these gaps could have been filled during Darwin's lifetime. Although Gregor Mendel's laws of inheritance were not discovered by the community of biologists until 1900, they had first been published in 1866. And before Darwin died in 1882, the most striking evolutionary change ever witnessed by man was taking place around him in his own country.

The change was simply this. Less than a century ago moths of certain species were characterized by their light coloration, which matched such backgrounds as light tree trunks and lichen-covered rocks, on which the moths passed the daylight hours sitting motionless. Today in many areas the same species are predominantly dark! We now call this reversal "industrial melanism."

It happens that Darwin's lifetime coincided with the first great man-made change of environment on earth. Ever since the Industrial Revolution commenced in the latter half of the 18th century, large areas of the earth's surface have been contaminated by an insidious and largely unrecognized fallout of smoke particles. In and around industrial areas the fallout is measured in tons per square mile per month; in places like Sheffield in England it may reach 50 tons or more. It is only recently that we have begun to realize how widely the lighter smoke particles are dispersed, and to what extent they affect the flora and fauna of the countryside.

In the case of the flora the smoke particles not only pollute foliage but also kill vegetative lichens on the trunks and boughs of trees. Rain washes the pollutants down the boughs and trunks until they are bare and black. In heavily polluted districts rocks and the very ground itself are darkened.

Now in England there are some 760 species of larger moths. Of these more than 70 have exchanged their light color and pattern for dark or even all-black coloration. Similar changes have occurred in the moths of industrial areas of other countries: France, Germany, Poland, Czechoslovakia, Canada and the U. S. So far, however, such changes have not been observed anywhere in the tropics. It is important to note here that industrial melanism has occurred only among those moths that fly at night and spend the day resting against a background such as a tree trunk.

These, then, are the facts. A profound change of color has occurred among hundreds of species of moths in industrial areas in different parts of the world. How has the change come about? What underlying laws of nature have produced it? Has it any connection with one of the normal mechanisms by which one species evolves into another?

In 1926 the British biologist Heslop Harrison reported that the industrial melanism of moths was caused by a special substance which he alleged was present in polluted air. He called this substance a "melanogen," and suggested that it was manganous sulfate or lead nitrate. Harrison claimed that when he fed foliage impregnated with these salts to the larvae of certain species of light-colored moths, a proportion of their offspring were black. He also stated that this "induced melanism" was inherited according to the laws of Mendel.

Darwin, always searching for missing evidence, might well have accepted Harrison's Lamarckian interpretation, but in 1926 biologists were skeptical. Although the rate of mutation of a hereditary characteristic can be increased in the laboratory by many methods, Harrison's figures inferred a mutation rate of 8 per cent. One of the most frequent mutations in nature is that which causes the disease hemophilia in man; its rate is in the region of .0005 per cent, that is, the mutation occurs about once in 50,000 births. It is, in fact, unlikely that an increased mutation rate has played any part in industrial melanism.

At the University of Oxford during the past seven years we have been attempting to analyze the phenomenon of industrial melanism. We have used many different approaches. We are in the process of making a survey of the present frequency of light and dark forms of each species of moth in Britain that exhibits industrial melanism. We are critically examining each of the two forms to see if between them there are any differences in behavior. We have fed large numbers of larvae of both forms on foliage impregnated with substances in polluted air. We have observed under various conditions the mating preferences and relative mortality of the two forms. Finally we have accumulated much information about the melanism of moths in parts of the world that are far removed from industrial centers, and we have sought to link industrial melanism with the melanics of the past.

Our main guinea pig, both in the field and in the laboratory, has been the peppered moth *Biston betularia* and its me-

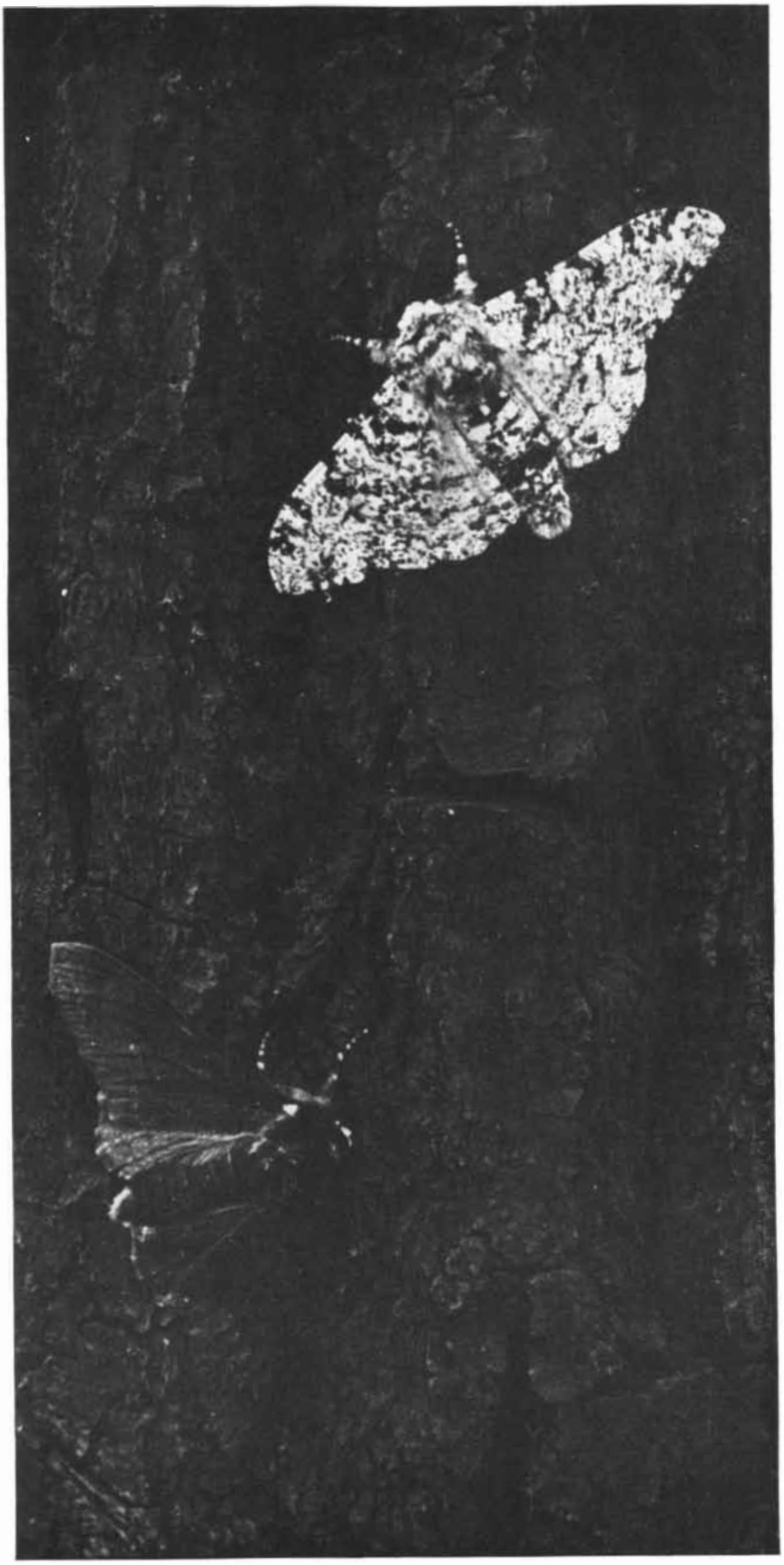
lanic form *carbonaria*. This species occurs throughout Europe, and is probably identical with the North American *Amphidasis cognataria*. It has a one-year life cycle; the moth appears from May to August. The moth flies at night and passes the day resting on the trunks or on the underside of the boughs of rough-barked deciduous trees such as the oak. Its larvae feed on the foliage of such trees from June to late October; its pupae pass the winter in the soil.

The dark form of the peppered moth was first recorded in 1848 at Manchester in England. Both the light and dark forms appear in each of the photographs at right and on the next page. The background of each photograph is noteworthy. In the photograph on the next page the background is a lichen-encrusted oak trunk of the sort that today is found only in unpolluted rural districts. Against this background the light form is almost invisible and the dark form is conspicuous. In the photograph at right the background is a bare and blackened oak trunk in the heavily polluted area of Birmingham. Here it is the dark form which is almost invisible, and the light form which is conspicuous. Of 621 wild moths caught in these Birmingham woods in 1953, 90 per cent were the dark form and only 10 per cent the light. Today this same ratio applies in nearly all British industrial areas and far outside them.

We decided to test the rate of survival of the two forms in the contrasting types of woodland. We did this by releasing known numbers of moths of both forms. Each moth was marked on its underside with a spot of quick-drying cellulose paint; a different color was used for each day. Thus when we subsequently trapped large numbers of moths we could identify those we had released and established the length of time they had been exposed to predators in nature.

In an unpolluted forest we released 984 moths: 488 dark and 496 light. We recaptured 34 dark and 62 light, indicating that in these woods the light form had a clear advantage over the dark. We then repeated the experiment in the polluted Birmingham woods, releasing 630 moths: 493 dark and 137 light. The result of the first experiment was completely reversed; we recaptured proportionately twice as many of the dark form as of the light.

For the first time, moreover, we had witnessed birds in the act of taking moths from the trunks. Although Britain has more ornithologists and bird watch-



**DARK AND LIGHT FORMS of the peppered moth were photographed on the trunk of an oak blackened by the polluted air of the English industrial city of Birmingham. The light form (*Biston betularia*) is clearly visible; the dark form (*carbonaria*) is well camouflaged.**

ers than any other country, there had been absolutely no record of birds actually capturing resting moths. Indeed, many ornithologists doubted that this happened on any large scale.

The reason for the oversight soon became obvious. The bird usually seizes the insect and carries it away so rapidly that the observer sees nothing unless he is keeping a constant watch on the insect. This is just what we were doing in the course of some of our experiments. When I first published our findings, the editor of a certain journal was sufficiently rash as to question whether birds took resting moths at all. There was only one thing to do, and in 1955 Niko Tinbergen of the University of Oxford filmed a repeat of my experiments. The film not only shows that birds capture and eat resting moths, but also that they do so selectively.

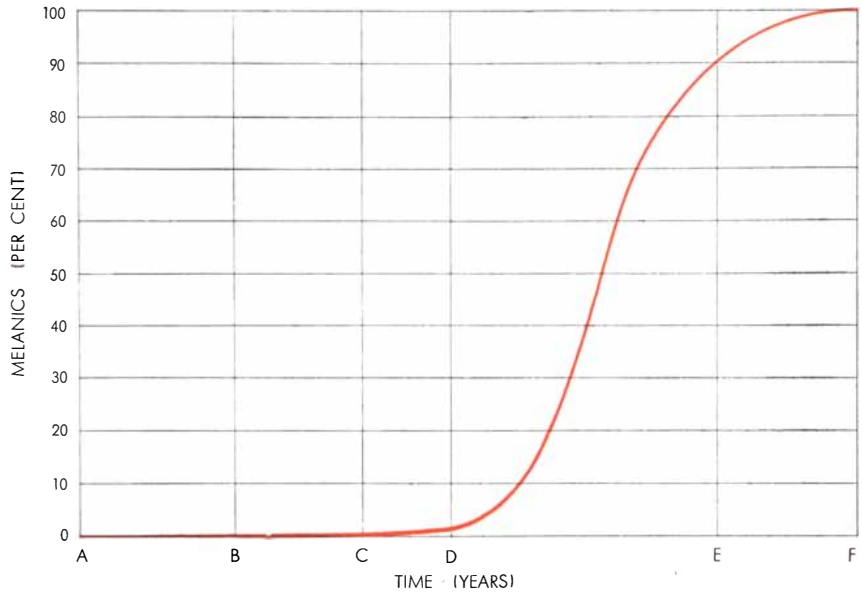
These experiments lead to the following conclusions. First, when the environment of a moth such as *Biston betularia* changes so that the moth cannot hide by day, the moth is ruthlessly eliminated by predators unless it mutates to a form that is better suited to its new environment. Second, we now have visible proof that, once a mutation has occurred, natural selection alone can be responsible for its rapid spread. Third, the very fact that one form of moth has replaced another in a comparatively short span of years indicates that this evolutionary mechanism is remarkably flexible.

The present status of the peppered moth is shown in the map on the opposite page. This map was built up from more than 20,000 observations made by 170 voluntary observers living in various parts of Britain. The map makes the following points. First, there is a strong correlation between industrial centers and a high percentage of the dark form of the moth. Second, populations consisting entirely of the light form are found today only in western England and northern Scotland. Third, though the counties of eastern England are far removed from industrial centers, a surprisingly high percentage of the dark form is found in them. This, in my opinion, is due to the long-standing fallout of smoke particles carried from central England by the prevailing southwesterly winds.

Now in order for the dark form of a moth to spread, a mutation from the light form must first occur. It appears that the frequency with which this happens—that is, the mutation rate—varies according to the species. The rate at which the light form of the peppered

**SAME TWO FORMS** of the peppered moth were photographed against the lichen-encrusted trunk of an oak in an unpolluted area. Here it is the dark form which may be clearly seen. The light form, almost invisible, is just below and to the right of the dark form.

moth mutates to the dark form seems to be fairly high; the rate at which the mutation occurs in other species may be very low. For example, the light form of the moth *Procus literosa* disappeared from the Sheffield area many years ago, but it has now reappeared in its dark form. It would seem that a belated mutation has permitted the species to regain lost territory. Another significant example is provided by the moth *Tethea oculatis*. Prior to 1947 the dark form of this species was unknown in England. In that year, however, many specimens of the dark form were for the first time collected in various parts of Britain; in some districts today the dark form now comprises more than 50 per cent of the species. There is little doubt that this melanic arrived in Britain not by mutation but by migration. It had been known for a considerable time in the industrial areas of northern Europe, where presumably the original mutation occurred.

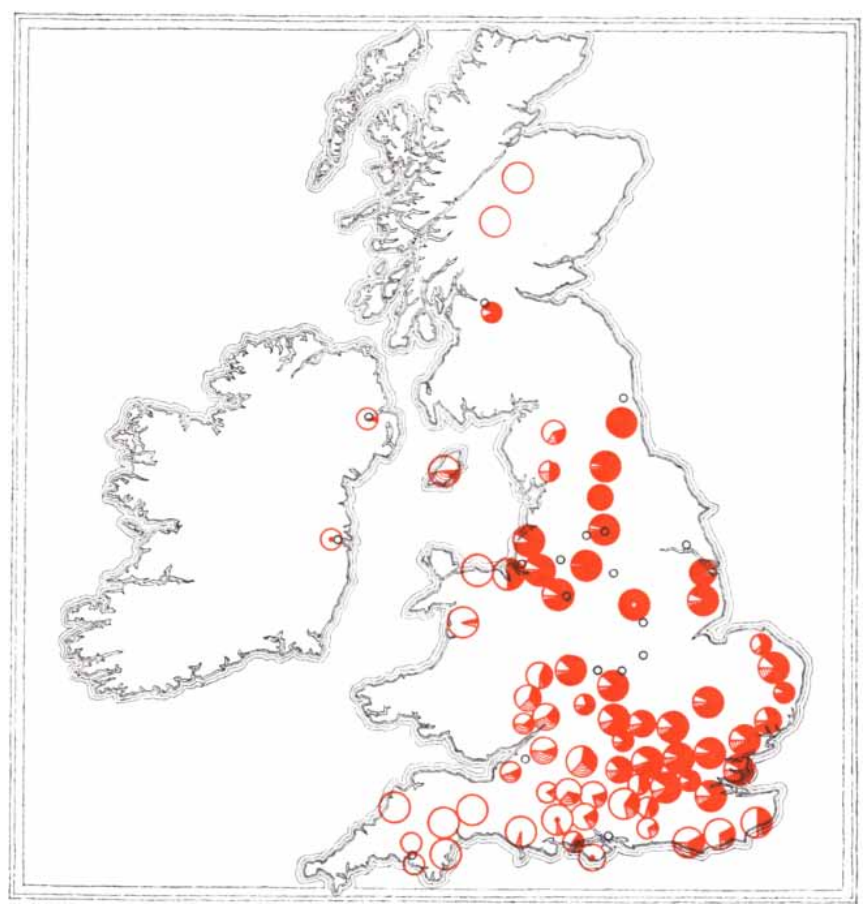



**SPREAD OF MUTATION from the light form to the dark (melanic) is expressed by this curve, discussed in detail in the text. The mutation occurs in the period AB, spreads slowly during BD and spreads rapidly during DE. During EF the light form is either gradually eliminated, as indicated by the curve, or remains at a level of about 5 per cent of the population.**

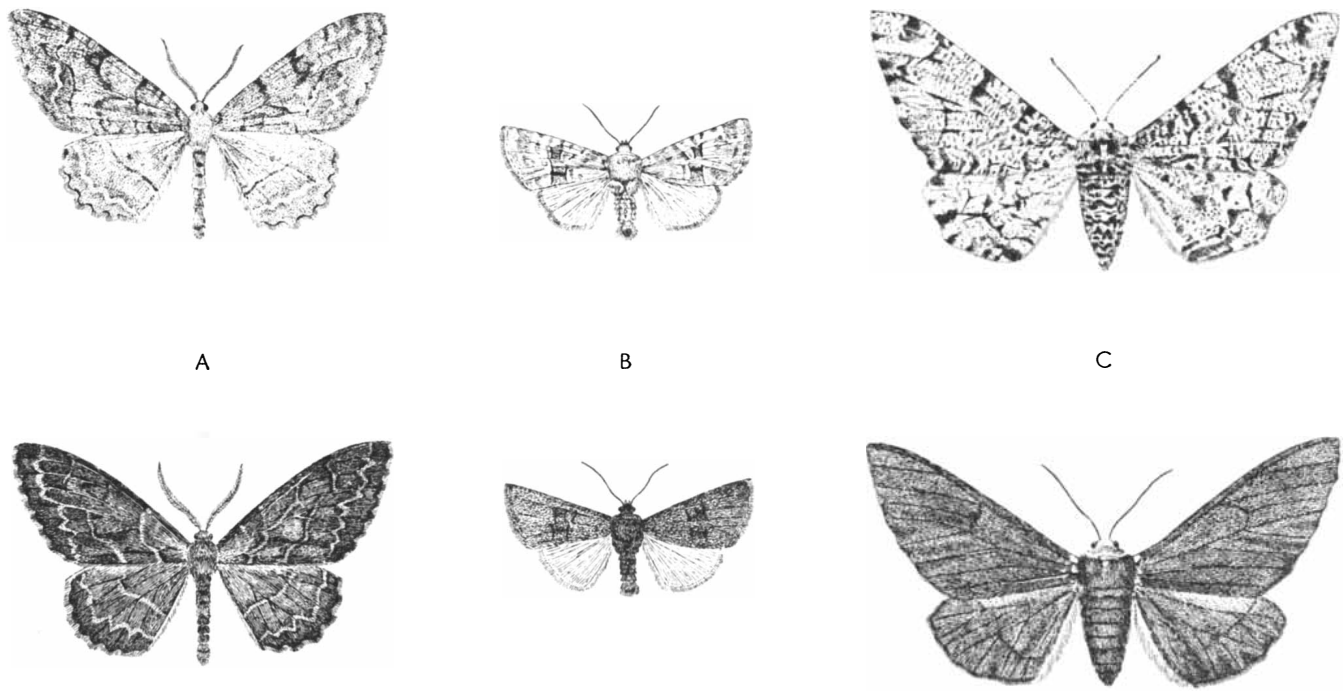
The mutation that is responsible for industrial melanism in moths is in the majority of cases controlled by a single gene. A moth, like any other organism that reproduces sexually, has two genes for each of its hereditary characteristics: one gene from each parent. The mutant gene of a melanic moth is inherited as a Mendelian dominant; that is, the effect of the mutant gene is expressed and the effect of the other gene in the pair is not. Thus a moth that inherits the mutant gene from only one of its parents is melanic.

The mutant gene, however, does more than simply control the coloration of the moth. The same gene (or others closely linked with it in the hereditary material) also gives rise to physiological and even behavioral traits. For example, it appears that in some species of moths the caterpillars of the dark form are hardier than the caterpillars of the light form. Genetic differences are also reflected in mating preference. On cold nights more males of the light form of the peppered moth appear to be attracted to light females than to dark. On warm nights, on the other hand, significantly more light males are attracted to dark females.

There is evidence that, in a population of peppered moths that inhabits an industrial area, caterpillars of the light form attain full growth earlier than caterpillars of the dark form. This may be due to the fact that the precipitation of pollutants on leaves greatly increases late in the autumn. Caterpillars of the dark form may be hardier in the presence



**PROPORTION OF FORMS of the peppered moth at various locations in the British Isles is indicated on this map. The open area within a colored circle represents the proportion of the light form *Biston betularia* recorded; the solid colored area, the proportion of the dark form *carbonaria*; the hatched colored area, the proportion of another dark form, *insularia*. Small black circles on the map indicate the location of major industrial centers.**




FIVE SPECIES OF MOTH that have both light and dark forms are depicted in their actual size. In each case the light form is at the top and the dark form is at the bottom. The species are: *Cleora repandata* (A), *Procus literosa* (B), *Biston betularia* (C), *Ectropis*

of such pollution than caterpillars of the light form. In that case natural selection would favor light-form caterpillars which mature early over light-form caterpillars which mature late. For the hardier caterpillars of the dark form, on the other hand, the advantages of later feeding and longer larval life might outweigh the disadvantages of feeding on increasingly polluted leaves. Then natural selection would favor those caterpillars which mature late.

Another difference between the behavior of *B. betularia* and that of its dark form *carbonaria* is suggested by our experiments on the question of whether each form can choose the "correct" background on which to rest during the day. We offered light and dark backgrounds of equal area to moths of both forms, and discovered that a significantly large proportion of each form rested on the correct background. Before these results can be accepted as proven, the experiments must be repeated on a larger scale. If they are proven, the behavior of both forms could be explained by the single mechanism of "contrast appreciation." This mechanism assumes that one segment of the eye of a moth senses the color of the background and that another segment senses the moth's own color; thus the two colors could be compared. Presumably if they were the same, the moth would remain on its background; but if they were different, "contrast conflict" would result and the moth would move off again. That moths tend to be restless when the colors conflict is certainly borne out by recent field observations.

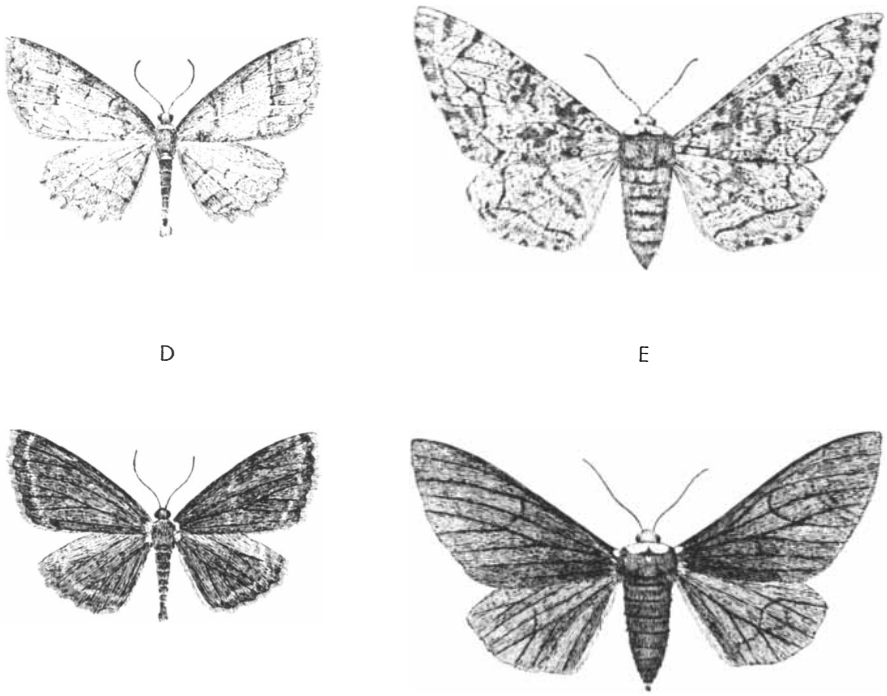
It is evident, then, that industrial melanism is much more than a simple change from light to dark. Such a change must profoundly upset the balance of hereditary traits in a species, and the species must be a long time in restoring that balance. Taking into account all the favorable and unfavorable factors at work in this process, let us examine the spread of a mutation similar to the dark form of the peppered moth. To do so we must consult the diagram at the top of the preceding page.

According to the mutation rate and the size of the population, the new mutation may not appear in a population for a period varying from one to 50 years. This is represented by AB on the diagram. Let us now assume the following: that the original successful mutation took place in 1900, that subsequent new mutations failed to survive, that the total local population was one million, and that the mutant had a 30-per-cent advantage over the light form. (By a 30-per-cent advantage for the dark form we mean that, if in one generation there were 100 light moths and 100 dark, in the next generation there would be 85 light moths and 115 dark.)

On the basis of these assumptions there would be one melanic moth in 1,000 only in 1929 (BC). Not until 1938 would there be one in 100 (BD). Once the melanics attain this level, their rate of increase greatly accelerates.

In the period between 1900 and 1938 (BD) natural selection is complicated by other forces. Though the color of the dark form gives it an advantage over the light, the new trait is introduced into a system of other traits balanced for the light form; thus the dark form is at first at a considerable physiological disadvantage. In fact, when moths of the dark form were crossed with moths of the light form 50 years ago, the resulting broods were significantly deficient in the dark form. When the same cross is made today, the broods contain more of the dark form than one would expect. The system of hereditary traits has become adjusted to the new trait.

There is evidence that other changes take place during the period BD. Specimens of the peppered moth from old collections indicate that the earliest melanics were not so dark as the modern dark form: they retained some of the white spots of the light form. Today a large proportion of the moths around a city such as Manchester are jet black. Evidently when the early melanics inherited one gene for melanism, the gene was not entirely dominant with respect to the gene for light coloration. As the




*consonaria* (D) and *Amphidasis cognataria* (E). All of the species are European except the last, which occurs in North America and may be identical with *Biston betularia*.

gene complex adjusted to the mutation, however, the new gene became almost entirely dominant.

When the dark form comprises about 10 per cent of the population, it may jump to 90 per cent in as little as 15 or 20 years. This is represented by period DE on the graph. Thereafter the proportion of the dark form increases at a greatly reduced rate.

Eventually one of two things must happen: either the light form will slowly be eliminated altogether, or a balance will be struck so that the light form continues to appear as a small but definite proportion of the population. This is due to the fact that the moths which inherit one gene for dark coloration and one for light (heterozygotes) have an advantage over the moths which inherit two genes for dark coloration (homozygotes). And when two heterozygotes mate, a quarter of their offspring will have two genes for light coloration, *i.e.*, they will be light. Only after a very long period of time, therefore, could the light forms (and with them the gene for light coloration) be entirely eliminated. This period of removal, represented by EF on the diagram, might be more than 1,000 years. Indications so far suggest, however, that complete removal is unlikely, and that a balance of the two forms would probably occur. In this balance the light form would represent about 5 per cent of the population.

The mechanisms I have described are without doubt the explanation of industrial melanism: normal mutation followed by natural selection resulting in an insect of different color, physiology and behavior. Industrial melanism involves no new laws of nature; it is governed by the same mechanisms which have brought about the evolution of new species in the past.

There remains, however, one major unsolved problem. Why is it that, in almost all industrial melanics, the gene for melanism is dominant? Many geneticists would agree that dominance is achieved by natural selection, that it is somehow related to a successful mutation in the distant past. With these thoughts in mind I recently turned my attention away from industrial centers and collected moths in one of the few remaining pieces of ancient Caledonian pine forest in Britain: the Black Wood of Rannoch. Located in central Scotland far from industrial centers, the Black Wood is probably very similar to the forests that covered Britain some 4,000 years ago. The huge pines of this forest are only partly covered with lichens. Here I found no fewer than seven species of moths with melanic forms.

I decided to concentrate on the species *Cleora repandata*, the dark form of which is similar to the dark form of the same species that has swept through central England. This dark form, like the industrial melanics, is inherited as a Mendelian dominant. Of just under 500 specimens of *C. repandata* observed, 10 per cent were dark.

*C. repandata* spends the day on pine trunks, where the light form is almost invisible. The dark form is somewhat more easily seen. By noting at dawn the spot where an insect had come to rest, and then revisiting the tree later in the day, we were able to show that on some days more than 50 per cent of the insects had moved. Subsequently we found that because of disturbances such as ants or hot sunshine they had had to fly to another tree trunk, usually about 50 yards away. I saw large numbers of these moths on the wing, and three other observers and I agreed that the dark form was practically invisible at a distance of more than 20 yards, and that the light form could be followed with ease at a distance of up to 100 yards. In fact, we saw birds catch three moths of the light form in flight. It is my belief that when it is on the wing in these woods the dark form has an advantage over the light, and that when it is at rest the reverse is true.

This may be one of many ways in which melanism was useful in the past. It may also explain the balance between the light and dark forms of *Cleora repandata* in the Black Wood of Rannoch. In this case a melanic may have been preserved for one evolutionary reason but then have spread widely for another.

The melanism of moths occurs in many parts of the world that are not industrialized, and in environments that are quite different. It is found in the mountain rain forest of New Zealand's South Island, which is wet and dark. It has been observed in arctic and subarctic regions where in summer moths must fly in daylight. It is known in very high mountains, where dark coloration may permit the absorption of heat and make possible increased activity. In each case recurrent mutation has provided the source of the change, and natural selection, as postulated by Darwin, has decided its destiny.

Melanism is not a recent phenomenon but a very old one. It enables us to appreciate the vast reserves of genetic variability which are contained within each species, and which can be summoned when the occasion arises. Had Darwin observed industrial melanism he would have seen evolution occurring not in thousands of years but in thousands of days—well within his lifetime. He would have witnessed the consummation and confirmation of his life's work.

# ANGIOTENSIN

## The discovery of this substance which can raise the blood pressure has shed new light on the causes of hypertension and on the role of the kidney in the control of circulation

by Irvine H. Page, F. Merlin Bumpus and Hans J. Schwarz

Under the constant variation of physical and emotional stress, the tissues in different parts of the body require constantly varying supplies of blood. The heart and the vascular system meet these demands through the mediation of the nervous system. By controlling the bore of the blood vessels the nerves divert blood from one tissue area and shunt it to another that is in more urgent need. Though the control network is little understood, it must work with high efficiency. It ensures, for example, that the vital brain centers do not lack for blood during the performance of some act requiring the full capacity of the brain.

But this is not the whole story. Few nerves penetrate to the arterioles of the capillary bed. But it is the contraction and relaxation of the muscle cells sparsely distributed along the length of these tiny vessels that causes them to constrict and dilate, and so determine the volume that flows into the capillary channels [see "The Microcirculation of the Blood," by Benjamin W. Zweifach; SCIENTIFIC AMERICAN, January]. Plainly some chemical system must share with the nervous system in controlling the delivery of the blood to the point at which it serves its vital functions.

The nature of the chemical control is a matter of clinical as well as scientific interest. Certain severe types of high blood pressure were long ago traced to chemical influences. For example, the tumor of the adrenal gland called pheochromocytoma is attended by extreme elevation in blood pressure, due to excess output of adrenalin and noradrenalin. These adrenal hormones powerfully constrict the arterioles in the capillary system, at times causing the patient's skin to blanch. Do other "pressor" substances play a similar role in other more common types of hypertension? Efforts to answer this question have not only improved the prospects for control of a widespread affliction, but have also found a new enzyme originating in the kidneys that has a powerful effect on capillary circulation.

From the beginning it seemed logical that the source of such a substance might be found in the kidneys. It is their function to maintain the constancy of the internal environment; they receive and process more than a quarter of the blood pumped out of the heart in each cycle of contraction. This high through-put keeps the tissues in the most distant reaches of the body in intimate if indirect contact with the kidneys. If we exclude the heart, it is difficult to think of an organ more likely to be involved in the control of circulation.

As early as the turn of the century extracts of kidney tissues were shown to raise the blood pressure in laboratory animals. In 1928 Franz Volhard in Germany suggested that an unidentified substance secreted by the human kidney might be the cause of some cases of hypertension. Then a Cleveland physician, Harry Goldblatt, showed that hypertension could be produced by constricting the artery of the kidney with a metal clamp. The implications of Goldblatt's finding were confirmed when physicians discovered clinical counterparts to his metal clamp in patients suffering from hypertension; the kidney arteries in these cases were constricted by arteriosclerotic plaques or other abnormalities.

But only about a fifth of the hypertensive patients showed these abnormalities. Clearly this particular kind of obstruction to the flow of blood to the kidneys did not cause all cases of hypertension. The truth is we do not yet know the precise mechanism which causes the release of the substance from the kidneys which raises blood pressure. We have labeled this mechanism "stress" in the illustration on the opposite page largely for convenience and to indicate our ignorance.

One of us (Page) had the good fortune to work with Volhard, and returned to this country to start work with Donald Van Slyke at the Rockefeller Institute and later with Oscar Helmer, Kenneth Kohlstaedt and A. C. Corcoran at the Indianapolis City Hospital with the object of isolating the pressor substances from extracts of kidney tissue. We had an extract, now called renin (pronounced ree-nin, and not to be confused with rennin, the milk-coagulating enzyme), which upon injection caused a rise in blood pressure in intact experimental animals. And when we injected renin into an amputated tail perfused with salt solution, it caused the blood vessels of the tail to contract. When we set out to purify renin, however, we ran into a most puzzling situation. The purer we made it, the greater the rise in blood pressure it would cause in intact animals but the less constriction it would produce in blood vessels perfused with salt solution. We escaped from this blind alley when we found that the addition of a little blood plasma to the salt solution fully restored the activity of the purified renin.

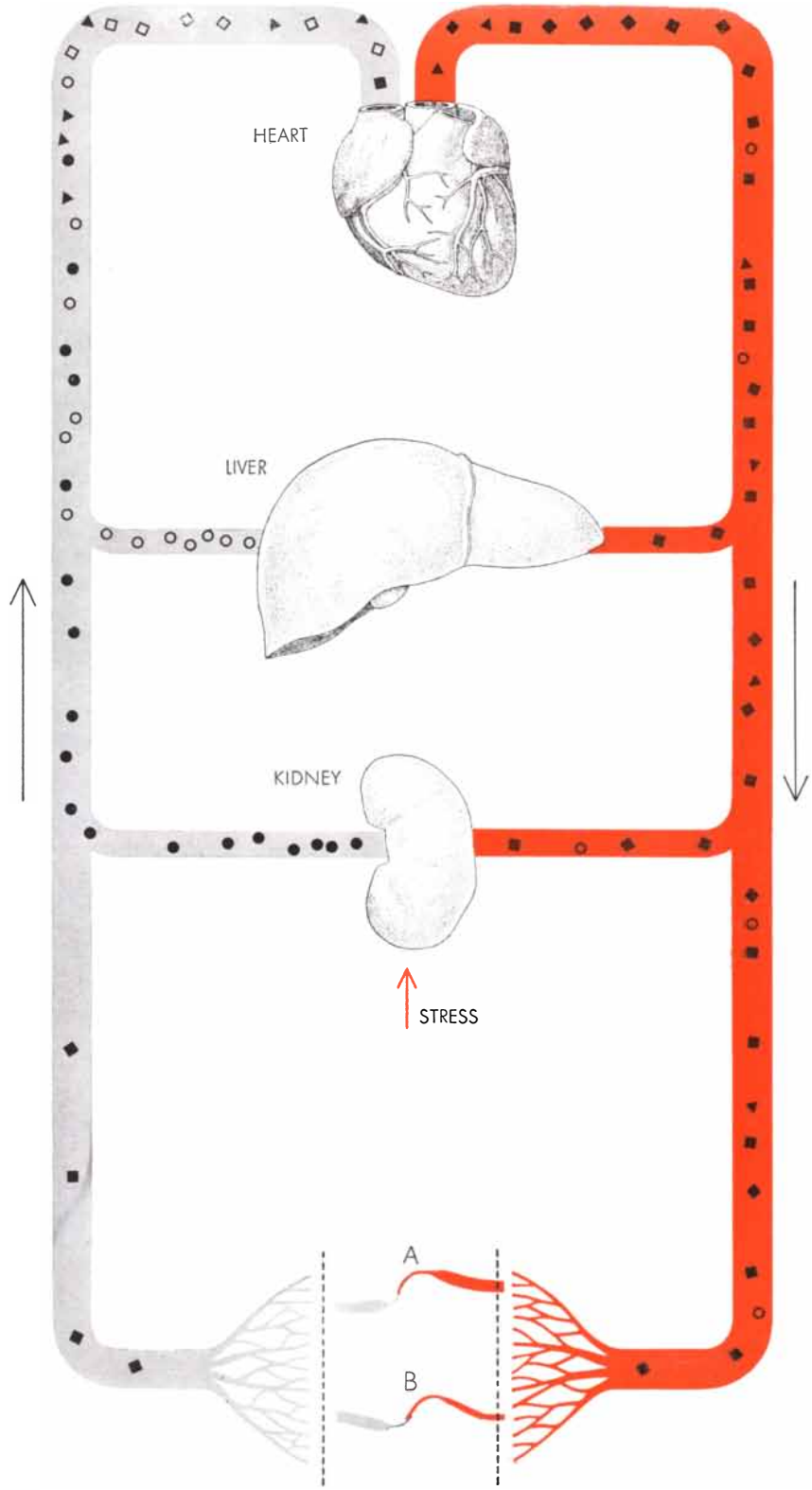
Now we thought we had the solution to the paradox: Renin had to be made active by plasma, most likely by some enzymatic mechanism. To confirm this deduction we incubated plasma and renin together, boiled them to stop the assumed enzymatic action and injected the product into an anesthetized cat. The cat's blood pressure rose sharply but remained elevated for only a few min-

utes. This was quite in contrast to the prolonged effect that followed the injection of renin alone into the bloodstream of a living animal. With a little further thought we made the right deduction: Renin was the enzyme which was destroyed by boiling, and it was renin which released some substance in the plasma. When injected alone into a live animal, renin continued to produce the pressor substance in reaction with a plentiful supply of plasma. Accordingly we sought to identify the substance in the plasma on which renin acted. We located this "renin-substrate" in the protein fraction of blood plasma called alpha-two globulin, and found that it was produced by the liver.

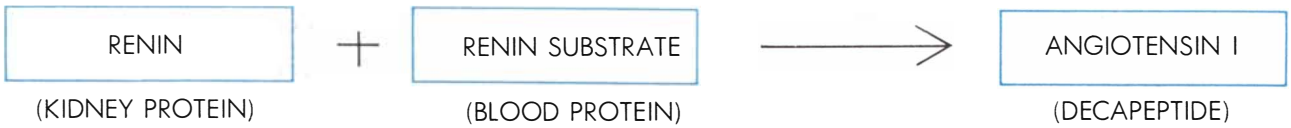
So now we had an enzyme contained in kidney cells that acted on a protein substrate in the bloodstream to liberate a third substance. We named this hypothetical substance "angiotonin." At about the same time a group of investigators working on the problem in Buenos Aires under Eduardo Braun Menéndez had come to the conclusion that the pressor substance was different from renin but that it was liberated by the kidneys. They called the hypothetical substance "hypertensin." The rival names remained in circulation for 17 years until their chief promoters got together over a cafeteria breakfast at the University of Michigan and agreed to sponsor the hybrid name of "angiotensin."

As we studied the chemistry of our third substance it became clear that it was a polypeptide, that is, a chain of amino acids. This was a step forward, but not a happy one. In those days no one knew much about the structure of peptides except that their activity depended upon the spatial arrangement of groups of atoms within the molecules, and that it was difficult to reconstruct the all-important arrangement from the fragments obtained by ordinary chemical analysis. Our group nonetheless pressed on with the slow work of purification and determination of structure, and was joined by other groups.

To isolate pure angiotensin we first sought its precursor, renin-substrate. This we obtained from hog blood. Even though the protein could not be made pure enough to crystallize, we were able to concentrate it approximately 1,000-fold. This indicated to us that renin-substrate constituted only a very small part of the alpha-two globulin fraction of blood, and confirmed our suspicion that angiotensin, originating with renin-substrate, must be effective in minute




**INFLUENCE OF KIDNEY ON CIRCULATION** is summarized in this diagram. Stress on the kidney stimulates the release of renin into the veins (*gray*) where it acts upon renin substrate (made in the liver) to release angiotensin I. "Converting enzyme" changes angiotensin I to angiotensin II. Arteries (*colored*) carry angiotensin II to the capillary beds (*bottom*) where arterioles (normally as in *A* of enlargement) are constricted (*B* of enlargement).




**BASIC REACTION** in the kidney's mechanism for controlling circulation is the action of renin, a protein released from the kidney, on the blood substance renin substrate to form angiotensin I. Renin, an enzyme, splits off part of the blood protein.

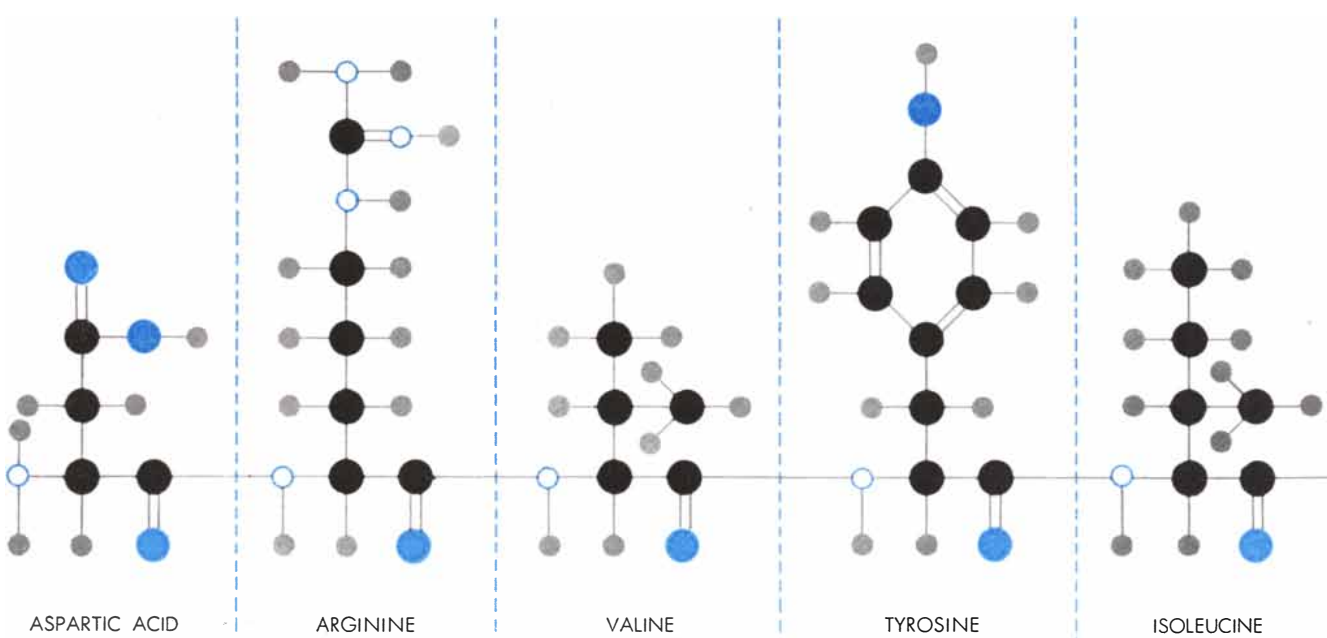
quantities. From the partially purified substrate we prepared an angiotensin that was about 75 per cent pure. The preparation yielded our first clue to the structure of the angiotensin molecule. We identified the amino acids at the ends of the molecular chain as aspartic acid and leucine (or its close chemical relative isoleucine).

Our early preparations produced two observable physiological effects: They elevated blood pressure, and they caused the muscle of the uterus to contract. As the work of purification went on we found that these two activities could be partially separated into two chemically different fractions of crude angiotensin. Both fractions affected blood pressure, but only one caused isolated uterine muscle to contract. Because it seemed to us that a substance that caused contraction in the involuntary "smooth" muscle of the uterus would play only a minor role in hypertension, we focused our efforts on the substance that affected the blood pressure alone.

Meanwhile Leonard T. Skeggs, Jr. and J. R. Kahn of Western Reserve University and the Crile Veterans Hospital, using selective solvents, succeeded in separating two forms of angiotensin. They identified one of these, "angiotensin I," as the direct product of the action of renin on the substrate. The other, "angiotensin II," was formed from angiotensin I by the action of a blood protein which they called "converting enzyme." It soon became clear that the uterine-muscle-contracting substance we had isolated was identical with their angiotensin II, and that this was the "true" angiotensin, the pressor substance we were seeking. Angiotensin I thus proved to be a precursor to angiotensin II. It induces a rise in blood pressure only because it is rapidly converted to angiotensin II in the bloodstream; it has no effect on isolated uterine muscle because the converting enzyme is not present in this organ.

Angiotensin was first isolated in pure form at St. Mary's Hospital in London by W. S. Peart, who worked with the product of the reaction between rabbit renin and beef blood. In 1956 Peart and D. F. Elliot identified the 10 amino acids that make up angiotensin I and worked out the sequence in which they appear in its molecular chain [*see illustration below*]. Skeggs and his co-workers later found a similar 10-unit structure in the angiotensin I of horse blood, and showed that the angiotensin II formed from this precursor was a chain of eight amino acids identical with the first chain except for the two amino acids missing from one end.

The final proof of the sequence of amino acids had to come through synthesis. Starting with the eight naturally occurring amino acids our group set out




**MOLECULE OF ANGIOTENSIN I** is a chain of 10 amino acids made up of atoms of carbon (*black balls*), hydrogen (*gray*), nitrogen (*white*) and oxygen (*colored*). The amino acids are linked by bonds joining the carboxyl (CO) group of one to


**CONVERSION OF ANGIOTENSIN** from the inactive decapeptide (10 amino acids) to the active octapeptide (eight amino acids) is accomplished by the converting enzyme, a normal constituent of blood. It splits off the last two amino acids of angiotensin I.

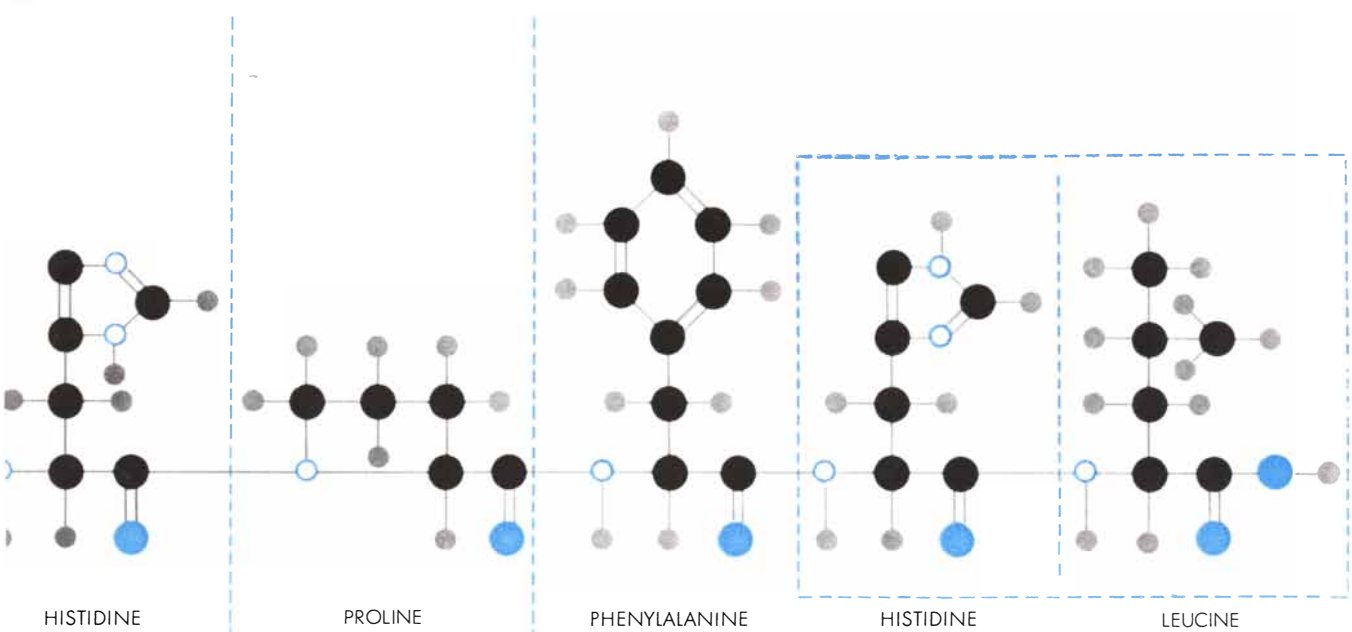
on the arduous task of copying nature. Our synthesis led through 26 steps, and therefore 26 intermediate compounds, each of which had to be laboriously purified and analyzed. Finally the last intermediate yielded a peptide identical in structure with angiotensin II. Synthetic angiotensin fully confirmed its identity by raising the blood pressure of men and animals and by stimulating the contraction of uterine muscle; it has proved more potent in the elevation of blood pressure than any other substance known. The synthesis established the composition and structure of natural angiotensin without ambiguity.

We could now define the kidney mechanism more specifically. Renin, an enzyme produced in the kidney, acts on renin-substrate, a protein that occurs in the blood, to produce angiotensin I, a peptide chain of 10 amino acids with the sequence shown in the illustration. The converting enzyme, another blood protein, then acts on the angiotensin I to split off a pair of amino acids from one end of the chain, yielding angiotensin II. The structure of angiotensin varies somewhat in detail from species to species, but the process appears to be the same in all.

One naturally asks the question: "Why does nature employ such a roundabout mechanism to achieve chemical control of blood pressure?" The answer may simply be that the two-step breakdown of renin-substrate to angiotensin II provides a way to store a reserve of a physiologically powerful substance in an inactive precursor form. In time of need the mechanism can be called upon to release angiotensin for its effects on the blood pressure. Prolonged release, induced by some abnormal physiological stress, could result in permanent hypertension. The digestive enzymes pepsin, trypsin and chymotrypsin are similarly stored as inactive proteins.

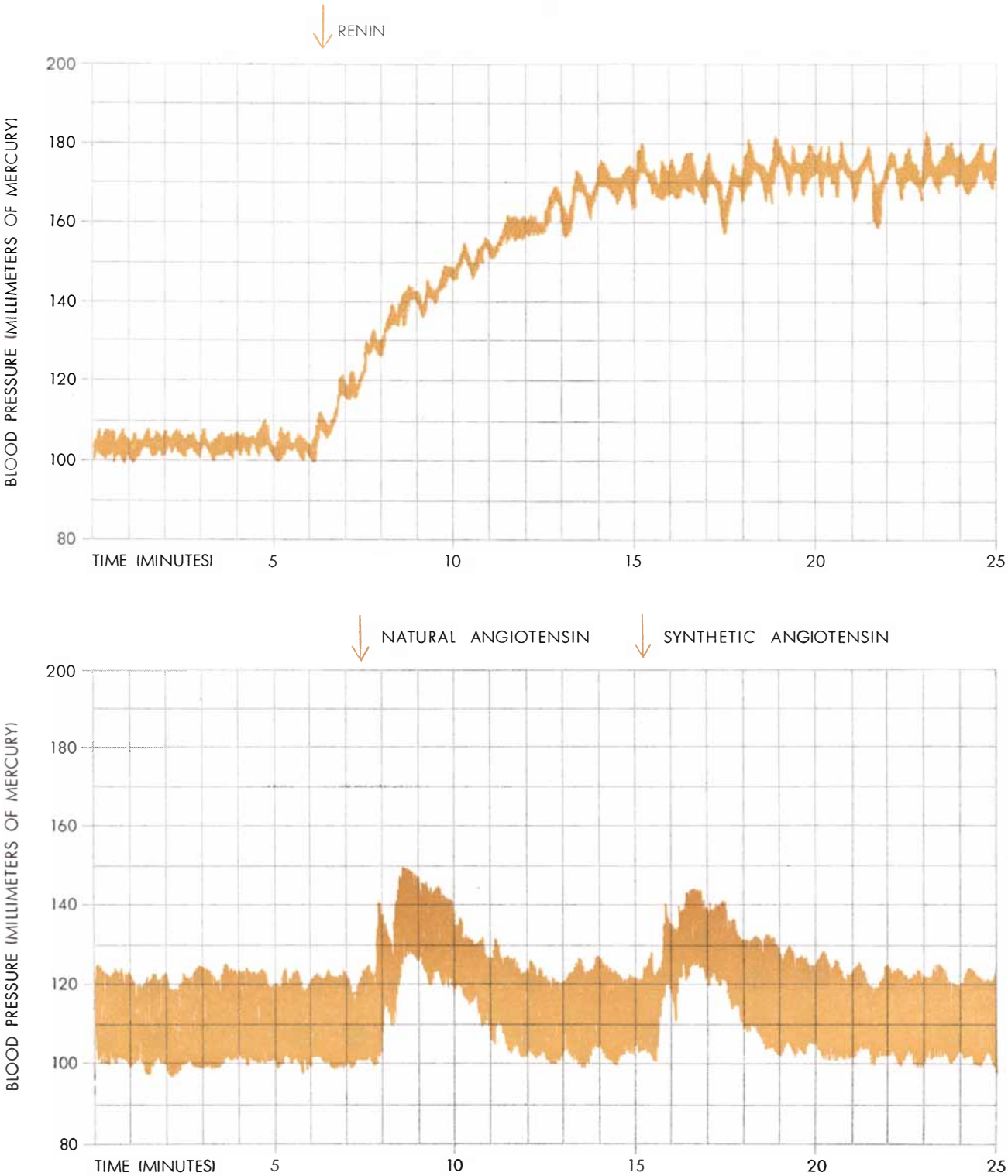
Several other peptides in the body exhibit the physiological properties of angiotensin. The pituitary gland secretes a hormone called vasopressin, which has a strong contractile effect on the capillary vessels, and another called oxytocin, which induces contraction in uterine muscle. Interestingly enough both of these resemble angiotensin II in being made up of eight amino acids. As yet, however, we have found no other structural similarity to explain the similarity of physiological activity.

We do not yet know which of the amino acid groups in angiotensin elicits its characteristic behavior. The activation of the molecule by the amputation of two amino acid groups suggests that these groups may cover or in some other way neutralize the physiologically active sequence. Lesser changes in the chemical structure of various hormones can modify their biological activity profoundly. But it is not easy to locate the




the amino (NH) group of the other. Angiotensin II is derived from angiotensin I by splitting off the last two amino acids (*box*). Structure shown is angiotensin from horse or hog blood; angiotensin from cattle has a second valine in place of isoleucine.

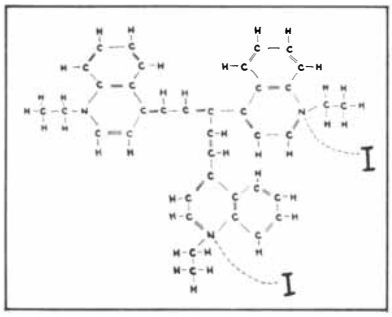
key feature in the structure of even so comparatively simple a molecule as angiotensin. It has only eight amino acid groups; they can, however, form a great number of permutations and combinations. With judicious replacement and rearrangement of some of the amino acids, it may be possible to synthesize peptides that are similar to angiotensin, yet lack its physiological potency. Such a molecule might be able to "fool" the body and occupy those places in the blood vessels where angiotensin normally acts, and thus keep it from stimulating the circulatory system. If we succeed in inhibiting the renin-angiotensin system, we may be well on our way to controlling one of the important humors of the kidney, and so to be able to counteract a widespread type of hypertension at its point of origin.




**BLOOD-PRESSURE RECORDS** of dogs injected with renin (*top*) and angiotensin (*bottom*) were redrawn from the original tracings to put them into the same scale. Arrows indicate time of injection. Renin induces a great increase in arterial pressure, sustained for over half an hour; angiotensin, either natural or synthetic, produces smaller increases lasting only a few minutes.

# Kodak reports on:

**trapping photons and transferring their energy . . . a film that separates the lemons from the oranges . . . the advantage of rising above a subject**



## Old model resonator

Look—with the eye of a quantum mechanic—at this marvelous little molecular resonating machine. For the trifling sum of $16.65 we can supply 400 quintillion of these machines. They will weigh ½ gram, all told, and will come in a small bottle labeled *Neocyanine* (Eastman 2067).

The two iodines come separately packed in the crystal lattice as ions. The points where they were detached, at the quaternary nitrogens, are positively charged, of course. Either of these two positive charges can be sent skittering back and forth through the branched chain of conjugated carbon atoms to bounce off the third nitrogen atom. All it takes to set the machine resonating thus is a photon of light or infrared that carries the difference in energy between quiescence of the positive charges and resonance thereof.

This little resonator has proved useful for trapping photons and transferring their energy to silver halide crystals. The silver halide thereupon responds photographically to wavelengths it would otherwise miss.

This is a 1925 model. We have since devised thousands of more advanced models of this basic type of resonator, but stock only the above and five other simple ones for off-the-shelf delivery: *Cryptocyanine* (Eastman 1334), *Dicyanine A* (Eastman 1532), *Pinacyanole* (Eastman 622), *Pinaflavole* (Eastman 1842), and *Orthochrome T* (Eastman 623). As dyes they are exceedingly powerful.

*For a discussion of the working parts from which such ultra-subminiaturized electronic machines can be built by the skillful worker, see a paper entitled "A Century of Progress in the Synthesis of Dyes for Photography." As long as our supply of reprints lasts, we can send you a copy free. Write to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company). The latest catalog, No. 41, lists some 3700 other compounds for research.*

*The cyanine dyes possess interest not only in applied physics but in biology as well. Many of them have strong and useful antifilarial, anthelmintic, and bacteriostatic activity. That the inhibition of* E. coli *by one of them has been found reversible by crude yeast and liver extract fascinates us.*

## Process E-3

Distinguished by the designation "(Process E-3)" from earlier versions, a new *Kodak Ektachrome Film* is aimed to please the worker who is pretty all-fired sure that for any trifling deficiency in his color transparencies the fault has lain not in himself, not in his technique, not in his equipment, but in his film.

Beyond the shadow of an illusion, this film is *sharper* than its predecessors. *Sharpness* differs from contrast and from resolving power. It represents ability to render a boundary—within how few microns the color on the transparency can change from (let us say) a certain yellow to a certain orange. This ability does not readily lend itself to quantitative statement.

We mention yellow and orange advisedly. A classic challenge to any color photographic process has been to distinguish between the hue of lemons and oranges in one bowl of fruit. The new film meets it handily. Greens are better, too.

More valuable to some users will be the fidelity of the new film to the visual appearance of such photographically elusive biological stains as eosin and fuchsin. The photomicrographer now gets not only an enhancement of the fine color discrimination for which *Ektachrome* was notable even before but a new advantage in speed. Exposure Index is 32 for the *Type B* (which requires only heat-absorbing and possibly U-V filters in the usual photomicrographic setups) and 50 for the *Daylight Type* (used with electronic flash). Statistics show that in 1/25 second you get only 20% of the vibration contained in 1/5 second.

*Kodak dealers now stock the new* Kodak Ektachrome Film (Process E-3) *in the usual sheet film sizes. For 120 and 620 roll film cameras it's called* Kodak Ektachrome Professional Film, Daylight Type (Process E-3). *They also carry various-sized kits of the new processing chemicals that Process E-3 requires. The processing cycle takes about an hour.*

*If a) you want paper prints and duplicate transparencies, and if b) you want to be able to manipulate your color balance toward a conception of reality transcending what can be built into inanimate film, and if c) you are willing to process both a negative and a positive before you judge your results, don't even bother with this new stuff. Stick to* Kodak Ektacolor Film and Paper.

## Geologists as larks

In Washington last spring, at the annual meeting of the American Society of Photogrammetry, the photogeologists were there with bells on, giving papers and happy as larks.

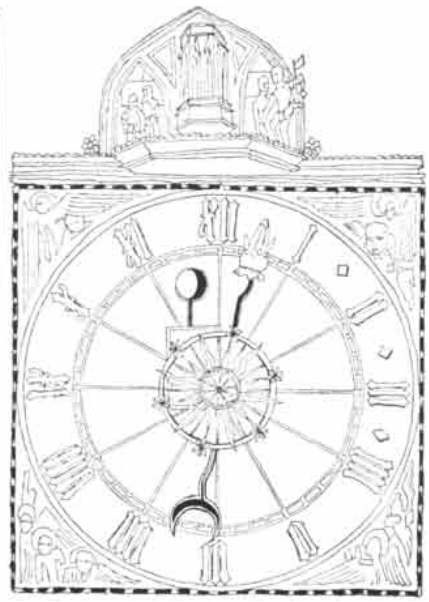
The higher you fly, said one, the quicker and clearer the big picture comes through of structural trends, stream alinements (such as might reflect fracturing in the bedrock, either jointing or shearing), topographic anomalies. The lower you fly, said another, the more subtle color differentiation you can pick up unblurred with the new high speed aerial color films (which we happen to make), and the easier, then, to follow across the miles the contact of various stratigraphic formations with each other and with alluvial and slope-wash deposits. In flatland areas, said a third, where the evidences for geological analysis are difficult or impossible to obtain, modern exploration for petroleum and minerals demands geomorphological study from aerial photographs.

*Do you see the problem? Saddle sores may still mark the field geologist who refuses to jump at conclusions, but his blinders can be struck off by a ride in an airplane mounting a suitable aerial camera in its belly. Does he have to go commercial or government to afford this, or beg for pictures to study? Maybe not. Maybe we can put him in touch with an aerial photographer who wants his modest business. Let him write Eastman Kodak Company, Government Sales Division, Rochester 4, N. Y. And if he wants to read the papers given in Washington, let him send $1.75 to the American Society of Photogrammetry, 1515 Massachusetts Avenue N.W., Washington 5, D. C., for the September, 1958, issue of its journal.*

*Price is subject to change without notice.*

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

Kodak
TRADE MARK



# SCIENCE AND

## *Steadier Support for Science*

The President's Science Advisory Committee has urged the Federal Government to strengthen its support of science and revise its ways of doing business with scientists. In a report made public by the White House, the Committee says that support for basic research has lagged, especially since the Korean war. A disproportionate amount of money has been spent on scientific "things" such as ballistic missiles, nuclear reactors and computers. Meanwhile there have been scant funds for fundamental studies in many fields.

The Committee also criticized the policy of supporting virtually all research through one-year contracts with individual scientists. This kind of contract is neither broad nor long enough to finance effectively the development of ideas that may lead to important discoveries. With termination dates always in the offing, the investigator gets bogged down in the paper work required to obtain new grants. The Committee cited one important earth-science laboratory where 200 scientists are working under 40 separate contracts.

The Government ought to consider new kinds of contracts to support the sort of research that crosses the borderlines of two or more sciences, the Committee proposes. Grants to finance broad programs or even the work of institutions would give scientific workers more freedom to change the direction of their research and would also help reduce the complexities of contract administration. The Committee suggests that contracts should be extended for up to three years so as to permit more sensible planning and greater efficiency.

## *Prospects for Nuclear Power*

Within 10 years nuclear power may be as cheap as power from fossil fuels in some parts of the U. S., and within 20 or 30 years it may be competitive throughout most of the country. This conclusion was reached by a committee recently appointed by the Atomic Energy Commission to review reactor policies and programs. The chairman of the committee is Alfonso Tammaro of the A.E.C.; the vice chairman, Henry D. Smyth of Princeton University, author of the celebrated "Smyth report."

The new report states that the A.E.C. will for the time being have to take responsibility for developing nuclear power, because the technology is not yet ripe to be turned over entirely to private industry. While judging the A.E.C.'s reactor program to be "generally sound," the committee recommends some changes. There should be a comprehensive assistance program to develop nuclear power in the near future for friendly foreign nations where energy is expensive. There should be more emphasis on breeder reactors, which generate power and create fresh fuel at the same time. The A.E.C. should shelve plans for building full-scale 200,000-kilowatt plants and concentrate instead on 50,000- to 80,000-kilowatt prototypes. There is no longer any need to demonstrate that nuclear power can be harnessed on a grand scale, the committee says, and smaller plants will yield just as much engineering information more quickly and more cheaply.

## *Pear-Shaped Planet*

The world is in worse shape than anyone suspected. Instead of being a sphere bulging at the Equator, the earth is decidedly pear-shaped, according to investigators of the National Aeronautics and Space Administration.

Precise measurements of the orbit of the Vanguard satellite launched last March reveal that sea level at the North Pole is 50 feet farther from the center of the earth than previously calculated; sea level at the South Pole is correspondingly lower. Outside the polar

regions the Northern Hemisphere is pinched in by about 25 feet and the Southern Hemisphere bulges by a like amount.

These findings indicate that the hot rock which supports the earth's crust cannot be perfectly plastic. It must have considerable rigidity, for viscous forces would not be great enough to maintain the deformity. J. A. O'Keefe, Ann Eckels and R. K. Squires, authors of the report, speculate that the odd bulges may be caused by convection currents in the rock surrounding the fluid core of the planet. They reported their results at the annual New York meeting of the American Physical Society.

### *Universal Inch and Pound*

The governments of the English-speaking nations have finally decided that the inch and the pound shall be the same the world over. The agreement was reached by directors of standards from Canada, New Zealand, the U. S., the United Kingdom, the Union of South Africa and Australia.

The inch has been redefined as a length equal to precisely 25.4 millimeters. This is about two parts per million shorter than the inch that has been standard in the U. S. and two parts per million longer than the British inch.

While it will be important in some meticulous scientific work, the new standard will not make much difference in industry. In fact the American Standards Association recommended the new inch for industrial measurements as early as 1933, and the National Advisory Committee for Aeronautics began using it in 1952.

The new international pound will be equal to .45359237 kilogram, slightly lighter than the old standard of .4535924277 kilogram. The adjustment of weight is relatively much less than the adjustment in length, but it may be more critical since weighing is generally much more precise than the measurement of length.

### *Submerged Spacemen*

Space travelers may make the first stage of their journey submerged in a tank of water. The buoyancy of water effectively reduces the inertia of the

body and thus protects it against enormous accelerative forces, such as would be produced by a rocket escaping at high speed from the earth.

Experiments conducted by Rodolfo Margaria, a physiologist at the University of Milan, show that mammals completely immersed in water can survive an acceleration of 1,000 g, that is, 1,000 times the acceleration due to gravity. Without the support of water, about 100 g is the upper limit.

Protection by immersion has its natural counterpart, Margaria points out. The brain floats in cerebrospinal fluid, which supports more than 97 per cent of the brain's weight. This is why a person may be able to take a 100-g bump on the head without losing consciousness. Severe brain injury is, in fact, unlikely as long as the skull is not damaged.

Margaria's research was supported in part by the U. S. Air Research and Development Command, and his report was published in *The Journal of Aviation Medicine*. In a companion article four U. S. Air Force investigators tell how they extended Margaria's work to men.

Breathing through a mask resembling those used by skin divers, the subjects were immersed half-reclining, half-sitting in a tank of water attached to the arm of a large centrifuge. Whirling subjected them to accelerations up to 14 g, which were prolonged so that the effect would be equivalent to that of a rocket attaining a velocity of 50,000 miles per hour. Comparison with previous human-centrifuge experiments showed that the subjects immersed in water had at least double the normal human tolerance for acceleration. Moreover, such aftereffects as dizziness and nausea were much less severe. These experiments were made by Captains Stuart Bondurant, William G. Blanchard and Neville P. Clarke and Lieutenant Franklin Moore at the Aero Medical Laboratory of the Wright-Patterson Air Force Base.

## *Color Made Easy*

An astonishingly simple way of producing pictures in full color by mixing light of only two different colors has been devised by Edwin H. Land, president of the Polaroid Corporation. The current issue of *Proceedings of the National Academy of Sciences* includes the first of three articles in which Land explains how his system works and how it may change theories of color vision.

Land makes simultaneous pictures through two filters, say a red one and a green one, and develops them on ordinary black-and-white emulsion. He then


# flight control for all environments

Flight is moving into new regions, requiring new types of flight control systems. ➢➢ Today, General Electric's Light Military Electronics Department builds autopilot and stabilization systems for such high performance aircraft as the Republic F-105 and the McDonnell F4H.

In development for your missile or space vehicle applications are components and systems tolerant of extreme acceleration, shock temperature, and radiation…400°C amplifiers… self-adaptive flight controls…reaction controls…advanced computers…pneumatic, hydraulic, and liquid metal control systems…inertial navigation systems and components.

Before you spend costly design time on your flight control system check with LMED. We can satisfy most of your needs from a wide range of integrated field-proven components—available on an off the shelf basis*.

The components and systems mentioned are only a few of the interesting new developments in LMED's Armament and Control Section. More complete details are available in brochure form—or better still—request one of our Sales Engineers to pay you a visit to explore your problems.

For your copy of a new brochure, "Missile and Space Vehicle Flight Controls", write: Manager-Marketing, General Electric Company, Light Military Electronics Department, Armament and Control Section, Johnson City, N. Y.—Dept. 9D.

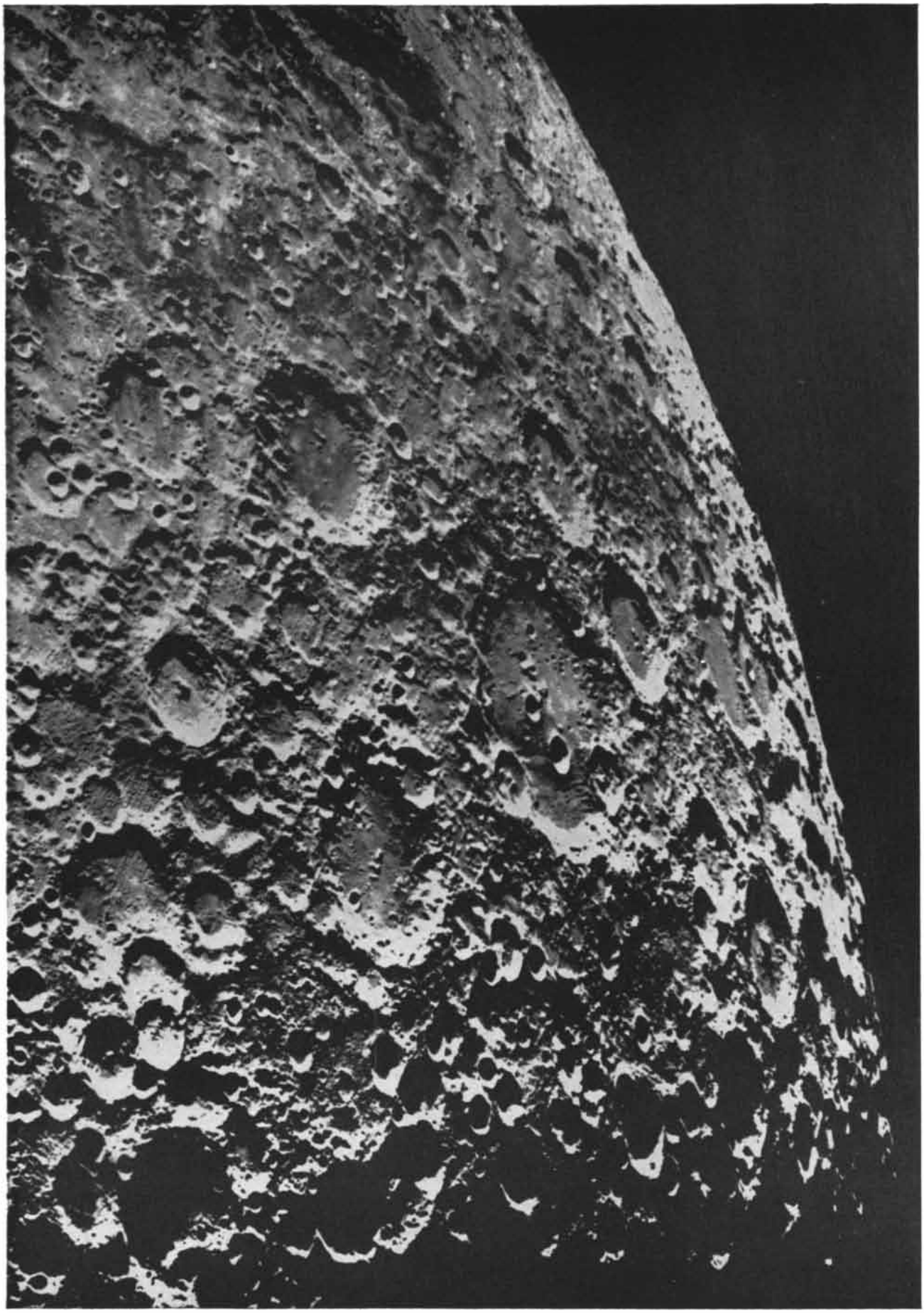

*HOT GAS SERVO SYSTEMS • HI-TEMP AMPLIFIERS • GYROS • STABLE TABLES • GEVIC VARIABLE INCREMENT COMPUTER • ACCELEROMETERS • ADDER - INTEGRATORS • GROUND SUPPORT AND TEST EQUIPMENT

LMED

GENERAL ELECTRIC

LIGHT MILITARY ELECTRONICS DEPARTMENT
FRENCH ROAD, UTICA, NEW YORK

A DEPARTMENT IN THE DEFENSE ELECTRONICS DIVISION



projects the "red" picture through a red filter and the "green" with no filter at all. When the two images are superimposed on a screen, the resulting image has the full range of natural color. Some who have witnessed his demonstrations say that Land's two-color system gives a color image as faithful as the best of today's color-film processes.

Land stresses the point that his system is not limited to two particular colors. Any two filters of sufficiently different color will work. In his opinion, the color message that the eye relays to the brain is determined only by the ratio of the short-wavelength stimulus to the long-wavelength stimulus.

### *PPLO*

An obscure class of microbes, the "pleuropneumonialike organisms" (PPLO), are apparently much more widespread and harmful than investigators had suspected. They seem to be responsible for a variety of diseases in poultry, cattle, sheep, pigs and goats and for arthritic inflammations in man.

Until the past few years little work has been done on these organisms, although they were identified in 1898 at the Pasteur Institute in Paris as the cause of a bovine form of pneumonia and were isolated in 1937 from human beings. There is now a surge of interest in PPLO, and in January more than 300 scientists from 10 nations compared notes on the organisms at a meeting sponsored by the New York Academy of Sciences.

Several reports pointed out that PPLO are closely akin to certain bacteria. They resemble particularly the "L forms" of bacteria, which grow only under special conditions and lack rigid cell walls. Paul F. Smith and George Rothblat of the University of Pennsylvania School of Medicine have discovered an odd serological relationship between a strain of PPLO and two diphtheria-like bacilli. The PPLO react with the antiserums of the bacilli, but the bacilli do not react with the antiserums of the PPLO.

PPLO can invade many parts of the human body, reports Harry E. Morton, also of the University of Pennsylvania School of Medicine. He has isolated the organisms from the genitourinary tract, the alimentary tract, the fluids of arthritic joints, eye tissues and skin lesions. When he injected PPLO into rats, they developed arthritis.

PPLO are commonly found in the vagina, particularly in married women between the ages of 15 and 40. The organisms seldom cause trouble, although

some women have suffered severe inflammations due to them after taking penicillin. Apparently the penicillin suppressed competing microorganisms and permitted the PPLO to proliferate.

### *Musical Feedback*

Experiments at the University of Oxford indicate that vibrato, the slight and rapid quaver of a singer's voice, is part of a feedback control system that helps the singer stay on pitch. Psychologists J. A. Deutsch and J. K. Clarkson have analyzed the system and found it to be remarkably sensitive. They report their work in *Nature*.

The authors observe that singers cannot hold a perfectly steady note; the frequency always fluctuates periodically by five or six cycles per second. If there is so much background noise that a singer cannot hear his own voice, he will sing badly out of tune. These facts suggested that the fluctuation, or vibrato, must be a "hunting" procedure resembling those that occur in automatically controlled machines.

Deutsch and Clarkson tested their ideas by ingeniously regulating the feedback of voice to ear. They had experimental subjects sing into a microphone, recorded the voices on tape and played them back to the singers through earphones. By adjusting the spacing between the recording and playback heads of the tape machine, they were able to make the feedback instantaneous or to delay it by a fraction of a second.

When the feedback was delayed by only .366 second, the vibrato was crude and the control was imprecise. The voices wandered much farther from the true frequency and hunted more slowly. Under ordinary conditions the feedback control system works rapidly and accurately. A singer hitting a 120 cycles-per-second note senses an error of only 1.6 cycles per second and begins to correct it within a 10th of a second.

### *The Migration of Angels*

With the advent of more powerful radar sets employing higher frequencies, radar operators have been bothered by "angels": clouds of dots that from time to time appear on the screen and sometimes become thick enough to obliterate what the operator is trying to see. Just what causes angels has been something of a mystery. Some scientists have suggested that various meteorological conditions may be responsible, but others have observed that this can scarcely be the explanation, for


# Versatility

Want an electronic team to fulfill your precision requirements? A facility geared to short lead time? Dedicated to absolute adherence to your specifications? Consider BJ Electronics' proven record of successful accomplishment in development of such diverse products as: Detectolab nuclear instruments, Northam miniature magnetic tape recorders and Vibrotron FM transducers. Here's experience gained from production of atmospheric sounding rockets (OWL), mobile radar test vans (SAGE) and sensitive transducers and accelerometers (ATLAS). Here's an organization able to adapt to your requirement without loss of time . . . or sacrifice of quality. Consider your need, then . . . consider our problem-solving versatility.

**Facilities brochure on request. BJ Electronics, Borg-Warner Corporation, 3300 Newport Boulevard, Santa Ana, California.**

BJ ELECTRONICS
BW
BORG-WARNER

angels usually move faster than the wind.

After independent studies, three British workers have concluded that angels are simply radar pictures of migrating birds, chiefly small songbirds. In *Proceedings of the Royal Society* they present their evidence:

Angel activity is at a peak near the end of March and again late in October. Small birds migrate over Britain at just these seasons.

There are daily peaks in angel activity about 10 p.m. and 10 a.m. Most small migrating birds feed during the day and start flying soon after dark. Others, including crows and starlings, fly early in the day.

Angels are more prevalent on clear days, especially after a stretch of stormy weather. Migrating birds tend to weather storms by staying on the ground, then resume flying on the first good day.

If birds are indeed responsible for angels, there seems to be little that radar operators can do to keep their screens clear. On the other hand, radar can be an invaluable tool for ornithologists, who up to now have had no reliable way to observe nighttime migration.

The authors of the reports were J. G. Tedd of the Royal Air Force Fighter Command, David Lack of the Edward Grey Institute of Field Ornithology at Oxford and W. G. Harper of the British Meteorological Office.

### *Weed Starvation*

Research with a commercial weed-killer has revealed the details of an enzyme system common to many plants. James L. Hilton of the U. S. Department of Agriculture's Agricultural Research Service found that he could counteract the effects of the weed-killer Dalapon by giving a weed a dose of the B-vitamin pantothenic acid. Pantoate, a chemical precursor of pantothenic acid, also helped, although it was less effective than the vitamin itself.

After further experiments Hilton discovered that weeds have an enzyme system that synthesizes pantothenic acid from pantoate and the amino acid beta-alanine. Evidently Dalapon (2,2-dichloropropionic acid) and related compounds attach themselves to the enzyme at the place ordinarily reserved for pantoate. This blocks the synthesis of the vitamin, which is essential to the plant.

As a result of this finding the U.S.D.A. is preparing a new series of weed-killers that have chemical structures similar to that of pantoate. They may be able to obstruct the pantothenic acid enzyme

structure even more effectively than the commercial compounds now available.

Hilton reported his work at the recent Northeastern Weed Control Conference in New York.

### *Soviet Teaching Instruments*

A good many U. S. high school and college students are soon going to learn physics with the help of instruments made in the U.S.S.R. The Ealing Corporation of Cambridge, Mass., has ordered 6,000 pieces of Soviet-made laboratory-demonstration equipment for delivery this spring. Samples of the 25 different kinds of instrument stole the show at an exhibition held in New York in conjunction with the recent meeting of the American Physical Society and the American Association of Physics Teachers.

The price tags on the Soviet instruments were astonishingly low. A hand rotator for demonstrating centrifugal force, for example, will sell for $15, compared to $41 for a similar machine made in the U. S. A projector for an optical bench will cost $75; a comparable U. S. model costs $300. Paul Grindle, president of Ealing, expects to undersell U. S. manufacturers by about two thirds across the board.

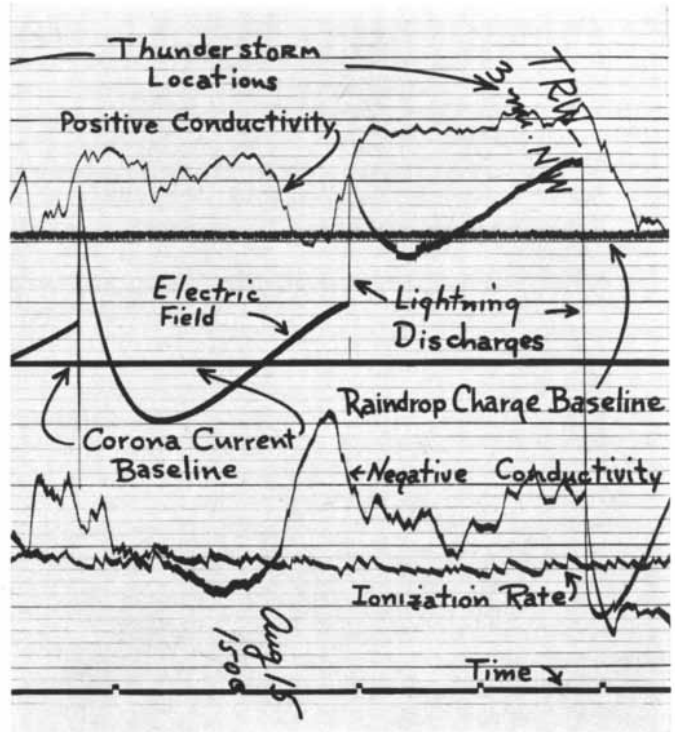
Grindle got the idea of importing Soviet apparatus on a recent trip to the U.S.S.R. He has ordered models identical with those used in Soviet schools. The manual that goes with each instrument will be printed in English as well as Russian, but all the switch and dial markings will be in Russian.

Reaction from U. S. teachers was immediate. Grindle picked up many orders at the exhibition. Sanborn C. Brown of the Massachusetts Institute of Technology, chairman of the Association of Physics Teachers' Committee on Apparatus for Educational Institutions, was, however, dubious about the quality of the Soviet instruments. He called it inferior to the best equipment made in the U. S., though better than much of the equipment in U. S. high schools.

U. S. manufacturers reacted more strongly. Last year equipment for elementary-science teaching was only a $6 million market, but new Federal and State programs in education will shortly expand it to around $150 million. Alfred A. Strelsin, president of Cenco Instruments, criticized Ealing on the grounds that it was cooperating in a "brazen Russian attempt to propagandize American youth by selling American schools made-in-Russia scientific classroom equipment."

**In research . . .**

The analog record at upper right, made by a Model 906A Honeywell Visicorder oscillograph, gave U. S. Weather Bureau scientists immediate readout of thunderstorm data at Mt. Washburn in Yellowstone National Park. As the storm system passed, the Visicorder measured and recorded positive and negative air conductivity, rate of ionization of air, raindrop charge, corona discharge current from an insulated tree and a 4′x 6′ grass plot, times of camera exposure photographing droplet size and electrical charge, atmospheric potential gradient, and time. In any research field where high-speed variables are under study, the direct-recording Visicorder is providing instantly-readable, high-sensitivity data at frequencies from DC to 5000 cps. Models are available with 8, 14, or 36 channel capacities.

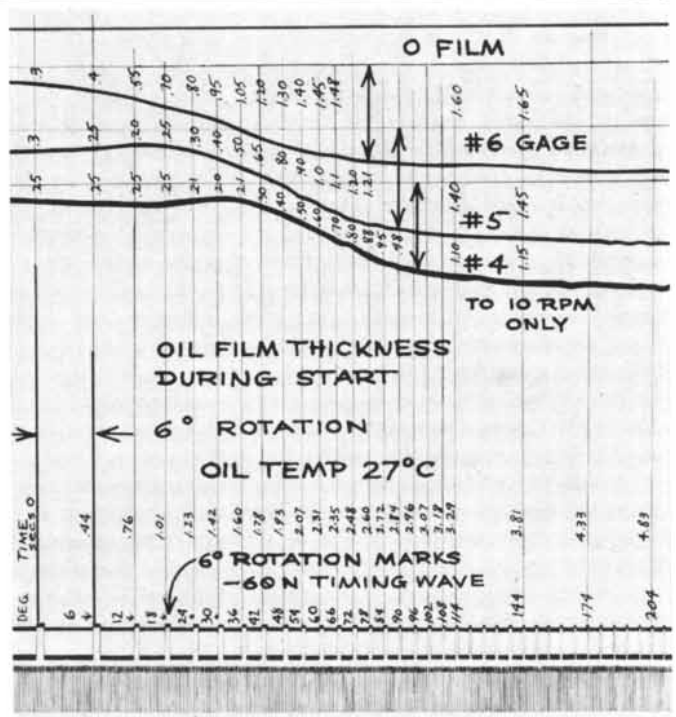



# these are records of leadership

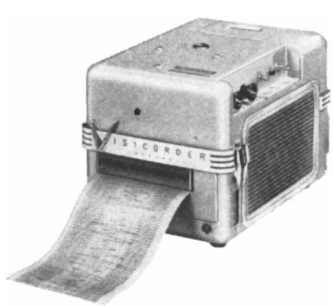
**In industrial use . . .**

The Visicorder record at lower right, made by design engineers at Westinghouse, measured oil film thicknesses on the bearing pads of a 67,500 KW water wheel generator supplied for Chief Joseph Dam at Bridgeport, Wash. In these tests, oil thickness encountered by the leading edge of the bearing (trace #6), center (#5) and trailing edge (#4) were found to be within the limits of safety as predicted by engineering assumptions. In this and hundreds of other scientific and industrial applications, Visicorders are pointing the way to new advances in product design, rocketry, computing, control, nucleonics, and production testing.

*For information on applying the unlimited usefulness of the Visicorder to your specific problems, phone your nearest Honeywell Industrial Sales Office.*




*Unretouched records 2/3 actual size.*




**Honeywell**

Industrial Products Group

**Reference Data:** Write for Visicorder Bulletins 906A and 1012.

*Minneapolis-Honeywell Regulator Co., Industrial Products Group, Heiland Division, 5200 E. Evans Ave., Denver 22, Colorado*

# THE WEAK INTERACTIONS

They are now recognized as reflecting a fourth force of nature. The other three are gravity, electromagnetism and the "strong" force which holds together the particles of the atomic nucleus

by S. B. Treiman

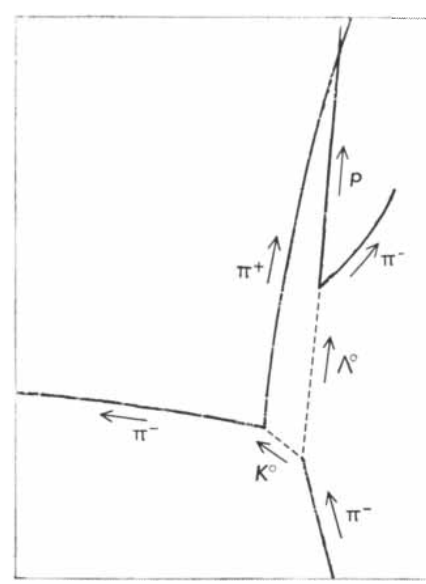
Just as physics was engrossed with the force of gravity throughout the 17th and 18th centuries, and with electromagnetic forces in the 19th century, so it was to be expected that physicists in this century would remain preoccupied with nuclear forces. The immensely powerful forces that bind together the elementary particles in the nucleus of the atom are as yet imperfectly understood. Their nature is expressed not only in the enormous energy released in the fusion and fission of atomic nuclei but in the creation of new and mysterious particles in violent nuclear collisions. Nonetheless the nuclear forces have already begun to share the center of the stage—perhaps only temporarily—with an entirely new class of forces. These are the unimaginably weak forces associated with the spontaneous decay and transformation of most of the new particles that so confound the structure of physical theory. Though our acquaintance with these forces is short, it has already led to some of the most disturbing and hopeful developments in modern physics.

We cannot, of course, observe forces. What we observe are interactions—the interaction of relatively substantial bodies in the case of gravity, the interaction of charged bodies and fields in the case of electromagnetic forces and the interaction of subatomic particles in the case of the nuclear and weak forces. Physicists began seriously to conjure with the weak interactions as such only a dozen years ago, when the list of "elementary" particles had already begun to assume alarming length. At present the list of experimentally discovered or theoretically inferred particles stands at 30 [*see chart on pages 74 and 75*]. None of the late-comers to the list has any part in the constitution of matter in the ordinary sense. All of them are unstable; most of them decay by weak-interaction processes. It was, in fact, the recognition of the weak interactions as the hallmark of one distinct class of particle transformations that gave the first hint of pattern and order in the multiplicity of particles.

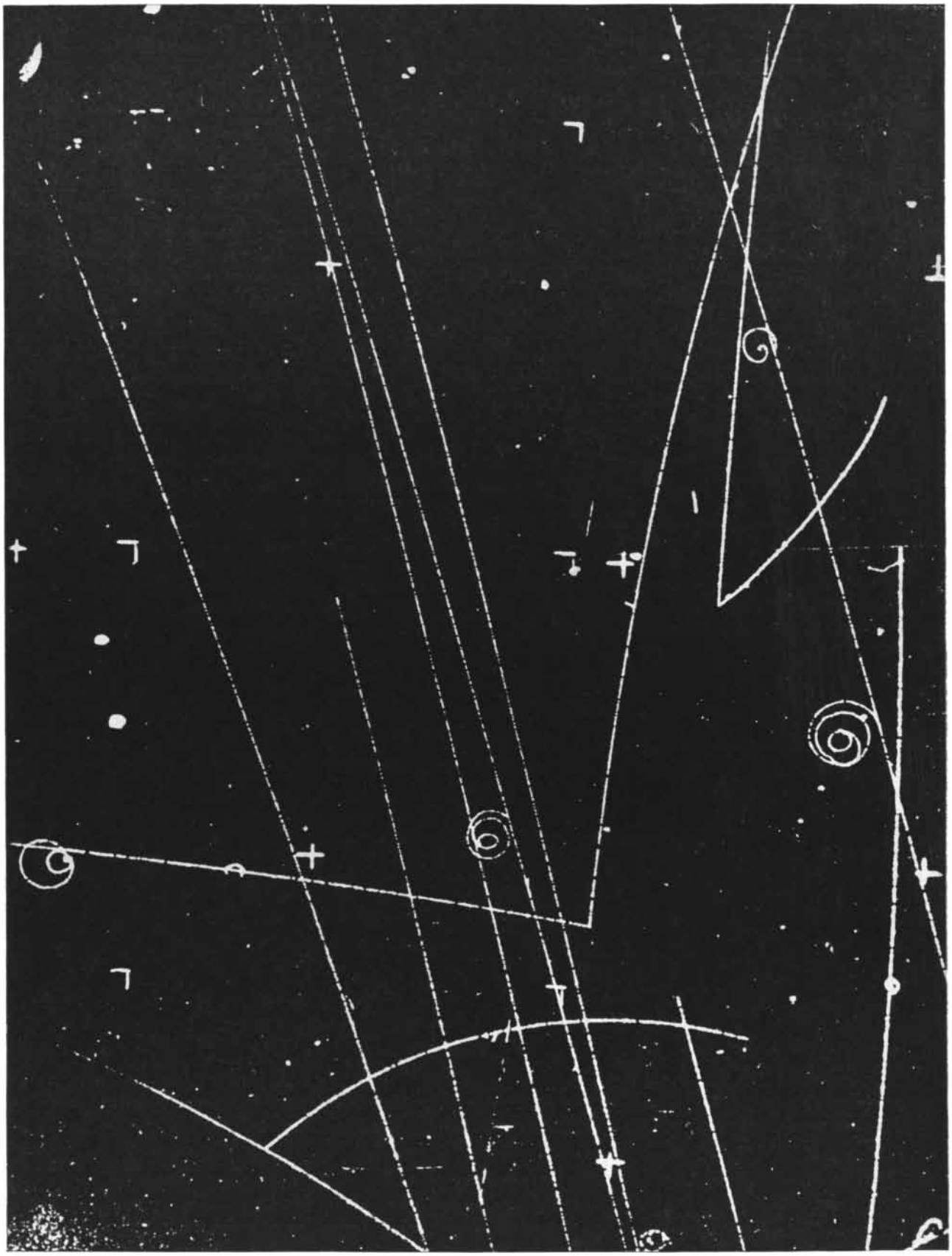
More recently certain anomalies observed in the weak interactions inspired the now famous collaboration of Tsung Dao Lee and Chen Ning Yang and of Chien Shiung Wu and her co-workers at the National Bureau of Standards. Their brilliant theoretical and experimental work showed that the weak interactions violate the parity principle. For the first time one of the sacred conservation laws of physics was found inoperable in nature. We can get an idea of the significance of this finding if we try to imagine physics without the law of conservation of energy, or try to think of order without symmetry. A second and equally sacred symmetry principle was toppled at the same time: the symmetry between matter and antimatter. We may yet find a way to resolve nature's apparent disregard for these central propositions of human understanding. If we succeed, it is clear that we will find that order in nature rests upon symmetries subtler than our theories have hitherto imagined.

## Reaction Rate and Strength

The notion of the weakness or strength of an interaction has, it must be admitted, somewhat medieval overtones. In the broadest sense what the physicist measures is the rate of a reaction: the absolute rate and the rate with respect to other reactions. He measures the rate as a function of the several variables in the process—the energies of the particles, their momenta and so on. One over-all determinant of rate is the amount of energy available in the reaction. But another and more fundamental determinant that turns up in the equations we invent to describe particle transformations is the intrinsic strength of the reaction. To be sure, these equations are exceedingly complicated, and they can be solved only when we make approximations of dubious validity. What is more, the whole point of our awe at the richness of particle physics is that we are sure our theories are incomplete and inadequate. Nonetheless the characterization of interactions in terms of intrinsic strength is meaningful enough and has uncovered




**DECAY of two fundamental particles by a weak-interaction process is illustrated in the bubble-chamber photograph at right, made by Luis W. Alvarez and his colleagues at the**



University of California. The events in the photograph are traced in the drawing at left. A high-energy negative pi meson ($\pi^-$), produced by the Berkeley Bevatron, enters the chamber at lower right. It strikes a proton in the liquid hydrogen of the bubble chamber, giving rise to a neutral K meson ($K^\circ$) and a lambda particle ($\Lambda^\circ$). Being uncharged, these two particles leave no track. The neutral K meson decays into a negative pi meson and a positive pi meson; the lambda particle, into a proton ($p$) and a negative pi meson.

patterns and clues that are leading us to deeper insights.

The rates observed in the strong and weak interactions are so widely different as to segregate these interactions unequivocally into two classes of particle reactions. Consider first the strong interactions which predominate in high-energy collisions. In one well-established "strong" process, the collision of a proton (a stable constituent of the atomic nucleus) and a pi meson (an unstable particle that contributes to the powerful forces within the nucleus) yields a lambda particle and a K meson (new unstable particles whose function in nature is still obscure). The time-scale of this reaction can be estimated in the following way. From a variety of experiments we know that the strong forces fall off sharply in space and reach across interparticle distances of no more than $10^{-13}$ centimeter (.0000000000001 cm.). By observation we know that the particles in the collision are traveling at velocities close to that of light, that is, nearly $3 \times 10^{10}$ centimeters per second (30,000,000,000 cm./sec.). To find the time interval during which the two particles are close enough to experience their mutual forces we divide the range of the forces by the velocity of the particles. The order of magnitude is $10^{-23}$ second, or approximately the time it takes light to travel across the diameter of a particle. For the particles to interact in such a brief instant, the forces between them must be immensely strong.

Now let us consider by contrast the time-scale of a weak interaction. We observe that the lambda particle created in the high-energy collision decays into its daughter particles (a proton and a pi meson) in a mean time of about $3 \times$

**FUNDAMENTAL PARTICLES** that are presently known are listed in the table at right. Negatively charged particles are indicated by a minus; positively charged particles, by a plus; neutral particles, by a zero. The particles in parentheses in the second column are antiparticles. In some cases the antiparticle is indicated by a bar over its symbol; in others, by a sign of charge opposite that of the "particle." The unit of mass in the third column is the mass of the electron. The particles to the right of an arrow in the fourth column are the particles into which the particle to the left of the arrow decays. Where there are alternative modes of decay, they are listed below the arrow. The symbol $<$ indicates "less than"; the symbol $\sim$, "approximately."

| PARTICLE | SYMBOL | MASS | PRINCIPAL MODES OF DECAY | LIFETIME (SECONDS) |
|---|---|---|---|---|
| PHOTON | $\gamma$ | 0 | STABLE | |
| NEUTRINO | $\nu\,(\bar{\nu})$ | 0 | STABLE | |
| ELECTRON | $e^-(e^+)$ | 1 | STABLE | |
| MU MESON | $\mu^-(\mu^+)$ | 206 | $\mu^- \rightarrow e^- + \nu + \bar{\nu}$ | $2.22 \times 10^{-6}$ |
| PI MESONS | $\pi^-(\pi^+)$ | 273 | $\pi^- \rightarrow \mu^- + \bar{\nu}$ | $2.56 \times 10^{-8}$ |
| | $\pi^0$ | 264 | $\pi^0 \rightarrow \gamma + \gamma$ | $< 10^{-15}$ |
| K MESONS | $K^-(K^+)$ | 967 | $K^- \rightarrow \mu^- + \bar{\nu}$<br>$K^- \rightarrow \pi^0 + \pi^-$<br>$K^+ \rightarrow \pi^+ + \pi^- + \pi^+$<br>$K^+ \rightarrow \pi^0 + \pi^+ + \pi^0$<br>$K^+ \rightarrow \pi^0 + e^+ + \nu$ | $1.2 \times 10^{-8}$ |

| | | |
|---|---|---|
| | $K_1^\circ$ | ~973 |
| | $K_2^\circ$ | ~973 |
| PROTON | $p\,(\bar{p})$ | 1836 |
| NEUTRON | $n\,(\bar{n})$ | 1839 |
| LAMBDA PARTICLE | $\Lambda^\circ\,(\bar{\Lambda}^\circ)$ | 2182 |
| SIGMA PARTICLES | $\Sigma^\circ\,(\bar{\Sigma}^\circ)$ | 2326 |
| | $\Sigma^+\,(\bar{\Sigma}^+)$ | 2328 |
| | $\Sigma^-\,(\bar{\Sigma}^-)$ | 2342 |
| XI PARTICLES | $\Xi^-\,(\bar{\Xi}^-)$ | 2585 |
| | $\Xi^\circ\,(\bar{\Xi}^\circ)$ | ? |

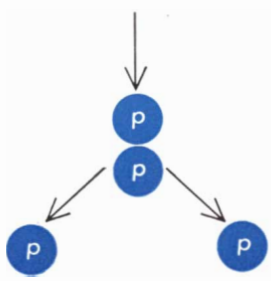
$10^{-10}$ second. On the time-scale of the strong interactions this is incredibly slow. If we magnify $10^{-23}$ second to a full second, $3 \times 10^{-10}$ second becomes one million years! It may still seem that the "long" time interval of $3 \times 10^{-10}$ second is in fact rather short and perhaps difficult to measure. But this is not so. Suppose the lambda particle is traveling with a speed one-third that of light, actually a rather low value in typical experiments. In its brief span of life it will travel three centimeters, quite a macroscopic and measurable distance. The lambda-decay process, typical of the weak interactions, needs all the time in the world.

From such observation we deduce that the weak interactions have only $10^{-14}$ the strength of the strong interactions. This is not an entirely precise statement, because our theories are crude. But the statement is striking enough. Between the strong interaction and the weak there is an enormous gap in strength.

Reference to the familiar electromagnetic interaction shows just how weak the weak interactions are. We think of electromagnetic forces as weak compared to the nuclear forces; they are in fact somewhat less than $10^{-2}$ (to be more exact, .0073) as strong. But the weak interactions are 12 decimal places weaker!

## Beta-Decay

The most instructive and the best known of the weak interactions is beta-decay. This is one of the processes, first observed at the turn of the century, by which naturally occurring radioactive elements give evidence of their instability. In a typical beta-radioactivity process, a neutron (neutral particle) in the nucleus spontaneously breaks down into a proton and an electron. Since the negatively charged electron flies off and the positively charged proton remains bound in the daughter nucleus, the atom is transformed to a species with one more unit of charge. The nature of the process was not clarified, of course, until some years after the radioactivity was first observed.




**LOW-ENERGY COLLISION of two protons leaves the particles unchanged. They carom off each other like billiard balls.**

If beta-decay can happen in some nuclei, why not in all? R. P. Feynman of the California Institute of Technology has given one answer: If matters stood otherwise, we would not be here to ask the question! A somewhat less theological and more fruitful explanation invokes the inviolate law of conservation of energy. For most nuclei beta-decay is prohibited by the law because the mass (a form of energy, in accord with the famous prescription $e=mc^2$) of the nucleus is smaller than the sum of the masses of the electron and the potential daughter nucleus. In a radioactive nucleus the situation is reversed, and the inherent instability of the neutron is allowed to manifest itself. The mass of the neutron itself exceeds the mass of proton and electron by the energy equivalent of 780,000 volts—a very tiny amount as these matters go. As a result the neutron ought to resist beta-decay. It does. Its lifetime is about 18 minutes, by far the longest of any unstable elementary particle on record.

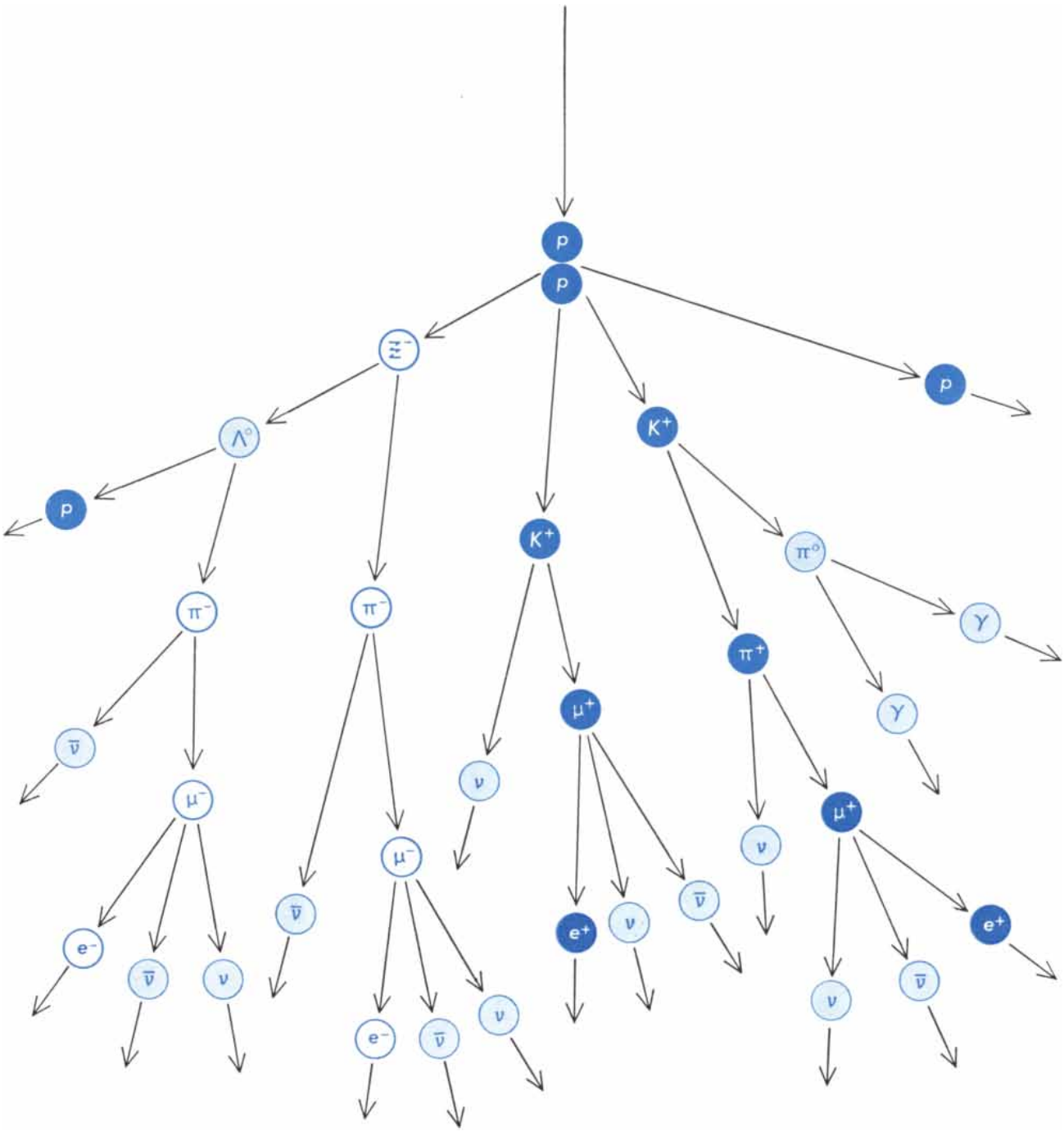
But we are not yet done with energy conservation. The excess 780,000 volts ought to appear in the energy of motion, that is, the kinetic energy, of the decay products. Careful measurement of neutron decay, however, demonstrates beyond any doubt that the proton and electron almost always carry off less kinetic energy (though never more), the amount varying from one event to another. When this situation was faced for the first time, the alternatives seemed grim. Physicists either had to accept a breakdown of the law of energy conservation, or they had to suppose the existence of a new and unseen particle. Such a particle, emitted along with the proton and the electron in the disintegration of the neutron, could save the central pillar of physics by carrying off the missing energy. This was in the early 1930s, when the introduction of a new particle was not the casual matter it is today. Nevertheless, after only the briefest vacillation, physicists chose the second alternative. Enrico Fermi, following ideas outlined originally by Wolfgang Pauli, spelled out the properties of the missing particle, which he named the neutrino.

No wonder the neutrino had been unseen! To balance the electrical charge in neutron beta-decay, it must be a neutral particle. Moreover, from subsequent beta-decay experiments we know that the neutrino has essentially no mass; indeed, there is every theoretical reason to suppose the mass is precisely zero. And the neutrino is essentially unstoppable and unreacting. The probability, for example, that a neutrino passing through the solid earth would be slowed down or do anything other than act as though it were in a vacuum is but one part in one million million. Only in recent years has it become possible to detect the neutrino directly, to catch it in the act of "doing something." The experimental effort required is heroic [see "The Neutrino," by Philip Morrison; SCIENTIFIC AMERICAN, January, 1956].

In many ways the neutrino is the strangest particle of all. It carries off the "missing" energy in beta-decay; it also accounts for the missing linear momentum and angular momentum—quantities which, like energy, satisfy basic conservation laws. Without the neutrino we could not have both beta-decay and the conservation laws. Yet once it is produced the neutrino heads off to the ends of the universe and, so far as we know, does nothing more. Neutrinos from the sun and other stars (and from nuclear reactors) course through matter but are in no active sense part of it.

## The New Particles

The conservation of energy plays the same pivotal role in the strong interactions. Suppose a proton is accelerated in a cyclotron and is then allowed to collide with another proton. What happens? At low energies a simple deflection takes place: the target particle is kicked into motion and the incident particle bounces off in some new direction. Just as when billiard balls collide, the final particles are the same as the initial ones and the energy with which they rebound equals the energy with which they collided. But go to higher energies, say 350 million electron volts. Competing reactions now set in. Sometimes the final products consist of a proton plus a neutron plus a new particle: the positive pi meson. It has been created *de novo* out of the energy made available by the collision. One of the protons has transformed into a neutron and a pi meson, revealing not only a new particle but a new interaction. At even higher collision energies one finds still other reactions taking place, other more massive particles being created in various combinations: K mesons, lambda




**HIGH-ENERGY COLLISION** of two protons produces a shower of particles. One of the original protons darts away unchanged (*upper right*). The other gives rise to a negative xi particle and two positive K mesons. These particles, being unstable, then decay into other particles, some of which in turn decay. At the end only stable particles remain, some 20 of them in the event depicted here.

particles, sigma particles, xi particles.

Much as these new particles may complicate the picture of matter, their production in the strong interactions serves to balance the energy account. The same is true of the other particles produced in collisions of these particles and in the processes, mostly weak interactions, by which they decay. The complexity of possible reactions and the profusion of particles are indicated by the diagram above, which depicts a typical sequence of reactions initiated by a very high-energy collision of two protons.

The proton-proton reaction suggests another ground for distinction between the strong and weak interactions, related to their respective intrinsic strengths. Usually one of the protons utilizes the collision energy to change into a neutron and a positive pi meson, via a strong interaction. But quite another weak reaction ought sometimes to take place. The proton should also be able to avail itself of collision energy to go through a beta transformation into a neutron plus a positron plus a neutrino. This reaction is permitted by the conservation of energy (also by the conservation of linear and angular momentum and by the conservation of charge, the positive charge of the proton being carried off by the positron, the anti-

particle of the electron). No doubt this reaction sometimes occurs when protons collide. But its intrinsic strength is so incredibly small that the process is never in fact observed. It happens, presumably, only once in $10^{14}$ collisions or so. This is a general situation. Whenever circumstances are such that both strong and weak interactions are possible, the strong overwhelmingly predominate. The weak processes reveal themselves only where the energy supply is such that the conservation of energy forbids the strong interactions.

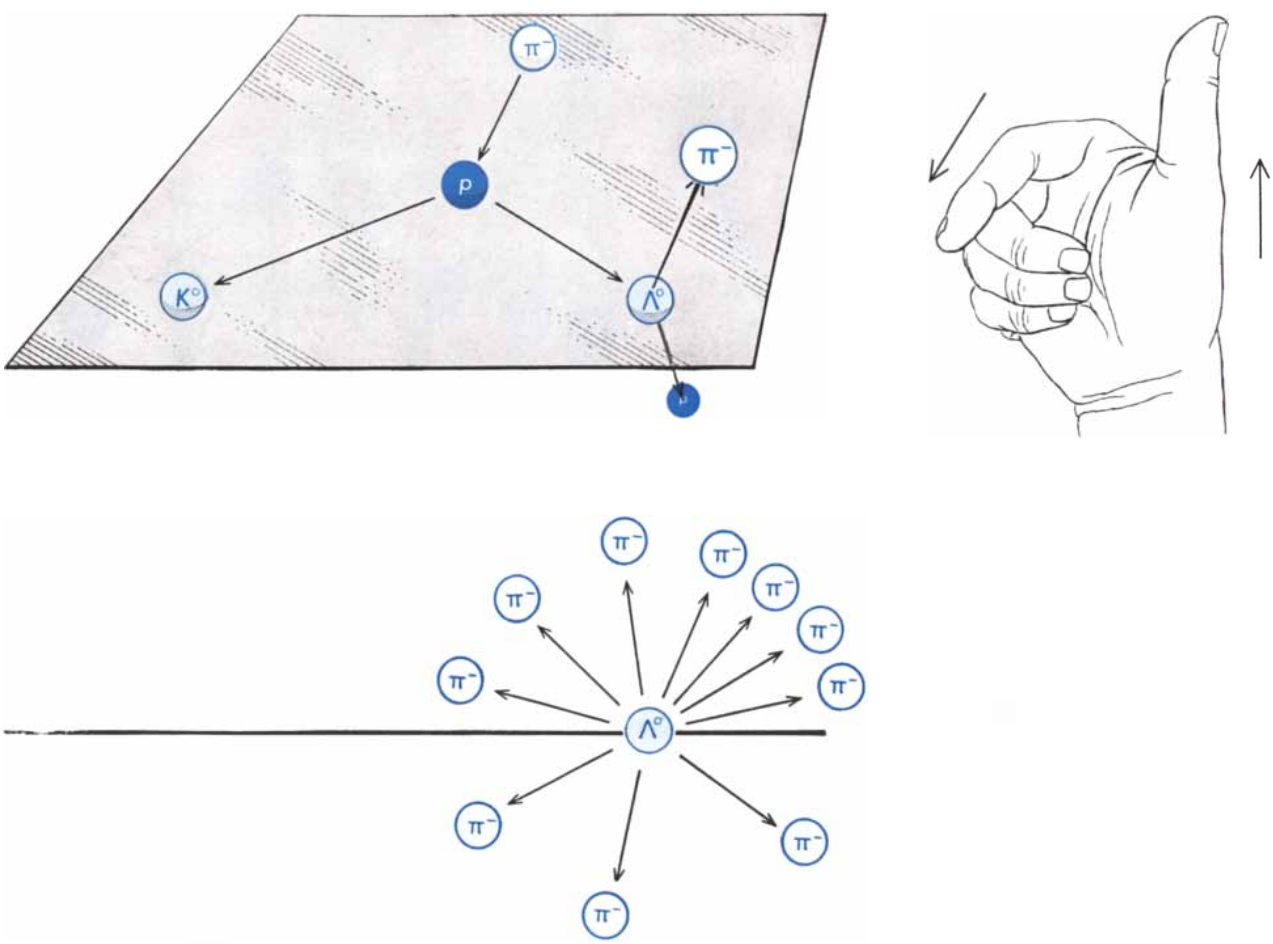
The weak interactions, however, are more common than this restriction might suggest. Consult the table of elementary particles on pages 74 and 75. With the exception of the photon, neutrino, electron and proton (and their antiparticles) every one of them is unstable. Only two of the unstable particles decay rapidly via strong processes which happen to be allowed by energy conservation. The remaining particles decay by way of weak interactions. The weak-decay lifetimes vary over a wide range, as one sees in the table. But most, and perhaps all, of this variation has to do with the differences in energy release. When analyzed in terms of intrinsic interaction strengths, the variations all but disappear. They are always of the same order: $10^{-14}$ the strength of the strong interactions.

Nobody doubts that this pattern reflects some deep unity underlying the whole set of weak interactions, but as yet we have no clear idea what this unity might be. One thing at any rate is clear. Weakness and strength, as in human affairs, are not intrinsic properties of the individual particles, but only of reactions among particles. There is but one exception: the neutrino enters only into weak processes; it is all weak.

## The Overthrow of Parity

What is the use of the weak interactions anyhow? Until recently they attracted little attention; they served to clear away the debris of high-energy collisions, the province of the strong interactions, removing the unstable products through leisurely decay processes—vital work perhaps, but a bit dull. Physicists nevertheless had to face the fact of these processes. When they began to look more closely, they found a paradox. The law of conservation of parity was being violated.

The puzzle had to do with the K meson. Sometimes it decays into two pi mesons, and sometimes into three. But this should be impossible; with all the conservation laws in force, the K meson would be permitted to decay in one manner or the other, but not both. Perhaps, it was at first thought, there are two kinds of K meson, each accounting for one of the two decay modes. It was easier to accept the existence of a new particle than to face the violation of a conservation law. But no evidence of any other differences between the two particles could be found; they really looked like one and the same. The situation grew untenable. Then, in 1956, Tsung Dao Lee of Columbia University and Chen Ning Yang of the Institute for Advanced Study drew the correct infer-




**RIGHT-HANDED CONVENTION** is applied to the production and decay of the lambda particle ($\Lambda^\circ$). In the drawing at top a negative pi meson ($\pi^-$) strikes a proton ($p$), giving rise to the lambda particle and a neutral K meson ($K^\circ$). The lambda particle then decays into a proton and a negative pi meson. In the right-handed convention the negative pi meson tends to go off "above" the plane formed by path of the lambda particle and that of the neutral K meson. This preference is suggested by drawing at bottom.

*99.999+% Pure*

# INDIUM

*available in ingot, stick, foil, sheet, and wire*

## Indium is a silvery white metal, non-tarnishable, very soft, malleable, ductile and crystalline. It is diamagnetic.

ASARCO

### PHYSICAL CONSTANTS

| | |
|---|---|
| Atomic number | 49 |
| Atomic weight | 114.76 |
| Boiling point | 2000°C (3632°F) |
| Crystal structure | Face-centered tetragonal |
| Density at 20°C (68°F) | |
| g/cc | 7.31 |
| lbs/cu. in. | 0.264 |
| troy ozs./cu. in. | 3.85 |
| Electrical resistivity (microhm-cm) | |
| (solid) 20°C (68°F) | 9 |
| (at melting point) 156°C (313°F) | 29 |
| Electrochemical equivalent | |
| In +++ (mg/coulomb) | 0.39641 |
| Electrode reduction potential | |
| In +++ ($H_2$ = 0.0 volt) | 0.34 |
| Latent heat of fusion (cal/g) | 6.8 |
| Latent heat of vaporization (cal/g) | 468 |
| Linear coefficient of thermal expansion/1°C | 33 x $10^{-6}$ |
| Mechanical properties: | |
| Tensile strength, psi | 380 |
| Elongation (% in 1") | 22 |
| Brinell hardness | 0.9 |
| Modulus of elasticity, psi | 1,570,000 |
| Melting point | 156.17 ± .05°C (313.1 ± .1°F) |
| Nuclear Data | |
| Stable Isotopes (113,115) | 2 |
| Thermal neutron cross section (2200 m/s) | |
| Absorption (barns) | 190 ± 10 |
| Scattering (barns) | 2.2 ± 0.5 |
| Solidification shrinkage | 2.5% |
| Specific heat (cal/g/°C) | |
| (solid) 20°C | 0.057 |
| Specific volume (cc/g) | |
| 20°C (68°F) | 0.136 |
| Thermal conductivity (cal/sq. cm/cm/°C/sec) | |
| 20°C | 0.057 |
| Valence | Usually 3, but also 2 and 1 |
| Vapor press. (mm Hg) | |
| 1249°C (2280°F) | 1 |
| 1466°C (2671°F) | 10 |
| 1756°C (3193°F) | 100 |
| 1863°C (3385°F) | 200 |
| 1982°C (3600°F) | 400 |

*For further information on ASARCO High Purity Elements, write on your company letterhead.*

WRITE: AMERICAN SMELTING AND REFINING COMPANY, 120 BROADWAY, NEW YORK 5, N. Y.

ence. They reminded their colleagues that the parity principle, tested and found trustworthy throughout the whole of the better-explored realm of strong interactions, had never in fact been tested for the weak interactions. Maybe the rule broke down in this otherworldly class. They proposed concrete tests that could decide the issue.

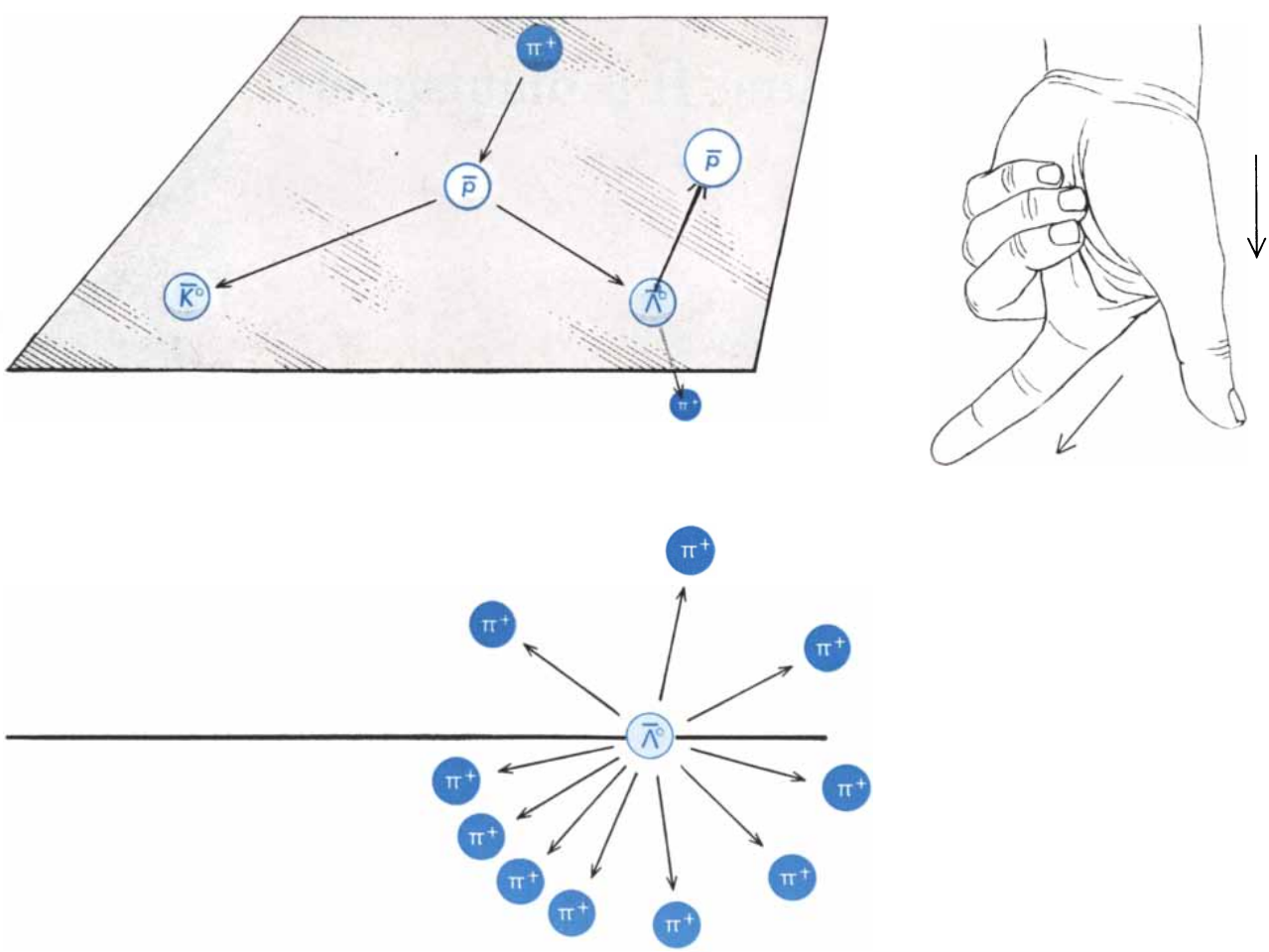
The story is by now a familiar one. Chien Shiung Wu of Columbia University and a group of collaborators at the National Bureau of Standards undertook a set of difficult and beautiful experiments on the beta-decay of polarized nuclei of cobalt 60. In January of 1957 they announced the overthrow of the parity principle.

Shortly thereafter groups at Columbia and the University of Chicago reported the same result from experiments involving the decay of pi and mu mesons; parity is not conserved here either. Later still a group at the University of California studied the decay of the charged K meson into a mu meson and a neutrino; once again parity was overthrown. Other workers proceeded to confirm the downfall of the battered principle in a great variety of nuclear beta-decay transformations and in the beta-decay of the free neutron itself. It was like a bandwagon at a political convention. The weak interactions were now at the center of the stage. In 1957 Miss Wu attended the International Conference on High-Energy Physics, a conclave devoted mainly to the strong interactions; "I am here," she could say, "on the strength of the weak interactions."

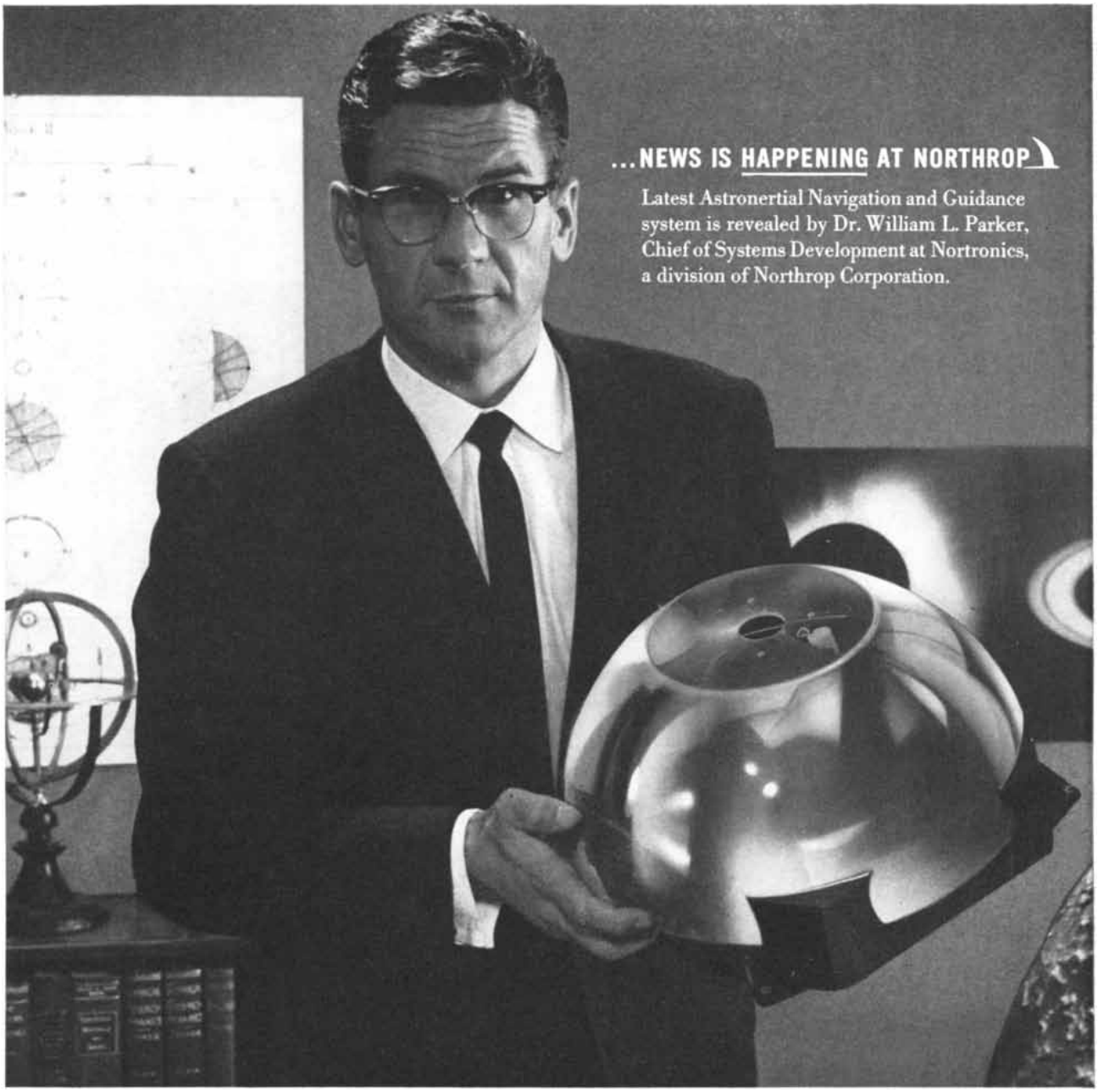
## The Lambda Particle

Some questions still remained. All of the processes for which the parity principle had been directly shown to be invalid have in common a special feature: in each there is at least one neutrino among the decay products. Could it be that parity violation is peculiar only to the neutrino, a particle which has borne other heavy burdens in the past? To be sure, the neutrino is not involved in the paradoxical decay of the K meson which had provoked all of these startling developments, but the evidence for parity violation in this case is indirect. A direct experimental test in at least one non-neutrino process was required before one could feel safe in attributing parity violation to weak interactions generally. The lambda particle offered an opportunity for such a test, and experiments were undertaken by groups working at the Brookhaven National Laboratory and at the University of California. By the summer of 1957 the results became known: here, too, parity is overthrown. The precise details of the manner and degree of parity violation in the various weak processes remain to be established. The breakdown of parity, however, now seems to be a quite general property of weak interactions, a further reflection of the deep unity that underlies them and sets them apart from the strong processes.

The parity principle is simple and classical. It asserts that the laws of nature do not distinguish between right




**LEFT-HANDED CONVENTION** is applied to the production and decay of the anti-lambda particle ($\bar{\Lambda}^\circ$). In the drawing at top a positive pi meson ($\pi^+$) strikes an antiproton ($\bar{p}$), giving rise to the anti-lambda particle and a neutral anti-K meson ($\bar{K}^\circ$). The anti-lambda particle then decays into an antiproton and a positive pi meson. If combined symmetry holds, in the left-handed convention the positive pi meson tends to go off "above" plane formed by the path of the anti-lambda particle and that of the neutral anti-K meson.




# NORTRONICS ASTRONERTIAL SYSTEM—ONLY GUIDANCE CONCEPT READY TO MEET THE CHALLENGE OF INTERPLANETARY NAVIGATION!

**READY NOW** for the day man first explores the planets, Nortronics' concept of Astronertial Guidance is the most accurate known for long-duration flights. Astronertial Systems now in production deliver a wide margin of added accuracy–using Nortronics' exclusive 24-hour star tracker to correct continuously for the small, then ever-compounding errors inherent in "pure" inertial systems.

**OPERATIONAL TODAY** in the USAF-Northrop Snark SM-62 – free world's first and only operational intercontinental guided missile – Nortronics Astronertial systems have furnished accurate guidance for more miles than all similar systems combined.

**CURRENT NORTRONICS SYSTEMS** trim weight to one-tenth, size to one-twentieth that of original systems. They are designed to deliver pinpoint accuracy in applications to all types of space vehicles, cruise and ballistic missiles, terrestrial manned aircraft, surface ships and submarines.

**NORTRONICS EXPERIENCE** in Astronertial Guidance dates back to 1946–to the design and development of the first successful intercontinental system. Now, Nortronics offers unique and proven capability in design, development and production of complete and integrated guidance systems, including their ground support and test equipment.

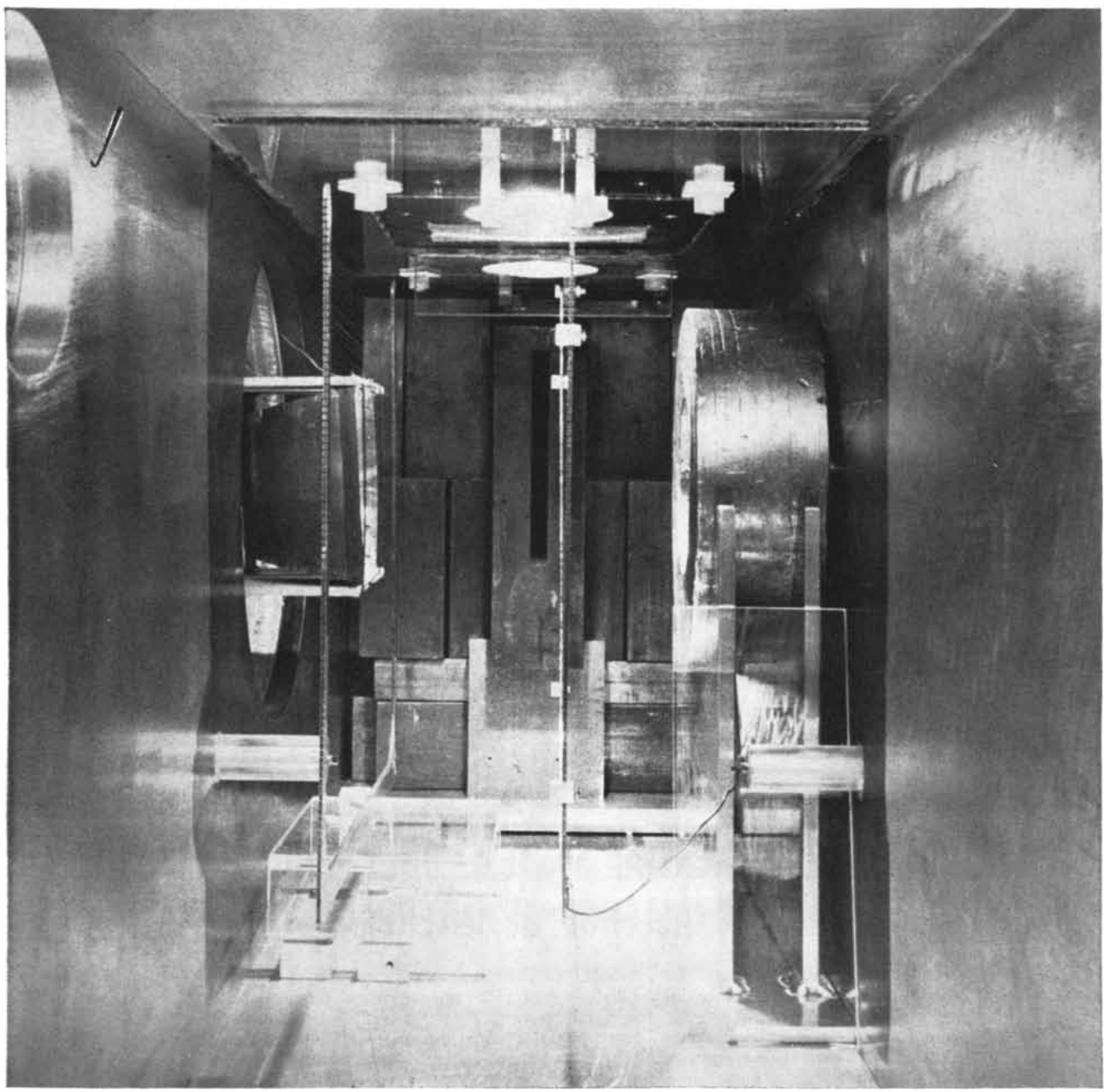
**NORTRONICS**

Hawthorne, California

A Division of Northrop Corporation

and left. You may think of examples that contradict this assertion; our hearts, for example, are nearly always on our left sides. But this is merely a fact of nature, not a law. In the domain of atomic and nuclear physics no intrinsic difference between right and left had ever been found. As sometimes happens in such situations, the powerful and fruitful principle of left-right symmetry had assumed the status of a self-evident truth, though voices were raised from time to time to remind us that few truths in physics are self-evident.

Let us look more closely at the implications of parity in the context of the production and decay of the lambda particle. In the tests that have actually been carried out, protons are bombarded by a beam of high-energy (one-billion-electron-volt) negative pi mesons. Among the competing reactions that take place, the one that concerns us is the process: pi meson plus proton yields lambda particle plus K meson. The lambda particle emerges, and we observe its decay, usually into a negative pi meson and a proton [*see illustration on page 78*]. The line of flight of the original bombarding pi meson and the line of flight of



**EXPERIMENTAL APPARATUS in this photograph was employed at the Argonne National Laboratory to demonstrate that parity was not conserved in the beta-decay of the neutron, another weak interaction process. Neutrons from a nuclear reactor were directed at a magnetized cobalt "mirror" which reflected only those neutrons with their "north" and "south" poles aligned in one way. This sent a beam of polarized neutrons to the vacuum tank shown in the photograph through the vertical slot in the background. As the neutrons passed down the tank a small fraction of them decayed into protons and electrons. The boxlike object at the left side of the tank is a proton counter. Within the cylinder at right is an electron counter. By this means the experimenters were able to show that the electrons tended to go off in a preferred direction, thus violating the conservation of parity. The experimenters were M. T. Burgy, V. E. Krohn, T. B. Novey and G. R. Ringo of the Argonne National Laboratory and V. L. Telegdi of the University of Chicago.**

the emerging lambda particle together define a plane, just as any two intersecting lines have done ever since Euclid. Now let us ask about the pi meson that is produced in the disintegration of the lambda particle. It can come off in any direction. But consider in particular only the two directions which are perpendicular to the plane: the "above" direction and the "below" direction. How do we decide which is above and which below? The words have no meaning until we make an arbitrary convention. Let us adopt such a convention.

Take your right hand and direct its index finger along the line of flight of the incident pi meson, and its middle finger along the line of flight of the lambda particle. Let us then say that your thumb is pointing "above" the plane. This fixes the meaning of "above," and hence of "below." If instead you were to take your left hand and follow exactly the same instructions, "above" and "below" would be interchanged.

Now the parity principle asserts that nature sets up no such arbitrary conventions to distinguish left and right; she does not care which set of definitions you choose. The decay pi mesons should thus emerge with equal probability "above" and "below" the plane. The experiments, however, showed that nature does make such a distinction. It was found that, in the sense of the right-handed convention, the pi mesons come out more often "above" than "below."

### Another Symmetry Overthrown

Very soon after the parity principle was called into question, and even before the first tests were carried out, physicists began to worry about another of their beloved symmetry principles: the symmetry between matter and antimatter. This principle, too, had served faithfully in the strong interactions, but it had never been tested for the weak interactions.

The principle in question here is not a simple, geometrical one like the left-right symmetry we have been discussing. It has its origin in the theory of quantum mechanics, and it is somewhat complex in detail. Nonetheless the principle can be described in a rather straightforward manner. The whole thing started with a beautiful mathematical theory of the electron that P. A. M. Dirac of the University of Cambridge developed 30 years ago. The theory immediately proved to be enormously successful in accounting for the detailed behavior of electrons in atoms. But in another direction it led to a startling result: the pre-

diction of a new particle, the positron. This antiparticle to the electron, with the same mass but opposite charge, was discovered several years later. The same theory also predicted the existence of antiprotons and antineutrons, particles that have been found only in more recent experiments. Dirac's ideas have since been generalized to cover all of particle physics. We now believe that to every particle there corresponds a distinct antiparticle, the only exceptions being the photon and the neutral pi meson, where particle and antiparticle are one and the same. In fact, even the neutrino has an antineutrino; it is the antineutrino which is emitted in neutron beta-decay. The Dirac theory, and its subsequent generalizations, had been constructed in such a way as to treat particles and antiparticles on an equal footing; that is, every reaction involving particles should have a corresponding reaction involving antiparticles, and the two sets of reactions should proceed in the same way in every detail. Understandably this notion of a basic symmetry between matter and antimatter assumed the status of a firm principle of physics. It threatened to become a self-evident truth.

Let us again consider lambda-particle decay and ask what the symmetry between matter and antimatter entails. The diagram on page 78 depicts the production and the subsequent decay of a lambda particle, and shows how these processes violate the parity principle. Now turn to the diagram on page 80. Here we deal with the corresponding antiparticle processes. Suppose that the initial energy of the anti-pi meson as well as the angle of its flight with the line of flight of the lambda antiparticle are the same as for the particle reactions shown in the diagram on page 78. The two diagrams thus differ only in that particles have been replaced by antiparticles. Now in the particle reaction we know that the decay pi mesons come off preferentially in the "above" direction, as defined in the right-handed convention. This preference reflects the breakdown of the parity principle. Be that as it may, the principle of symmetry between matter and antimatter requires that the same preference for "above," defined by the same right-handed convention, should hold in the antiparticle reaction. In other words, particle and antiparticle should both violate parity in the same way. If it were otherwise, there would be an intrinsic distinction between matter and antimatter, which the symmetry principle forbids.

As a matter of fact our hypothetical antiparticle experiment has not yet been carried out, though it no doubt will be in due course. However, the symmetry of matter and antimatter not only relates their reactions to one another; it also has certain internal consequences for either kind of reaction taken alone. The analysis is rather technical. What it comes to in the case of the particle processes is this. If matter-antimatter symmetry holds, then the asymmetry between "above" and "below" cannot exceed a certain calculable amount. In the experiments that have been carried out, this upper limit is exceeded by a wide margin. This means that the decay pi meson in the antiparticle reaction comes off preferentially in the "below" direction, as defined by the right-handed convention. Similar tests have been made for beta-decay, and for pi-, mu- and K-meson decay, with the same result. We conclude that symmetry between matter and antimatter does not obtain in these processes or, presumably, in weak interactions generally.

Two cherished symmetry principles have now been undermined by the weak interactions: left versus right, matter versus antimatter. The question is: Can anything of these symmetries yet be saved? There is one possibility. What happens if we simultaneously interchange right and left, matter and antimatter? Perhaps this combined symmetry survives, even in the world of the weak interactions. The diagram on page 80 shows what this would entail. In the particle reactions it is a fact that the decay pi mesons prefer "above," as defined by a right-handed convention. If the combined symmetry is valid, then in the antiparticle reactions the decay pi mesons should have the same preference for "above," but the "above" direction is now defined by a left-handed convention.

Once again it is not actually necessary to go to the antiparticle experiments to test combined symmetry. The principle has internal consequences for purely "particle" reactions, and these are accessible to test. Highly accurate and difficult beta-decay experiments now under way should soon decide the matter with high reliability. At the moment the outlook for the principle of combined symmetry is favorable.

Suppose the principle holds true. Then it would be no violation of the laws of nature if somewhere in the universe a Tsung Dao anti-Lee and a Chen Ning anti-Yang are presently searching their hearts for the reason why. Their hearts, of course, would be on their right sides.


Imagine an unattended warehouse run by ant-like machines! It *could* be done, thanks in part to some modern magic from Automatic Electric!

Electric fork trucks, equipped with automatic memories, would follow preset instructions. Each truck would pick up and store items – *and* would take inventory. At the end of the day, it would hand in a tabulated work ticket, then park itself for the night!

Making machines mind in this manner is an old story with AE. For automatic control is a *telephone* art – and AE pioneered its principles! *In fact, almost every device or system that is operated automatically uses the type of switching and relay units originated or manufactured by Automatic Electric.*

That explains why people who want to make things happen automatically are coming to AE for the answers.

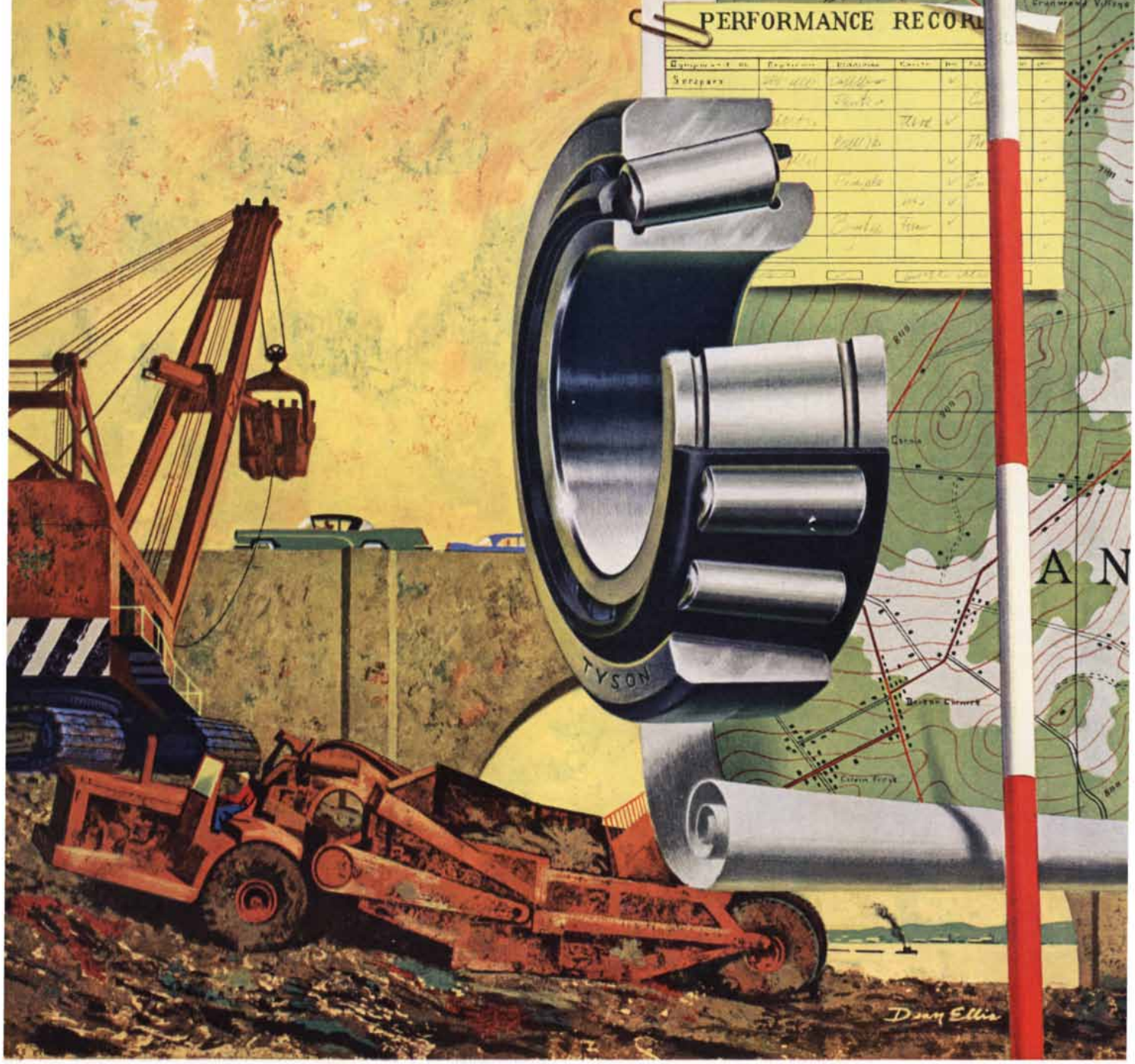
Whether *you* need engineering advice, basic components or a control "package," to get things rolling, just write the Director, Industrial Products Engineering, Automatic Electric, Northlake, Illinois.

We'll roll up our sleeves to prove once again, *AE can do!*

**AUTOMATIC ELECTRIC**

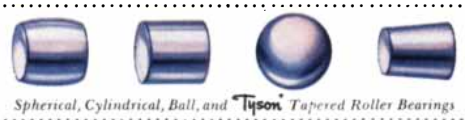
MAKING IDEAS WORK AUTOMATICALLY

Subsidiary of GENERAL TELEPHONE




# THIS PAINTING NOW HANGS IN THE SKF GALLERY

It is a work of Dean Ellis, an artist who is most often retained by manufacturers like SKF to present their products in a striking setting. This particular painting originally appeared as the illustration of an advertisement entitled "Parts Determine Performance" in which SKF stressed how the quality of bearings affects the overall performance of an end product. The advertisement also suggested that SKF, as makers of the most complete line of highest quality ball and roller bearings, is in a prime position to offer both experienced engineering assistance and dependable source of supply to its customers. It is a sales argument that grows in validity each passing day. 7839



Spherical, Cylindrical, Ball, and "Tyson" Tapered Roller Bearings

EVERY TYPE—EVERY USE

SKF®

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

®REG. U.S. PAT. OFF.

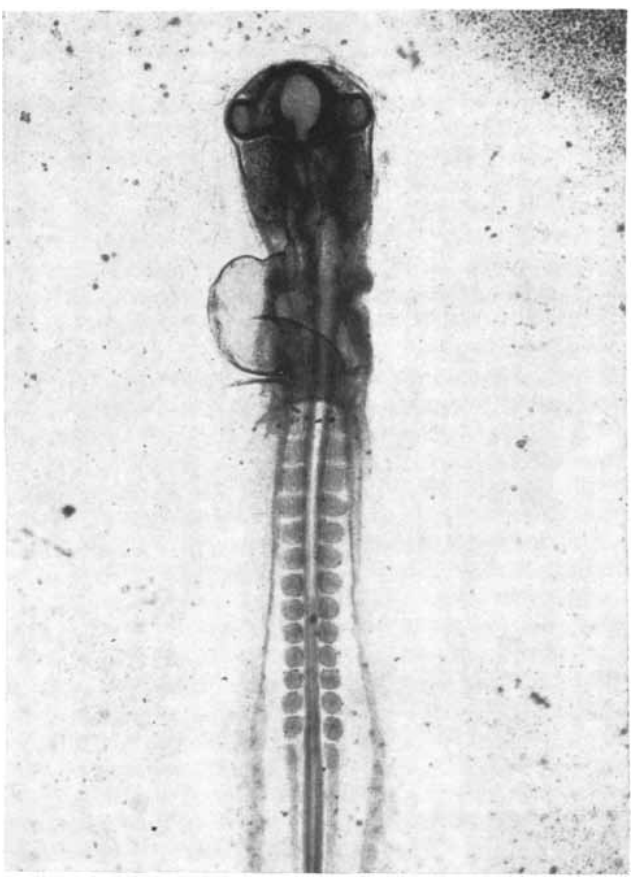
# The First Heartbeats

*The heart of the chick embryo begins to beat on the second day of development. New chemical techniques now make it possible to investigate the formation of the heart at an even earlier stage*

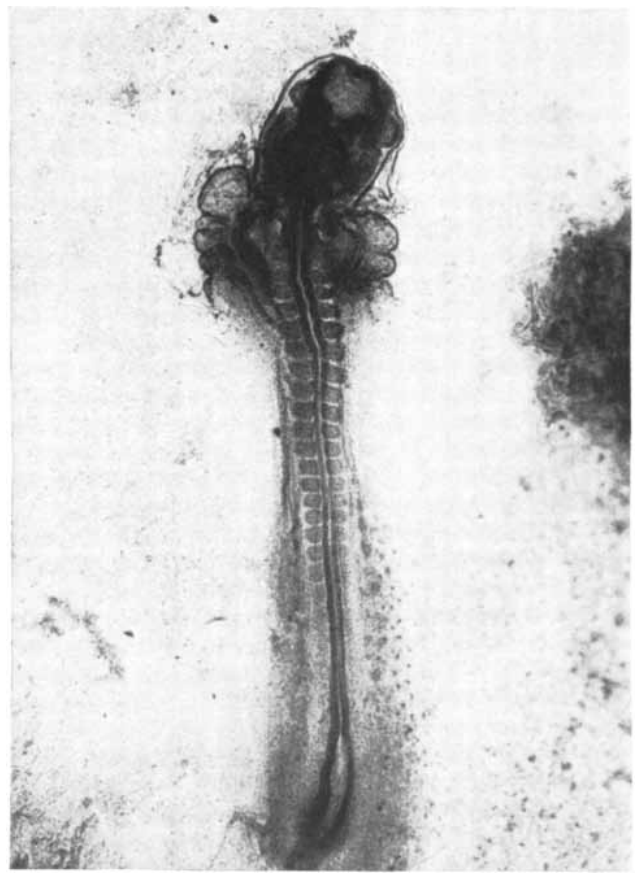
by James D. Ebert

In superstition, legend and sentiment the beating of the heart is synonymous with life itself. The last heartbeat surely marks the end of life. The first heartbeat does not, however, denote the beginning. Although the heart begins to beat when most of the other organs are still unformed and the heart itself is but a simple tube, embryologists have traced the origin of the heart to even more primitive stages of development. In this work the microsurgery of classical embryology is now extended by the powerful techniques of biochemistry. A battery of subtle chemical reactions has disclosed the formation of the first fibrils that go to make up the heart-muscle fibers, and has detected the synthesis of the contractile proteins that compose the fibrils.

In the human embryo the heart and major blood vessels develop almost entirely between the third and eighth weeks of life. By the second month, when the embryo is just over an inch long, the heart has assumed its adult form. The major sequence of events in the formation of the heart is essentially the same in all vertebrate animals. In this article the heart of the chick will

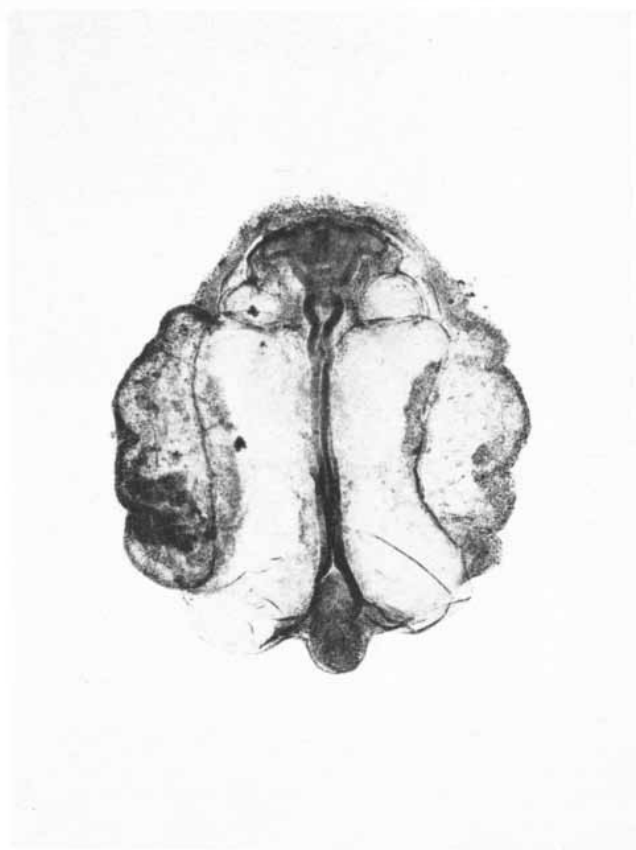


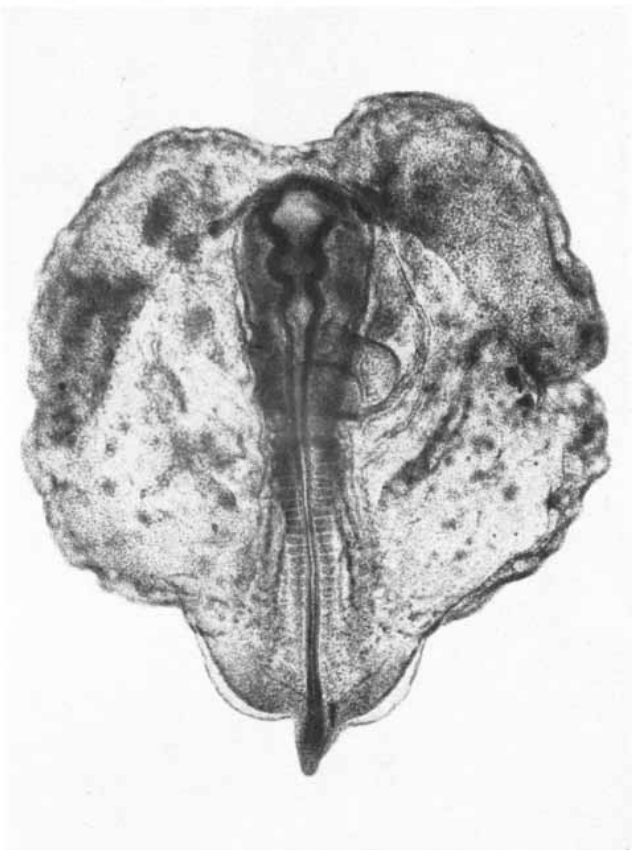
NORMAL HEART IN A CHICK EMBRYO one and a half days old appears as a pouchlike structure protruding toward the left of the mid-line in this photograph of the underside of the embryo.



DOUBLE HEART IN A CHICK EMBRYO resulted from treatment with acetylcholine in experiments of Robert DeHaan. Acetylcholine interferes with merging of paired primitive structures.

SODIUM FLUORIDE added to the medium on which the early embryo at the left was cultivated has destroyed its heart-forming areas, leaving the two eyelike holes. At right is a normal embryo that was cultivated for the same length of time without the inhibitor.





ANTIMYCIN A, a metabolic inhibitor used to treat the embryo at left, prevented the development of the heart and other mesodermal structures, but left the nervous system intact. In the normal embryo shown at the right the heart may be seen just to the right of center.

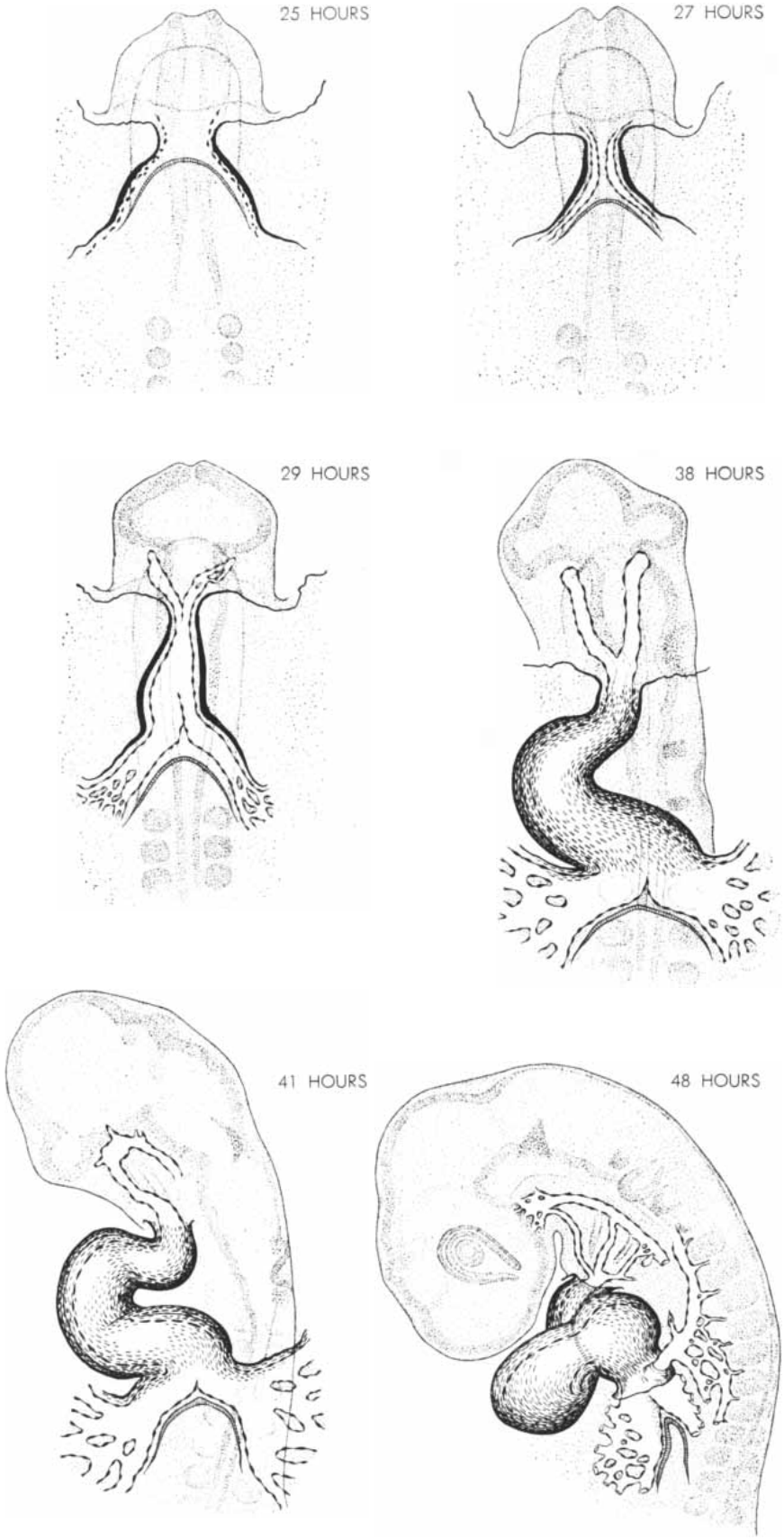
serve to illustrate the process for the entire vertebrate order, from fish to man.

Two sets of primitive structures on opposite sides of the embryo give rise to the simple tube in which the first heartbeats occur. Each set consists of a delicate thin-walled tube and an adjacent ribbon of cells which are destined to become muscle [*see illustration on next page*]. Near the mid-line of the embryo the tubes fuse to form a larger tube sheathed with muscle cells. The fusion progresses from the head toward the tail, first forming the ventricle (which gives rise to the two chambers that pump blood out of the heart) and then the atrium (which gives rise to the chambers that take blood into the heart).

As the tube forms, so it begins to beat. Florence R. Sabin of the Johns Hopkins School of Medicine described the first beats in 1920 in a famous paper on the origin of the heart of the chick embryo; other investigators, using motion pictures and time-lapse photography, have added to the story. The first twitching can be seen early in the second day of development. The slow but rhythmical beat begins along the right side of the ventricle and gradually involves the whole ventricular wall, spreading from the tail end of the embryo toward its head. Soon the entire muscle of the ventricle is contracting synchronously, periods of pulsation alternating with periods of rest. Meanwhile the atrium has been forming below the ventricle. As the atrium takes shape, it too begins to contract, and at a more rapid rate than the ventricle. The ventricle, however, increases its rate of contraction to keep pace. The contractions now set the blood in motion.

The last region to develop is the "pacemaker," which controls the contractions of the fully formed heart. When this region starts contracting, the beat of the whole heart accelerates further. In the embryonic heart the region with the highest rate of contraction sets the pace for the entire organ; if the various regions are cut apart and isolated from one another, each tends to revert to its characteristic rhythm. What synchronizes their contractions at this early stage is a mystery; nerve fibers have not yet grown out from the central nervous system to the heart, nor has the heart's own internal system of communication been established. Perhaps the answer lies in the intrinsic contractile properties of the muscle, or in the activity of chemical regulators.

On the third day of development the ventricle, which is now U-shaped, assumes its ultimate position behind the




**EMBRYONIC CHICK HEART forms from primitive structures that appear about 25 hours after an egg is incubated. Delicate tubes and accompanying ribbons of cells move toward the mid-line and merge into a single tube surrounded by a coat of muscle. First the ventricle forms (*29 hours*). Then, as the fusion moves rearward, the atrium forms behind the ventricle (*41 hours*). Finally the "pacemaker" forms behind atrium. These drawings are adapted from Bradley M. Patten's *Early Embryology of the Chick*, published by the Blakiston Company.**

atrium. The structures that divide the ventricle and atrium each into two chambers appear in the course of the fourth day. By the fifth day the chick heart is substantially complete.

So much is visible to the eye. But what events presage the formation of the primitive tube?

The chick embryo begins to develop while the fertilized egg is moving down the oviduct of the hen. In a newly laid egg the embryo is already large enough to be seen with the naked eye; it is a tiny white disk on the surface of the yolk. At this point it is composed of only two layers of tissue: the epiblast (including both the ectoderm and the future mesoderm) and the endoderm. If it is now cut up so that its fragments may be grown in tissue culture, pulsating tissue will grow from pieces taken from the edges of the embryonic disk but not from those taken from its center. Apparently the heart-forming cells are distributed around the periphery of the embryo at the end of the two-layer phase. As development proceeds, some of the cells of the upper layer migrate toward the midline of the embryo. There an elongated opening—the "primitive streak"—has formed. The migratory cells move through this opening into the interior to form the third embryonic cell layer: the mesoderm. Tissue-culture studies at successive stages in this process indicate that the heart-forming cells are among the migratory mesodermal cells.

Maps of the embryo based on such studies show that the heart-forming cells move first toward the tail end of the embryo and then through the primitive streak into the mesoderm, assembling in regions on either side of the head end of the primitive streak. Under the artificial conditions of tissue culture, or of transplantation to another site in the embryo, it appears that a much larger population of cells is able to form heart than actually takes part in building the organ. There is no striking difference of shape or extent between the right and left heart-forming areas, but the left side has a greater capacity to form heart muscle. This example of bilateral asymmetry in the embryo was discovered in 1943 by Mary E. Rawles of Johns Hopkins University, who mapped the heart-forming capacities of the chick embryo at this early stage [*see illustration at the top of page 92*].

In normal development the two heart-forming regions gradually move toward each other, and the primitive structures that arise in them merge near the midline. But one can prevent the two re-

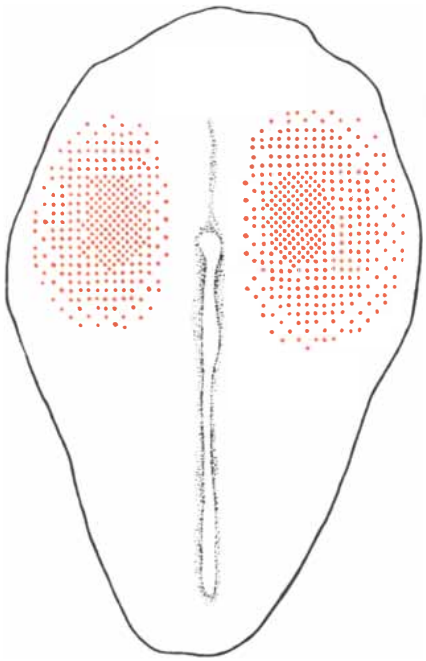
gions from joining by removing the wedge of tissue lying between them, by inserting a barrier or merely by holding them apart. The embryo will then develop two separate hearts. Both hearts usually have normal shape and orientation, but occasionally the right heart develops as the mirror image of the normal left heart.

Alteration of the chemical environment of the embryo can also induce double hearts to form. Recently my associate Robert DeHaan has found that substances such as "Versene" or acetylcholine, which are capable of binding or displacing calcium, exert this effect. Calcium and magnesium salts act as a sort of cement in the tissue structure; for example, calcium ions may interact with charged groups of atoms on the surfaces of adjacent cells and thereby hold the cells together. The calcium-binding agents make calcium ions unavailable at a critical period, disturbing the intercellular relations in the embryo sufficiently to prevent the movement of the heart-forming areas.

Although heart muscle arises from the mesoderm, we cannot say whether the process involves the mesoderm alone or the interaction of the mesoderm with other tissue layers. Many significant embryonic events involve such interaction. Experiments by Robert L. Bacon, then at Yale University, have indicated that interaction of the mesoderm and the endoderm is necessary for the normal development of the salamander heart. The situation in the chick is not altogether clear. The fragments transplanted for tissue-culture experiments usually include cells of all three embryonic layers. If the fragments lack endodermal cells, pulsating masses still develop, but they are not as well organized as those which arise when endoderm is included.

At what point do the cells that are to form the heart assume their chemical identity as heart cells? When do they begin to synthesize the special constituents of heart muscle? One of the first clues came from experiments I conducted at Johns Hopkins University nearly 10 years ago. At that time advances in the field of immunology led Ruth Cooper of Princeton, A. M. Schechtman of the University of California at Los Angeles and other embryologists to utilize antigen-antibody reactions in the study of embryos. The antigen in this case is furnished by that organ in the adult animal which the investigator wishes to trace in the embryo.

An extract of the characteristic proteins of an organ in the chicken, for ex-



**HEART-FORMING AREAS in the chick embryo were mapped by Mary E. Rawles of Johns Hopkins University. Density of dots indicates degree of heart-forming capacity.**

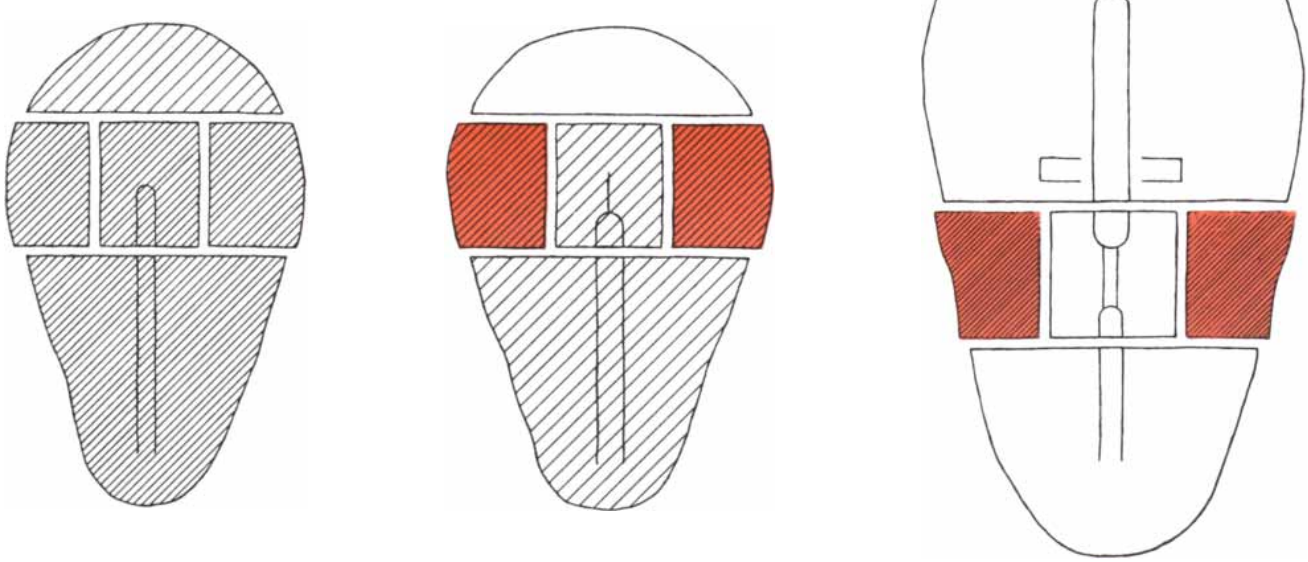
ample, will induce the formation of antibodies when injected into a rabbit. The antibodies that appear in the rabbit blood serum will react in turn with chicken tissues. Since each organ of the chicken contains a mixture of proteins, some of which are found in other tissues of the animal, the rabbit serum will contain a mixture of antibodies. However, by "absorbing" the serum with the various chicken tissues, one can remove all the antibodies except those for the proteins peculiar to the organ under investigation.

By this procedure I prepared a serum that would react only with chicken heart. The "anti-heart" serum gave rise to a clear-cut reaction when it was mixed with an extract of the chick embryo at the primitive-streak stage—several hours before the appearance of the primitive structures of the heart. The reaction showed that the early embryo contains substances identical with or closely related to those of the adult heart. This conclusion was soon supported by the finding that early embryos do not develop a heart when grown on a medium containing anti-heart serum, although the serum does not affect the emergence of other organs. Here was promising evidence that immunological reactions might be used to detect the first appearance of the proteins specific to the formation of heart muscle in the embryo.

We know that three proteins—actin, myosin and tropomyosin—make up about 75 per cent of the total protein of muscle. Myosin extracted from the adult chicken heart contains three molecular components, each of which can elicit antibodies when injected into rabbits. By absorbing the anti-heart-myosin serum with myosin extracted from the leg muscle of chickens we succeeded in preparing antibodies specific for heart myosin, and had thus developed a chemical tool that could distinguish it from the myosin of other types of muscle. We found that this serum did not react with extracts of embryonic tissue before the appearance of the primitive streak. Heart myosin first shows up shortly after prospective mesodermal cells have begun their migration from the periphery of the embryonic disk toward the primitive streak. At the termination of movements through the streak, heart myosin is distributed widely, probably in the mesoderm. (It has not been detected in the endoderm, but its absence from the ectoderm has not been established.)

This distribution surprised us, because embryologists had long believed that a group of cells had to be established at a certain location in the embryo before it could give rise to specialized tissues. Two to three hours after the mesoderm is completed, however, heart myosin is restricted to the heart-forming regions. We found that heart actin, the other component of the contractile fibril, becomes detectable just when the heart-forming regions become demonstrable.

The localization of heart myosin may result from the movement of cells; that is, the cells capable of synthesizing this myosin sort themselves out from among the other mesodermal cells and come together in the heart-forming regions. But another view suggests that the cells outside the two heart-forming regions lose their ability to produce heart myosin through the failure or the inhibition of one or more steps in the



**DISTRIBUTION OF HEART-MUSCLE PROTEINS was determined by testing cut-up embryos with antiserums. Heart actin (*colored*) does not appear in the young primitive-streak embryo (*left*), and in embryos a few hours older (*center and right*) it is confined to areas on either side of the primitive streak. Heart myosin (*hatching*) is widespread in the young embryo but gradually becomes concentrated in the same areas where actin is found. Density of hatching indicates the intensity of the myosin reaction.**

# THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

### HOW TO TAKE A SNAPSHOT OF A SATELLITE IN FLIGHT

If snapshooting satellites is on your agenda, contact either Boller & Chivens/-Joseph Nunn, South Pasadena, California, or the Perkin-Elmer Corporation, Norwalk, Connecticut.

In collaboration, these two firms make just what space photographers need. It's called the IGY Satellite Tracking Camera. And, of necessity, it's somewhat larger than the cameras most of you are accustomed to using. Like this.

Twelve of these cameras are now in use around the world. Each is designed to, first, take a picture when fixed on and following the *satellite*. This renders the subjects as a point against a background of streaks from the brightest stars. Then a second exposure is taken with the camera fixed on and moving with the *stars*. This provides the reference for determining the satellite's location.

And us? We provide the mirror blanks for Perkin-Elmer, who in turn handle the complete optical system. (The West Coast firm provides mechanical components and does the assembling.) The blanks we furnish are 31¾″ in diameter and 7″ thick. They are made from glass No. 7160, the very same glass used in casting the now-famous, 20-ton, 200″ disc for the Mt. Palomar Observatory.

The big advantage in using this particular glass is its very low linear coefficient of expansion—23 x $10^{-7}$ per ° C. Low expansion means a minimum of distortion, a much-appreciated contribution in the complex optics called for in taking pictures of satellites.

These king-sized mirrors lead us quite naturally to remind you that *Corning can do almost anything with glass*. Find out for yourself. Get a copy of "This Is Glass." Use the coupon for quick service.

### NEW GIANT GLASS FLASK FOR THE IN-BETWEEN TASK

What intrigues the man in the picture is the *size* of the crystal clear vessel he is examining.

His interest is justified because as far as we know this is the *biggest* all-glass reaction flask on the market. It's new; it measures 18 inches in OD and stands 26 inches high. Capacity is 20 gallons.

We provide this size—along with 5 and 10-gallon versions—for people (maybe you) who need to fill the gap between lab and pilot plant.

You also can get all the trimmings. Like the five-opening all-glass cover that's visible behind the flask. Such covers can be had with pipe flanges, ⅁, or socket joints. Accessories include inlet tubes, condensers, blind caps, clamps and thermometer wells. Need one? Just write for details.

This outsized glassware is all made from PYREX brand glass No. 7740—a glass that performs admirably because of the virtues detailed elsewhere on this page.

Which brings us to this diminutive and relatively intricate container known as a Warburg flask. It's quite commonplace to biochemists who use it for measurement of cell respiration and tissue metabolism. It's also a stock item with us.

We call the big ones and the little ones *both* to your attention because it points up the fact that size or shape is a consideration—*not* a limitation—to the skilled glassworkers at Corning.

Investigate by tossing us any one of your tough problems. We'll look for a glass answer and let you know soon what we can do.

### PLUMBING FOR POSTERITY

An increasingly popular fixture in labs, hospitals, schools, chem plants, and photoengraving shops is the glass drainline.

With good reason. Glass drainlines are fashioned from PYREX brand glass No. 7740.

This is the glass that ends your worries about corrosion. For example, if you were disposing of waste hot hydrochloric acid, your PYREX pipe would still be around at the end of 200 years.

And glass is smooth; very little chance for block-up in the pipe. If such does occur, however, you can spot the exact point and take corrective action, without having to take down the whole system.

In fact, almost anything made from PYREX brand glass No. 7740 will be around for quite a while because this glass is able to cope with thermal shock and physical knocks, too.

Available in many forms—tubing, rod, pipe, plate, and all kinds of shapes.

Fill in the gaps in your files with these basic references: PE-30, all about glass drainlines; IZ-1, design considerations in glass. Any or all, free. Use the coupon.

CORNING MEANS RESEARCH IN GLASS

**CORNING GLASS WORKS** 49 Crystal Street, Corning, N.Y.

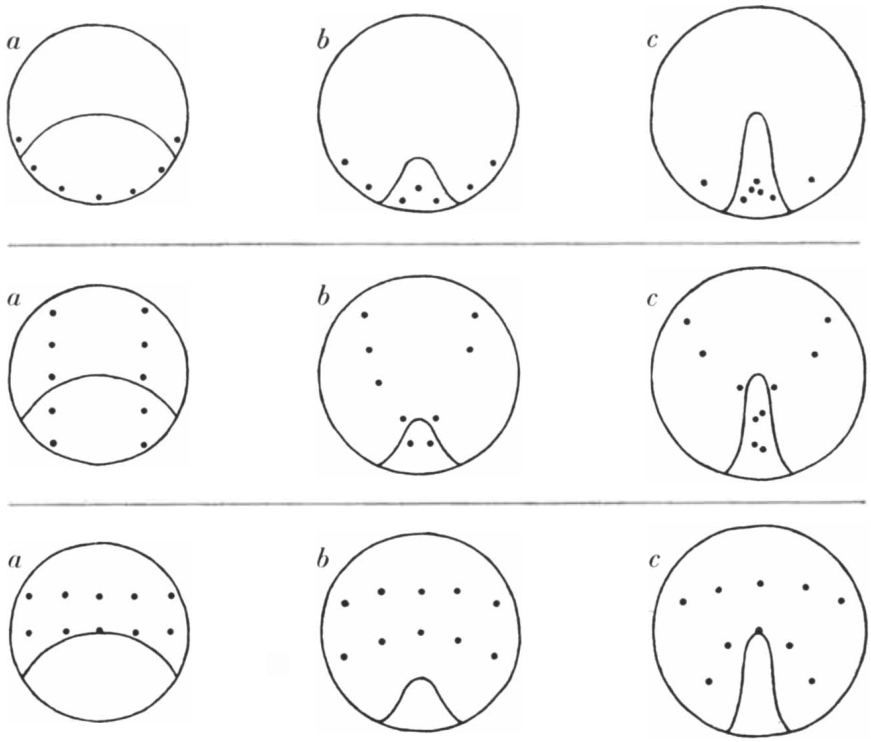
Please send me; ☐ "This Is Glass"; ☐ Drainline Manual, PE-30; ☐ Design Manual IZ-1: ☐ Info on Reaction Flasks

Name_____ Title_____

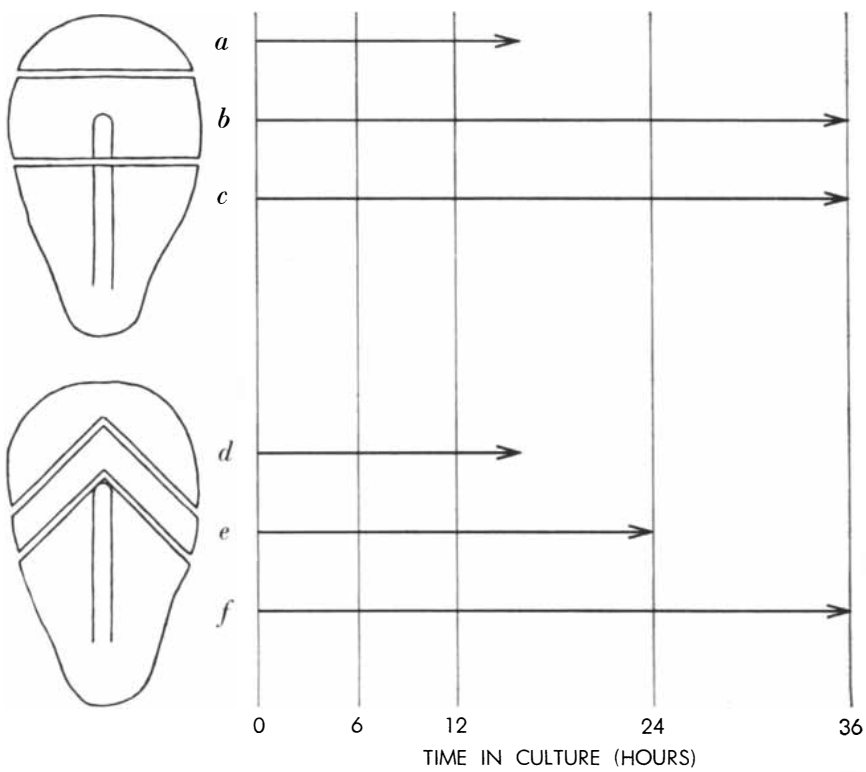
Company_____

Street_____

City_____ Zone____ State_____




**MOVEMENTS OF CELLS** as the primitive streak formed in young chick embryos were traced by Nelson Spratt of the University of Minnesota. He marked embryos (*a*) with carbon particles (*shown as dots in these diagrams*) and then observed them at later stages in development (*b and c*). Similar movements carry heart-forming cells into the mesoderm.




**FATE OF HEART MYOSIN** in cultured fragments of a chick embryo is not the same as that of the intact embryo. When fragments of embryos at left were cultured, myosin (*arrows*), disappeared from cultures of *a*, *d* and *e*. It was still retained after 36 hours in cultures of *b*, *c* and *f*. Of these only *b*, *e* and *f* would have retained myosin in the intact chick embryo.

synthesis. It is not a simple task to dissociate these phenomena; at such early stages of development cell movements and changes in synthetic processes are closely related.

In searching for a clue to the reason why heart myosin disappears from tissues outside the heart-forming regions, we have tested the synthetic capacities of isolated fragments of the embryo. Embryos were cut in various ways; the fragments were cultured separately and then analyzed for their myosin content with anti-heart-myosin serum. The results were confusing. If the embryo is cut as shown at upper left in the lower illustration on this page, the sections grown in isolation do not behave as they do in the intact embryo. In normal embryonic development section *a* and section *c* both lose the capacity to synthesize heart myosin, while section *b* retains this capacity. In isolation, however, section *c* develops into pulsating muscle, and after 36 hours still reacts with antibodies for heart myosin. Isolated section *a*, on the other hand, does not form pulsating masses, and shows no sign of heart myosin in about 12 hours. If the embryo is cut somewhat differently, as shown at lower left in illustration, then only section *f* retains myosin for longer than 24 hours. In short, these experiments have not yielded the hoped-for clarification of the role of location in determining which cells will specialize in the production of heart myosin.

It must be emphasized, however, that we are using antibodies reactive to the heart myosin of adult animals in our effort to detect embryonic heart myosin. The parts of a molecule essential to its physiological function are not necessarily those that combine with an antibody, and the fact that both the embryonic and the adult molecule react with the same antibody does not establish the identity of the two substances. It shows only that the immunologically active groups of the two molecules are identical or have a close similarity. Strictly speaking, our immunological techniques prove merely that certain cross-reacting groups are present. We have not yet determined whether the myosin first detected is adult heart myosin, or a subunit of that molecule, or a complete myosin molecule closely related to but not identical with the adult protein (as in the case of fetal and adult hemoglobin molecules).

It thus appears that in the formation of heart muscle certain of the contractile proteins are synthesized first and later aggregated in the form of fibrils that can contract. As yet we have little evidence on this point outside that furnished by

# CHECKMATE

## in the face of enemy countermeasures

Air Defense is a chess game for keeps—a game in which our nation and the rest of the free world are the stakes. The strategy of the game anticipates enemy actions and countermeasures and provides for that extra measure of ability to win.

At Bendix, the capability to operate in the presence of enemy countermeasures is inherent in system design.

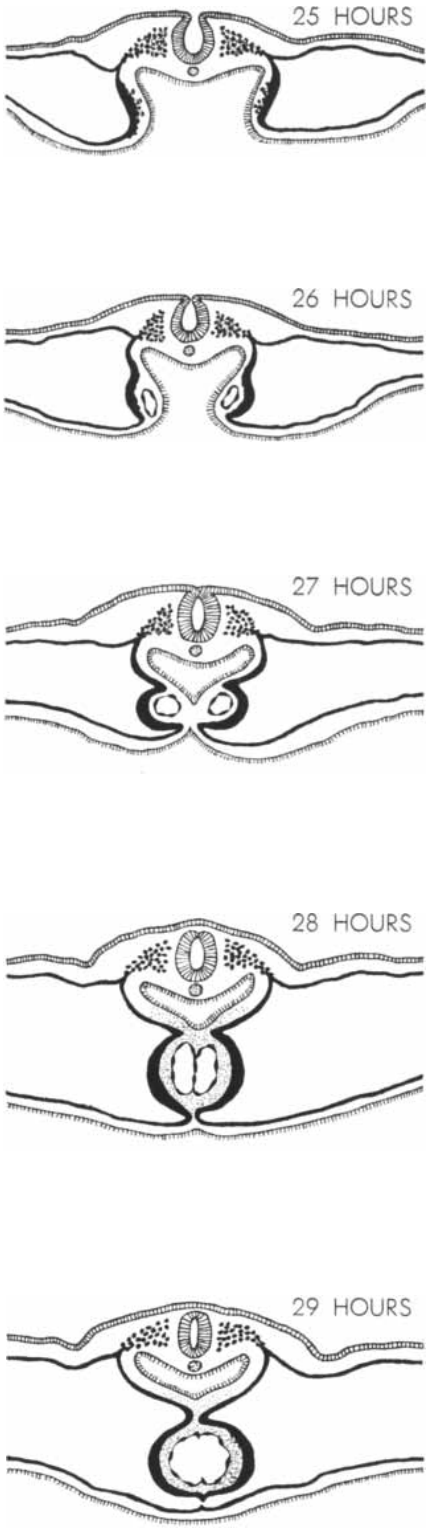
All types of countermeasures—deception, multiple-jamming, and camouflage—are included in Bendix threat evaluation. The effectiveness of these countermeasures is investigated for advanced detection, raid resolution, tracking, and weapon control techniques.

Facing up to the sophisticated threat is the prime objective of Bendix in air defense projects. The Systems Division, working cooperatively with the Radio Division, is engaged in programs involving passive techniques, electronic scanning, frequency diversity, data processing, anti-jam circuits, special radars, bistatic detection, and anti-submarine warfare.

Other projects for which the Bendix Systems Division has system management and engineering responsibility are the EAGLE air-to-air missile system, global weather reconnaissance, supersonic target drones, and radiation-resistant mission and traffic control. These programs and emphasis on counter-countermeasures exemplify Bendix Systems leadership.

Bendix Systems Division
ANN ARBOR, MICHIGAN

Bendix
AVIATION CORPORATION



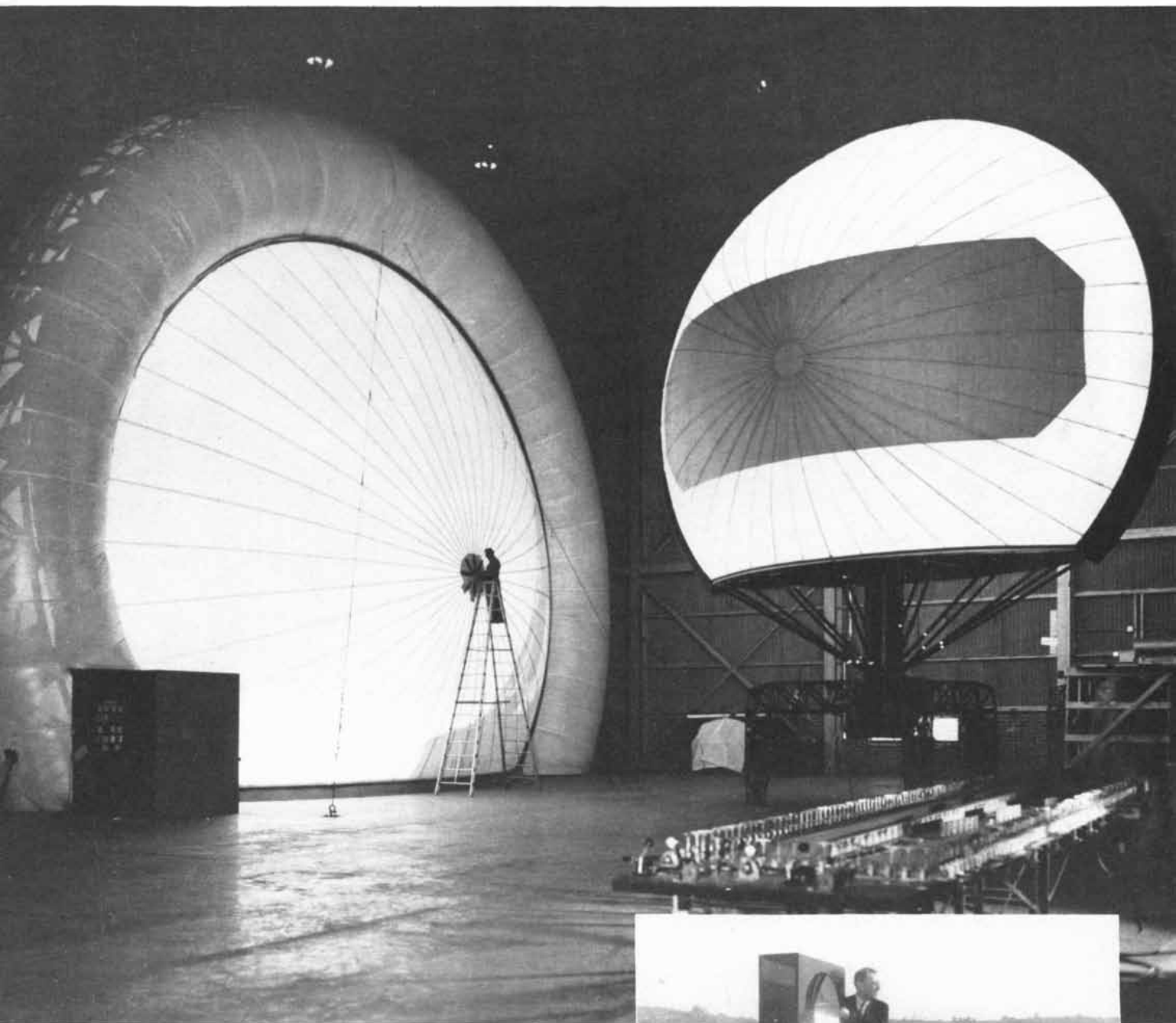

TRANSVERSE VIEW of the developing chick heart shows primitive structures (*top*) arising from the mesoderm (*heavy black dots and lines*). They move together and finally merge into one large tube (*bottom*) having two layers. Also pictured are developing neural tube (*hatched structure above heart*) and foregut (*V-shaped structure*). These drawings are adapted from Bradley M. Patten's *Early Embryology of the Chick*, published by the Blakiston Company.

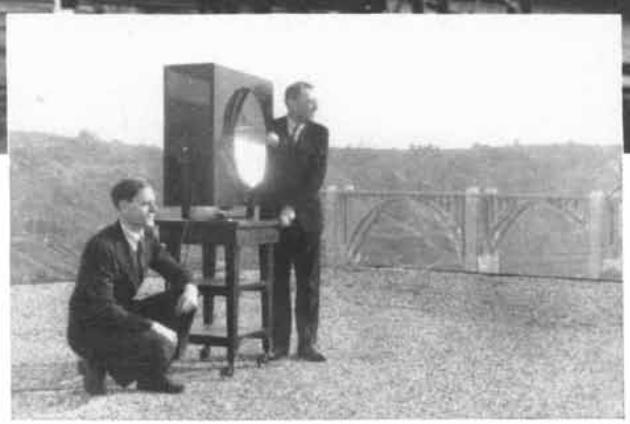
immunological experiments, although some electron microscope studies have also suggested a stepwise organization of the fibril. We cannot, however, be sure of this; in developing skeletal muscle immunological techniques have detected myosin only after the first simple fibrils have formed.

The selective effects of various substances that interfere with normal cell chemistry have produced additional striking evidence that the heart-forming regions are distinguished chemically well before structures of the heart appear. Nelson Spratt of the University of Minnesota has employed certain enzyme inhibitors to show that the metabolic pathways operating in the development of the brain and of the heart differ markedly. In studies I completed recently in collaboration with Lowell Duffey we cultivated early chick embryos in a medium containing traces of the metabolic inhibitor antimycin A, a substance produced by the *Streptomyces* mold. We found that concentrations of this inhibitor as low as .1 microgram per embryo block almost completely the development of the regions destined to form muscle, but leave the developing brain and spinal cord intact. Another metabolic inhibitor, sodium fluoride, has a similar effect. In low concentrations it primarily affects the heart, but at high concentrations it causes the embryo to disintegrate according to a clear-cut pattern starting in the heart-forming regions. At any given stage of development, from the appearance of primitive streak through the establishment of the heart, the locations of the cells destroyed by sodium fluoride coincide with the sites that have the greatest capacity to form heart muscle, and with the areas that have the greatest capacity for the synthesis of actin and myosin. Thus the primary forces in the formation of the heart seem to be operating almost at the very outset of embryonic development.

With the present rapid advance of biochemical techniques we should soon be able to state accurately when and where a given protein is first formed. To ensure continued progress, however, the biochemist must learn from embryology about cellular organization, the role of the cell surface and the interactions of cells and tissues. One of the most effective tools of the experimental embryologist has been microsurgery. Now "chemosurgery" provides another means for deliberate intervention in the pattern of development and for the alteration of its course under experimental control.

# Westinghouse With 25 Years Of Leadership Is Meeting Today's Detection Problems





Westinghouse has been in the radar field since 1933. In that year, Westinghouse engineers, pioneering in radar techniques, detected automobiles on a highway by beaming ultra short radio waves experimentally off a rooftop of the Westinghouse East Pittsburgh Plant (illustrated at right).

Westinghouse has delivered over 35,000 radar sets . . . and continues its role today in ground and shipboard radar for air defense and tactical missions, airborne radar for reconnaissance, AEW, mapping, ASW and missiles, and such specialized areas as pulse-doppler, infra-red, ECCM, and 3-D radar techniques.

Shown is one of the most significant advances in the field of tactical military equipment—the lightweight, highly mobile Paraballoon® Antenna, developed at the ***Electronics Division***.

**NON-ROTATING ANTENNA.** A new kind of radar antenna, the Helisphere is considered a possible forerunner of those to be used for powerful antimissile radars of the future. The antenna, pictured at the Westinghouse ***Research Laboratories***, produces a rotating radar beam without rotation of the antenna structure itself.

**INFRA-RED.** Westinghouse has been actively at work in infra-red research, design and development since World War II. Extensive programs are now being conducted for applications of infra-red techniques to present and future military requirements as well as the space age. Pictured is an infra-red seeker, newly designed at Westinghouse ***Air Arm Division***.

**BIGGEST RADAR TUBE.** Heart of the longest range shipborne radar ever put in service, a magnetron tube nicknamed "Big Maggie" was developed at the Westinghouse ***Electronic Tube Plant*** at Elmira. "Big Maggie" delivers over 10 million watts of peak power, enough to search out enemy planes over 400 miles away.

**MOLECULAR SYSTEMS.** A new, low-noise amplifier developed by scientists at Westinghouse ***Research Laboratories*** for ***Air Arm Division*** application. This two level solid-state maser is one aspect of a broad Westinghouse program of molecular engineering for radar and other electronic systems of the future.

**WORLDWIDE SERVICE.** Wherever Westinghouse radar is in operation . . . land, sea and air . . . field engineers of the ***Electronics Service Department*** assist and instruct in the operation and servicing of radar manufactured by the ***Air Arm*** and ***Electronics Divisions***. Graduate engineers provide this Westinghouse service the world over.

**COMPLETE TEST FACILITIES.** Radar undergoes composite test at ***Electronics Division***. A complete computer facility is available here and at ***Air Arm Division***. Included are IBM 704 and large REAC, together with all environmental, shock, vibration and other test equipment necessary for the development of present and contemplated land, sea, air and space-borne systems.

**200-MAN FLIGHT TEST FACILITY.** Engineers at ***Air Arm Division*** install Aero 13-F radar and computer, latest and most advanced radar built by Westinghouse. Flight test facility includes over 200 people and all facilities necessary to completely service, instrument and test avionic equipment in Westinghouse owned and bailed aircraft.

*For additional information on detection systems and applications at Westinghouse, write to:*
Director, Customer Relations, Westinghouse Defense Products Group
1000 Connecticut Ave., N.W., Washington 6, D.C.

# Westinghouse

**DEFENSE PRODUCTS**

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

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

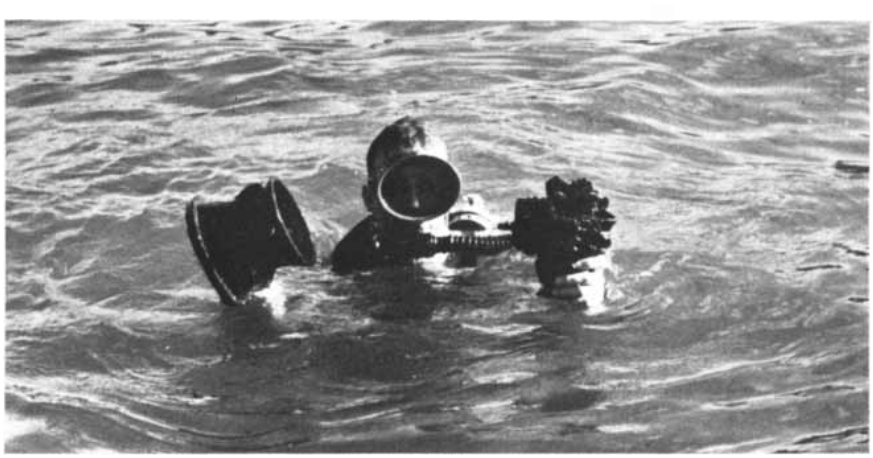
# Underwater Archaeology in the Maya Highlands

*At the bottom of a Guatemalan lake skin divers have found objects sacrificed to the lake spirits as early as 2,500 years ago. These finds help trace the history of a little-known branch of the Maya*

by Stephan F. Borhegyi

When we hear the word "Maya," we usually think of the impressive flat-topped pyramids which archaeologists have cleared from the rain forest of Guatemala and southern Mexico. Or we may think of a second Maya area farther to the north on the plain of Yucatan, where the Spaniards pillaged the cities built by the ancestors of the present Indian inhabitants. Run your finger down the map from Yucatan southward across the rain forest and you come to a little-known third center of Maya civilization. This center lies in the Sierra Madre, which runs along the Pacific coast of Guatemala and of the Mexican province of Chiapas. Here in the cool highlands west of Guatemala City live nearly four million Maya Indians, cousins of the more familiar northern lowland tribes. In pre-Columbian times these highland Maya comprised one of the Western Hemisphere's great civilized states. Less advanced than the northerners (they made little use of the 365-day calendar, hieroglyphic writing and the corbelled arch), they nonetheless possessed a rich cultural tradition dating from about 1000 B.C. Today this tradition is yielding its history to an unusual kind of archaeology.

For the past few years the archaeology of the Maya highlands has proceeded on a modest scale. The ancient religious center of Kaminaljuyu and a number of other sites have been excavated, but for the most part the diggings have managed to stay out of the public eye.

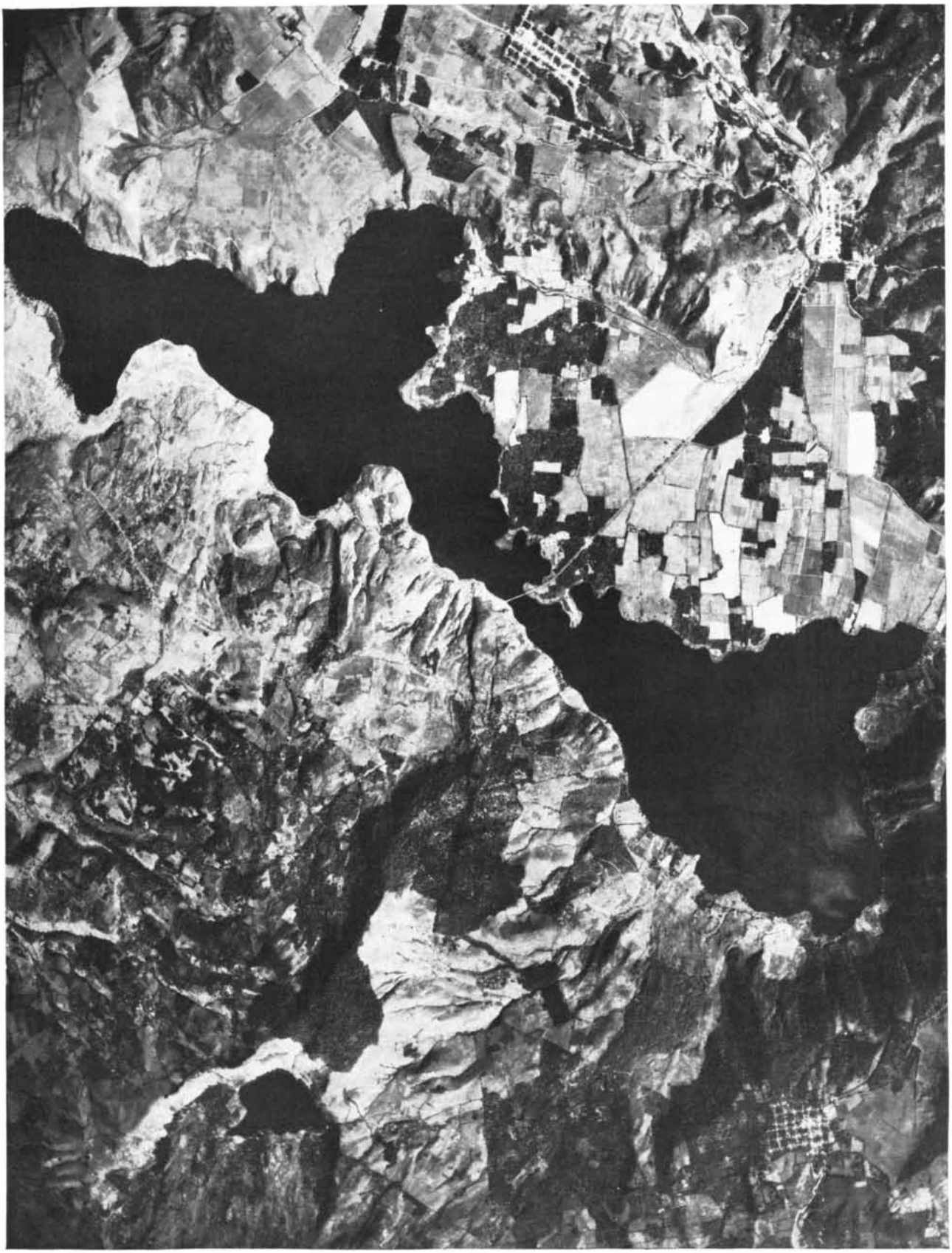


**SKIN DIVER** in this photograph, wearing an aqualung, has just surfaced with two Maya incense burners from Lake Amatitlan in highland Guatemala. He is Jorge Samayoa, one of the lake's many amateur sportsmen-turned-archaeologists cooperating with the author.

The reasons for this are twofold. First, the highland Maya rarely built in stone. Lacking the soft limestone of Yucatan, or metal tools with which to hew their own hard igneous rock, the highland architects resorted to sun-dried earth, adobe and plaster—materials that have crumbled with the passage of time and the tilling of the soil. Today every highland palace and temple has collapsed into a grassy mound, and smaller structures have almost vanished beneath the fields of Indian corn.

Second, there is none of that specious glamour that surrounds archaeological research in inaccessible places. Almost without exception the highland sites lie on the outskirts of modern towns, close to highways, railroads and all the comforts of civilization. No expeditions need be outfitted. There is none of the romantic austerity of camp life. The rainforest pyramids are another matter. Set in the deepest jungle, unseen for 1,000 years save by wandering chicle-gatherers and primitive Lacandon-Maya hunting bands, their appeal to the imagination is undeniable. Small wonder that the lowland Maya have eclipsed the fame of their highland relatives!

But every dog has its day, and the highland Maya have at last begun to attract attention. Curiously this has been brought about not by the archaeologist's spade but by modern techniques of free diving. By 1954 the new sport of aqualung diving had become an international pastime, and in that year a group of amateur divers began to probe the waters of Guatemala's Lake Amatitlan in search



LAKE AMATITLAN, set among volcanic peaks, is shown in this aerial photograph. From its western, or lower, basin (*upper left*) divers have recovered Maya offerings dating from about 500 B.C. Temple sites on the shore date from 1000 B.C. to 1500 A.D.

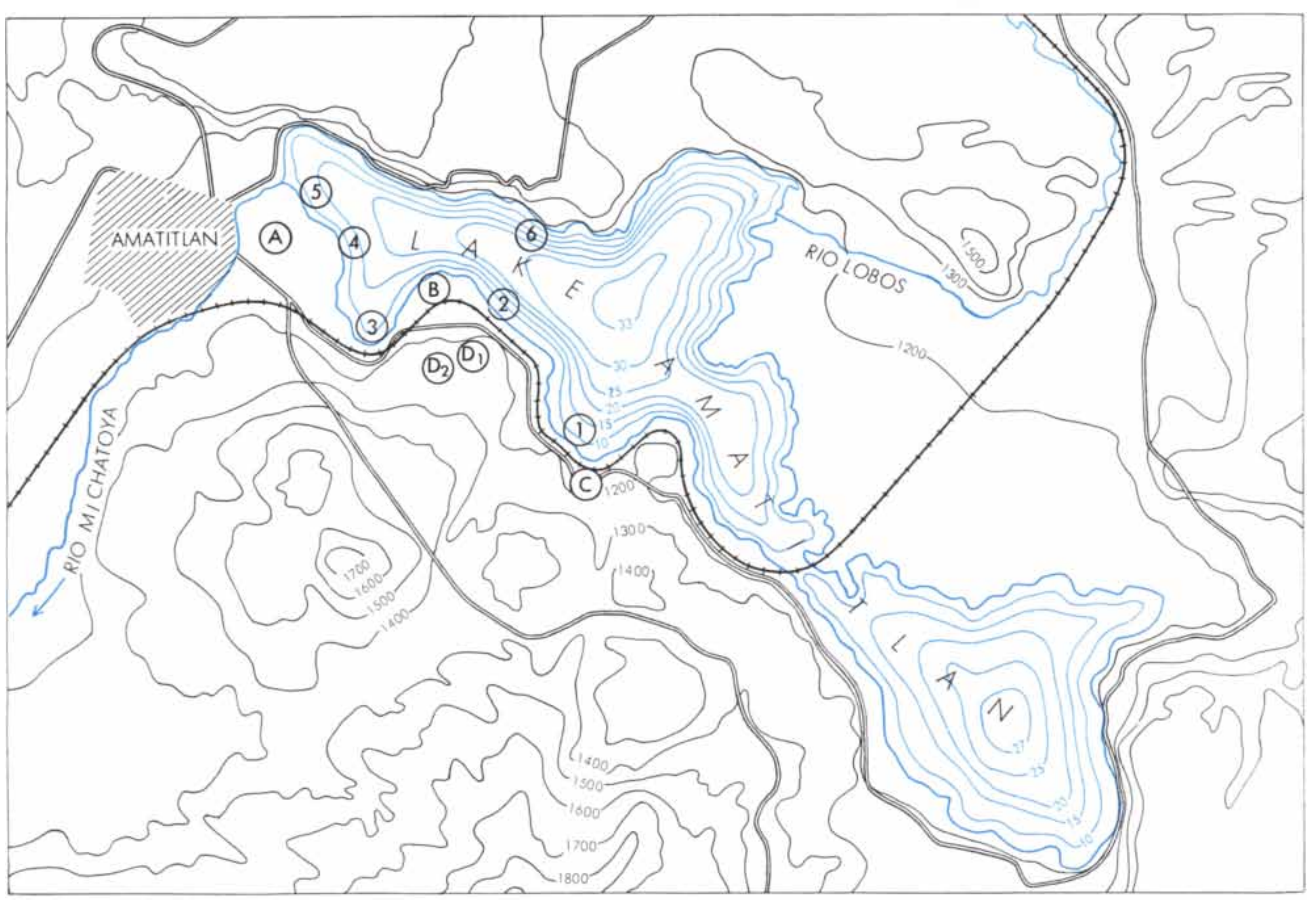
of fishing grounds. In April, 1955, one of these diving enthusiasts, Manfred Töpke, retrieved an interesting archaeological specimen from the bottom of the lake. It was the first of more than 600 intact pottery vessels, incense burners and stone sculptures discovered by the skin divers.

In the summer of 1957, when the news of these finds reached me, I was excavating in the highlands with a group of students from the summer school of San Carlos University. I wasted no time in getting in touch with the skin divers and examining their collections. With their help I mapped out a plan for a systematic survey of the lake bottom and shore. Jacques-Yves Cousteau, inventor of the aqualung, had initiated underwater archaeology five years before with his famous exploration of a Greek shipwreck near Marseilles. Since then much of the Mediterranean and Danish coast had been explored by skin divers, but this was to be one of the first such adventures in the Americas.

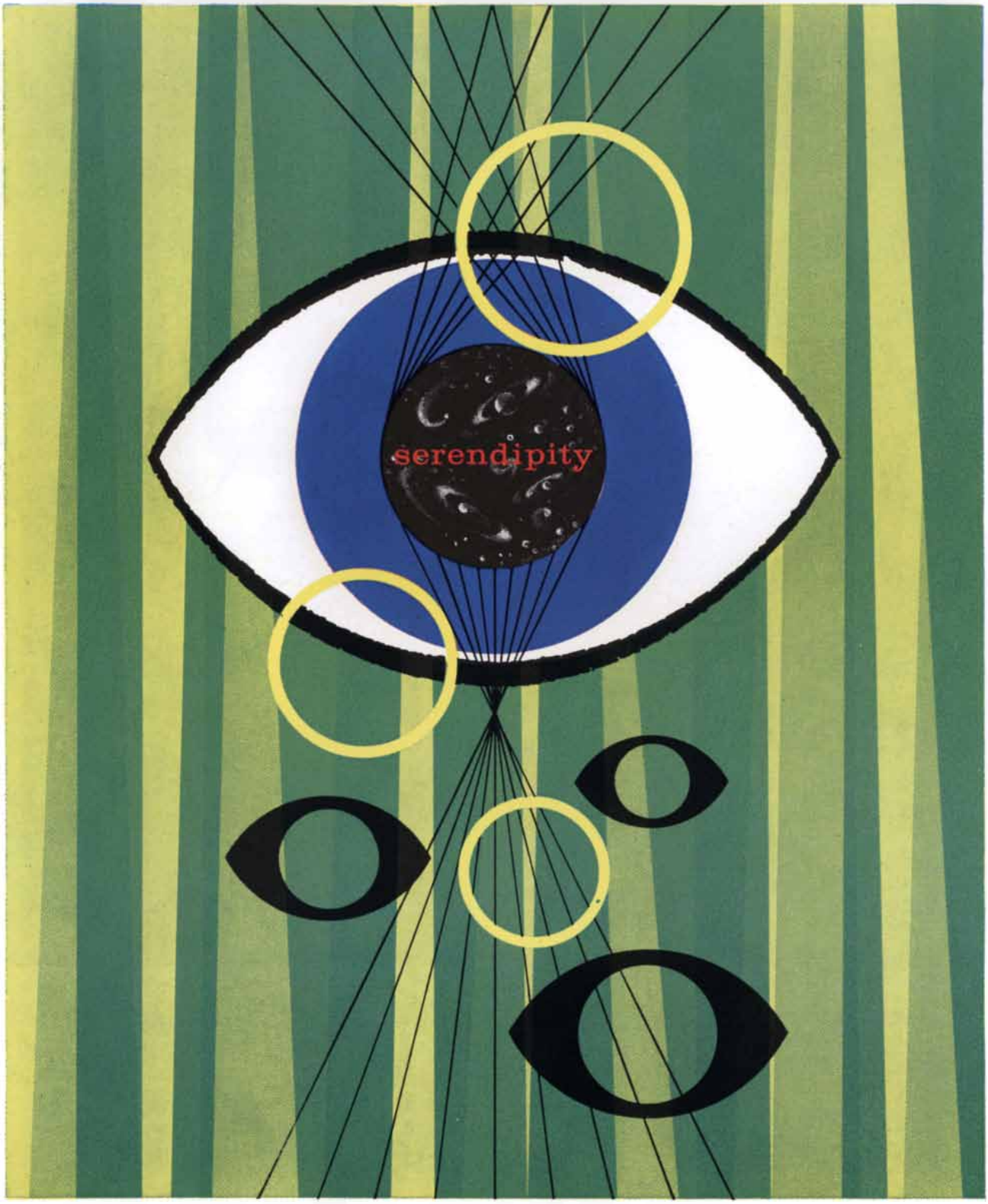
To be sure, the discovery of archaeological specimens in Lake Amatitlan came as no great surprise. As early as the mid-19th century travelers to Guatemala had made mention of apparently ancient pottery vessels found along the lake shore and in its shallow waters. Eduard Seler, a noted German archaeologist, visited the lake in 1896 and described "curious spiked vessels occasionally decorated with maguey-like leaf decorations." A later visitor, Marshall Saville of the Heye Foundation in New York, not only witnessed the recovery of pottery vessels from the lake by fishermen but also located two archaeological sites on the lake shore. During the 1940s members of the Carnegie Institution Guatemalan research team and I investigated and mapped these sites and others in the lake area. No one was aware, however, of the immense quantity and diversity of the underwater material.

Lake Amatitlan is a beautiful resort 17 miles south of Guatemala City on the highway from the capital to the Pacific seaport of San José. Its altitude is some 4,000 feet. Attractive week-end cottages belonging to the country's wealthier citizens line the shore, and in good weather the lake sees a good deal of swimming, boating and water-skiing. Two lakeside hotels feature thermal baths, said to be beneficial for arthritis and rheumatism. A short distance from the lake shore is the colonial town of San Juan Amatitlan, whose 6,000 permanent residents are mostly "Ladinos" of mixed Spanish and Pokomam-Maya ancestry. Spectacular lava hills surround the lake. In certain areas sulfurous water hot enough to boil an egg bubbles from the lake bottom or along the shore. Geysers appear and disappear erratically at various locations on the south side of the lake. The lake derives its name from the Amate tree (*Ficus moraceae*), which abounds on the southern shore.

The first task of our group was to prepare accurate maps of the lake. This we did with the aid of aerial photographs from the Guatemalan Bureau of Cartography plus some up-to-date bathymetric maps. We now tried to locate the exact sites of all underwater discoveries made by local skin divers since 1955. The upper basin of the lake is joined to the lower basin by a narrow channel only six feet in depth, crossed by a railroad

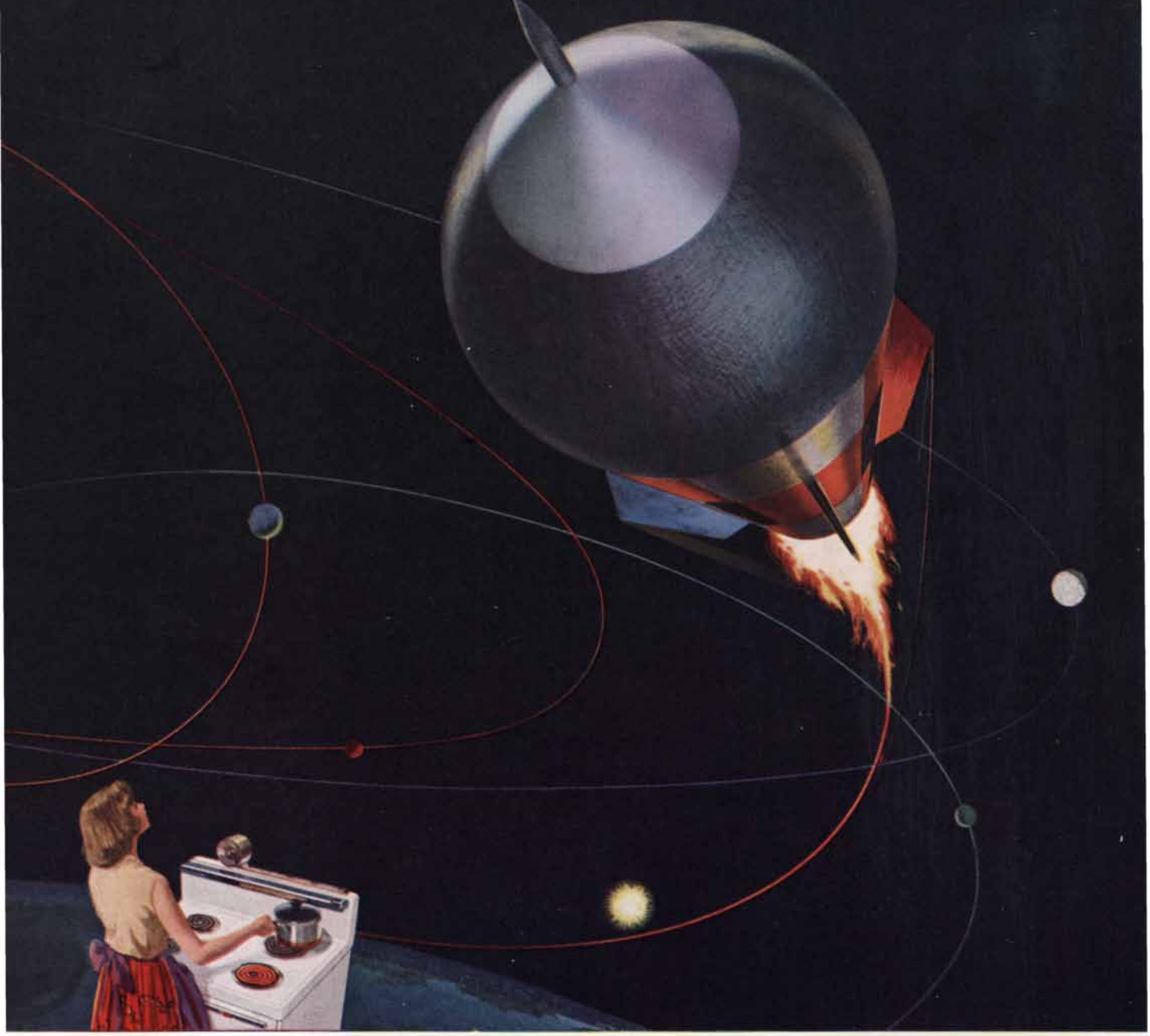



ARCHAEOLOGICAL SITES at Lake Amatitlan include lake-bottom deposits of offerings (*numbered 1 through 6*) and lake-shore sites of ancient groups of buildings (*lettered A through D2*). The colored contours indicate the depth of the lake in meters; the black contours, the height of the land above sea level in meters. In both map and plan views on page 106 and 108 north is at the top.




**look for the professional challenge . . .** *available only to those who possess the creative initiative to explore, in thought, beyond what is known about space travel, and return with the serendipity that only the few would recognize. If you are one of those exceptional individuals who is seeking a challenge such as this, communicate with N. M. Pagan, Director of Technical and Scientific Staffing, Martin-Denver, P. O. Box 179, (G-2), Denver 1, Colorado.*

**MARTIN**
DENVER DIVISION



# *From the Kitchen to the Stars*

Already used as insulation inside the heating elements of electric appliances, magnesium oxide is destined for an important part in the drama of advanced materials technology. Unique properties, discussed in the column opposite, promise exciting possibilities in the coming conquest of space. Immediate applications are seen in the fields of refractories and atomic energy. If you have problems of extreme heat abrasion or corrosion, perhaps Carborundum can help. Write to Carborundum, Research & Development Division, Dept. SA-3, Niagara Falls, New York.

*Where conventional materials fail . . . call on*

**CARBORUNDUM**

Registered Trade Mark

ADVANCED MATERIALS TECHNOLOGY

bridge [*see map on page 102*]. Since the Guatemalan divers reported that there was nothing to be found in the upper basin, we concentrated our efforts in the lower. The depth of this portion of the lake varies from 10 to 130 feet. Nearly 600 archaeological specimens in the divers' and other private collections were cleaned, photographed, described and measured. Each piece was catalogued according to its original location beneath the waters of the lake. We found that most of the material came from nine underwater deposits, seven of them near hot springs off the south shore and the other two in deeper water off the north shore. Fortunately for us the divers had made their collections with considerable care. They had carried depth gauges and taken accurate notes, numbering the specimens according to their original location. The specimens consisted of offering bowls, spiked vessels and incense burners. They ranged from a few inches to four and one-half feet in height. The incense burners were double-chambered or three-pronged; many bore unusual designs: cacao trees and pods, papaya fruits and flowers, quetzal birds, jaguar heads, spider monkeys, snakes, lizards, bats and even human skulls—motifs hitherto rare or unknown in the highland Maya area. Among the many Maya gods represented were the rain god, Chac or Tlaloc; the jaguar god; the sun god; Eecatl, the wind god (a form of Quetzalcoatl, the feathered serpent); Xipe Totec, a fertility god; and the death god. There were also beautifully executed human heads peering from the jaws of animals and monsters and the beaks of birds.

It soon became apparent that certain types of vessel and design motif were restricted to particular underwater localities. This raised the intriguing possibility that each underwater deposit might represent a different time period. The location of the deposits in relation to the shore line strongly suggested that the specimens had been thrown into the lake as offerings, probably to the lake or water gods. To confirm the time sequence of the sites it was necessary to reinvestigate all the archaeological sites on the shore. During the summers of 1957 and 1958, with the help of students from the San Carlos University summer school, the mapping and test excavations of all five archaeological sites on the southern shore were completed.

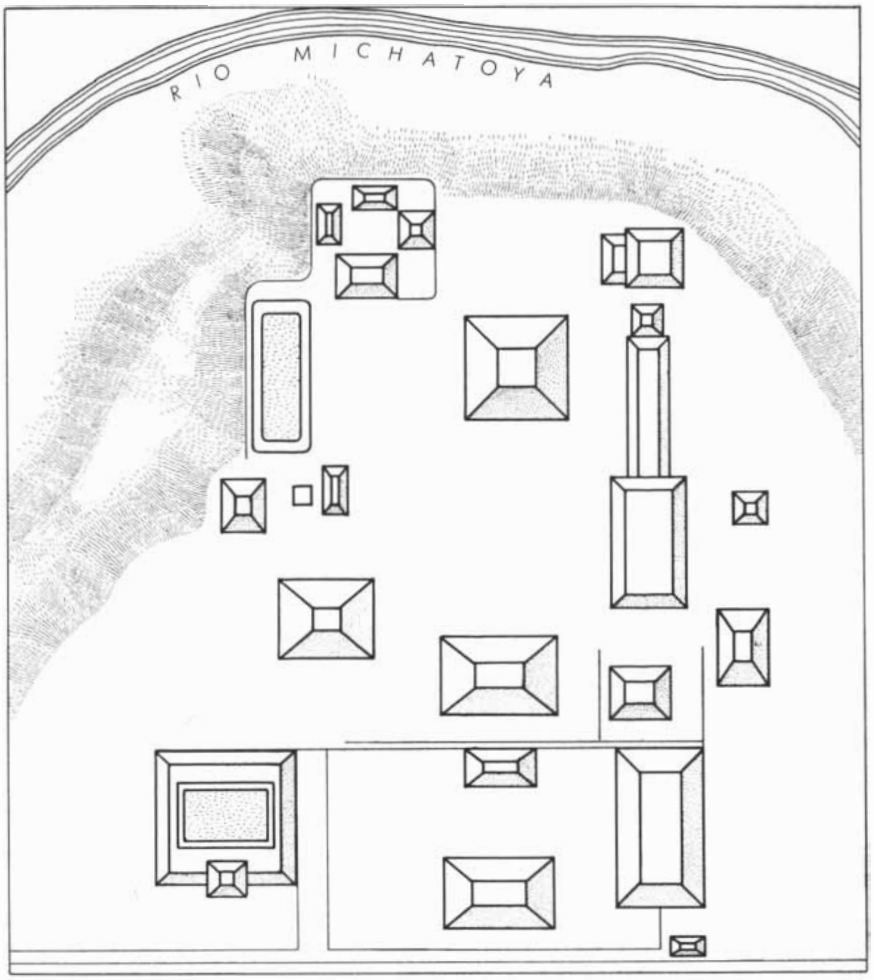
Site B (Contreras), the oldest lakeshore site, shows an occupation from the beginning to the end of the Maya Pre-Classic Period (about 1000 B.C. to 200 A.D.). It consists of five mounds located 300 yards from the shore behind the Contreras Yacht Club [*see bottom illustration on next page*]. Since Contreras lies only a few feet above the level of the modern lake, we can assume that the water level has not risen for at least 2,000 years.

Site C (Mejicanos) consists of four mounds, also at or a little above lake level. The site occupies a small inlet valley, hemmed in on three sides by steep mountains which still show traces of pre-Columbian agricultural terracing. The mounds have been almost obliterated by modern corn cultivation and the use of their material for roads, but their remains are still distinguishable. They were constructed of stone and earth and were probably faced with adobe. Fragments of pottery collected from the site indicate that the major occupation of Mejicanos was during the Early Classic Period (200 to 600 A.D.).

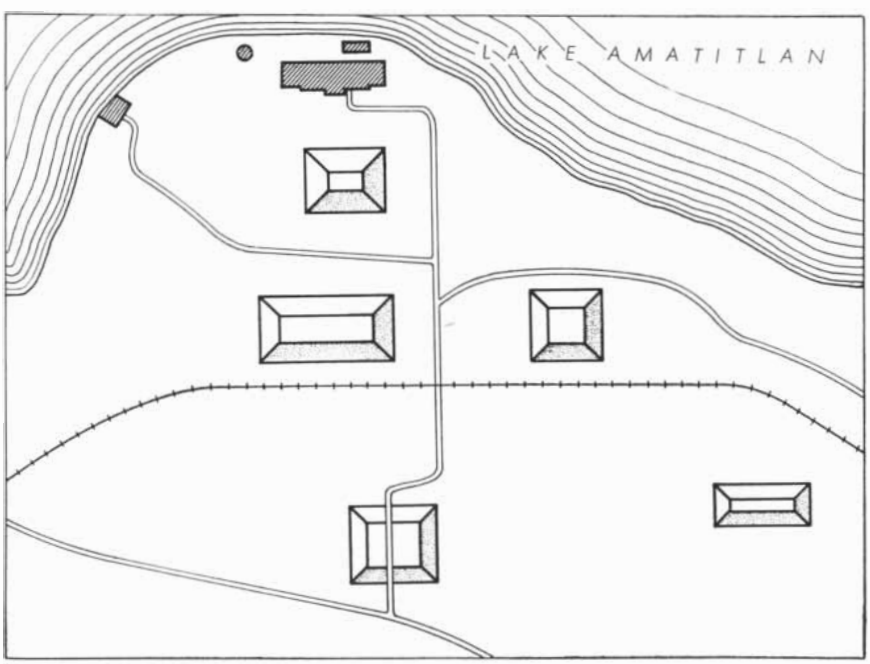
Considerably larger is Site A (Amatitlan), located on higher ground overlooking the west end of the lake. Retreat to higher and more easily defensible positions characterized Maya behavior during periods of disturbance, so we need not infer a rise in the lake level. The site comprises buildings laid out in orderly fashion around aligned plazas. There are about 25 mounds of various sizes, two of them ancient ball courts. Extensive artificial terracing is still in evidence on the sides of the promontory. Many of the structures are faced with masonry of roughly cut stones and some with well-cut and dressed blocks. Several test pits and surface specimens indicate that the site was occupied during the entire Classic Period (200 to 1000 A.D.).

Two other sites, Contreras Alto (Site D1) and Los Jicaques (Site D2), were discovered on the slopes some 500 feet higher than Site B. Both of these sites must have been quite extensive, each with 10 to 15 large mounds and handsomely cut stone masonry. Although the majority of the pottery collected from the two sites dates back to the late Pre-Classic and Classic periods, enough Post-Classic pottery was found on the surface to indicate the possibility that this area was still inhabited at the time of the Spanish conquest in 1524 A.D. One, or both of the sites may represent the long-searched-for ruins of "Tzacualpal," indicated on a map made in 1690 by the Guatemalan historian Francisco de Fuentes y Guzmán.

Our excitement was great when our records of the specimens brought up by



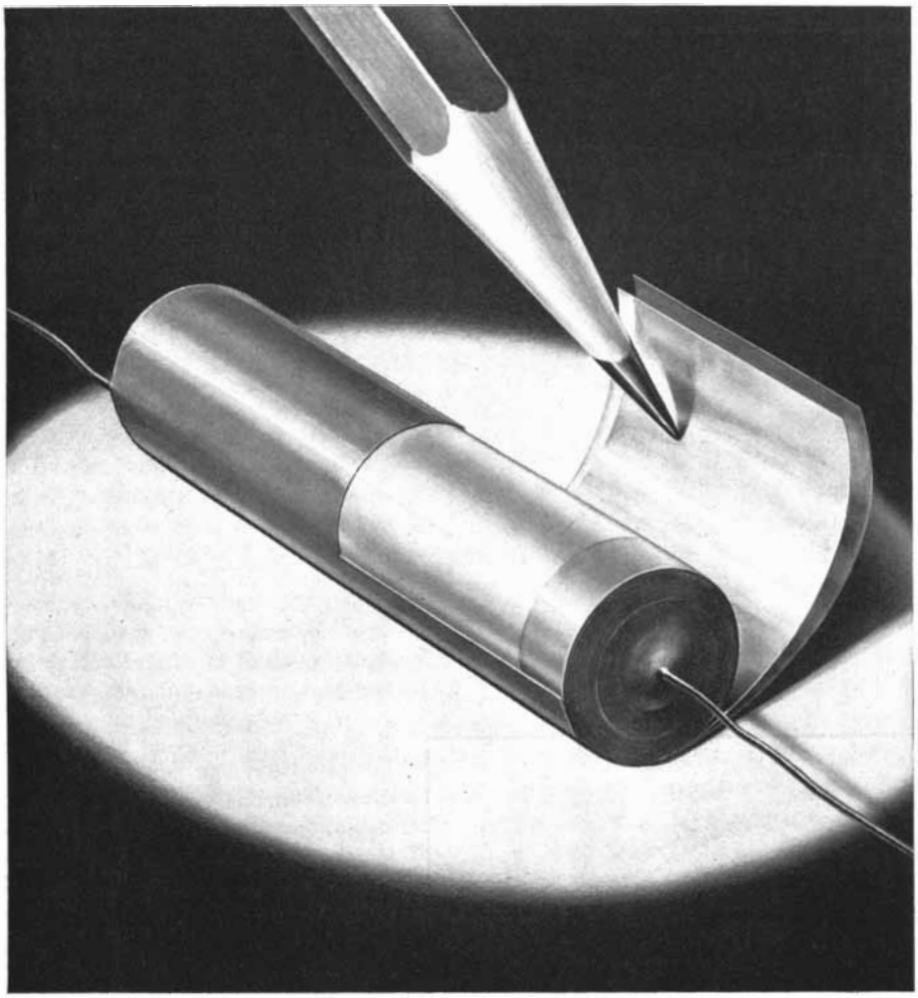

SITE A (AMATITLAN), the largest lake-shore site, dates from the Classic Period (200 to 1000 A.D.). The buildings reconstructed here include two ball courts (*stippled rectangles*).




SITE B (CONTRERAS) is the oldest site, dating from the Pre-Classic Period (about 1000 B.C. to 200 A.D.). It stands near the south shore of Lake Amatitlan, 300 yards above the Contreras Yacht Club (*hatched buildings*). Modern roads and a railroad cross the area.

divers showed that there was a definite correlation between the type and age of the underwater specimens and those found at the nearest archaeological site on the shore. This correlation was confirmed by our student divers, who made many descents to each of the nine underwater deposits. The underwater specimens fall into an orderly sequence which corroborates our time-scale for the sites on the shore; we now have a record of the fact that the lake area had been continuously inhabited for nearly 3,000 years. Thus the region, though not comparable in architectural grandeur to Kaminaljuyu, the largest of the highland Maya sites, has a rich and full archaeological record. On the basis of this record I shall now attempt to reconstruct the history of the lake area.

While the archaeological record does not begin before about 1000 B.C., we can assume that prior to this time wandering Maya groups entered the highlands from the Pacific-coast area, and settled in more or less stable communities in the many fertile mountain valleys. Soon the domestication of corn and beans made it possible for these communities to set aside their food surplus for times of scarcity; this eased the tremendous pressure of keeping alive from one day to another. Increasing leisure made it possible and practical for members of the communities to manufacture objects of artistic and utilitarian value. Their various kinds of pottery and stone implements provide the first tangible chapter of prehistory. While archaeological data indicate a large population in the nearby Valley of Guatemala, no permanent structures remain to document this earliest period at the lake. However, utensils and figurines from the Contreras site suggest that a settlement of some sort must have existed. The main occupations of these first settlers, as in later times, were fishing, hunting and farming. Religious ideas from the ceremonial center of Kaminaljuyu reached this community around 1000 B.C., attested by the beginning of mound building. The gods became ever more important as men depended upon them to bless and protect their corn and bean plots. Gradually the ritual magic practiced by individuals gave way to organized religious offerings and ceremonies. Religion was probably the concern of the menfolk, who erected buildings and monuments and carved sculptures in honor of their gods or their dead. The religion at this time was unsophisticated in concept, being entirely animistic; every aspect of nature had its spiritual



### PROPERTIES OF "MYLAR"

"Mylar" offers a unique combination of properties that may help you improve performance and lower costs of your product. Here are two of the many important properties for evaluation.

**REMARKABLE TOUGHNESS.** "Mylar" is the strongest flexible plastic film ever made...tough even in extra-thin gauges!


**SUPERIOR CHEMICAL RESISTANCE:** Unaffected by oils, grease, most acids and alkalis, moisture and solvents.

*Western Electric reports . . .*

# Du Pont MYLAR® cuts capacitor costs

**PROBLEM:** Western Electric was searching for a dielectric material which, when used in a film-foil construction, would cut capacitor manufacturing costs.

**SOLUTION:** Du Pont "Mylar"* polyester film. According to Western Electric, the moisture resistance of "Mylar" minimized the need for a costly outer metal enclosure. Capacitor design was simplified . . . over-all size was reduced while electrical stability under normal operating conditions was maintained.

**RESULTS:** Capacitors insulated with "Mylar" provide excellent performance for selected types of equipment produced by Western Electric. These new capacitors achieve high reliability and long life. Materials savings have been realized through reductions in size and use of less costly encapsulation.

**HOW CAN "MYLAR" HELP YOU?** Whether you make heavy-duty cable or tiny components, you may be able to capitalize on the outstanding combination of properties found in tough, transparent "Mylar" film. For more information on how "Mylar" can help you improve product performance, solve knotty development problems, or help cut costs, send in the coupon.

DU PONT
REG. U. S. PAT. OFF.
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

DU PONT **MYLAR®** POLYESTER FILM

*"MYLAR" *is Du Pont's registered trademark for its brand of polyester film.*

E. I. du Pont de Nemours & Co. (Inc.)
Film Dept., Room SA-3, Nemours Bldg., Wilmington 98, Del.

Please send booklet listing properties, applications and types of "Mylar" polyester film available.

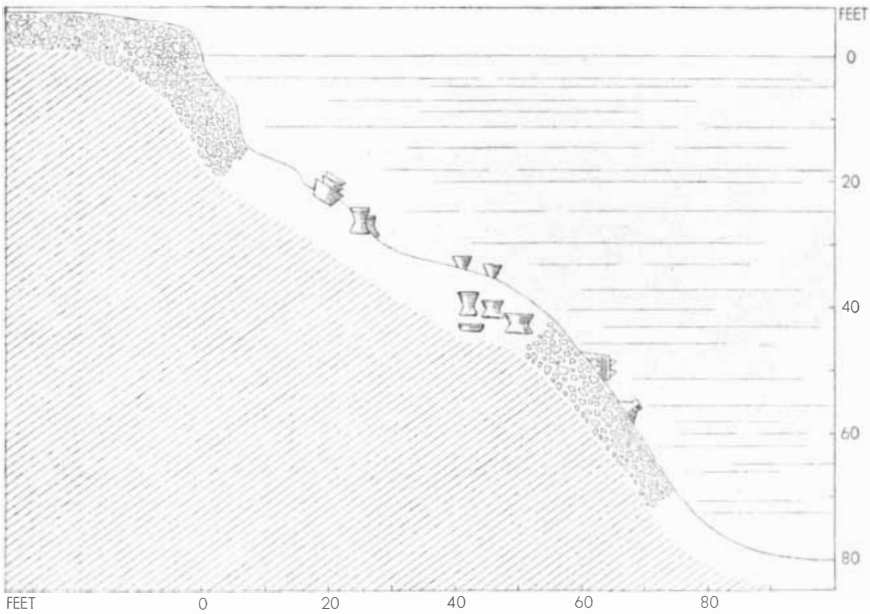
Application_____

Name_____ Title_____

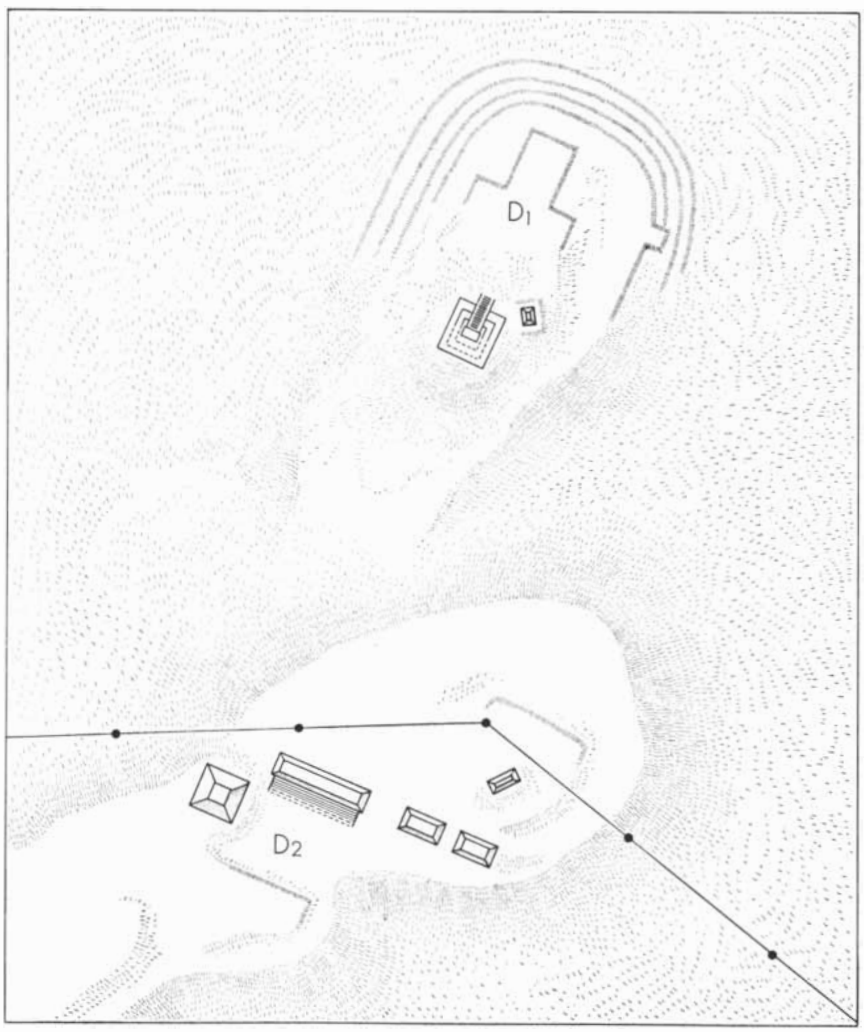
Company_____

Address_____

City_____ State_____




**SITE C (MEJICANOS) belongs to the Early Classic Period (200 to 600 A.D.). Shown here are offerings from Site C carried under water by lava flow in which they were embedded.**



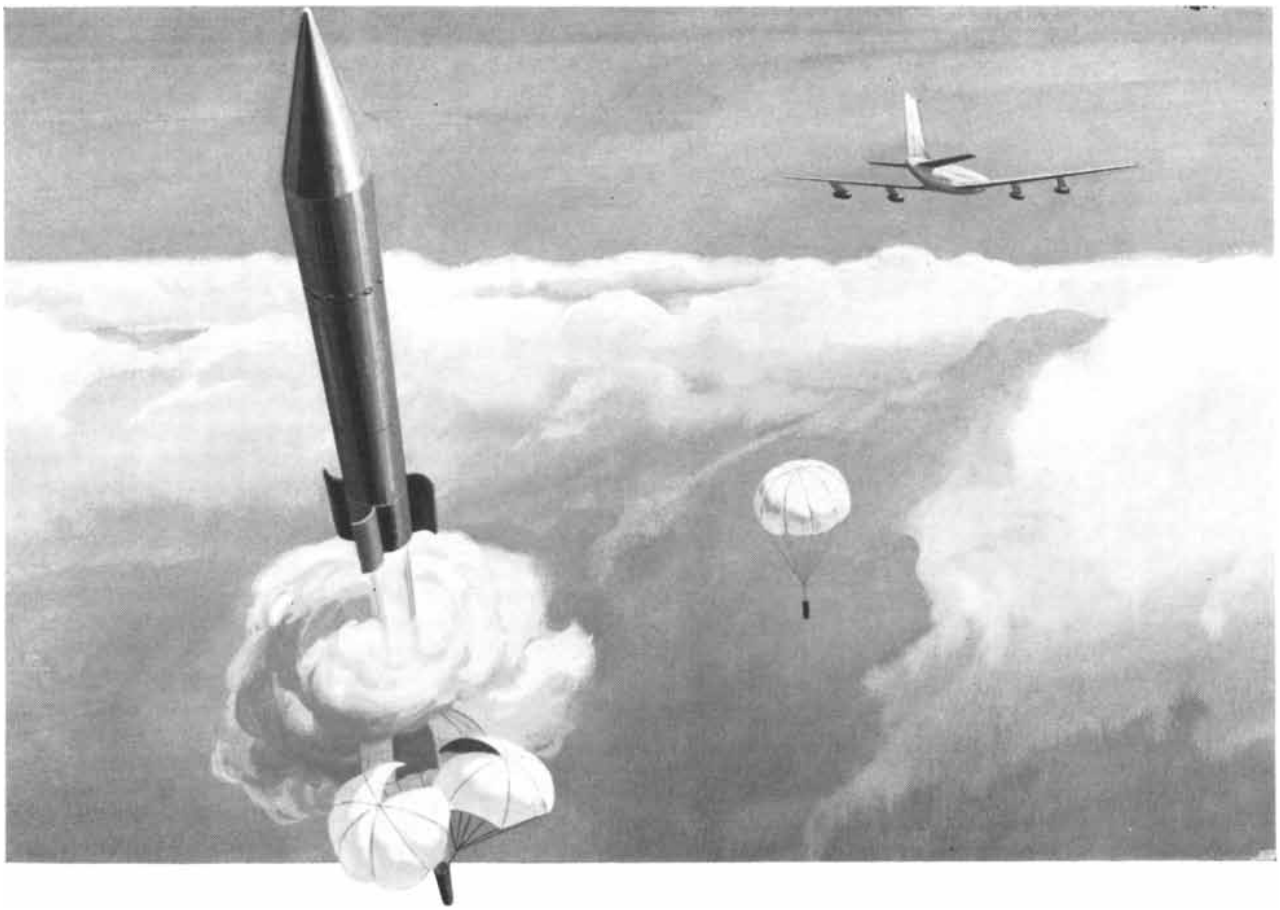

**SITES D1 AND D2, referred to as Contreras Alto and Los Jicaques, are hillside settlements probably inhabited until the time of the Spanish conquest. One or both may be the "lost" city of Tzacualpal shown on an old colonial map. A modern power line crosses Site D2.**

counterpart. It is easy to see why the sulfurous springs and geysers on the southern shore of Lake Amatitlan would be awe-inspiring to these pre-Columbians. This awe, combined with fear of the four-peaked active volcano Pacaya overlooking the lake, could easily have made men believe that particularly powerful spirits or gods dwelt in the area. By about 500 B.C. it was customary to cast offerings into the lake waters to appease the gods. But offerings at this time were neither as specialized nor as abundant as those in later periods.

Apparently the Contreras site was abandoned by the beginning of the Early Classic Period, sometime around 200 A.D. Two new ceremonial centers were then established, one at Mejicanos, adjacent to the hot springs, and the other at Contreras Alto on the nearby hill slopes. The latter site, of considerable size, may indicate a growing population that needed to build and cultivate the surrounding agricultural terraces. Mejicanos, with its four small mounds on the shore, must have served only as a shrine for pilgrims, who by now came in droves, bringing rich and varied offerings to the water gods. The number and variety of specimens from the underwater deposits of Lavaderes nearby suggest that by this time the lake had become a pilgrimage center for highlanders from far and near.

Periodic eruptions of the volcano Pacaya may also have prompted some offerings. Our divers found bowls in groups of four or five, standing erect and occasionally embedded in lava on the lake floor. This could only mean that to placate the angry gods residing in the volcano these objects had been placed in lava flows near the shore and were thus carried into the lake. Major eruptions, probably accompanied by earthquakes, may have prompted the more extravagant offerings, including human sacrifices. One of our divers recovered at Lavaderes a brown-black jar with a modeled Tlaloc face on the neck. It was unusually heavy and upon investigation turned out to contain liquid mercury. After further cleaning we found in it fragments of cinnabar and graphite and nearly 400 ceremonially smashed fragments of jade ear-spools, the most treasured jewelry of the Maya.

Another diver brought up an offering bowl containing a cranium, apparently of a woman somewhere between 16 and 25 years old. The cranium still showed faint traces of red ocher. Human sacrifice, or at least offerings of bodies of the dead, was probably not an uncommon



# NEW GLOBAL WEATHER SYSTEM TO USE JETS AND ROCKETS TO PROBE UPPER AIR

A flying weather-sensing system designed to probe the atmosphere on a global scale is under development for the Air Force by the Bendix Systems Division, Ann Arbor, Mich. The Boeing Airplane Company is the major sub-contractor.

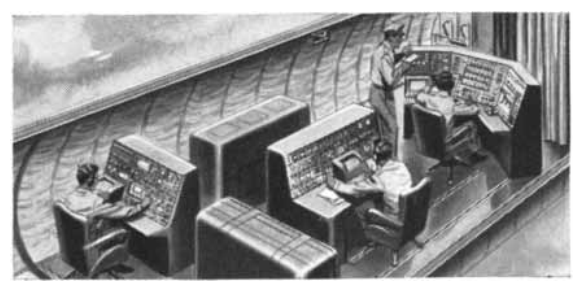
The new system is man's most ambitious attempt to understand and forecast weather. It will be particularly valuable over arctic regions and oceans where weather surveillance is especially difficult.

The new airborne weather stations, consisting of four-engined Air Force jets, equipped with multiple radars, instrument packed rockets, atmospheric sensing equipment and electronic computers, will be in communication with ground stations that will process and relay weather data over a national network.

The jet planes will fly at altitudes up to 50,000 feet. They will make 4,800 mile flights and will measure cloud formations and look inside storms with radar sweeps extending 150 miles from the aircraft. At periodic intervals radiosondes, or instrument packed units that radio information back to the aircraft, will be launched by rocket to probe the jet stream and other atmospheric phenomena at altitudes up to 150,000 feet. Radiosondes also will be dropped by parachute to "read" weather data closer to earth. They will measure air pressure, temperature, dew point, icing rate, wind speed and direction, index of refraction, ozone (a rare form of oxygen existing at high altitude), solar energy balance, and atmospheric electricity.

While weather and geophysical data are vital factors in the military use of air power and missiles, the new program is unique in having important peacetime applications. In addition to informing the Air Force it will also supply weather information to commercial airlines, the Weather Bureau, and to weather forecasting services serving industries and agriculture.

The development of this new weather system is another step in Bendix'* long experience with weather sensing devices. The Bendix-Boeing development team includes the Bendix Research Laboratories, for new techniques; Bendix Pacific, for airborne radar; and Bendix Friez Instrument Division, the world's oldest and largest manufacturers of instruments for weather bureaus as well as for scientific and industrial users. *TRADEMARK



Cutaway shows how observers in plane monitor and control the weather-sensing system with the aid of a special electronic computer.

*A thousand products* Bendix AVIATION CORPORATION Fisher Bldg., Detroit 2, Mich. *a million ideas*

**OFFERINGS found at the bottom of the lake include censer covers shaped like a jaguar (*top*) and a Mexican god (*middle*), either the "Old Fire God" or Quetzalcoatl. At bottom is a young woman's ocher-stained cranium in a bowl, possible evidence of human sacrifice.**

practice among the pre-Columbian inhabitants of the Amatitlan region. Frequent representation of Xipe Totec, a god associated with human sacrifice, and many incense burners depicting jaguars and human skulls, strengthen the possibility that this unsavory practice had entered religious ritual by the Classic Period (200-1000 A.D.). Similar evidence of human sacrifice is abundant among the northern Maya. All of the specimens found from this period bespeak the religious and artistic influence of nearby Kaminaljuyu and even of Teotihuacan in central Mexico.

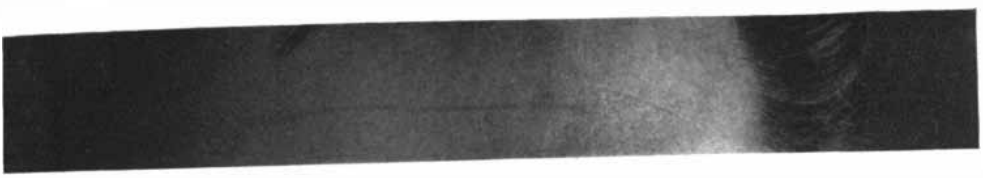
At the end of the Classic and during the following Post-Classic period (1000-1500 A.D.) two more large population centers had come into prominence, that of the hilltop sites Amatitlan (Site A) and Los Jicaques (Site D2). The number of buildings and ball courts at these sites suggests that they were not merely ceremonial centers but also permanent residences, at least for the governing classes. We have yet to determine whether they were cities in the true sense. We also question whether the inhabitants of these sites were completely Maya in origin, since this is the time when Nahuat-speaking Pipil and Toltec groups from Mexico began to infiltrate the highlands. According to the *Account Book of the Town of San Juan Amatitlan, 1559-1562*, an important document in the Smithsonian Institution, the town was inhabited shortly after the Spanish conquest both by people who spoke Pocomam-Maya and by others who spoke Nahuat. The Pipil and Toltec preference for spiked vessels and the representation of speech scrolls, jaguars, spider monkeys, human skulls and intricate vines and flowers can be seen in many late Classic and Post-Classic objects recovered from the lake bottom, indicating that these Mexican groups were present. Amatitlan and Los Jicaques must have been flourishing at the time of the Spanish conquest of Guatemala in 1524, for the historian Fuentes y Guzmán included them on his map made in 1690. One matter not yet established is whether Pipil, Toltec and Maya inhabitants shared the same settlements or merely lived as friendly neighbors.

Unfortunately we do not know much of colonial times at the lake. Our best documents are the writings of an enterprising English Dominican friar, Thomas Gage, a parish priest of San Juan Amatitlan during the years 1635-36. According to Brother Thomas, Amatitlan was by then a prosperous commercial center surrounded by numerous large sugar plantations. Commoners and gentry

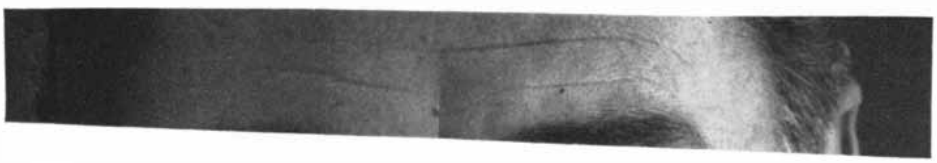
*progress report on Aeronutronic*

# MEN

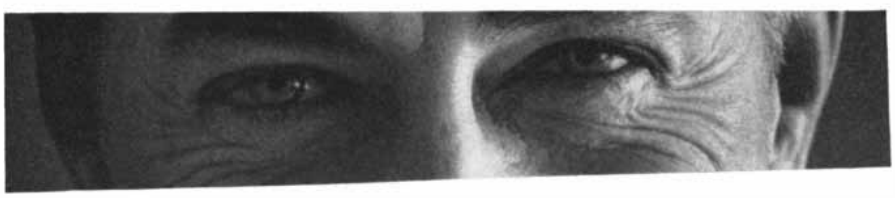
# WITH



# OPEN



# MINDS



Men with open minds hold the key to the future. They're creative men. They're skilled men. And they face the vast problems of the future eagerly and with confidence. They know that tomorrow—for America and the world—is what they make it.

These are the men—exceptional scientists and engineers—who are at home at Aeronutronic.

Ford Motor Company created Aeronutronic to conceive, design, and manufacture new products to meet the needs of a new age. Here advanced research, space sciences, missile technology, range systems, space vehicles, computers, and tactical weapon systems are major fields of research.

In the Ford tradition, the men at Aeronutronic go as far and as fast as skill and brains can carry them. Such men are needed at Aeronutronic's new 200-acre Research Center at Newport Beach, California. Engineers and scientists will find unequalled opportunities with Aeronutronic. Why not look into it today?

*For information regarding positions, interests, facilities or products, write to Mr. K. A. Dunn, Aeronutronic Systems, Inc., Bldg. 45, 1234 Air Way, Glendale, California, or call CHapman 5-6651.*

**AERONUTRONIC**

*a subsidiary of* FORD MOTOR COMPANY

NEWPORT BEACH, GLENDALE, SANTA ANA AND MAYWOOD, CALIFORNIA

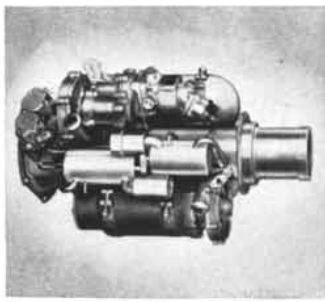
OFFICE OF ADVANCED RESEARCH • COMPUTER DIVISION
SPACE TECHNOLOGY DIVISION • RANGE SYSTEMS DIVISION
TACTICAL WEAPON SYSTEMS DIVISION

**INCENSE BURNER found in the lake is of the "three-pronged" variety. The decoration depicts a finely molded Maya face looking out through the beak of an unidentified bird.**

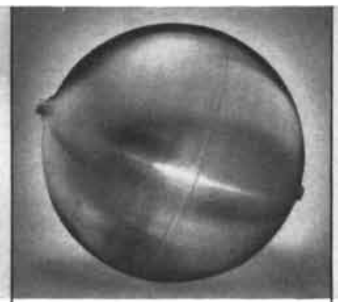
from the capital still came there to bathe and take the waters, or to fish or row about the lake in boats or *canoas.*

Lake Amatitlan still plays a mystical role in the beliefs of present-day highland Maya Indians and Ladinos. The majestic stone church on the town plaza of San Juan Amatitlan is the home of an elaborately carved Spanish colonial wooden figure of the Santo Niño de Amatitlan, acclaimed for its miraculous healing powers. According to local legend, similar magical powers were once attributed to a carved stone idol called Jefe Dios which in pre-Columbian days stood on a cliff on the north shore of the lake. One night during the 17th century, the story goes, there was a great rumbling in the earth accompanied by a severe hailstorm, and the stone idol sank beneath the waters of the lake. The following morning devout visitors to the "pagan" shrine of Jefe Dios found in its place the charming wooden statue of the Santo Niño (Christ Child), and with elaborate ceremonies it was removed to the church on the town plaza.

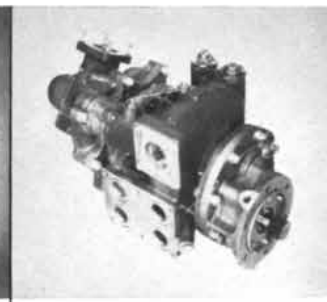
Ever since then on May 3, the day of the Festival of the Cross, devout pilgrims from all parts of the Republic of Guatemala come to the Fiesta of Amatitlan. The little wooden figure of the Christ Child is borne from the church in a magnificent religious procession across the lake to the spot where legend places its miraculous appearance. Hundreds of gaily painted boats and canoes follow the statue on its journey; flowers and fruits are thrown into the lake by the pilgrims. It would seem that this modern Christian festival is a survival of ancient Maya lake rituals. In it we can see another example of the persistence of human ideas. The pre-Columbian belief that powerful spirits inhabited Lake Amatitlan, and with it the desire to placate these spirits, has survived virtually unchanged over a period of 3,000 years. It has managed to withstand or incorporate all foreign religious influences, including Christianity.



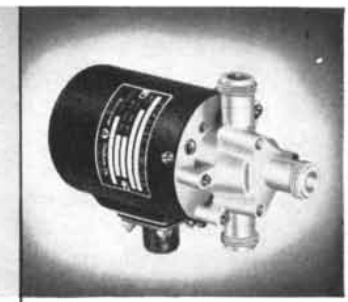
Solid-propellant auxiliary power unit



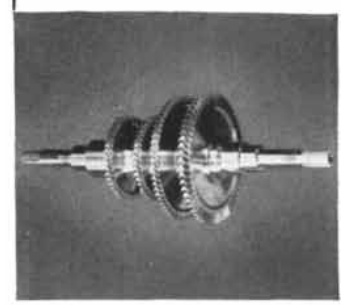
Titanium missile pressure vessel



Combination main and after-burner fuel pump



Coaxial switch



Four-stage turbine wheel

## 100 MILLION JET ENGINE BLADES
## 1.1 MILLION AIRCRAFT AND MISSILE FUEL PUMPS
## APU'S FOR 6 DIFFERENT MISSILES

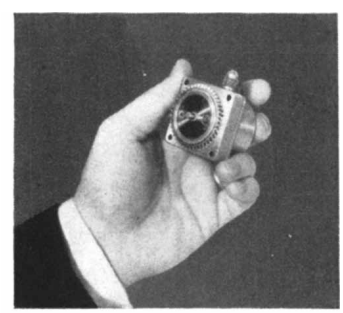
# TAPCO GROUP

These are some of the products of the TAPCO Group of Thompson Ramo Wooldridge Inc. With $150,000,000 of high-efficiency production facilities, TAPCO is one of the nation's leaders in the development and manufacture of mechanical systems, equipment, and components that must meet stringent performance specifications under extreme conditions of temperature, corrosion, and stress.

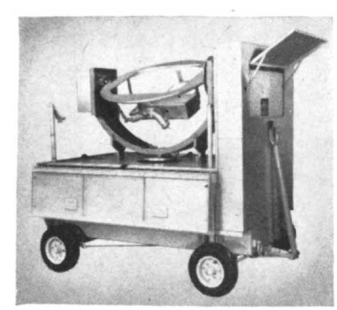
Through its metallurgical and chemical laboratories, TAPCO continually extends its capabilities in the technology of high-temperature alloys, powder metallurgy, cermets, ceramics, and other materials. TAPCO was one of the principal pioneers in the fabrication of titanium, and is currently engaged, in cooperation with E. I. du Pont de Nemours & Co., in the development of manufacturing techniques to handle niobium and its alloys.

In product design and development, TAPCO's 500-man engineering team is experienced in a wide range of specialties, including hydraulics, aerodynamics, electronics, pneumatics, thermodynamics, and nucleonics.

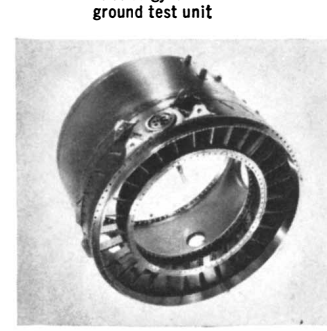
Aircraft and missile technology increasingly demands mechanical systems, equipment, and components that can meet uncommon requirements of precision, strength, and reliability under the most severe environmental conditions. The combination of engineering, metallurgical and manufacturing competence represented in the $160,000,000 per year activities of the TAPCO Group provides an integrated capability of unusual effectiveness for the design and manufacture of such products.



100,000 rpm turbine-driven alternator



Missile gyro ground test unit



Jet engine case assembly

**Thompson Ramo Wooldridge Inc.**

MAIN OFFICES
CLEVELAND 17, OHIO
LOS ANGELES 45, CALIFORNIA

## New techniques, new instrumentation, factually reported for you in the

HEWLETT-PACKARD

# hp JOURNAL

## Typical subjects:

**MICROWAVE DEVICE NOISE FIGURE.** What it means, how to measure it, automatic noise figure recording, new meters and noise sources.

**MEASURING DC VOLTAGES DOWN TO 1 μV.** New techniques, new instruments permit direct readings of extremely small voltages.

**TESTING QUARTZ PLATES FOR 5 x $10^{-8}$ WEEK ACCURACY** in new 10 MC electronic counter.

**"NO-CONNECTION" MEASUREMENTS OF DC CURRENTS.** New milliammeter approach requires no soldering; doesn't load circuit.

**AUTOMATIC PRINTED RECORDS FROM DIGITAL VOLTMETERS;** straightforward method of recording; new equipment available.

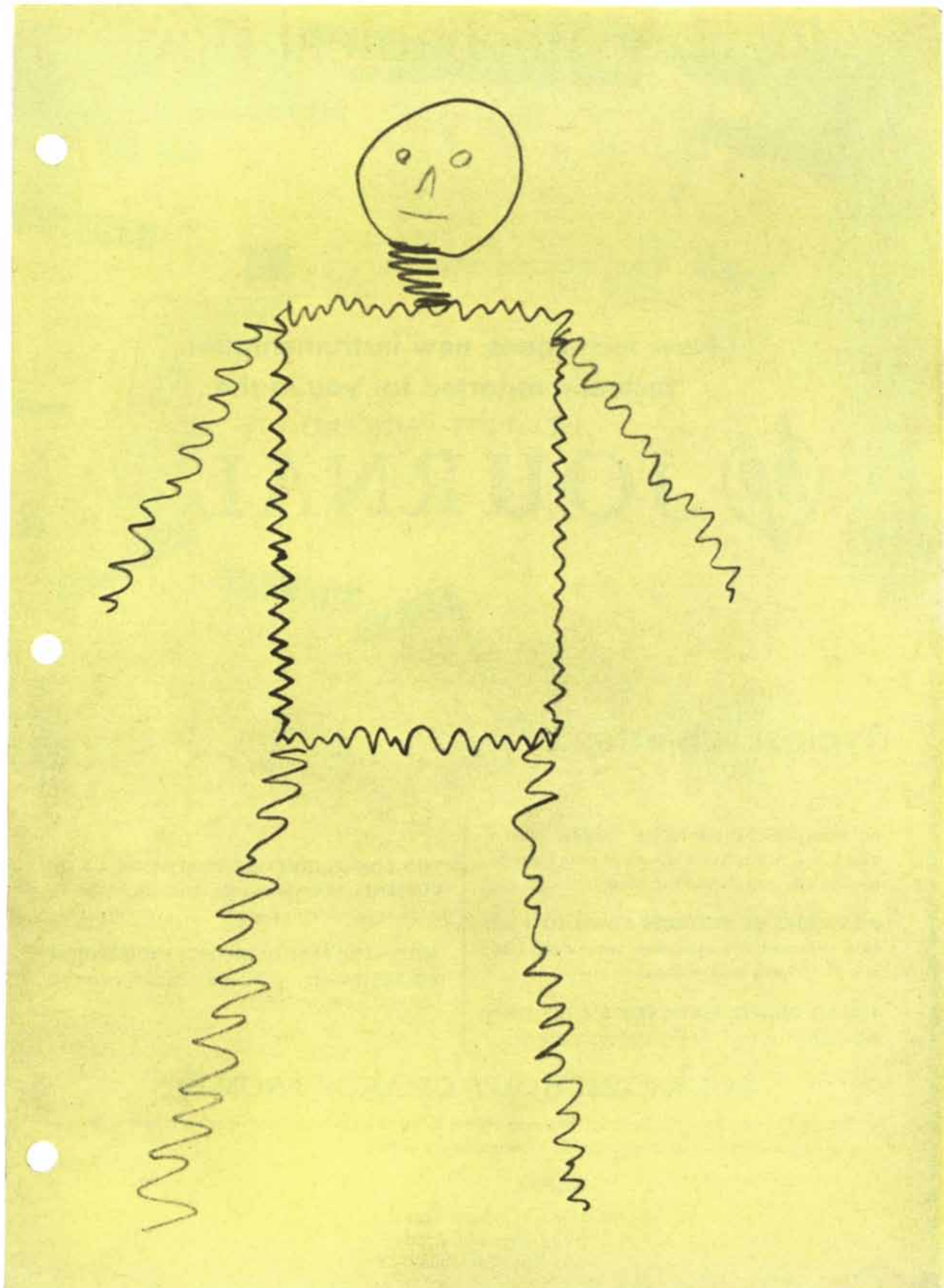
## YOURS WITHOUT CHARGE FROM hp

The hp Journal, reporting throughout the year on measuring developments in all spectra, is sent without charge to engineers in electronics and allied fields. Simply write:

**EDITOR,**

Hewlett-Packard Journal
5222 Page Mill Road
Palo Alto, California

***Complete Coverage in Electronic Test Instruments***



EARLY SELF-PORTRAIT by Joey shows a robot made of electrical wires. The figure symbolizes the child's rejection of human feelings. Reared by his parents in an utterly impersonal manner, he denied his own emotions because they were unbearably painful.

# Joey: A "Mechanical Boy"

*A case history of a schizophrenic child who converted himself into a "machine" because he did not dare be human. His story sheds light on emotional development in a mechanized society*

by Bruno Bettelheim

Joey, when we began our work with him, was a mechanical boy. He functioned as if by remote control, run by machines of his own powerfully creative fantasy. Not only did he himself believe that he was a machine but, more remarkably, he created this impression in others. Even while he performed actions that are intrinsically human, they never appeared to be other than machine-started and executed. On the other hand, when the machine was not working we had to concentrate on recollecting his presence, for he seemed not to exist. A human body that functions as if it were a machine and a machine that duplicates human functions are equally fascinating and frightening. Perhaps they are so uncanny because they remind us that the human body can operate without a human spirit, that body can exist without soul. And Joey was a child who had been robbed of his humanity.

Not every child who possesses a fantasy world is possessed by it. Normal children may retreat into realms of imaginary glory or magic powers, but they are easily recalled from these excursions. Disturbed children are not always able to make the return trip; they remain withdrawn, prisoners of the inner world of delusion and fantasy. In many ways Joey presented a classic example of this state of infantile autism.

At the Sonia Shankman Orthogenic School of the University of Chicago it is our function to provide a therapeutic environment in which such children may start life over again. I have previously described in this magazine the rehabilitation of another of our patients ["Schizophrenic Art: A Case Study"; SCIENTIFIC AMERICAN, April, 1952]. This time I shall concentrate upon the illness, rather than the treatment. In any age, when the individual has escaped into a delusional world, he has usually fashioned it from bits and pieces of the world at hand. Joey, in his time and world, chose the machine and froze himself in its image. His story has a general relevance to the understanding of emotional development in a machine age.

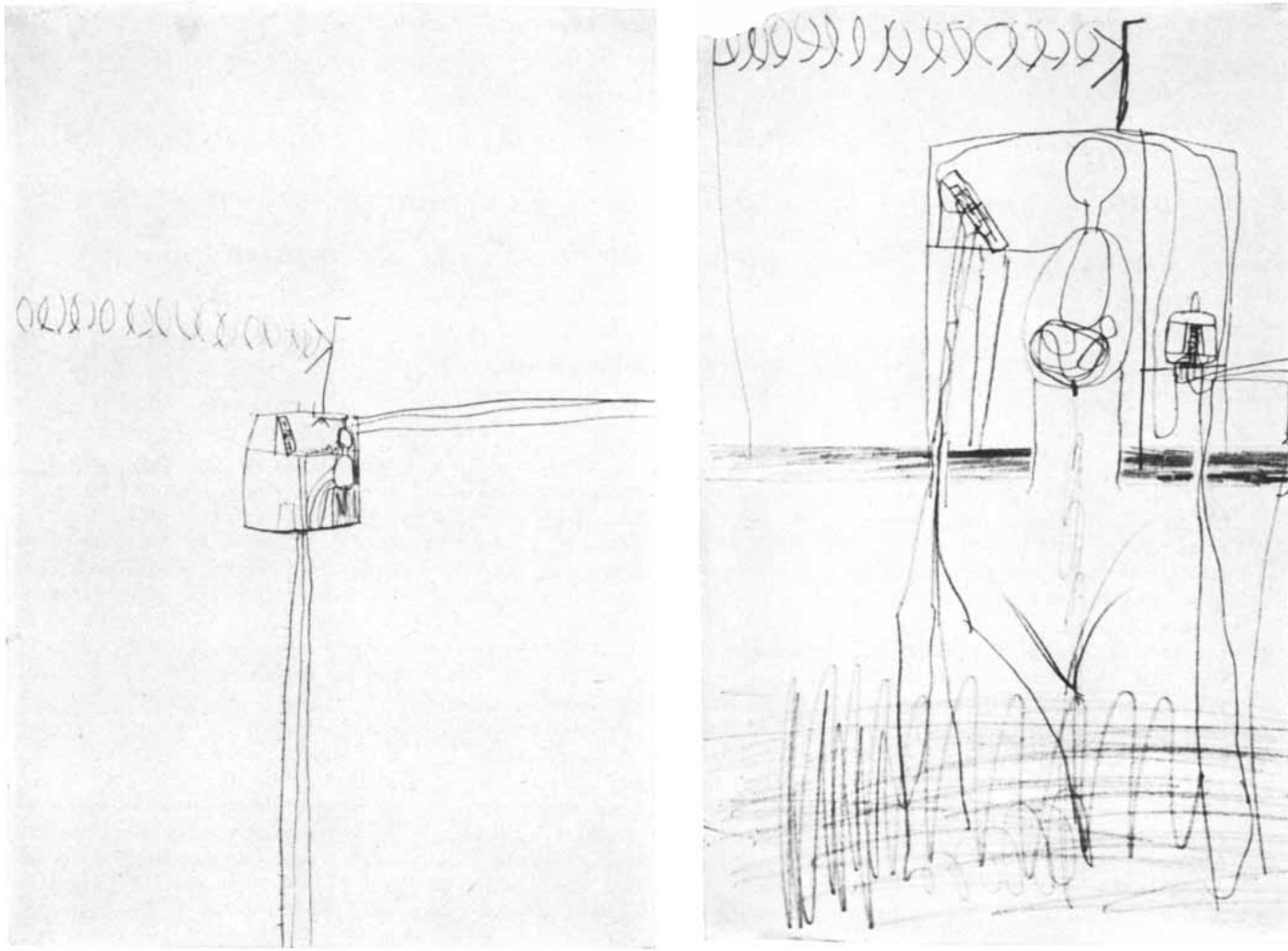
Joey's delusion is not uncommon among schizophrenic children today. He wanted to be rid of his unbearable humanity, to become completely automatic. He so nearly succeeded in attaining this goal that he could almost convince others, as well as himself, of his mechanical character. The descriptions of autistic children in the literature take for their point of departure and comparison the normal or abnormal human being. To do justice to Joey I would have to compare him simultaneously to a most inept infant and a highly complex piece of machinery. Often we had to force ourselves by a conscious act of will to realize that Joey was a child. Again and again his acting-out of his delusions froze our own ability to respond as human beings.

During Joey's first weeks with us we would watch absorbedly as this at once fragile-looking and imperious nine-year-old went about his mechanical existence. Entering the dining room, for example, he would string an imaginary wire from his "energy source"—an imaginary electric outlet—to the table. There he "insulated" himself with paper napkins and finally plugged himself in. Only then could Joey eat, for he firmly believed that the "current" ran his ingestive apparatus. So skillful was the pantomime that one had to look twice to be sure there was neither wire nor outlet nor plug. Children and members of our staff spontaneously avoided stepping on the "wires" for fear of interrupting what seemed the source of his very life.

For long periods of time, when his "machinery" was idle, he would sit so quietly that he would disappear from the focus of the most conscientious observation. Yet in the next moment he might be "working" and the center of our captivated attention. Many times a day he would turn himself on and shift noisily through a sequence of higher and higher gears until he "exploded," screaming "Crash, crash!" and hurling items from his ever present apparatus—radio tubes, light bulbs, even motors or, lacking these, any handy breakable object. (Joey had an astonishing knack for snatching bulbs and tubes unobserved.) As soon as the object thrown had shattered, he would cease his screaming and wild jumping and retire to mute, motionless nonexistence.

Our maids, inured to difficult children, were exceptionally attentive to Joey; they were apparently moved by his extreme infantile fragility, so strangely coupled with megalomaniacal superiority. Occasionally some of the apparatus he fixed to his bed to "live him" during his sleep would fall down in disarray. This machinery he contrived from masking tape, cardboard, wire and other paraphernalia. Usually the maids would pick up such things and leave them on a table for the children to find, or disregard them entirely. But Joey's machine they carefully restored: "Joey must have the carburetor so he can breathe." Similarly they were on the alert to pick up and preserve the motors that ran him during the day and the exhaust pipes through which he exhaled.

How had Joey become a human machine? From intensive interviews with his parents we learned that the process had begun even before birth. Schizo-



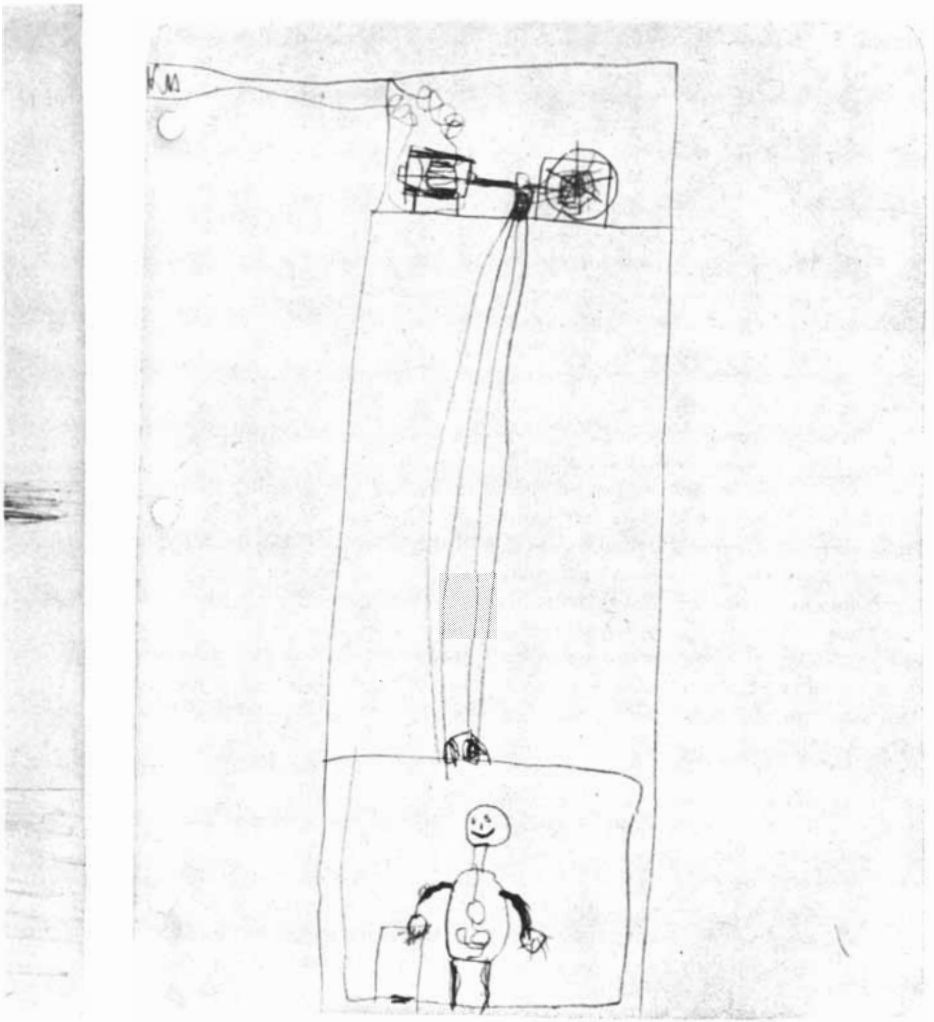
**GROWING SELF-ESTEEM** is shown in this sequence of drawings. At left Joey portrays himself as an electrical "papoose," completely enclosed, suspended in empty space and operated by wireless signals. In center drawing his figure is much larger, though

phrenia often results from parental rejection, sometimes combined ambivalently with love. Joey, on the other hand, had been completely ignored.

"I never knew I was pregnant," his mother said, meaning that she had already excluded Joey from her consciousness. His birth, she said, "did not make any difference." Joey's father, a rootless draftee in the wartime civilian army, was equally unready for parenthood. So, of course, are many young couples. Fortunately most such parents lose their indifference upon the baby's birth. But not Joey's parents. "I did not want to see or nurse him," his mother declared. "I had no feeling of actual dislike—I simply didn't want to take care of him." For the first three months of his life Joey "cried most of the time." A colicky baby, he was kept on a rigid four-hour feeding schedule, was not touched unless necessary and was never cuddled or played with. The mother, preoccupied with herself, usually left Joey alone in the crib or playpen during the day. The father discharged his frustrations by punishing Joey when the child cried at night.

Soon the father left for overseas duty, and the mother took Joey, now a year and a half old, to live with her at her parents' home. On his arrival the grandparents noticed that ominous changes had occurred in the child. Strong and healthy at birth, he had become frail and irritable; a responsive baby, he had become remote and inaccessible. When he began to master speech, he talked only to himself. At an early date he became preoccupied with machinery, including an old electric fan which he could take apart and put together again with surprising deftness.

Joey's mother impressed us with a fey quality that expressed her insecurity, her detachment from the world and her low physical vitality. We were struck especially by her total indifference as she talked about Joey. This seemed much more remarkable than the actual mistakes she made in handling him. Certainly he was left to cry for hours when hungry, because she fed him on a rigid schedule; he was toilet-trained with great rigidity so that he would give no trouble. These things happen to many children. But Joey's existence never registered with his mother. In her recollections he was fused at one moment with one event or person; at another, with something or somebody else. When she told us about his birth and infancy, it was as if she were talking about some vague acquaintance, and soon her thoughts would wander off to another person or to herself.



still under wireless control. At right he is able to picture the machine which controls him, and he has acquired hands with which he can manipulate his immediate environment.

When Joey was not yet four, his nursery school suggested that he enter a special school for disturbed children. At the new school his autism was immediately recognized. During his three years there he experienced a slow improvement. Unfortunately a subsequent two years in a parochial school destroyed this progress. He began to develop compulsive defenses, which he called his "preventions." He could not drink, for example, except through elaborate piping systems built of straws. Liquids had to be "pumped" into him, in his fantasy, or he could not suck. Eventually his behavior became so upsetting that he could not be kept in the parochial school. At home things did not improve. Three months before entering the Orthogenic School he made a serious attempt at suicide.

To us Joey's pathological behavior seemed the external expression of an overwhelming effort to remain almost nonexistent as a person. For weeks Joey's only reply when addressed was "Bam." Unless he thus neutralized whatever we said, there would be an explosion, for Joey plainly wished to close off every form of contact not mediated by machinery. Even when he was bathed he rocked back and forth with mute, engine-like regularity, flooding the bathroom. If he stopped rocking, he did this like a machine too; suddenly he went completely rigid. Only once, after months of being lifted from his bath and carried to bed, did a small expression of puzzled pleasure appear on his face as he said very softly: "They even carry you to your bed here."

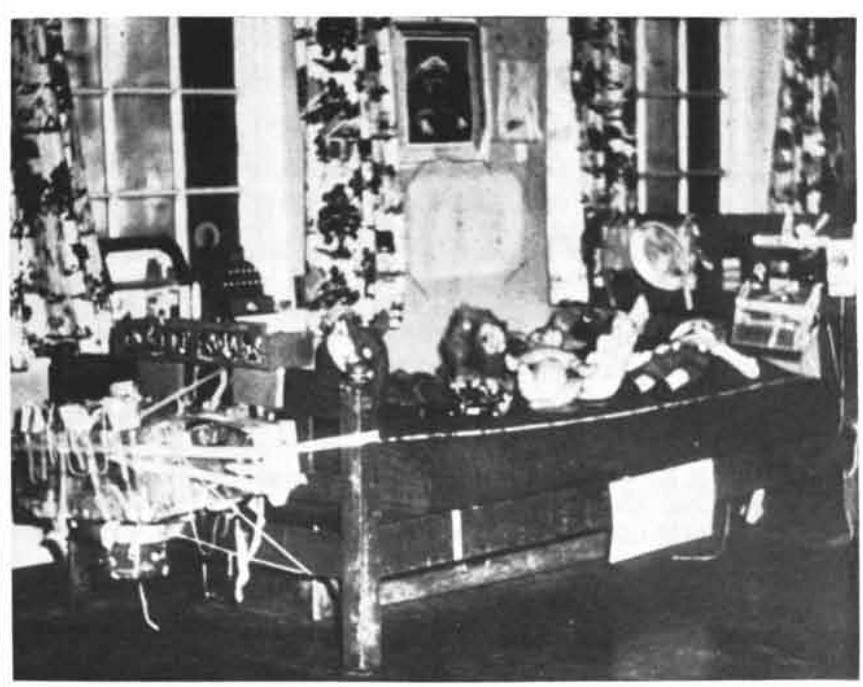
For a long time after he began to talk he would never refer to anyone by name, but only as "that person" or "the little person" or "the big person." He was un-

able to designate by its true name anything to which he attached feelings. Nor could he name his anxieties except through neologisms or word contaminations. For a long time he spoke about "master paintings" and "a master painting room" (*i.e.*, masturbating and masturbating room). One of his machines, the "criticizer," prevented him from "saying words which have unpleasant feelings." Yet he gave personal names to the tubes and motors in his collection of machinery. Moreover, these dead things had feelings; the tubes bled when hurt and sometimes got sick. He consistently maintained this reversal between animate and inanimate objects.

In Joey's machine world everything, on pain of instant destruction, obeyed inhibitory laws much more stringent than those of physics. When we came to know him better, it was plain that in his moments of silent withdrawal, with his machine switched off, Joey was absorbed in pondering the compulsive laws of his private universe. His preoccupation with machinery made it difficult to establish even practical contacts with him. If he wanted to do something with a counselor, such as play with a toy that had caught his vague attention, he could not do so: "I'd like this very much, but first I have to turn off the machine." But by the time he had fulfilled all the requirements of his preventions, he had lost interest. When a toy was offered to him, he could not touch it because his motors and his tubes did not leave him a hand free. Even certain colors were dangerous and had to be strictly avoided in toys and clothing, because "some colors turn off the current, and I can't touch them because I can't live without the current."

Joey was convinced that machines were better than people. Once when he bumped into one of the pipes on our jungle gym he kicked it so violently that his teacher had to restrain him to keep him from injuring himself. When she explained that the pipe was much harder than his foot, Joey replied: "That proves it. Machines are better than the body. They don't break; they're much harder and stronger." If he lost or forgot something, it merely proved that his brain ought to be thrown away and replaced by machinery. If he spilled something, his arm should be broken and twisted off because it did not work properly. When his head or arm failed to work as it should, he tried to punish it by hitting it. Even Joey's feelings were mechanical. Much later in his therapy, when he had formed a timid attachment to another child and had been rebuffed, Joey cried: "He broke my feelings."

Gradually we began to understand what had seemed to be contradictory in Joey's behavior—why he held on to the motors and tubes, then suddenly de-



**MACHINE-LIKE CONSTRUCTIONS controlled Joey's life. Shown here is the apparatus he built to "live him" as he slept. Other "machines" controlled his eating and elimination.**


# *Corrosion from boiling mineral acids?*

## TEST "HAYNES" ALLOYS

The low corrosion rates on the test specimen indicate the remarkable resistance of HAYNES alloys to mineral acids . . . even at the boiling point. These alloys reduce corrosion damage and product contamination from mineral acids at all temperatures. You will find, too, that they have outstanding resistance to chlorides, halogens, mixed acids, and alkalies.

The penetration rates shown on the disks were obtained as a result of laboratory tests. How closely will they match up with data obtained under actual operating conditions? You can find out for sure by testing them.

We'll be glad to send you samples. But to narrow down the number, we suggest you send us a letter outlining your corrosion problem. For full information on HAYNES corrosion-resistant alloys, their properties, forms, the corrosives they will resist, ask for a copy of our 104-page book.

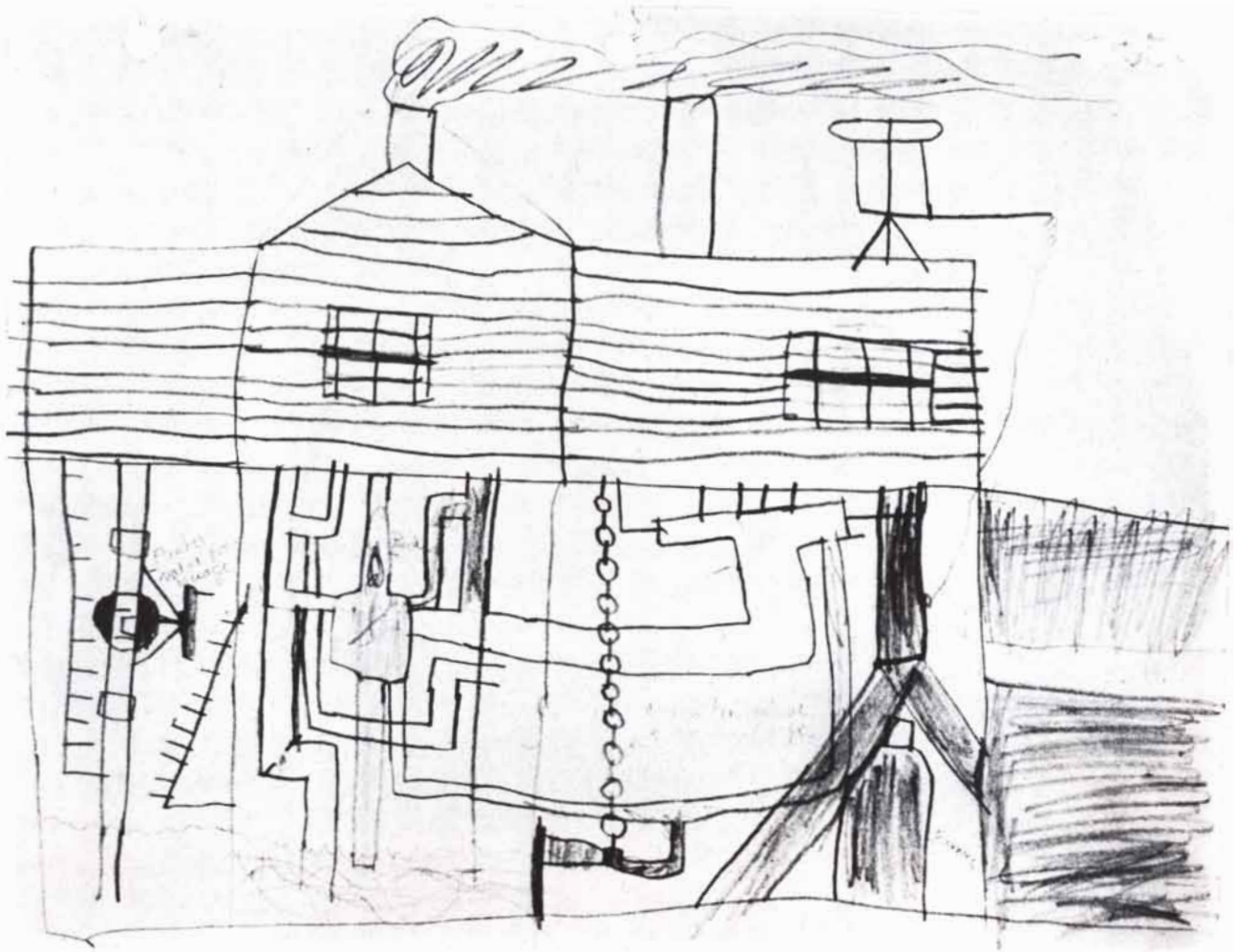

**HAYNES ALLOYS**

**HAYNES STELLITE COMPANY**

*Division of*
*Union Carbide Corporation*
Kokomo, Indiana

UNION CARBIDE

The terms "Haynes" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.



**ELABORATE SEWAGE SYSTEM in Joey's drawing of a house reflects his long preoccupation with excretion. His obsession with sewage reflected intense anxieties produced by his early toilet-training, which was not only rigid but also completely impersonal.**

stroyed them in a fury, then set out immediately and urgently to equip himself with new and larger tubes. Joey had created these machines to run his body and mind because it was too painful to be human. But again and again he became dissatisfied with their failure to meet his need and rebellious at the way they frustrated his will. In a recurrent frenzy he "exploded" his light bulbs and tubes, and for a moment became a human being—for one crowning instant he came alive. But as soon as he had asserted his dominance through the self-created explosion, he felt his life ebbing away. To keep on existing he had immediately to restore his machines and replenish the electricity that supplied his life energy.

What deep-seated fears and needs underlay Joey's delusional system? We were long in finding out, for Joey's preventions effectively concealed the secret of his autistic behavior. In the meantime we dealt with his peripheral problems one by one.

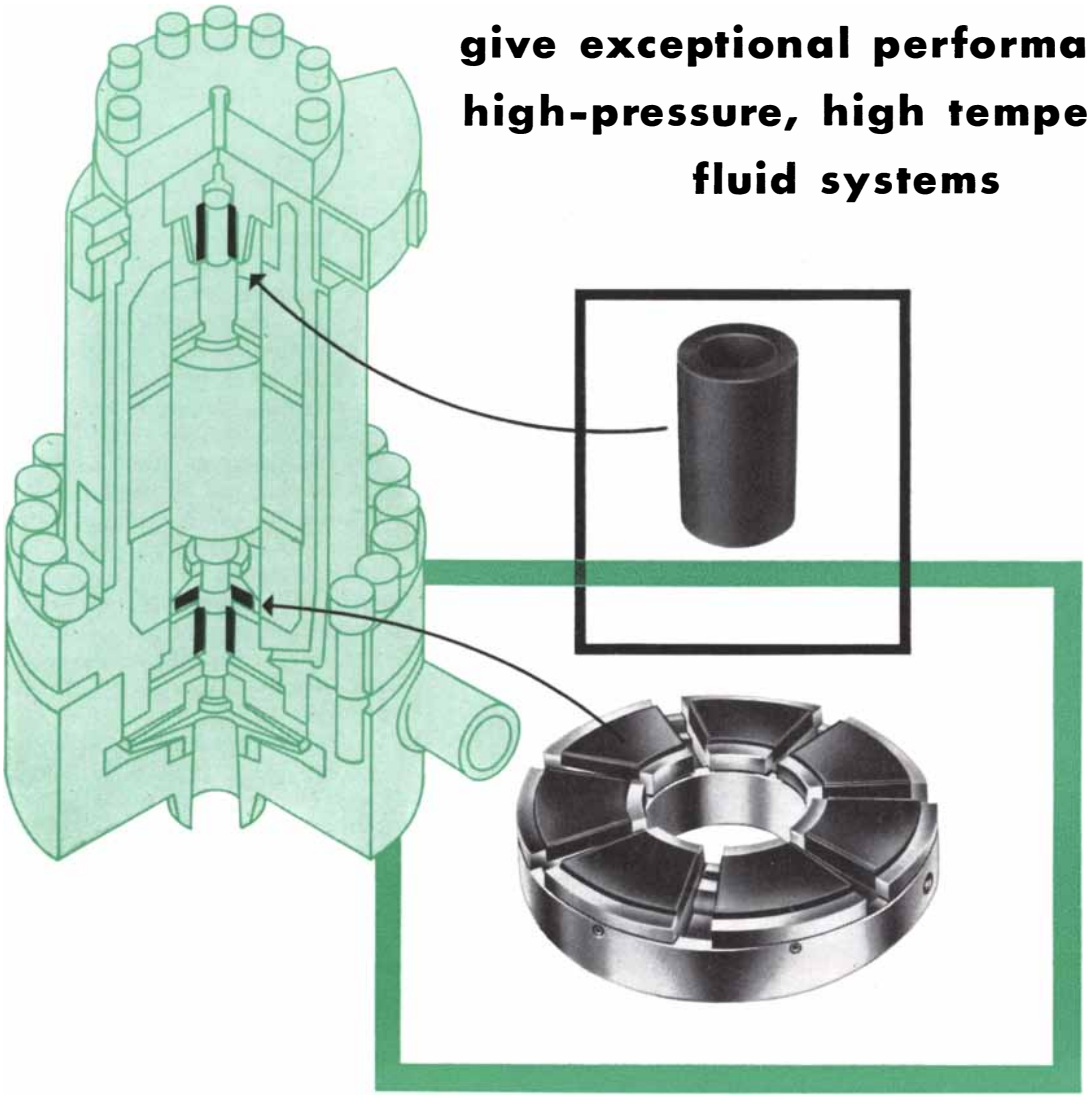
During his first year with us Joey's most trying problem was toilet behavior. This surprised us, for Joey's personality was not "anal" in the Freudian sense; his original personality damage had antedated the period of his toilet-training. Rigid and early toilet-training, however, had certainly contributed to his anxieties. It was our effort to help Joey with this problem that led to his first recognition of us as human beings.

Going to the toilet, like everything else in Joey's life, was surrounded by elaborate preventions. We had to accompany him; he had to take off all his clothes; he could only squat, not sit, on the toilet seat; he had to touch the wall with one hand, in which he also clutched frantically the vacuum tubes that powered his elimination. He was terrified lest his whole body be sucked down.

To counteract this fear we gave him a metal wastebasket in lieu of a toilet. Eventually, when eliminating into the wastebasket, he no longer needed to take off all his clothes, nor to hold on to the wall. He still needed the tubes and motors which, he believed, moved his bowels for him. But here again the all-important machinery was itself a source of new terrors. In Joey's world the gadgets had to move their bowels, too. He was terribly concerned that they should, but since they were so much more powerful than men, he was also terrified that if his tubes moved their bowels, their feces would fill all of space and leave him no room to live. He was thus always caught in some fearful contradiction.

Our readiness to accept his toilet habits, which obviously entailed some hardship for his counselors, gave Joey the confidence to express his obsessions in drawings. Drawing these fantasies was a first step toward letting us in, however

# water-lubricated GRAPHITAR®
(CARBON-GRAPHITE)
# bearings in "canned" motor pumps give exceptional performance in high-pressure, high temperature fluid systems

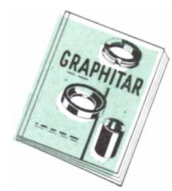


Special hermetically sealed motor-pumps, known also as "canned" motor pumps, were developed by Westinghouse Electric Corporation to handle radioactive water with zero leakage. These same pumps have proven a convenient means of pumping high temperature fluids for a number of nuclear reactors and other 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.**



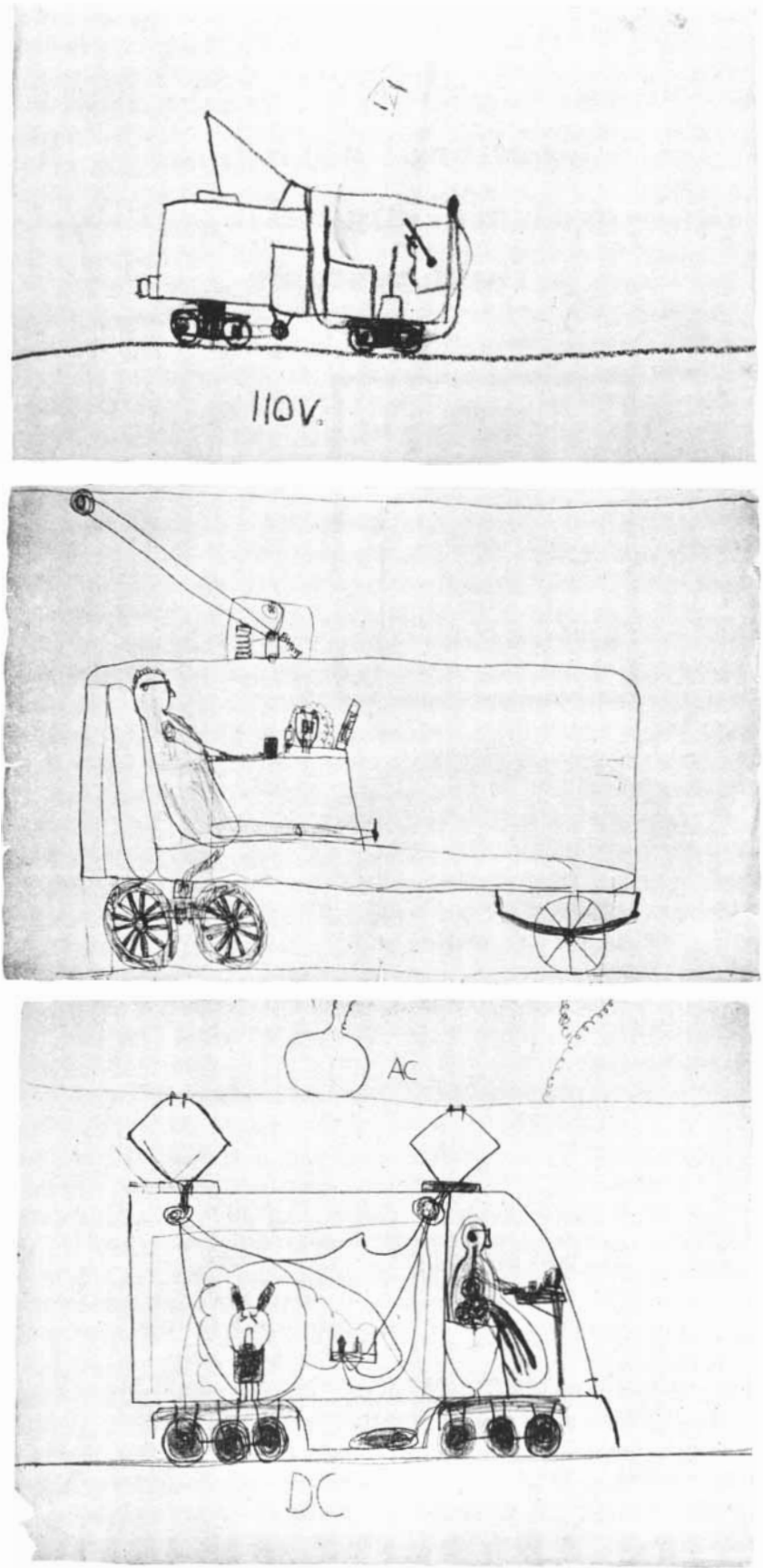

R-266-1

# 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

123



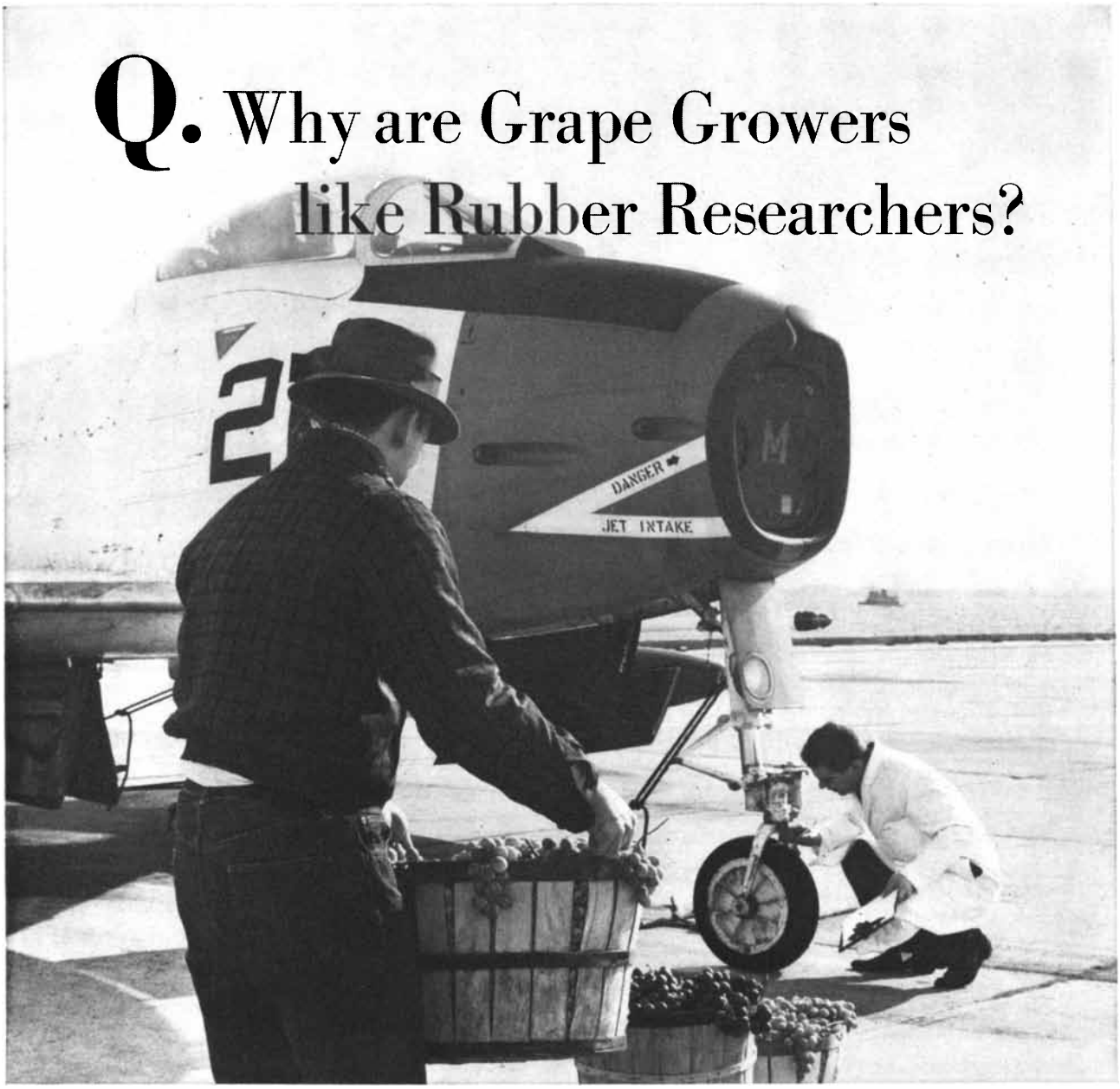

**GROWING AUTONOMY is shown in Joey's drawings of the imaginary "Carr" (car) family. Top drawing shows a machine which can move but is unoccupied. Machine in center is occupied, but by a passive figure. In bottom drawing figure has gained control of machine.**

distantly, to what concerned him most deeply. It was the first step in a year-long process of externalizing his anal preoccupations. As a result he began seeing feces everywhere; the whole world became to him a mire of excrement. At the same time he began to eliminate freely wherever he happened to be. But with this release from his infantile imprisonment in compulsive rules, the toilet and the whole process of elimination became less dangerous. Thus far it had been beyond Joey's comprehension that anybody could possibly move his bowels without mechanical aid. Now Joey took a further step forward; defecation became the first physiological process he could perform without the help of vacuum tubes. It must not be thought that he was proud of this ability. Taking pride in an achievement presupposes that one accomplishes it of one's own free will. He still did not feel himself an autonomous person who could do things on his own. To Joey defecation still seemed enslaved to some incomprehensible but utterly binding cosmic law, perhaps the law his parents had imposed on him when he was being toilet-trained.

It was not simply that his parents had subjected him to rigid, early training. Many children are so trained. But in most cases the parents have a deep emotional investment in the child's performance. The child's response in turn makes training an occasion for interaction between them and for the building of genuine relationships. Joey's parents had no emotional investment in him. His obedience gave them no satisfaction and won him no affection or approval. As a toilet-trained child he saved his mother labor, just as household machines saved her labor. As a machine he was not loved for his performance, nor could he love himself.

So it had been with all other aspects of Joey's existence with his parents. Their reactions to his eating or noneating, sleeping or wakening, urinating or defecating, being dressed or undressed, washed or bathed did not flow from any unitary interest in him, deeply embedded in their personalities. By treating him mechanically his parents made him a machine. The various functions of life—even the parts of his body—bore no integrating relationship to one another or to any sense of self that was acknowledged and confirmed by others. Though he had acquired mastery over some functions, such as toilet-training and speech, he had acquired them sepa-

# Q. Why are Grape Growers like Rubber Researchers?




**A.** ***Exciting advances in both fields are directly related to chemical progress pioneered by Merck.*** Thanks to GIBREL®—Merck's new plant growth stimulant—grape growers are able to increase berry size and crop yield by as much as 50%. Farmers everywhere are vitally interested in more efficient crop production with GIBREL. Its "vitamin-like" action triggers normal growth in many plants by supplementing the growth-promoting substances naturally found in plants.

Another Merck chemical, MAGLITE® Y, meets the special processing requirements of the rubber industry's most important new synthetic—a heat-resistant elastomer with promising applications in jet aircraft tires and other rubber products that must perform under extremely high temperatures. A reactive magnesium oxide, MAGLITE is also available in D, K and M grades that are particularly well suited for various product or processing needs of many different elastomers.

MAGLITE and GIBREL are representative of Merck research and production that speed progress in nearly every field served by chemistry. For technical information bulletins on either product write to Department SA-1

**MERCK & CO., INC.** • Chemical Division • **Rahway, New Jersey**

**GENTLE LANDSCAPE painted by Joey after his recovery symbolizes the human emotions he had regained. At 12, having learned to express his feelings, he was no longer a machine.**

rately and kept them isolated from each other. Toilet-training had thus not gained him a pleasant feeling of body mastery; speech had not led to communication of thought or feeling. On the contrary, each achievement only steered him away from self-mastery and integration. Toilet-training had enslaved him. Speech left him talking in neologisms that obstructed his and our ability to relate to each other. In Joey's development the normal process of growth had been made to run backward. Whatever he had learned put him not at the end of his infantile development toward integration but, on the contrary, farther behind than he was at its very beginning. Had we understood this sooner, his first years with us would have been less baffling.

It is unlikely that Joey's calamity could befall a child in any time and culture but our own. He suffered no physical deprivation; he starved for human contact. Just to be taken care of is not enough for relating. It is a necessary but not a sufficient condition. At the extreme where utter scarcity reigns, the forming of relationships is certainly hampered. But our society of mechanized plenty often makes for equal difficulties in a child's learning to relate. Where parents can provide the simple creature-comforts for their children only at the cost of significant effort, it is likely that they will feel pleasure in being able to provide for them; it is this, the parents' pleasure, that gives children a sense of personal worth and sets the process of relating in motion. But if comfort is so readily available that the parents feel no particular pleasure in winning it for their children, then the children cannot develop the feeling of being worthwhile around the satisfaction of their basic needs. Of course parents and children can and do develop relationships around other situations. But matters are then no longer so simple and direct. The child must be on the receiving end of care and concern given with pleasure and without the exaction of return if he is to feel loved and worthy of respect and consideration. This feeling gives him the ability to trust; he can entrust his well-being to persons to whom he is so important. Out of such trust the child learns to form close and stable relationships.

For Joey relationship with his parents was empty of pleasure in comfort-giving as in all other situations. His was an extreme instance of a plight that sends many schizophrenic children to our clinics and hospitals. Many months passed before he could relate to us; his despair that anybody could like him made contact impossible.

When Joey could finally trust us enough to let himself become more infantile, he began to play at being a papoose. There was a corresponding change in his fantasies. He drew endless pictures of himself as an electrical papoose. Totally enclosed, suspended in empty space, he is run by unknown, unseen powers through wireless electricity

[*see illustration at left on pages 118 and 119*].

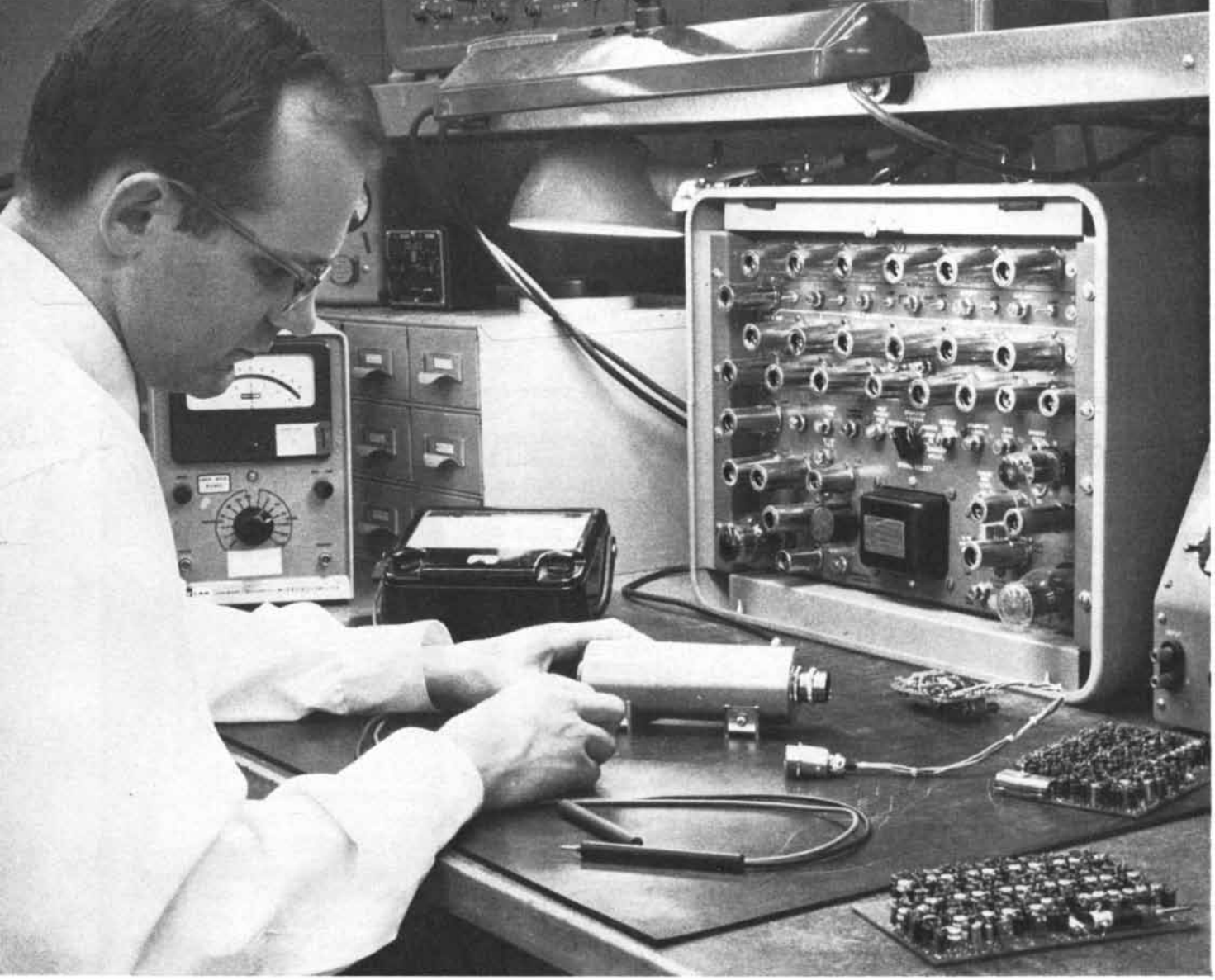
As we eventually came to understand, the heart of Joey's delusional system was the artificial, mechanical womb he had created and into which he had locked himself. In his papoose fantasies lay the wish to be entirely reborn in a womb. His new experiences in the school suggested that life, after all, might be worth living. Now he was searching for a way to be reborn in a better way. Since machines were better than men, what was more natural than to try rebirth through them? This was the deeper meaning of his electrical papoose.

As Joey made progress, his pictures of himself became more dominant in his drawings. Though still machine-operated, he has grown in self-importance [*see middle illustration on pages 118 and 119*]. Another great step forward is represented in the picture at right on the same two pages. Now he has acquired hands that do something, and he has had the courage to make a picture of the machine that runs him. Later still the papoose became a person, rather than a robot encased in glass.

Eventually Joey began to create an imaginary family at the school: the "Carr" family. Why the Carr family? In the car he was enclosed as he had been in his papoose, but at least the car was not stationary; it could move. More important, in a car one was not only driven but also could drive. The Carr family was Joey's way of exploring the possibility of leaving the school, of living with a good family in a safe, protecting car [*see illustrations on page 124*].

Joey at last broke through his prison. In this brief account it has not been possible to trace the painfully slow process of his first true relations with other human beings. Suffice it to say that he ceased to be a mechanical boy and became a human child. This newborn child was, however, nearly 12 years old. To recover the lost time is a tremendous task. That work has occupied Joey and us ever since. Sometimes he sets to it with a will; at other times the difficulty of real life makes him regret that he ever came out of his shell. But he has never wanted to return to his mechanical life.

One last detail and this fragment of Joey's story has been told. When Joey was 12, he made a float for our Memorial Day parade. It carried the slogan: "Feelings are more important than anything under the sun." Feelings, Joey had learned, are what make for humanity; their absence, for a mechanical existence. With this knowledge Joey entered the human condition.



# ELECTRONICS / EXPANDING THE FRONTIERS

Significant contributions to the advancement of the state of the art in electronics have been made by Lockheed engineers and scientists. As manager of important missile and weapon systems, the Division has solved a variety of problems in the electronics field. These include: computer development; telemetry; radar and data link; transducers and instrumentation; microwave devices; antennas and electromagnetic propagation and radiation; ferrite and MASER research; solid state electronics, including devices, electro-chemistry, infrared and optics; and data reduction and analysis.

Over one-fifth of the nation's missile-borne telemetering equipment was produced by Lockheed last year. Its PAM/FM miniaturized system provides increased efficiency at one-fourth the weight of FM/FM missile-borne systems.

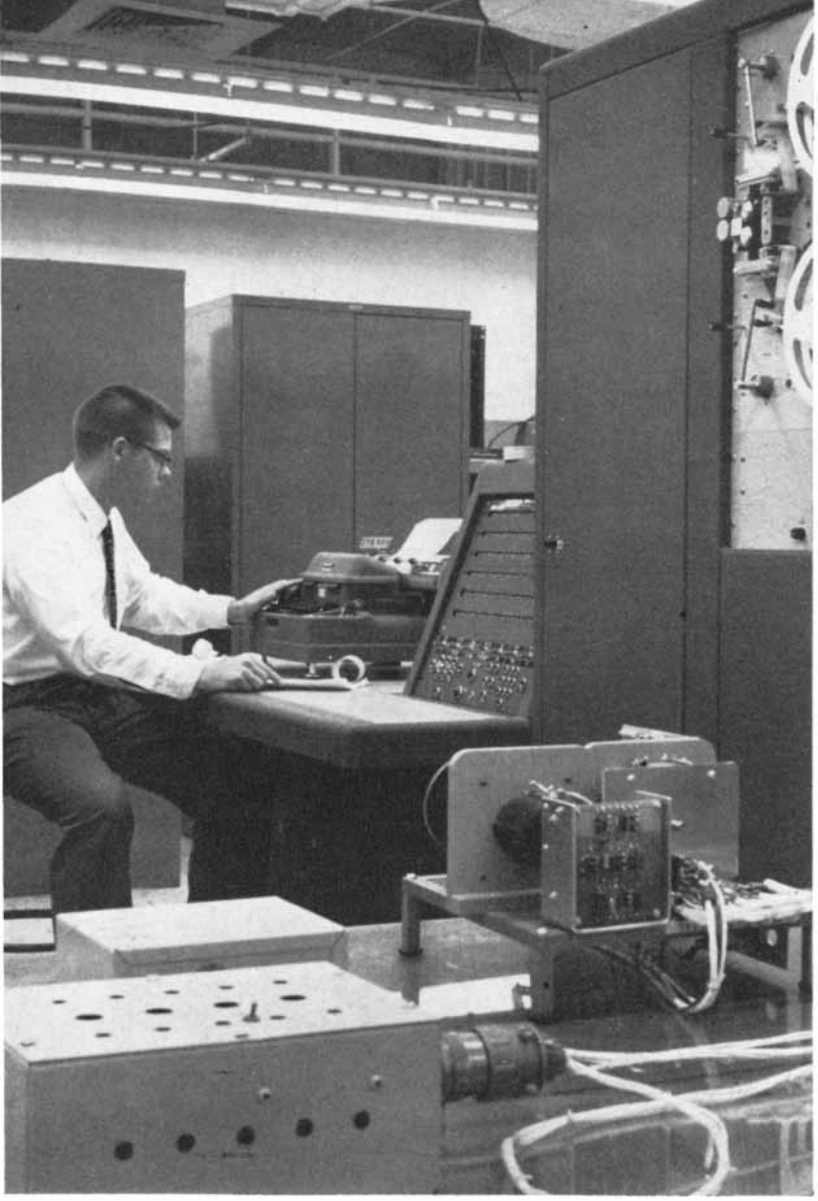
Advanced development work in high-energy batteries and fuel cells has resulted in a method for converting chemical energy directly into electrical power that promises a fuel utilization of almost 100% and an energy conversion efficiency of 70% or better.

Areas of special capability in computer development include the design of large scale data handling systems; development of special purpose digital computing and analog-digital conversion devices; development of high speed input-output equipment; and advanced research in computer technology, pattern recognition, self-organizing machines, and information retrieval.

Other major developments are: a digital flight data recorder able to record each of 24 channels every few seconds; digital telemetry conversion equipment to reduce telemetered test data to plotted form rapidly and inexpensively; advancements in the theory of sequential machines; and a high speed digital plotter that can handle some four thousand points per second with the finished plot programmed into the data tape as a continuous curve.

Lockheed Missiles and Space Division is engaged in all fields of the art—from concept to operation. Its programs reach far into the future and deal with unknown environments. It is a rewarding future which scientists and engineers of outstanding talent and inquiring mind are invited to share. Write: Research and Development Staff, Dept. C-36, 962 W. El Camino Real, Sunnyvale, California.

*"The organization that contributed most in the past year to the advancement of the art of missiles and astronautics"*—NATIONAL MISSILE INDUSTRY CONFERENCE AWARD.



*(top left)* 6″ miniaturized TV camera, a Lockheed first in both the missile and television fields.

*(top right)* Automatic Checkout and Readiness Equipment ("ACRE") system developed by Lockheed combines outstanding performance at lowest cost in the industry. It includes internal, stored programs; magnetic drum memory and internal self-verification and has wide commercial application as well as for weapons systems.

*(below)* The Division's $3,500,000 advanced computer center is the most modern in the world. Equipment includes 8 analog computers and 2 Univac 1103A digital computers with complete support equipment.

## OF SPACE TECHNOLOGY

# *Lockheed*

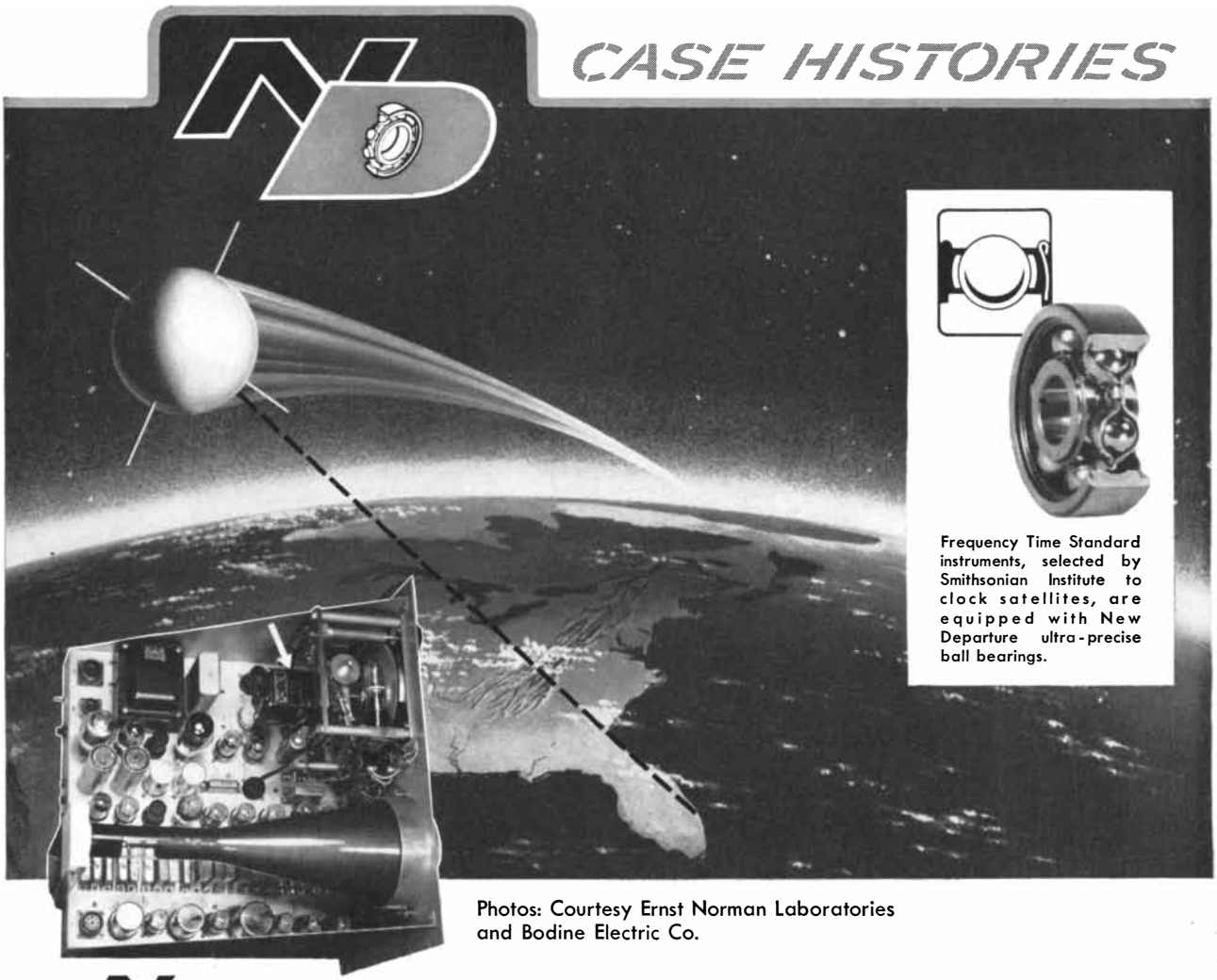
## MISSILES AND SPACE DIVISION

SUNNYVALE, PALO ALTO, VAN NUYS,

SANTA CRUZ, SANTA MARIA, CALIFORNIA

CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO

CASE HISTORIES





Frequency Time Standard instruments, selected by Smithsonian Institute to clock satellites, are equipped with New Departure ultra-precise ball bearings.

Photos: Courtesy Ernst Norman Laboratories and Bodine Electric Co.

# Ultra Precise Ball Bearings Help "Clock" A Satellite!

**CUSTOMER PROBLEM:**

Require ultra-precise bearing design for Bodine electric motor used in satellite-tracking micro-clock. Bearings must provide uniformly low starting torque, precise location of rotor shaft and minimum maintenance, to help mechanism achieve time determinations to 0.001 second.

**SOLUTION:**

N/D Sales Engineers studied special bearing requirements, and recommended New Departure ultra-precise ball bearings. These ball bearings measured up to every requirement for micro-clock motors . . . thanks to New Departure's advanced equipment for research, development and production. N/D equipped micro-clocks, selected by the Smithsonian Institute, are operating in a dozen locations around the world right now, keeping track of vital satellite movements . . . to accuracies of one millisecond and better!

If you're manufacturing or designing electric motors for any high precision applications, including instruments, why not call on New Departure? N/D engineering and research facilities are turning out the latest in high precision instrument ball bearings and advanced ball bearing designs. For more information write Department B-3.

NEW DEPARTURE

DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

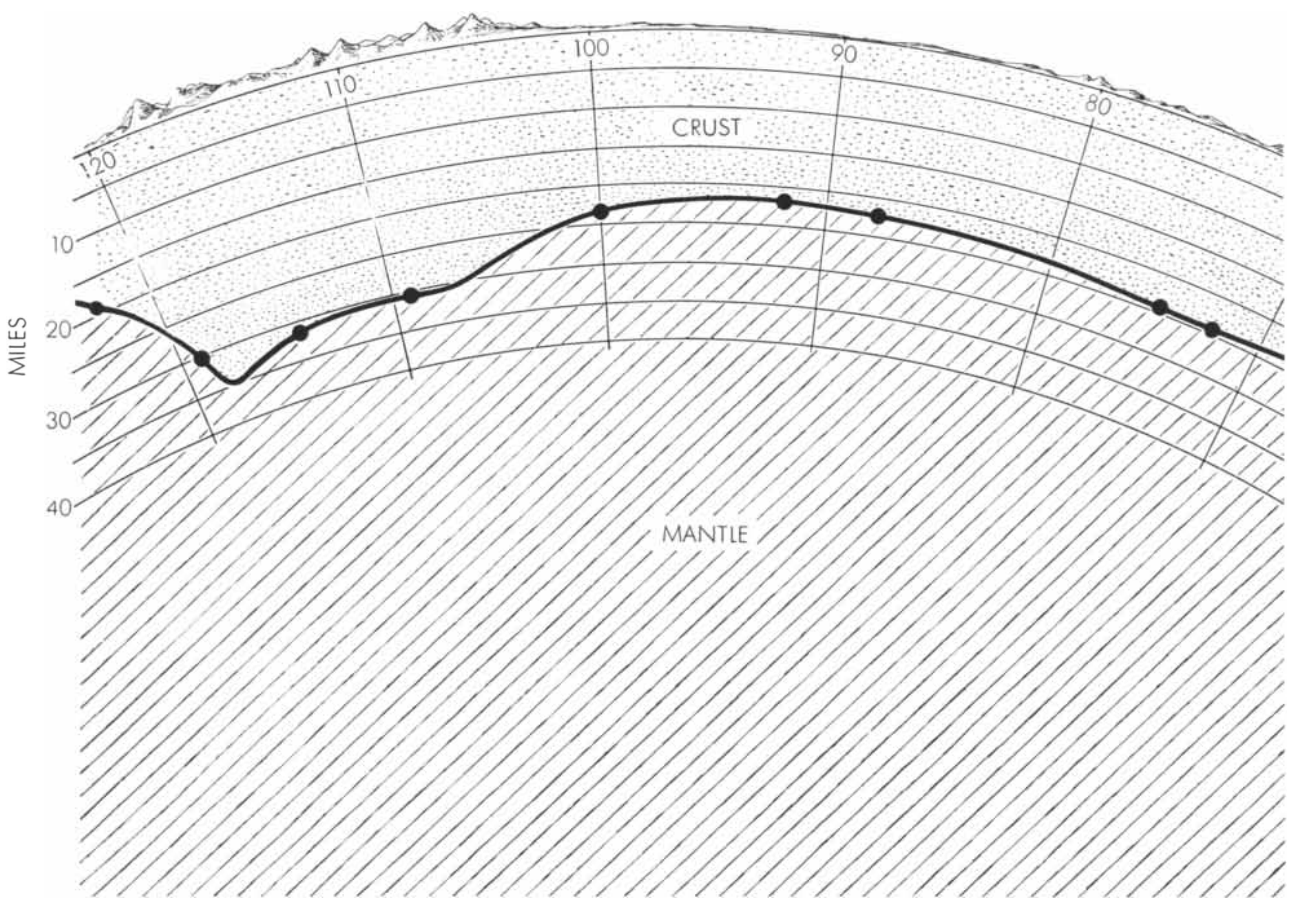
NOTHING ROLLS LIKE A BALL

# LONG EARTHQUAKE WAVES

## Seismologists are tuning their instruments to record earth motions with periods of one minute to an hour and amplitudes of less than .01 inch. These waves tell much about the earth's crust and mantle

by Jack Oliver

The hi-fi enthusiast who has struggled to improve the response of his equipment in the bass range at around 20 cycles per second will have a fellow-feeling for the seismologist who is attempting to tune his instruments to the longest earthquake waves. But where hi-fi deals in cycles per second, seismology measures its frequencies in seconds per cycle. A relatively short earthquake wave has a duration of 10 seconds. At present the most informative long waves have periods of 15 to 75 seconds from crest to crest. With more advanced instruments seismologists hope soon to study 450-second waves. The longest so far detected had a period of 3,400 seconds—nearly an hour! Since these long earthquake waves travel at .9 to 2.8 miles per second, they range in length from 10 miles up to the 8,000-mile length of the earth's diameter. Their amplitude, however, is of an entirely different order: one of these waves displaces a point on the surface of the earth at some distance from the shock by no more than a hundredth of an inch, even when excited by



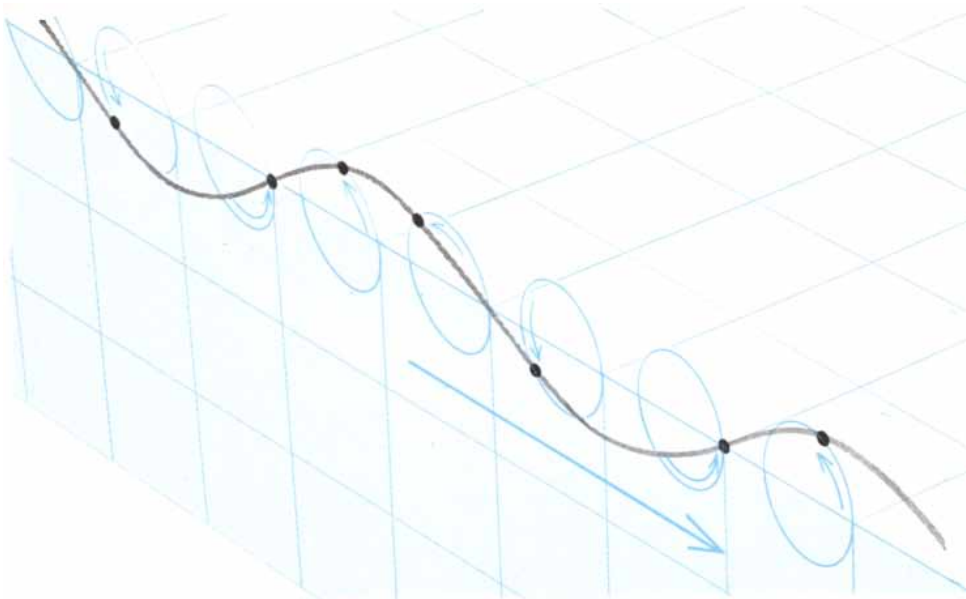

**SUBTERRANEAN TOPOGRAPHY** of the North American continent is being plotted by study of surface earthquake waves, which reveal boundary between the crust and the mantle. The heavy black curve traces this boundary. The dots on the curve are the points at which the depth of the boundary was established. The surface of the earth is curved in the scale of the diagram. The vertical scale of the topography and of the crust and mantle below, however, are exaggerated 20 times. The numbers at top are degrees of longitude.

earthquakes of the greatest magnitude. To measure such a small motion that takes such a long time presents one of the most challenging tasks of instrumentation to be encountered anywhere in modern science.

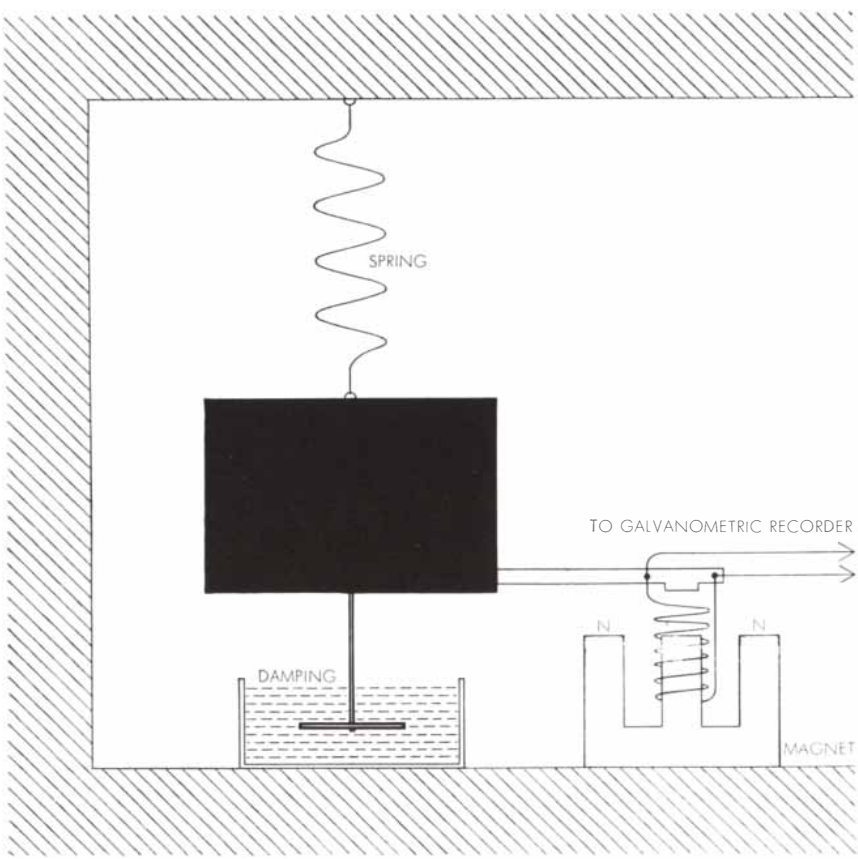
The seismologist has important reasons for going to all this trouble—in contrast, perhaps, to the true votary of hi-fi who regards frequencies as ends in themselves. From the shorter-period seismic waves that travel through the interior of the earth we have developed a remarkably full picture of the structure of our planet. These "body waves" have distinguished the concentric spheres of the earth's crust, mantle and core, and have given us a measure of the densities and the states of matter that prevail under the ascending pressures toward the earth's center. Now the long waves are adding a new dimension to our knowledge. They are surface waves, analogous to the ripples on the surface of a pond, which radiate from the center of a disturbance. Although only a few observatories are equipped to record them well, the long waves have already helped to establish one of the most significant facts we know about our planet. Under the continents the earth's crust reaches down to depths of 25 miles; under the oceans the crust is but three or four miles thick. Thus the boundary between crust and mantle, the so-called Mohorovicic discontinuity, lies only 9 or 10 miles below the surface of the ocean, and the "inside" of the earth is closer to the surface than we had thought [*see illustration on page 137*].

So far as we know all major earthquakes are associated with the rupturing or faulting of the rock in the crust or mantle. Except in the very strongest shocks the rupturing process takes but a few seconds and occurs along a fault line only 10 or 20 miles in length. The original disturbance is limited in space and time, yet it excites vibrations in a wide spectrum of wavelengths throughout the entire earth. The body waves, which penetrate deep into the earth and return to the surface bearing information about the interior, are of two types. One is the compression (P) wave, in which the particle motion is in the direction of the wave; the other is the shear (S) wave, in which the motion is at right angles to the line of travel. The fact that the core does not transmit this second wave constitutes the principal evidence for the idea that its structure is nonrigid or "liquid."

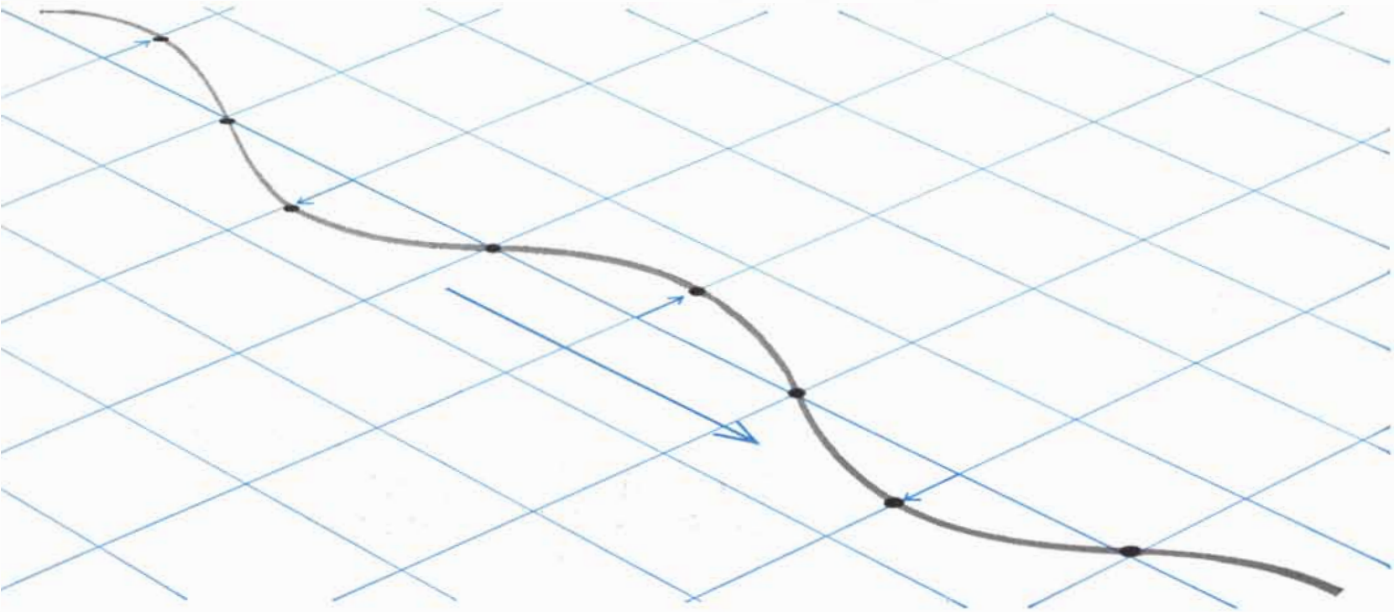
The surface waves are also of two



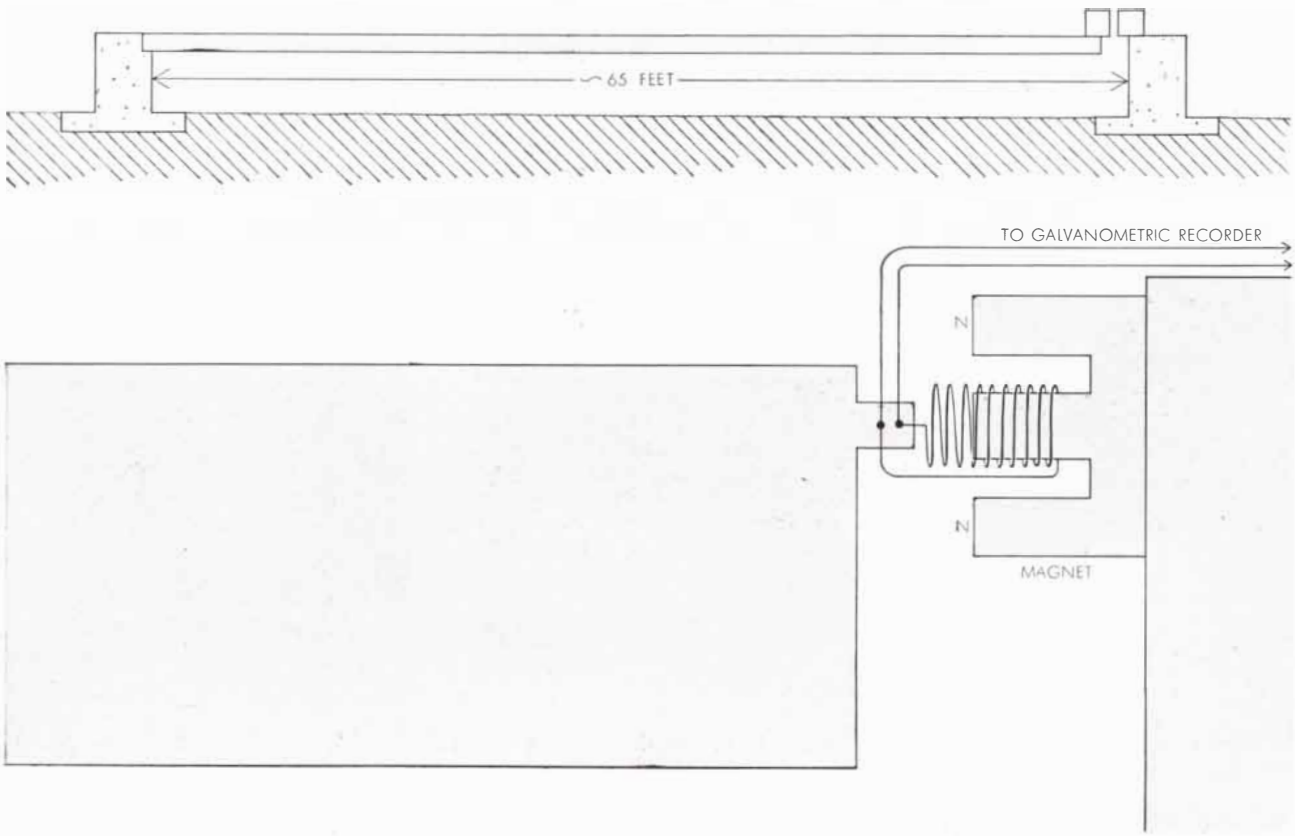
**SEISMIC SURFACE WAVES are of two kinds, the Rayleigh wave (*above*) and the Love wave (*opposite page*). The Rayleigh wave moves in the vertical plane like a ripple, as shown**




**SEISMOMETERS are of two types, the inertial seismometer (*above*) and the strain-gauge seismometer (*opposite page*). The inertial instrument measures the motion of the earth with**

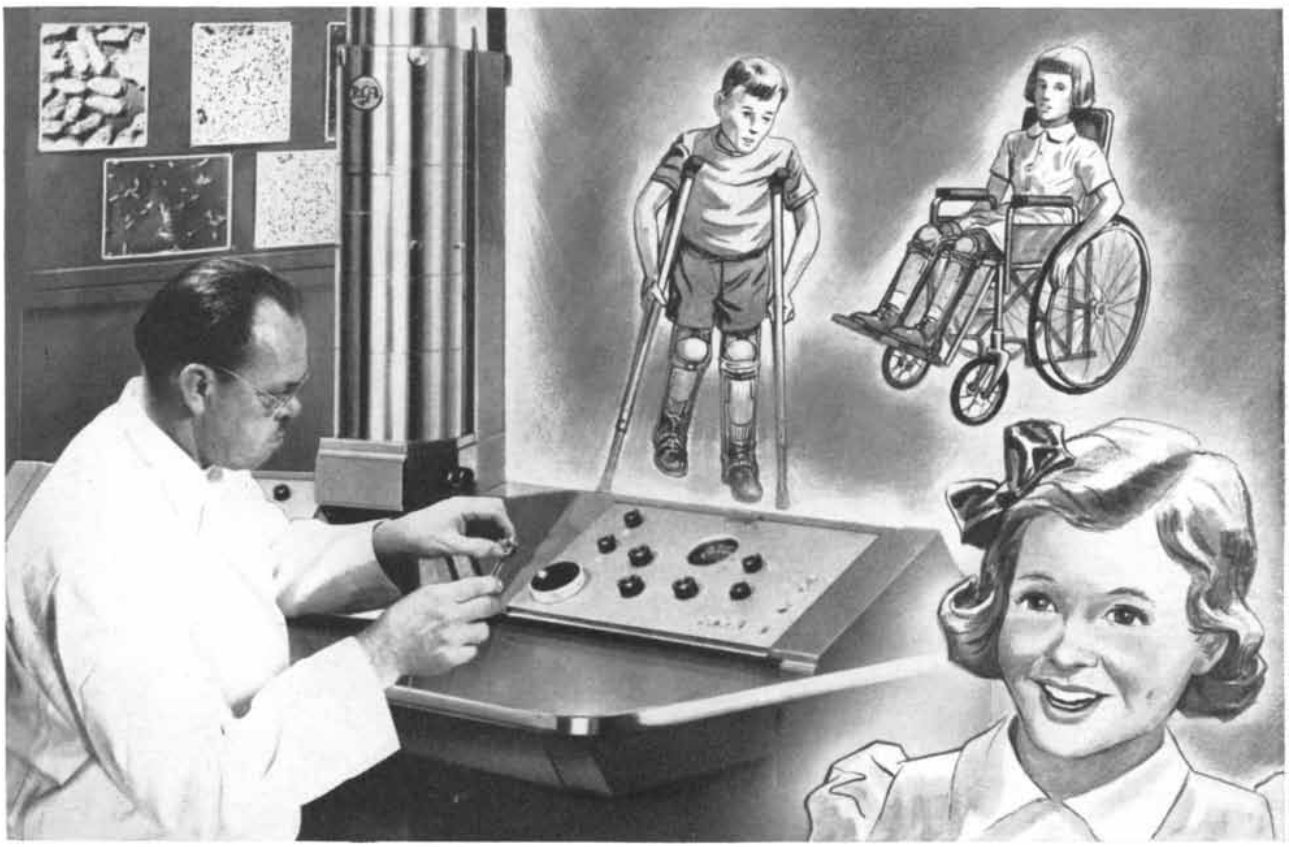


by the gray line. The black dots on the ellipses show the retrograde motion of any given surface particle in the path of the wave. In the Love wave the motion of a particle is in the horizontal plane and at right angles to the direction in which the wave is propagated.




respect to a large mass (*black rectangle*) suspended from a weak spring. The strain seismometer measures the motion of one pier set in the earth with respect to the end of a rigid bar attached to a second pier that is fixed in the earth some distance from the first.

MASTERING THE MOLECULE . . . WITH ELECTRON MICROSCOPY



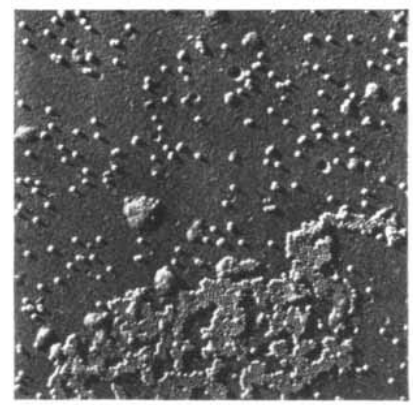
# RCA Electron Microscope aids Parke-Davis to develop large-scale poliomyelitis vaccine

In developing a large-scale method of poliomyelitis vaccine preparation, an RCA Electron Microscope enabled Parke-Davis virologists to positively identify isolated polio virus. From this achievement stemmed much useful information regarding the morphological and anatomical characteristics of the polio virus.

Virus research is but one of the varied fields in which the RCA Electron Microscope is aiding man's quest for knowledge. The ability to produce direct electron image magnifications up to 200,000, a convenient grouping of controls, and the automating of many operations contribute to its high efficiency and assure adjustment ease and operating simplicity. These, plus unique high-speed vacuum system, amazing stability and radio-frequency power supply, are features that have made the RCA Electron Microscope the most widely accepted instrument of its kind. The usefulness of these microscopes has been further extended by a newly developed Electron Diffraction Chamber which permits both transmission and reflection electron diffraction studies on all EMU electron microscopes.

Also of vital importance in the sphere of research and development are the world's most versatile x-ray diffraction and spectroscopy instruments now offered by RCA.

Both installation supervision and contract service to keep your instrument operating at peak efficiency are available from the RCA Service Company.



Photomicrograph of poliomyelitis virus (Mahoney strain) magnified 65,000X.

Made by Dr. A. R. Taylor of Parke-Davis & Company, Detroit, Michigan.

*Full particulars on request. Write to RCA, Dept. R-111, Building 15-1, Camden, N.J. In Canada: RCA VICTOR Company Limited, Montreal.*

**RADIO CORPORATION of AMERICA**

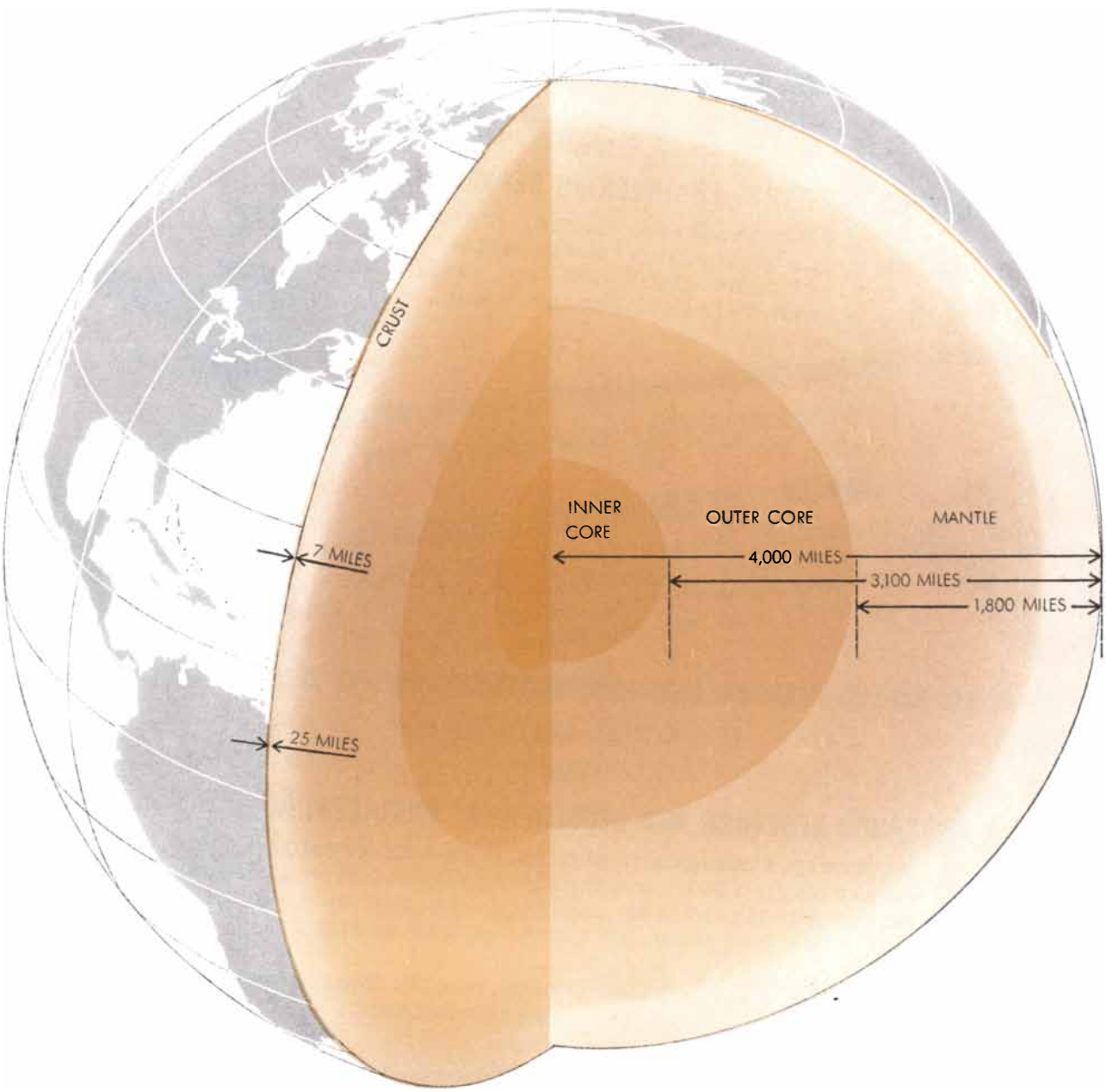
**CAMDEN, N. J.**

Tmk(s) ®

kinds. During the passage of the Love wave (named for its 19th-century discoverer A. E. H. Love) the ground vibrates horizontally at right angles to the direction of the wave. The Rayleigh wave (named for Lord Rayleigh, who described it in 1900) more closely resembles a ripple in water; when it passes a point on the surface, the point moves around an ellipse in a direction parallel but opposite to the direction of the wave [*see illustration at top of preceding two pages*]. Though they move through the earth simultaneously, the two waves are not associated in any way. On the seismograph they record complementary but different information.

The surface waves that reach the seismological observatory are characteristically long because the shorter-period components of the original disturbance tend to die out on the way. It is not known for sure whether body waves contain components of longer period. In any case, it was around the body waves of shorter period that most of the instrumentation of seismology was designed.

The basic instrument is a mass suspended from a weak spring [*see illustration at the bottom of page 132*]. With different suspensions the mass may be used to measure either the vertical or the horizontal component of a seismic wave. Because of its inertia the mass tends to remain fixed in space; when a seismic waves passes, the loose coupling




**INTERNAL STRUCTURE OF THE EARTH is revealed by earthquake waves. Body waves penetrating deep into the earth have resolved the discontinuities in elasticity which differentiate the inner core, the outer core, the mantle and the crust. Surface waves have now established that the boundary between the mantle and crust lies much deeper below the continents than below the sea.**

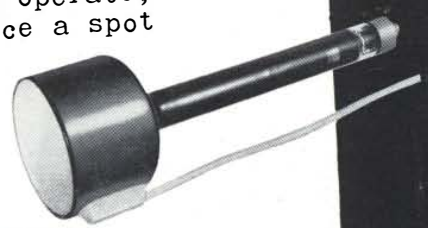
# Fallen Barriers...

"SOLAR" BLIND MULTIPLIER PHOTOTUBES
from
**PHOTOSENSITIVE DEVICES DEPARTMENT**

Several photocathodes have been designed to fill the need for high ultraviolet response to the presence of white light and are now available in a series of multiplier phototubes.

HIGH RESOLUTION CATHODE-RAY TUBES
from
**CATHODE-RAY TUBE ENGINEERING DEPARTMENT**

A family of cathode-ray tubes, practical to operate, low in price and consistently able to produce a spot size of less than .001" are now available in 3-, 5- and 7-inch diameter tubes.



RUGGEDIZED DIRECT VIEW STORAGE TUBE
from
**STORAGE TUBE ENGINEERING DEPARTMENT**

A compact, 4-inch direct view storage tube specifically ruggedized for military applications and designed for maximum storage time is ready for new equipment design.

ULTRA-FINE GRAIN SCREEN
from
**PHOSPHOR RESEARCH AND DEVELOPMENT ENGINEERING**

An extremely fine grain phosphor screen capable of resolving a .001" spot with minimum conical dispersion and electrically stable has been created to take advantage of new Du Mont electron gun design.

...These are just a few of many new Du Mont developments. Tell us your specific tube requirements...

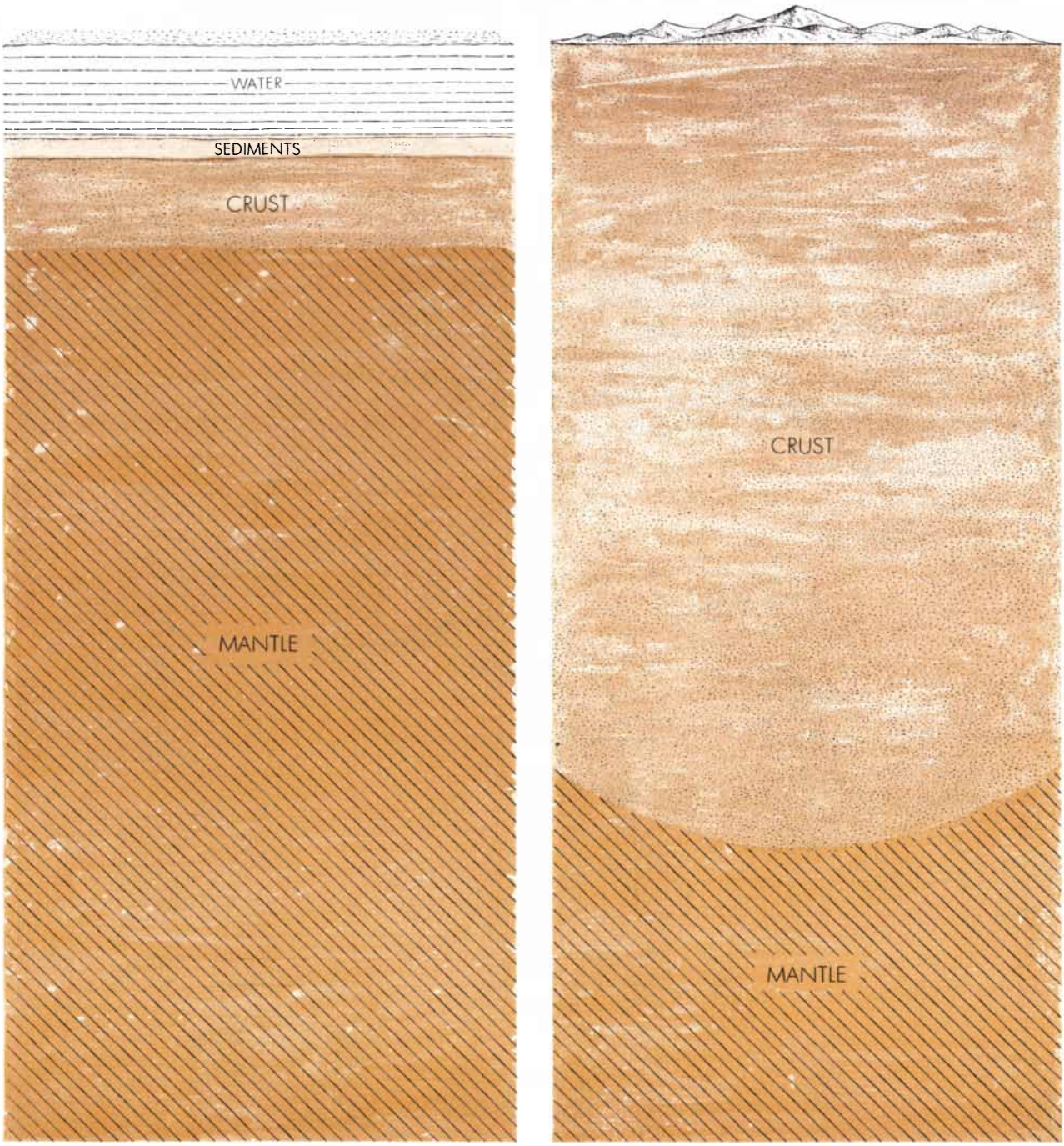
**DU MONT®** Precise **PHOTOELECTRONICS**

INDUSTRIAL TUBE SALES, ALLEN B. **DU MONT** LABORATORIES, INC., 750 Bloomfield Ave., Clifton, New Jersey, U.S.A.

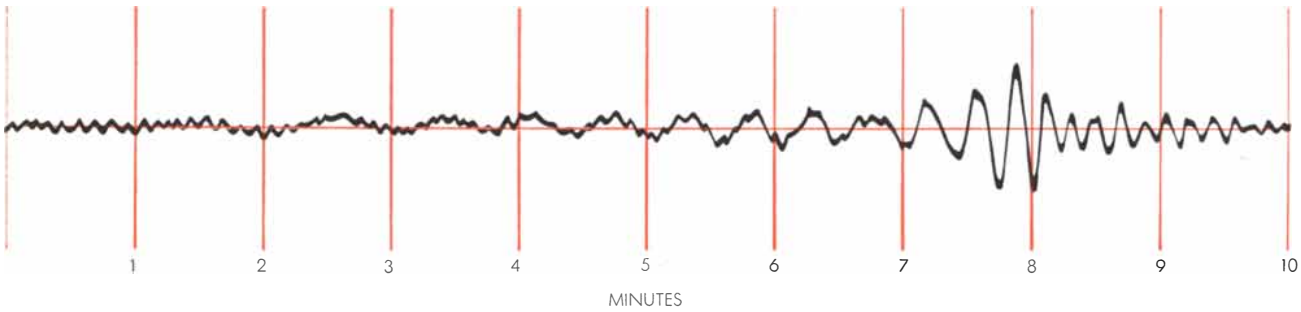
of the spring permits the earth to move with respect to the mass and insulates the mass from the disturbance. Measurement of the movement of the earth relative to the mass reveals the motion of the earth at the station.

Unfortunately the inertial seismometer works well only for those waves that are shorter than its own natural frequency, or free period of oscillation. It is difficult to construct an instrument with a free period greater than 15 seconds, especially for the measurement of the vertical component of ground motion. Recently ingenious new ways of suspending the inertial mass and damping its motion have doubled this figure, and a few test instruments have operated with a period of oscillation as great as 100 seconds.

The poor response of the seismometer at longer periods may be offset by using a device to detect the relative motion of the earth that favors those periods. The usual instrument is a galvanometer, which is coupled to the seismometer by a coil mounted on the mass and operating in the field of a magnet fixed to the




**THICKNESS OF THE CRUST** has been shown by surface waves to vary sharply as between the oceans and the continents. The boundary between the mantle and the crust lies only seven miles below sea level; subtracting average depth of the ocean and sediments the suboceanic crust is only 3.5 miles thick. Crust below continents goes down some 25 miles, plunging deeper under mountains.

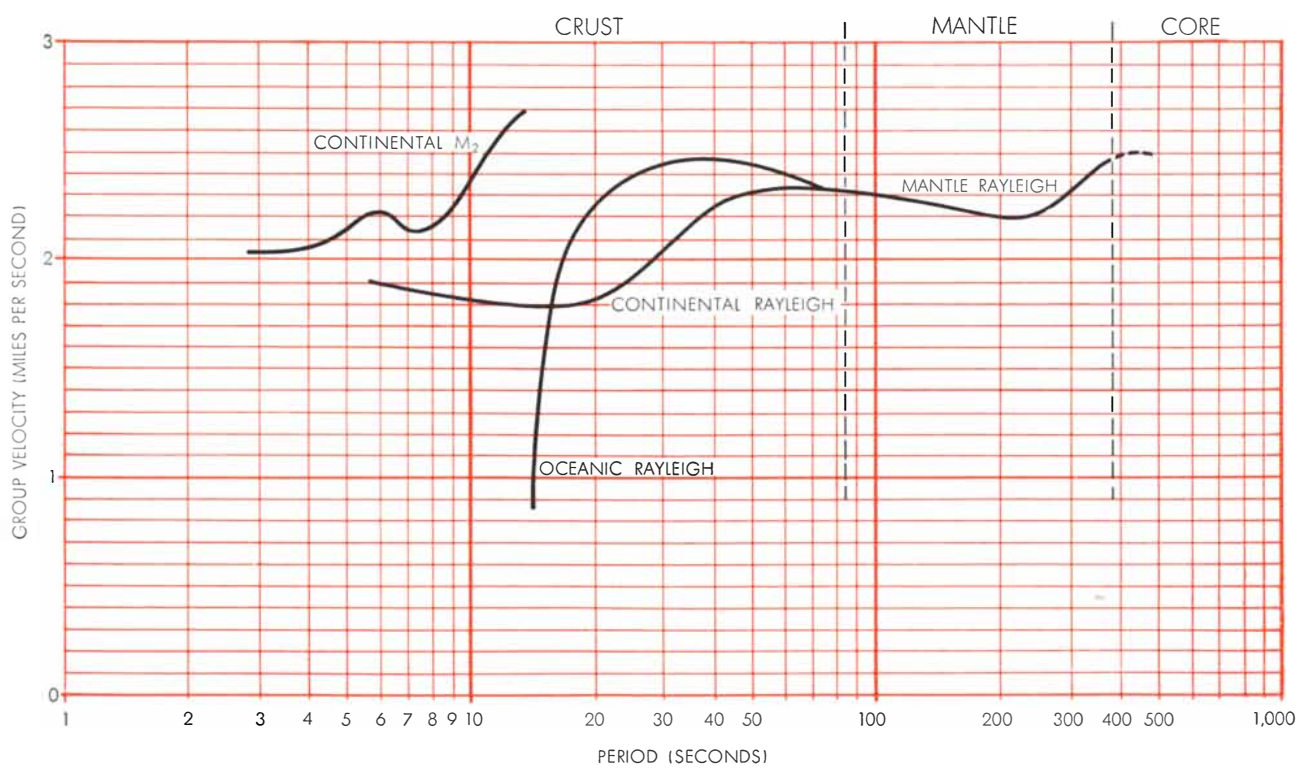



**TRAIN OF SEISMIC WAVES, as recorded on seismometer, shows how variation in velocity disperses waves excited in same instant by earthquake. Longer waves (disregard high-frequency "noise") register in first minutes (*left*); shorter waves come minutes later.**

earth [*see illustration at bottom of page 132*]. In the galvanometer the current generated by the earth motion energizes an electromagnet which then rotates because it is suspended in the field of a permanent magnet. Here again large inertias, weak coupling and damping can achieve a long-period response. At the Lamont Geological Observatory of Columbia University an instrument designed by Maurice Ewing and Frank Press successfully combines a 15-second seismometer with a 75-second galvanometer; it has recorded seismic waves of 480 seconds' duration. The observatory now has 30-second and 100-second combinations in routine operation, awaiting signals from the next major earthquake.

An entirely different type of instrument is the strain seismometer, developed by Hugo Benioff of the California Institute of Technology. This instrument measures the change in distance (the earth "strain") between a pier set in the earth and the free end of a long rigid rod attached to another pier set in the earth at a distance of 50 to 100 feet. Inherently more responsive to long waves, its performance may also be improved by a long-period galvanometer. The strain seismometer has traced waves of 300 seconds on several occasions, and has evidenced its great potential in registering the record 3,400-second wave. At present only a few stations have strain seismometers, and they are equipped to measure only the horizontal components of earth strain. A pair of strain seismometers arrayed at right angles to each other will produce a full record of a Love wave but will register only the horizontal motion set up in the earth by a Rayleigh wave.

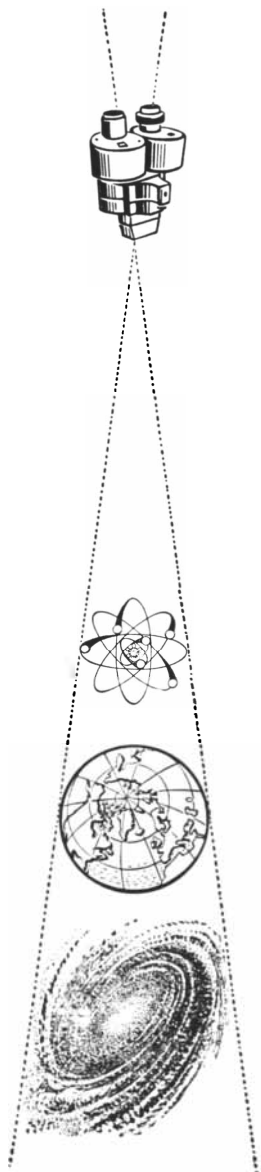
Waves of different length become vehicles for information about the rock through which they pass because




**RAYLEIGH-WAVE VELOCITIES (*vertical coordinate*) show variation in character of rock below the surface. Waves of greater length (*horizontal coordinate*) "feel" the rock at greater depth. The higher velocity of the shorter and shallower oceanic waves, of periods from 75 down to 15 seconds, shows that higher-density mantle rock comes closer to the surface. The lower velocity of continental surface waves starting at 75 seconds, and hence at great depth, reflects the lesser density of the thick layer of continental crustal rock.**

Autometric
CORPORATION
PARAMOUNT BUILDING, TIMES SQUARE, NEW YORK 36, N.Y. BRYANT 9-8700

PAUL RAIBOURN
PRESIDENT



Eighteen months ago Autometric announced that it holds "proprietary rights in and manufactures apparatus for pre-programmed control of actual universes, particularly where wayward or inimical autochthons cause capricious responses to control stimuli."

This statement was an appeal to those scientists who recognized its precise technical language to join us. Their response was gratifying.

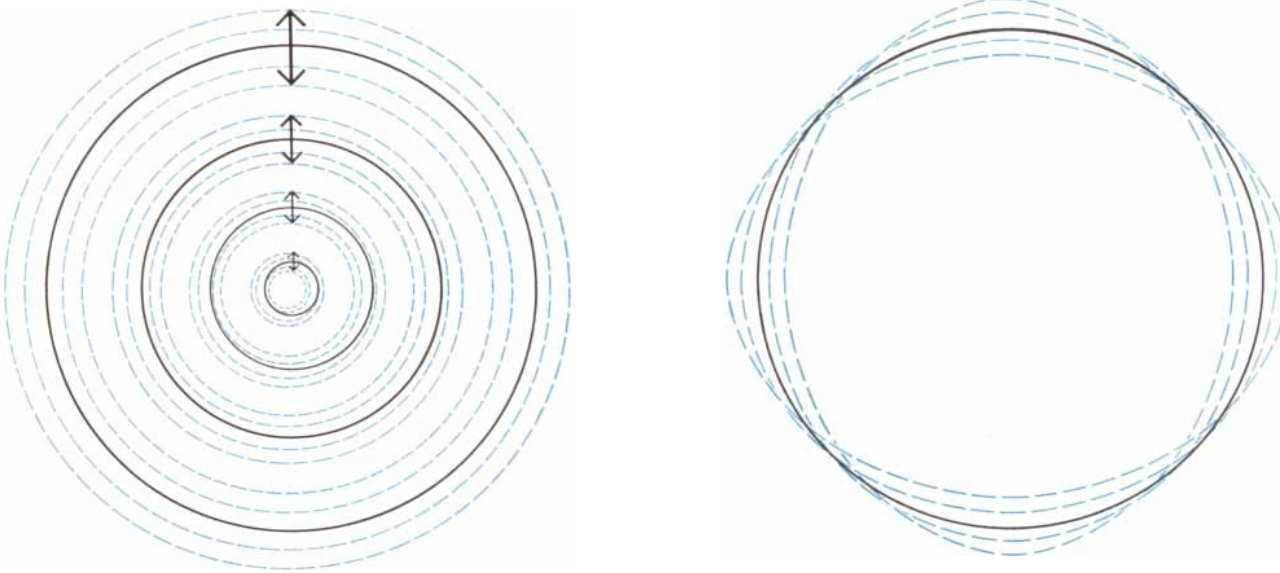
With their aid, Autometric's capabilities for getting answers simply and directly have been developed. These have been proven by numerous flights and by geophysical measurements which were then compared with the best previous work of many men with analogue and digital aids.

As a result, we now hold large prime contracts for geophysical work in partnership with several of America's largest corporations. We are being requested to become active in other projects of unusual size and significance. We face difficult practical problems of expansion.

In handling these masses of complex data, we have problems of rapid computation and of miniaturized storage and presentation of undigitalized information and abstractions therefrom.

Basically however, we are working beyond such problems since the tough practical decisions demanded by the work-a-day world seem invariably to present themselves in terms of conflicting and incoherent data. A best decision under such conditions is our goal.

We would like to hear from individuals and organizations whose capabilities and experience will be of help to us. Please write in confidence to Robert Dressler, Vice President. Your inquiry will receive personal attention. We are a family of people, not an institution.



**FREE OSCILLATIONS** of the earth in its natural frequencies of long period may set up standing waves of several forms. In the radial mode (*left*) the motion of particles is along the radii of the earth in a series of compression waves resembling sound waves. In the "football" mode (*right*) the earth alternately assumes the prolate (long axis vertical) and oblate (long axis horizontal) form.

they travel at different speeds and arrive at different times. An earthquake liberates waves of a wide range of periods at about the same time. Though the Love and Rayleigh waves are confined to the surface, they probe—in a sense, "feel"—a depth that depends upon their length. Since the elastic properties of the earth generally increase with depth, the waves of greater length travel faster, often more than twice as fast, as the shorter, shallower and slower waves. The seismograph station some distance from the quake thus records not a sudden impulsive disturbance, but a long train of waves, sometimes lasting several minutes and sometimes several hours, depending upon the paths the waves have severally traversed. The long-period waves, traveling quickest, arrive earliest. A seismogram recording a typical dispersed wave-train is reproduced at top of page 138.

The record of the arrival times of waves of different length, plus knowledge of the time and location of the earthquake, make it possible to compute the individual and average velocity of waves along the great-circle path between the quake and the station. The velocities provide a measure of the elasticity and, for practical purposes, the density of the rock. Thus seismic-wave spectroscopy yields an analysis of the earth's interior structure.

From observation of a number of earthquakes Ewing and his collaborators have charted the relation between wavelength, depth and velocity for Rayleigh waves of periods from 3 to 480 seconds [*see illustration at bottom of page 138*]. The chart shows a sharp divergence between the waves of 75 seconds or less duration that arrived at the Lamont Observatory, near New York City, via oceanic and continental pathways. From periods of 75 seconds down to 15 seconds the velocity of the oceanic waves maintains a high level and then drops off to an extremely low value. This curve shows us that mantle rock of relatively high elasticity, through which waves travel at high velocity, lies at a very shallow depth: only 10 miles below the surface of the ocean. The abrupt fall in the curve at 15 seconds marks the transition to the less elastic rock of the crust and shows the crust to be only three or four miles thick. Then, because compression waves in the ocean water and unconsolidated bottom sediments load the vertical component of the Rayleigh waves, the velocity decays to extremely low values. The slope of the curve in this region gives three miles as the combined depth of the water and the sediments. Subtracting the average depth of the ocean obtained from soundings, we find that the sediments range from a quarter to a half mile in thickness.

The velocity-period curve for waves traveling across continents falls below the ocean curve at 75 seconds. This curve tells us that the lower-velocity crustal rock must go down to great depths beneath the surface of the continents. The falling off of the continental velocity curve at 75 seconds places the boundary between mantle and crust—the Mohorovicic discontinuity—at a depth of 20 to 25 miles. This substantial contrast in the thickness of the crust as between the continents and the oceans had been indicated by explosion soundings at a few discrete points at sea and on land. Surface-wave records during the past few years have now established that the crust beneath the oceans is uniformly thin.

Though surface-wave seismology rests upon techniques for measurement of long waves, it is apparent that the shorter surface waves, which "feel" the rock at shallower depths, hold great interest for us. They can tell us much of what we want to know about the crust and upper mantle. Moreover, seismic waves, like waves of all other kinds, increase in resolving power with decrease in length; they can "see" structures of dimensions comparable to their own length. They should thus deliver quite fine-grained information, for example, on variations in the density of continental rock. Unfortunately their very capacity to resolve structural detail causes them to be scattered and absorbed when they encounter such details. The earth, in effect, filters out the short waves and transmits the long. However, just as an organ pipe or violin string may vibrate in harmonics as well as in a fundamental frequency, so may the surface waves. Such higher-

# *Man-Machine Relationships a Growing Field for* **Operations Research**

Mathematicians, Physicists and Engineers with experience or strong interest in Operations Research on large-scale automated systems will be interested in the major expansion program at System Development Corporation.

SDC's projects are concerned primarily with man-machine relationships in automated systems in a number of fields, including air operations. The application of new and advanced digital computer techniques is particularly important in optimizing these man-machine relationships. SDC activities constitute one of the largest Operations Research efforts in the history of this growing field.

Senior positions are among those open. Areas of activity include: Mathematics, Systems Analysis, Forecasts, Cost Analysis, Operational Gaming, Design Analysis, Performance Evaluation.

Those who have professional questions or desire additional information are invited to write Dr. William Karush, Head of the SDC Operations Research Group. Address System Development Corporation, 2420 Colorado Avenue, Santa Monica, California.

***"Method for First-Stage Evaluation of Complex Man-Machine Systems"*** *A paper by Mr. I. M. Garfunkel and Dr. John E. Walsh of SDC's Operations Research Group is available upon request. Address inquiries to the authors.*

SDC

**SYSTEM DEVELOPMENT CORPORATION**
Santa Monica, California

11-85

mode, shorter-period harmonics accompany the longer waves on continental pathways. Their resolving power makes surface waves a potent medium for deduction of earth structure.

Love waves convey information in almost all respects parallel to that supplied by Rayleigh waves. Since their motion is restricted to the horizontal plane, however, they are not affected by the liquid layer of the ocean. In consequence they do not fall to the extremely low velocities attained by the suboceanic Rayleigh waves.

Surface waves with periods of 75 seconds or more are so long that they cannot "see" or "feel" such minor variations in the crust as the difference between oceans and continents. They derive their velocities primarily from the earth's mantle and may even be affected by the core. When better instrumentation is available, the long Rayleigh waves in particular may give us new information on the deep interior not available from body waves.

The long waves of both types have another useful quality in their resistance to attenuation and decay. Actually waves of all periods attenuate at the same rate, if attenuation is measured in loss per wavelength. Translated into distance this means that the very long waves can travel to much greater distances. Nearly 24 hours after the great Kamchatka earthquake of 1952 the Lamont Observatory was still able to record long waves that had traveled around the earth more than seven times —a total of 187,000 miles.

Waves of such length and longevity begin to verge on the dimensions of another class of wave: the free oscillations of the earth itself. In contrast to earthquake waves, which are propagated from centers of disturbance and travel to distant points, the earth's free oscillations are standing waves. By analogy, a long pipe between two floors in a building may be used as a speaking tube to carry traveling waves, provided all the waves are short with respect to the length of the tube. With wavelengths increased to a length comparable to that of the tube—that is, "tuned" to the tube —the sound waves become standing waves, and the tube becomes a whistle or an organ pipe. This is the nature of the 3,400-second wave detected by the strain seismometer at Cal Tech. That wave was excited by a tremendous earthquake. For regular observation of the free oscillations of lower amplitude excited by more frequent smaller earthquakes it will be necessary to make cer-

tain improvements in our instruments.

Though experimental data are scanty, the earth's free oscillations have intrigued mathematicians since the early 19th century. As a result a considerable body of theory is ready for the test of observation when that becomes possible. Theoreticians have usually considered a simple homogeneous sphere undergoing free vibration due to elastic and gravitational forces. They have shown that three major types of vibration are possible: a rotatory or torsional vibration in which motion of any point is always in the horizontal plane; a radial mode in which the sphere dilates and contracts uniformly; and a spheroidal mode in which the sphere oscillates from a prolate to an oblate spheroid, assuming the shape of a football during a part of the oscillation. For each type of oscillation there is an infinity of higher modes of increasing complexity.

Recently electronic calculators were put to work on the computation of the length of the vibration periods for the three long-period modes, based upon simplified data for a real earth with varying composition and elasticity. The calculator yielded an estimate of 42 minutes 30 seconds for the torsional mode, 20 minutes 44 seconds for the radial mode, and 56 minutes 44 seconds for the "football" mode. These figures are in close agreement with the consensus of calculations for purely theoretical spheres. Love himself had calculated the football mode at almost exactly one hour for a sphere of the earth's dimensions and the rigidity of steel.

Both calculations for the football mode come well within the limit of observational error for the longest-recorded, 3,400-second wave (56 minutes 40 seconds)! In this case, it happens, the close fit of theory and observation is a disappointment. The small difference means that the long waves lack the resolving power to enable us to learn much from them about the details of the earth's interior. We must content ourselves with what they tell us about the average properties of the earth. The higher-mode harmonics of the free oscillations, however, should possess the needed resolving power and promise to open a new field of investigation.

The hi-fi seismologist has good reason, therefore, for tuning in on the bass scale of the earth's oscillations. Lest anyone think that we are content with periods of one hour, let me say that space in the seismograph vault at Lamont Observatory is available immediately for an instrument responsive to earth motion of even greater periods.

# How Du Pont Fibers Help Solve the Problems of Modern Industry

• Fibers are no longer limited to the age-old vegetable, animal or mineral strands woven to bring out the best in a limited range of properties. In every use shown at right — and in dozens of others — Du Pont man-made fibers are doing jobs impossible for natural fibers. The reason: Du Pont's family of man-made fibers have been tailored to meet a wide range of performance requirements. For example, nylon provides great strength and toughness. "Dacron" polyester fiber combines acid resistance with high strength and low stretch. "Orlon" acrylic fiber offers excellent weather resistance. "Super Cordura" high tenacity rayon gives highest strength per dollar. "Teflon" TFE-fluorocarbon fiber has such a low coefficient of friction it's used as a bearing material.

The versatility of these fibers is almost endless. They can be knitted, woven, felted, braided, twisted, or made into paper. And they can be combined with other materials — such as elastomers and resins — to improve strength, flex life, abrasion or acid resistance. Du Pont has the experience to help you apply these fibers to new applications. Let us help you with your next materials problem.

**DU PONT FIBERS FOR INDUSTRY**

DU PONT
REG. U.S. PAT. OFF.

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

*Registered Du Pont trademarks

E. I. du Pont de Nemours & Co. (Inc.)
Textile Fibers Department
5518-A Nemours Building, Wilmington 98, Delaware

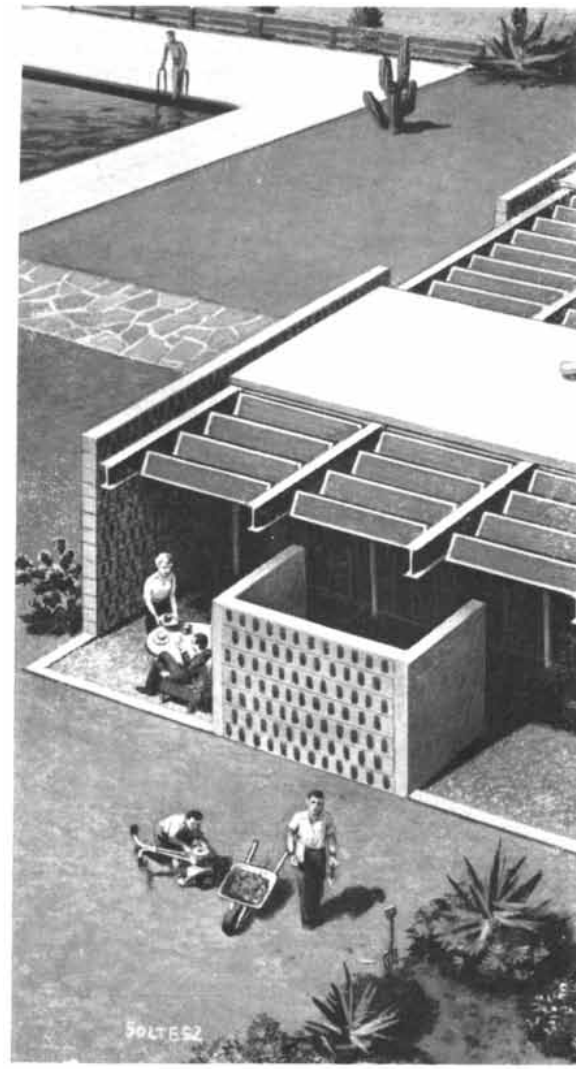
Please send me more information on industrial applications of Du Pont fibers. I am interested in evaluating these materials for:_____

_____

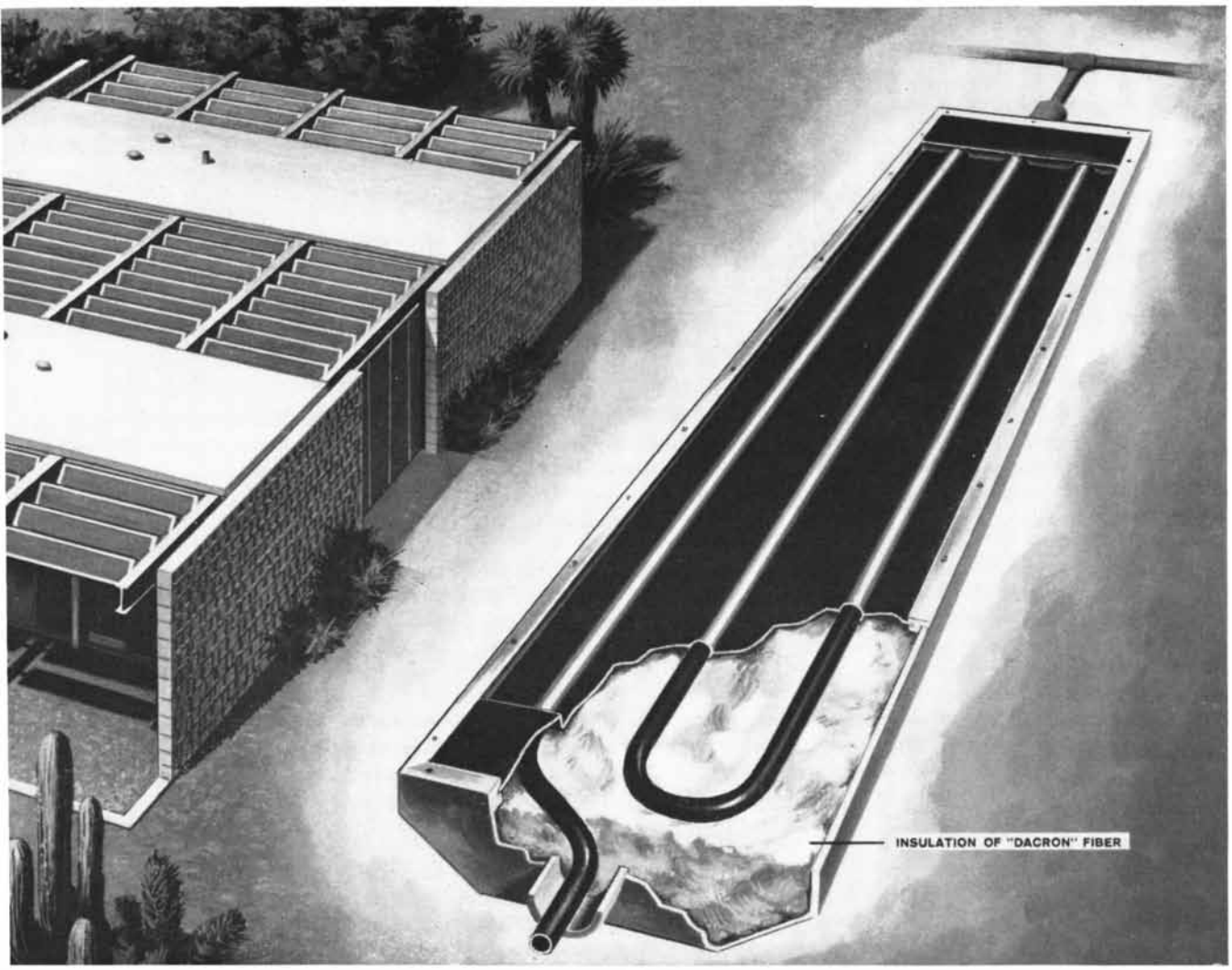
*Name* _____

*Address* _____

*City & State* _____

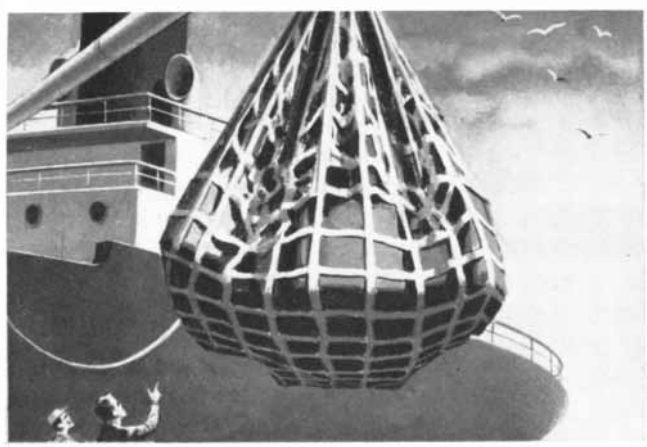


**FUN FOR THE FAMILY** and the elimination of a storage problem are sure to make this inflatable runabout popular. The seven-tube construction of this unsinkable boat is made possible by neoprene-coated nylon fabric. This lightweight, strong material brings the boat's weight down to 40 pounds. Nylon fiber is not weakened by salt water, gasoline, lubricants. It is resilient . . . can take shock. Portable boat has nylon lifeline and case.




**SOLAR HOUSE** uses the sun's energy to meet all heating requirements. Water circulating through copper tubes is heated by the sun. The tubes are installed within tilting louvers controlled by an astronomical clock. Batts of "Dacron" polyester fiber prevent loss of heat from the tubes during cold weather, and in summer the batts protect the house against external heat. "Dacron" fiber has excellent resistance to high temperatures and oxidation. This tough fiber is light in weight . . . isn't weakened by rot or mildew under moist conditions.

**PAPER TRAMPOLINE** dramatizes great strength of the new synthetic-fiber papers. Tear strength is about 10 times as great as for a good kraft paper and is actually of the same order of magnitude as woven fabrics. Fold endurance ranges as high as 75 times that of cellulosic papers. The new papers made of nylon, "Dacron" or "Orlon" fibers resist heat, chemicals, weathering, moisture—are dimensionally stable. Potential uses for these new papers are so broad that they are being classed as entirely new engineering materials. We welcome your inquiry.



**SUPER-STRENGTH CARGO NETS** are made of flat nylon webbing. The nylon net occupies one-quarter of stowage space of manila nets of similar capacity. Unlike manila, these nets can be stowed safely while wet and can easily be handled by one man. Lightweight nylon fibers provide tensile strength comparable to that of steel and excellent elastic recovery after shock loads. They resist abrasion, too.

*Enjoy the "Du Pont Show of the Month"—on CBS-TV*

# MATHEMATICAL GAMES

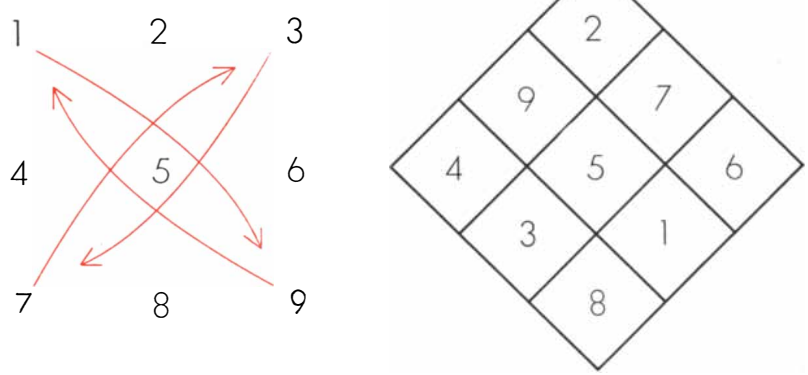
## *Concerning the properties of various magic squares*

by Martin Gardner

The traditional magic square is a set of integers in serial order, beginning with one, arranged in square formation so that the total of each row, column and main diagonal is the same. Some notion of the fantastic lengths to which this largely frivolous topic has been analyzed may be gained from the fact that in 1838, when much less was understood about magic squares than is known today, a French work on the subject ran to three volumes. From ancient times until now the study of magic squares has flourished as a kind of cult, often with occult trappings, whose initiates range from such eminent mathematicians as Arthur Cayley and Oswald Veblen to laymen such as Benjamin Franklin.

The "order" of a magic square is the number of cells on one of its sides. There are no magic squares of order two, and only one (not counting its rotations and reflections) of order three. An easy way to remember this square is as follows: First write the digits in order as shown in the illustration at left below, then move each corner digit to the far side of the central digit as indicated by the arrows. The result is the magic square shown in the illustration at right below, which has a constant of 15. (The constant is always half the sum of $n^3$ and $n$, where $n$ is the order.) In China, where this square is called the *lo-shu*, it has a long history as a charm, and today is still found on amulets worn in the Far East and India.

Magic squares grow quickly in complexity when we turn to order four. There are exactly 880 different types, again ignoring rotations and mirror images, many of which are much more magical than required by the definition of a magic square. One interesting species, known as a symmetrical square, appears in Albrecht Dürer's famous engraving *Melencolia* [*see opposite page*]. Dürer never explained the rich symbolism of this masterpiece, but most authorities agree that it depicts the sullen mood of the thinker unable to engage in action. In the Renaissance the melancholy temperament was thought characteristic of creative genius; it was the affliction of scholars "sicklied o'er with the pale cast of thought." In Dürer's picture unused tools of science and carpentry lie in disorder about the disheveled, brooding figure of Melancholy. There is nothing in the balance scales, no one mounts the ladder, the sleeping hound is half-starved, the winged cherub waits for dictation while time is running out in the hourglass above. The wooden sphere and curiously truncated stone tetrahedron suggest the mathematical base of the building arts. Apparently the scene is bathed in moonlight. The lunar rainbow arching over what appears to be a comet may signify the hope that the somber mood will pass. Giorgio de Santillana, in his book *The Age of Adventure*, sees in this strange picture "the mysterious wondering pause of the Renaissance mind at the threshold of the as-yet-only-dreamt-of powerhouse of Science."




*How the* lo-shu *can be formed*

Fourth-order magic squares were linked to Jupiter by Renaissance astrologers, and were believed to combat melancholy (which was Saturnian in origin). This may explain the square in the upper right-hand corner of the engraving. It is called symmetric because each number added to the number symmetrically opposite the square's center yields 17. Owing to this fact there are many four-cell groups (in addition to rows, columns and main diagonals) that total the fourth-order constant of 34; for example, the four corner cells, the four central cells, the two-by-two squares at each corner, and many others. A square of this type can be constructed by an absurdly simple method. Merely write in square array and in serial order the numbers 1 to 16, then invert the two main diagonals. The result is a symmetrical magic square. Dürer interchanged the two middle columns of this square (which does not affect its properties) so that the two middle cells of the bottom row would indicate the year he made the engraving.

The earliest recorded fourth-order square, found in an 11th- or 12th-century inscription at Khajuraho, India, is shown at the top of the illustration on page 148. It belongs to a species known as diabolic squares (also called "pandiagonal" and "Nasik"), which are even more astonishing than the symmetrical ones. In addition to the usual properties, diabolic squares are also magic along all "broken diagonals." For example, cells 2, 12, 15 and 5, and cells 2, 3, 15 and 14, are broken diagonals that can be restored by putting two duplicate squares alongside each other. A diabolic square remains diabolic if a row is shifted from top to bottom or bottom to top, and if a column is moved from one side to the other. If we form a mosaic by fitting together a large number of duplicate diabolic squares, we have a field on which any four-by-four group of cells


*Albrecht Dürer's* Melencolia. *At upper right is a magic square*

will be diabolic. Any four adjacent cells on the field, up and down, left and right or diagonally, will yield the constant.

Perhaps the most dramatic way of exhibiting the diabolic properties of such a square is described by mathematicians J. Barkley Rosser and Robert J. Walker, both of Cornell University, in a paper published in 1938. We simply bring together the top and bottom of the square to make a cylinder, then stretch and bend the cylinder into a torus [*see illustration below*]. All rows, columns and diagonals now become closed loops. If we start at any cell and move two squares away in any direction along a diagonal, we always arrive at the same cell. This cell is called the "antipode" of the cell where we began. Every pair of antipodes on this diabolic doughnut will total 17. Every loop of four cells, diagonally or orthogonally, adds up to 34, as does any square group of four cells.

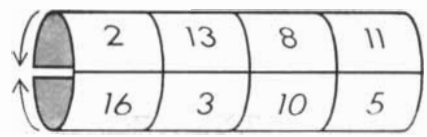
A diabolic square remains diabolic under five different transformations: (1) a rotation, (2) a reflection, (3) a transfer of a row from top to bottom or vice versa, (4) a transfer of a column from one side to the other, (5) a rearrangement of cells according to the plan shown in the illustration at the top of page 152. By combining these five transformations one can obtain 48 basic types of diabolic squares (384 if rotations and reflections are included). Rosser and Walker show that these five transformations constitute a "group" (an abstract structure with certain properties) that is identical with the group of transformations of the hypercube (four-dimensional cube) into itself.

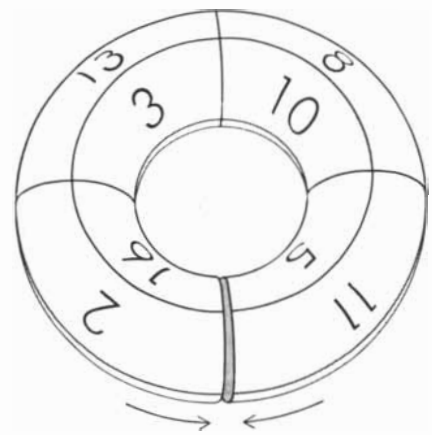
The relation of diabolic squares to the hypercube is easily seen by transferring the 16 cells of such a square to the 16 corners of a hypercube. This can be shown on the familiar two-dimensional projection of a hypercube [*see illustration on page 150*]. The sum of the four corners of each of the 24 square faces of this hypercube will be 34. The antipodal pairs, which add up to 17, are the diagonally opposite corners of the hypercube. By rotating and reflecting the hypercube, it can be placed in exactly 384 different positions, each of which maps back to the plane as one of the 384 diabolic squares.

Claude Fayette Bragdon, a prominent U. S. architect and occultist who died in 1946, was fascinated by his discovery that on most magic squares a line traced from cell to cell in serial order will produce an artistically pleasing pattern. Other patterns can be found by tracing only the odd or only the even cells. Bragdon used "magic lines" obtained in this manner as a basis for textile patterns, book covers, architectural ornaments and the decorative chapter headings of his autobiography *More Lives Than One*. His design for the ventilating grill in the ceiling of the Chamber of Commerce in Rochester, N. Y., where he lived, is derived from the magic line of the *lo-shu*. A typical example of a magic line is shown in the illustration at the bottom of page 152, where it is drawn on the Dürer square.

One of the great unsolved problems of recreational mathematics is that of finding a method for calculating the number of different squares of a given order. At present not even the number of fifth-order squares is known, though it has been estimated at more than 13 million. The number of fifth-order diabolic squares, however, has been established by Rosser and Walker as 28,800 (this includes rotations and reflections). Diabolic squares are possible in all orders above four except those divisible by 2 but not by 4. There is none, for ex-

| | | | |
|---|---|---|---|
| 7 | 12 | 1 | 14 |
| 2 | 13 | 8 | 11 |
| 16 | 3 | 10 | 5 |
| 9 | 6 | 15 | 4 |




*The diabolic doughnut*

**Engineers – Scientists Required for many aspects of General Electric's Aircraft Nuclear Propulsion Program...**


# APPLIED RESEARCH & DEVELOPMENT AT THE PhD LEVEL ON AN INTER-DISCIPLINARY BASIS

Opportunities now exist for a number of scientists and engineers with imaginative minds and established reputations to contribute to extremely sophisticated nuclear propulsion systems, where theoretical advances must be wedded to new standards of reliability and performance.

*Qualified engineers and scientists are invited to inquire about these opportunities to pursue original work in a pioneering area with General Electric.*

Write in confidence, including salary requirements, to:
Mr. G. W. Travers, Div. 59-MC

**AIRCRAFT NUCLEAR PROPULSION DEPT.**

**GENERAL ELECTRIC**

P.O. Box 132 Cincinnati 15, Ohio

| | |
|---|---|
| **Metallurgy** | Advise Materials Testing Laboratory on materials problems and techniques. Direct experimental, physical, mechanical and electrical tests. Analyze data. |
| **Physics or Nuclear Engineering** | Carry out reactor analysis and nuclear design of power plants, including formulation of nuclear design specifications and test requirements. |
| **Ceramics, Physical Chemistry or Ceramic Engineering** | Supervise applied ceramic research including fabrication processes, testing of ceramic bodies; development of novel ceramic materials. |
| **Physics** | Conduct theoretical investigations of effect of neutrons and photons on matter. |
| **Mathematics, Electrical Engineering** | Engineering analysis of physical systems in electro-mechanical areas, deriving equations associated with systems study. Develop generalized digital program for parametric study of these systems. |
| **Mathematics** | Apply advanced mathematical procedures and approaches in resolving complex problems in areas of reactor analysis. |
| **Physics or Nuclear Engineering** | Advanced Reactor Analysis. Plan objectives of experimental reactor investigations, which adequately combine potentialities of experimental techniques and improvement of theoretical methods. |
| **Physical Metallurgy or Mechanical Engineering** | Undertake responsibility for studies regarding various materials used in moderator materials development. |
| **Nuclear Engineering** | Plan, design and analyze specific nuclear shield tests — part of broad nuclear shield design program. |
| **Physics** | Participate in shield physics experiments, to provide fundamental data for shield design. |

***A number of additional positions in areas described above are also available to candidates with a Master's Degree.***

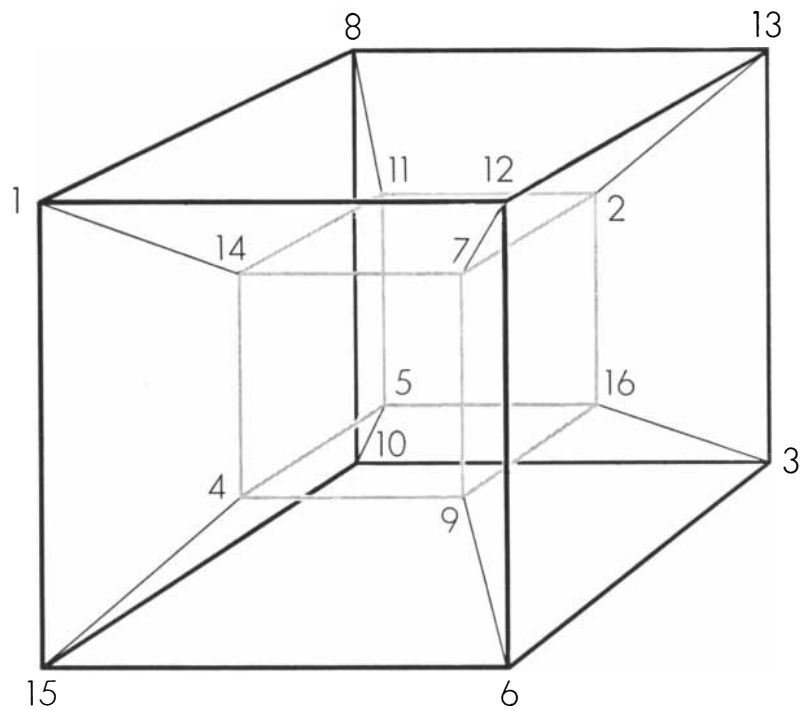
ample, of order six. Diabolic cubes and hypercubes also exist, but (as Rosser and Walker have shown in unpublished papers) there are no cubes of orders 3, 5, 7, $8k$ plus 2, $8k$ plus 4 or $8k$ plus 6, where $k$ is any integer. Diabolic cubes are possible in all other orders.

The first logic problem left unanswered last month is best handled by three matrices: one for combinations of first and last names of wives, one for first and last names of husbands and one to show sibling relationships. Since Mrs. White's first name is Marguerite (premise 5), we have only two alternatives for the names of the other wives: (1) Helen Black and Beatrice Brown or (2) Helen Brown and Beatrice Black.

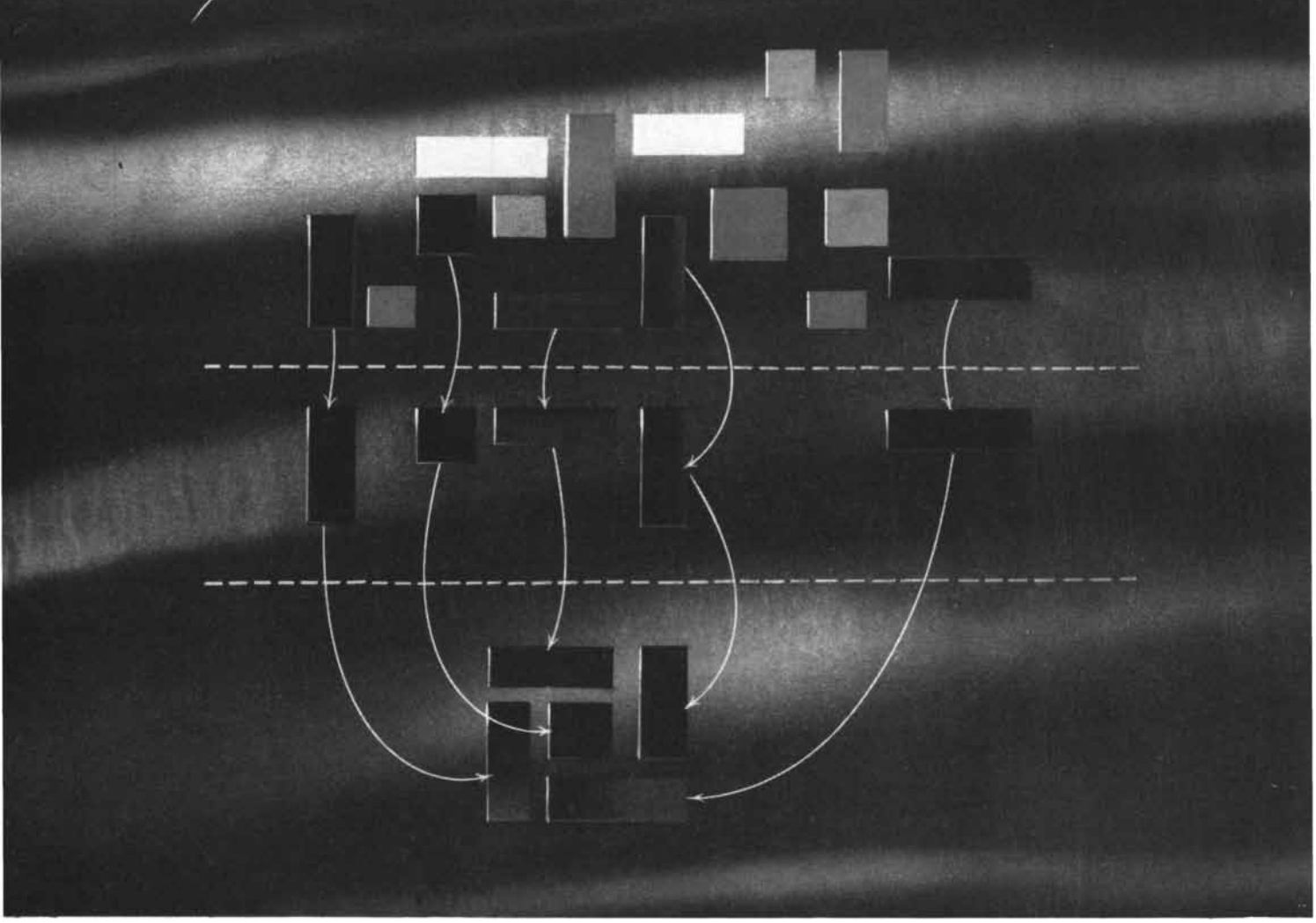
Let us assume the second alternative. White's sister must be either Helen or Beatrice. It cannot be Beatrice, because then Helen's brother would be Black; Black's two brothers-in-law would be White (his wife's brother) and Brown (his sister's husband); but Beatrice Black is not married to either of them, a fact inconsistent with premise 4. Therefore White's sister must be Helen. This in turn allows us to deduce that Brown's sister is Beatrice and Black's sister is Marguerite.

Premise 6 leads to the conclusion that Mr. White's first name is Arthur (Arthur Brown is ruled out because that would make Beatrice prettier than herself, and Arthur Black is ruled out because we know from premise 5 that Black's first name is William). Therefore Brown's first name must be John. Unfortunately premise 7 informs us that John was born in 1868 (50 years before the Armistice), which is a leap year. This would make Helen older than her husband by one day more than the 26 weeks specified in premise 3. (Premise 4 tells us that her birthday is in January, and premise 3 tells us her husband's birthday is in August. She can be exactly 26 weeks older than he only if her birthday is January 31, his on August 1, and there is no February 29 in between!) This eliminates the second of the two alternatives with which we started, forcing us to conclude that the wives are Marguerite White, Helen Black and Beatrice Brown. There are no inconsistencies because we do not know the year of Black's birth. The premises permit us to deduce that Marguerite is Brown's sister, Bea-

| | | | |
|---|---|---|---|
| 1 | 8 | 13 | 12 |
| 14 | 11 | 2 | 7 |
| 4 | 5 | 16 | 9 |
| 15 | 10 | 3 | 6 |




*Projection of diabolic hypercube and diabolic square to which it gives rise (top)*



*Report from IBM* *Yorktown Research Center, New York*

## OPTIMUM COMPUTER DESIGN FROM SYMBOLIC LOGIC

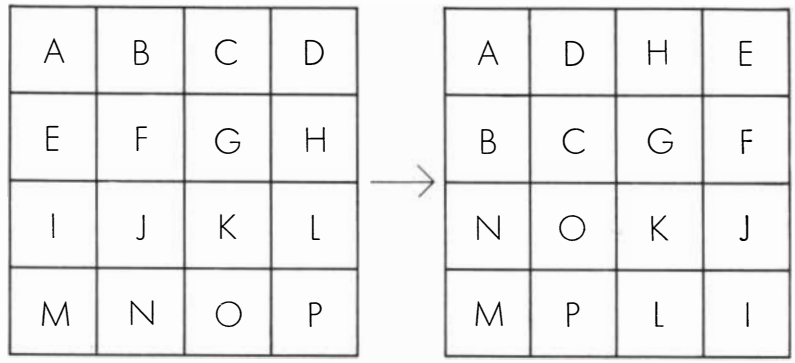
Symbolic logic sets up special languages in which problems of inference and definition are dealt with rigorously at the Poughkeepsie Laboratory of the IBM Yorktown Research Center. A group of research workers is making a general study of the application of symbolic logic to computer design. This work is yielding important results of both practical and theoretical interest.

Let us assume that computers are made up of many input-output devices hooked together in various sequences. Because these devices can be neatly correlated with a special class of logical functions, they may be thought of as logical boxes. Two chief problems have been posed by the IBM research group: (1) Which *selections* of logical boxes will best serve the needs of design, and (2) How are the boxes *to be put together* most effectively in given cases? An impressive body of answers is being gathered to each question. These are often possible just because an engineering problem has been reduced to a logical one. This reduction provides new design techniques in which computers are used as more effective aids. For example, suppose we wish to know which five-input, one-output device is logically most efficient. There are billions of alternatives, but a directed computer search can be set up so that the answer is obtained in a short time merely by scanning a small part of these.

The application of symbolic logic to machine design poses many challenging questions, some of great theoretical interest, others more specific with important practical consequences. Logic has already had a marked effect upon the design of electronic computers but should play an even greater role in the future.

**IBM® RESEARCH**

*Investigate the many career opportunities available in exciting new fields at IBM.*
*International Business Machines Corporation, Dept. 659-C, 590 Madison Avenue, New York 22, New York*




*One of five transformations which do not destroy the diabolism of a diabolic square*

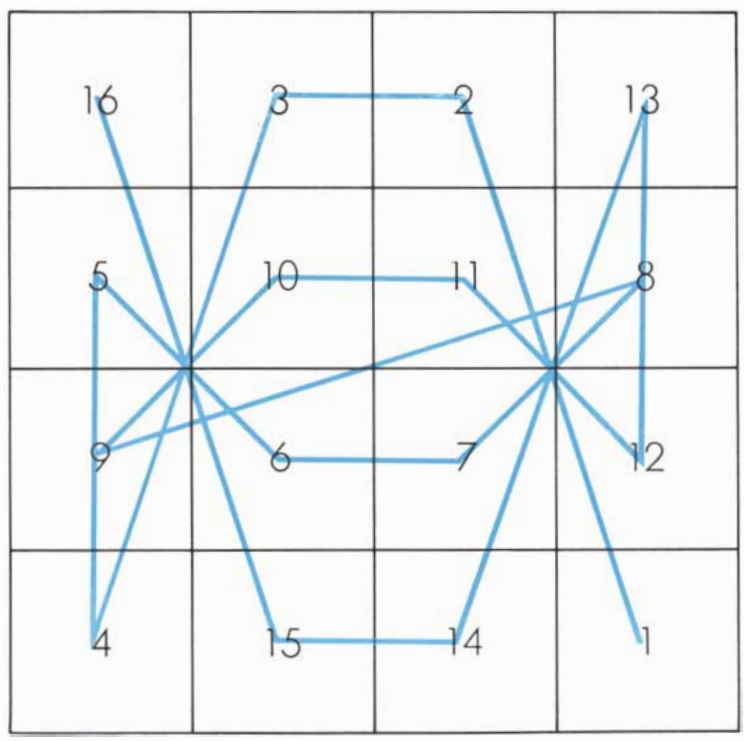
trice is Black's sister, and Helen is White's sister, but leave undecided the first names of White and Brown.

In the problem of the stamps on the foreheads, B has three alternatives: his stamps are (1) red-red, (2) green-green, or (3) red-green. Assume they are red-red.

After all three men have answered once, A can reason as follows: "I cannot have red-red (because then C would see four red stamps and know immediately that he had green-green, and if C had green-green, B would see four green stamps and know that he had red-red). Therefore I must have red-green."

But when A was asked a second time, he did not know the color of his stamps. This enables B to rule out the possibility that his own stamps are red-red. Exactly the same argument enables B to eliminate the possibility that his stamps are green-green. This leaves for him only the third alternative: red-green.

The answer to Eddington's problem of the four men is 13/41 as the probability that D is telling the truth. All combinations of truth-telling and lying that have an odd number of lies (or truths) prove to be inconsistent with Eddington's statement. This eliminates from the table of 81 possible combinations all but 41, of which 13 end with a true statement by D. Because each of the other three men is telling the truth in exactly the same number of valid combinations, the probability of having told the truth is the same for all four men.




*The "magic line" of Dürer's square*

NEW

# Thermal Plant Simulator simplifies nuclear training

You quickly get the feel of nuclear power plant response with the new Honeywell Thermal Plant Simulator. When used with the Reactor Simulator, it realistically simulates operation of a reactor with a non-boiling coolant *and* a thermal plant with heat exchanger and steam loop.

The Thermal Plant Simulator provides valuable training in thermal loop dynamics . . . simply, safely, economically. To set up a typical atomic power plant program, just plug in prewired connectors that mate appropriate computing networks and instruments. For non-standard programs, an integral general-purpose patchboard permits complete flexibility.

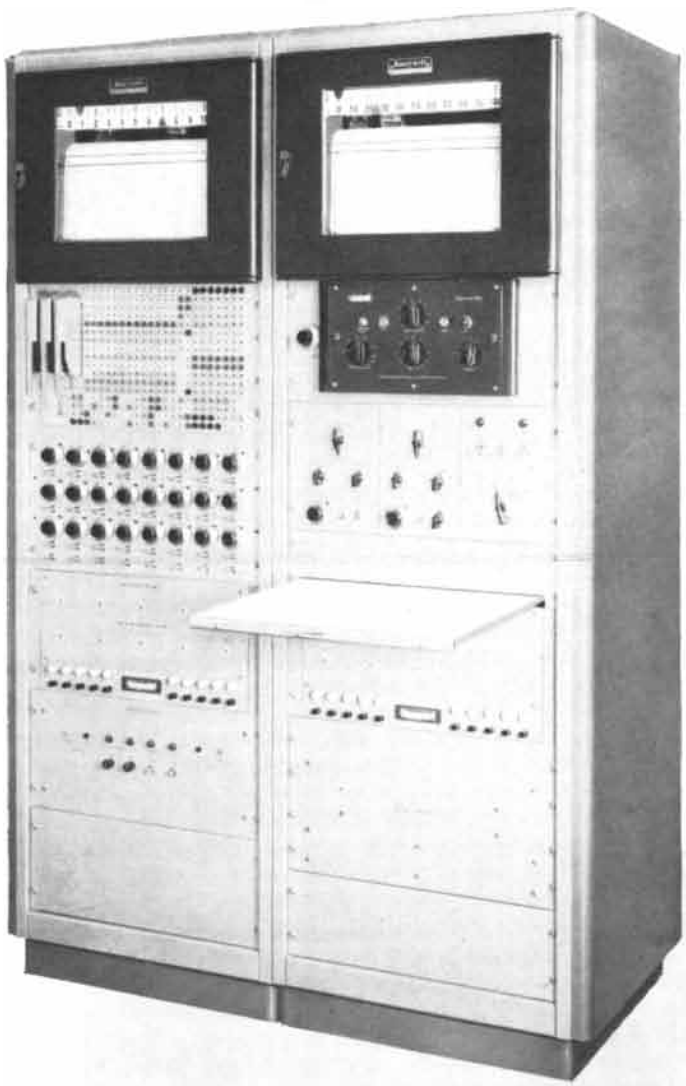
The Thermal Plant Simulator gets reactor flux information directly from the Reactor Simulator, simulates operation of a thermal plant, and feeds back control data to the Reactor Simulator. Together, they permit complete and detailed studies of neutron and thermal dynamics. Thus they provide realistic training that can be duplicated only through operation of an actual nuclear power plant.

Your nearby Honeywell field engineer can give you full details. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

**Honeywell**

H HONEYWELL *First in Control*



**THERMAL PLANT SIMULATOR** has plug-in connectors for typical power plant programs . . . patchboard panel for non-standard programs.

**NUCLEAR REACTOR SIMULATOR** teams up with Thermal Plant Simulator to provide realistic nuclear power plant training.

GET READY FOR THE SPACE ERA! SEE THE SATELLITES . . . THE MOON ROCKETS

# UNUSUAL TELESCOPE BUYS

## AND OTHER OPTICAL BARGAINS

### CLOSEOUT! MECHANICAL DRAWING SET
**Regular Price $18.00—Our Price Only $6.00 Ppd.**

American mfr. couldn't compete with foreign imports—thus you get a terrific bargain, even far below import prices. 10 handsome pieces in velvet-lined case. Nickel plated brass—precision American-made. We guarantee you'll be satisfied or money refunded.

**Stock No. 50,200-S.....$6.00 Postpaid**
**Quantity Price: 5 Sets for $5.50 each Postpaid**
**10 Sets for $5.00 each Postpaid**


Photographers! This is an actual photograph of the moon taken through our Astronomical Telescope by a 17-year-old student.

### See the Stars, Moon, Planets Close Up!
### 3" ASTRONOMICAL REFLECTING TELESCOPE
### 60 to 160 Power—An Unusual Buy!
**Famous Mt. Palomar Type**

You'll see the Rings of Saturn, the fascinating planet Mars, huge craters on the Moon, Star Clusters, Moons of Jupiter in detail, Galaxies! Equatorial mount with lock on both axes. Aluminized and overcoated 3" diameter high-speed f/10 mirror. Telescope comes equipped with a 60X eyepiece and a mounted Barlow Lens, giving you 60 to 160 power. An Optical Finder Telescope, always so essential, is also included. Sturdy, hardwood, portable tripod.

**Free with scope: Valuable STAR CHART and 272 page "Astronomy Book."**

**Stock No. 85,050-S.....$29.95 Postpaid**

### NEW! STATIC ELECTRICITY GENERATOR
**Sturdy, Improved Model!**

See a thrilling spark display as you set off a miniature bolt of lightning. Absolutely safe and harmless. Sturdily made—it stands 14" high. Turn the handle and two 9" plastic discs rotate in opposite directions. Metal collector brushes pick up the static electricity, store it in the Leyden jar type condenser until discharged by the jumping spark. Countless tricks and experiments. 24 page instruction booklet included.

**Stock No. 70,070-S.....$12.95 Postpaid**

### CAMERA HOLDER for TELESCOPES

Bracket attaches permanently to reflecting or refracting telescopes. Removable rod holds camera over eyepiece to take pictures of Moon . . . or terrestrial telephoto shots of distant objects. White metal projection screen permits you to see the sun spots! Includes brackets, 28¾" rod, projection screen, screws, directions.

**Stock No. 70,162-S.....$9.95 Postpaid**

### 4¼" REFLECTING TELESCOPE! Up to 270X!

With this scope you can see everything as above but with greater power plus will split finer stars. Mirror has twice the light gathering power. Mirror guaranteed to give theoretical limit of resolution. Rack and pinion focusing, hardwood tripod, real equatorial mounting—only one adjustment follows stars! Aluminum tube. 6 power finder telescope. 2 standard size eyepieces and mounted Barlow lens give you powers of 40X, 90X, 120X, and 270X. Low-cost accessory eyepiece available for higher powers. Free handbook and Chart. Shipping weight 25 lbs.

**Stock No. 85,006-S.....$74.50 f.o.b.**

### Take Telephoto Shots Thru
### 7 x 50 MONOCULAR

This is fine quality, American made instrument—war surplus! Actually ½ of U.S. Govt. 7 x 50 Binocular. Used for general observation both day and night and to take fascinating telephoto shots with your camera. Brand new. $95 value. Due to Japanese competition we close these out at a bargain price. Directions and mounting hints included.

**Stock No. 50,003-S.....$15.00 Pstpd.**

### ERECT IMAGE LOW POWER MICROSCOPE
### 5X, 10X, 20X

**$80.00 Value—Only $19.95**

Extremely sturdy with rack and pinion focusing, color corrected optics, turntable microscope body for inclined viewing, three different powers, long working distance under objectives, sufficient eye relief for easy viewing. Made from war surplus optical instrument so that you actually get $80.00 of value. Weighs 4 lbs., 13" high. 10-DAY FREE TRIAL! Accessory objectives available for powers of 15X, 30X, 40X.

**Stock No. 70,172-S.....$19.95 Postpaid**

### 8 POWER ELBOW TELESCOPE—WAR SURPLUS
**$200 Gov't. Cost—Only $13.50**

Big 2" objective, focusing eyepiece 28mm focal length—Amici erecting system—turret mounted filters, clear, red, amber and neutral—reticle illumination. Sparkling, clear, bright image—6° field (325 ft. at 1,000 yds.). Focus adjusts 15 ft. to infinity. 28mm F.L. eyepiece alone is worth more than $12.50.

**Stock No. 70,173-S.....$13.50 Postpaid**

### INFRARED SNIPERSCOPE TELESCOPE & PARTS

See in the dark—without being observed. War Surplus Sniperscope M-2, contains the famous IP25A image tube. Gov't cost about $1200. Instrument complete, ready to use. Includes Power Pack, infrared light source. Will operate from 6 V auto battery. Battery or transformer available.

**Stock No. 85,053-S..$150.00 fob.**

Save still more money! Build your own Sniperscope! We will furnish instructions—parts, including: Power Packs, IP25A image tubes, light units, filters, etc. For details—request FREE catalog "S".

### SALE! TERRIFIC WAR SURPLUS BARGAIN!
### AERIAL CAMERA LENSES

**Government Cost $1218—Now Low as $39.50 Used**

Made by B & L and E. K. 24" F.L. f/6, in 23" long Lens Cone. Use as long range. Big Bertha Telephoto lens—for Richest field (wide field, low power) telescope, etc. Lenses are 4" dia.—precision 4-element type. Aero Tessar and Aero Ektar. Easily removed. Diaphragm (f/6 to f/22) is included. Open approx. 1" to 3½". Lens and cone—wt. 25 lbs. Sturdy carrying trunk—wt. 26 lbs.

**Stock No. 85,059-S 24" used Price $39.50 f.o.b. Utah**
**Stock No. 85,060-S 24" new Price $59.50 f.o.b. Utah**

### WAR SURPLUS AMERICAN-MADE
### 7X50 Binoculars

Big savings! Brand new! Crystal clear viewing—7 power. Every optical element is coated. An excellent night glass—the size recommended for satellite viewing. Individual eye focus. Exit pupil 7mm. Approx. field at 1,000 yds. is 376 ft. Carrying case included. American 7 x 50's normally cost $195. Our war surplus price saves you real money.

**Stock No. 1533-S.....only $55.00 pstpd.**
**(Tax included)**

### TWO-STAGE ROCKET TOY—

Simple, safe—demonstrates principles of jet rockets. Uses water and air as fuel. First stage soars up 200 to 300 ft.—then 2nd stage is automatically released, going still higher. A 2nd stage satellite is also included and may be substituted. Made of Butyrate plastic. Set includes fuel supply tank and air injection pump.

**Stock No. 70,157-S.....$2.98 pstpd.**

### MAKE YOUR OWN POWERFUL ASTRONOMICAL TELESCOPE
**GRIND YOUR OWN ASTRONOMICAL MIRROR**

Kits contain mirror blank, tool, abrasives, diagonal mirror and eyepiece lenses. You build instruments ranging in value from $75.00 to thousands of dollars.

| Stock No. | Dia. Mirror | Thickness | Price |
|---|---|---|---|
| 70,003-S | 4¼" | ¾" | $ 7.50 postpaid |
| 70,004-S | 6" | 1" | 11.95 postpaid |
| 70,005-S | 8" | 1⅜" | 19.50 postpaid |
| 70,006-S | 10" | 1¾" | 30.75 postpaid |
| 70,007-S | 12" | 2⅛" | 54.75 postpaid |

### REPLICA GRATING—Low, Low Cost
Take Unusual Color Photos at Night.

It's here—after decades of effort. Replica Grating—on film—at very low price. Breaks up white light into full spectrum colors. An exciting display. 13,400 lines per inch. Diffraction Grating has been used to answer more questions about the structure of the material world and the universe than any other single device. Use it for making spectroscopes, for experiments, as a fascinating novelty. First time available such large size—so cheaply—comes in clear plastic protector.

**Stock No. 50,202-S**—includes 2 pcs. 8" x 5½"—**1** transmission type, 1 reflecting type. **$2.00 pstpd.**

### American Made—Over 50% Saving
### STEREO MICROSCOPE

Years in development. Equals $300 to $400 instrument. Precision American made. Used for checking, inspecting, small assembly work. Up to 3" working distance. Clear, sharp, erect image. Wide, 3 dimensional field. 2 sets of objectives on rotating turret. 23X and 40X.

**Stock No. 85,056-S.....$99.50**
**f.o.b. Barrington, N.J.**

Low Power Supplementary Lens Attachment for above Stereo—provides 15X down to 6X with clear, extra large 1½" field at 6X.

**Stock No. 30,276-S.....$7.50**

### 50-150-300 POWER MICROSCOPE

**Amazing Value—Equal of a $75.00 Instrument! 3 Achromatic Objective Lenses on Revolving Turret! Imported!** The color-corrected, cemented achromatic lenses in the objectives give you far superior results to the single lenses found in the microscopes selling in this range. Results are worth the difference! Fine rack and pinion focusing.

**Stock No. 70,008-S....$14.95 Pstpd.**

### MOUNTED 500 POWER OBJECTIVE

. . . Threaded for easy attachment on above microscope. Achromatic lenses for fine viewing. 3 mm. focal length.

**Stock #30,197-S.....$5.00 Pstpd.**

### WRITE FOR FREE CATALOG-S

96 pages! Over 1,000 items. Optics for the Space Era! Huge selection of lenses, prisms, war surplus optical instruments, parts and accessories. Telescopes, Microscopes, Satellite Scopes, Binoculars, Infrared Snipperscopes, etc. Request Catalog-S.


ORDER BY STOCK NUMBER . SEND CHECK OR MONEY ORDER . SATISFACTION GUARANTEED!

## EDMUND SCIENTIFIC CO., BARRINGTON, NEW JERSEY

# THE AMATEUR SCIENTIST

## *How short-term weather forecasts were made on the basis of electrical effects*

Conducted by C. L. Stong

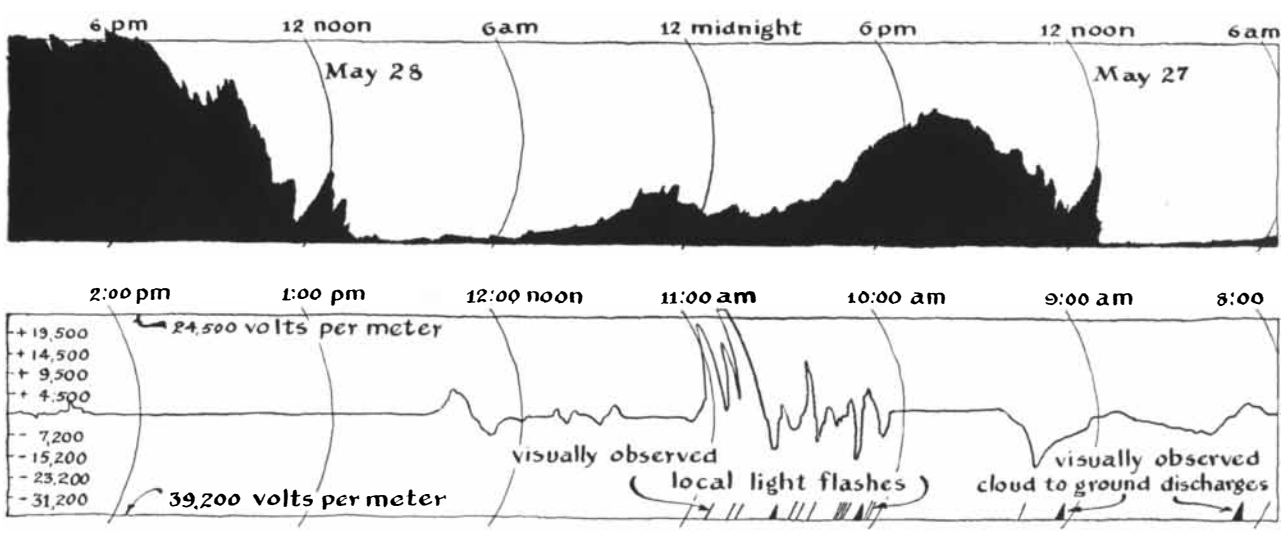
The atmospheric processes which we observe as weather give rise to two major electrical effects. One is the 360,000-volt potential that is maintained between the surface of the earth and the ionosphere by the activity of thunderstorms. In consequence of this charge we walk around even on clear days with our heads in air that is some 200 volts positive with respect to the ground under our feet. During thunderstorms the field can locally build up to tens of thousands of volts. The second effect also has its origin in thunderstorms. A portion of the energy liberated by lightning takes the form of electromagnetic waves called sferics (from atmospherics). These account for the familiar "static" heard on radio receivers. Each lightning stroke radiates at least one sferic, and some 20 million strokes occur on earth every day. Part of the energy released by these strokes escapes into space, but most of it echoes between the earth and the ionosphere until it is dissipated as heat. These effects have been studied intensively by Douglas A. Kohl, Principal Engineer of General Mills, Inc., in Minneapolis, Minn.

Writes Kohl: "Most of the rainfall in the U. S. and many spectacular windstorms stem from thunderstorms or cumulo-nimbus cloud activity characterized by the separation of electric charge. When the stress of these charges exceeds the dielectric strength of the atmosphere, a discharge occurs that has far-reaching consequences. The uniform pattern of the electric field is disrupted, and if lightning accompanies the discharge, sferics are radiated. Both the field disturbance and sferics can be detected and measured with relatively simple apparatus, the former over an area of 50 to 200 square miles and the latter for hundreds of miles. The resulting data provide meaningful clues to approaching weather. My initial interest in the electrical aspects of weather has grown into a full-scale avocation which I can recommend to anyone with more than a passive interest in meteorology.

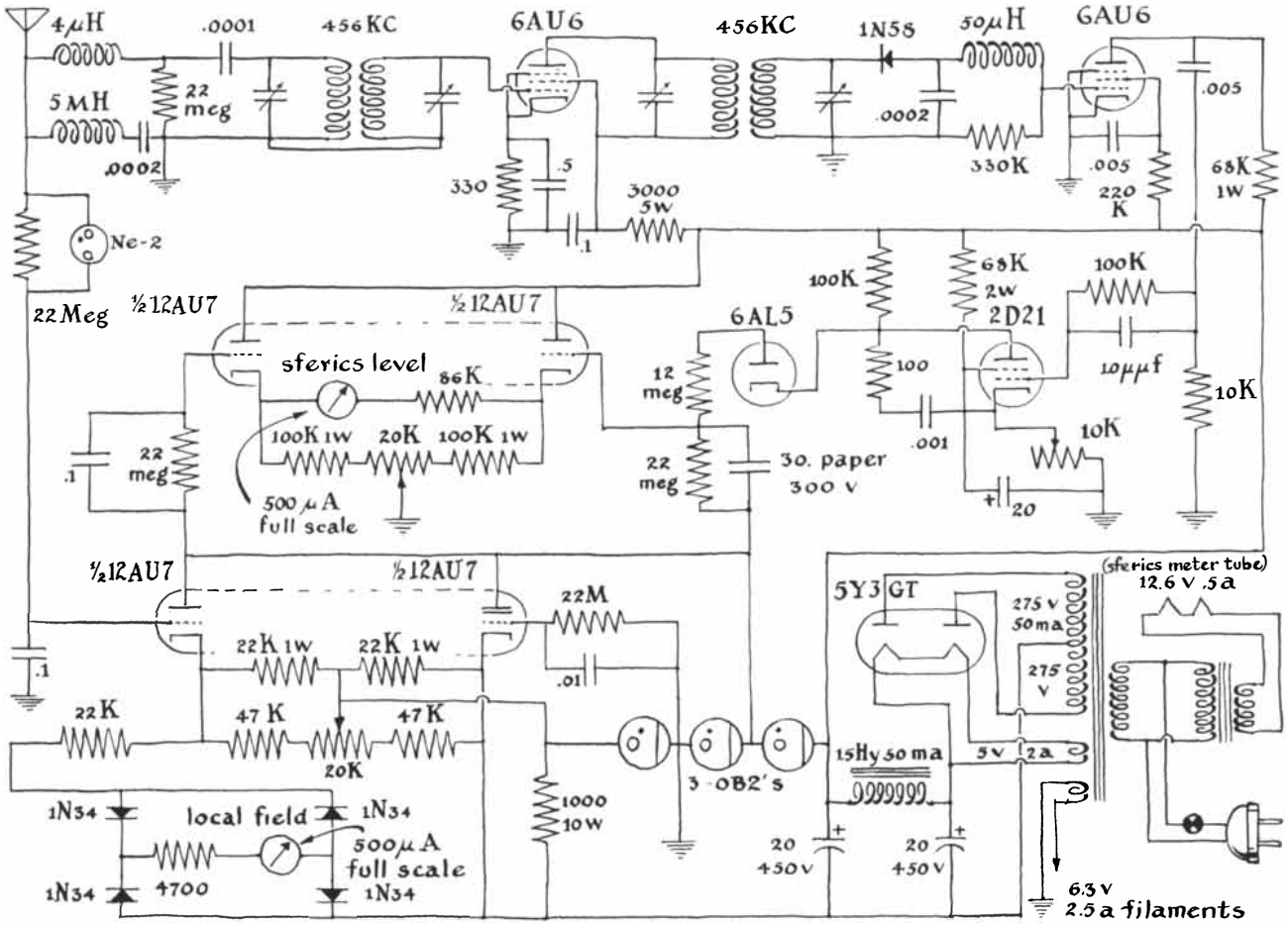
"To the eye, lightning appears deceptively simple: merely a big spark which, it is said, never strikes twice in the same place. This impression vanishes when a discharge is recorded with responsive instruments. Strokes from cloud to cloud, from cloud to ground or from the top of a cloud to the bottom are nearly aways preceded by complex minor discharges, or leaders, which precede the main arc. The leaders advance in stepwise fashion, following routes along the most highly stressed regions between centers of opposite charge. These junior discharges trigger the main arc by moving the centers of charge progressively closer. Fields of extreme intensity result, and the final transfer of charge follows the ionized pathways created by the leaders.

"The leaders usually begin about a thousandth of a second before the main arc, and often advance in as many as 30 steps. Each step produces an electromagnetic disturbance and an abrupt change in the electric field. Not all leaders end in an arc, particularly when they are associated with rapidly growing cumulo-nimbus clouds. They can still be detected electrically.

"Another characteristic of lightning is the multiple stroke of the main arc. Single strokes are uncommon. Multiple strokes are usually completed within a few millionths of a second; otherwise they extend over several thousandths of




*Records of "sferics"* (top) *and of disturbances in the intensity of the earth's electric field* (bottom)




*Schematic diagram of a circuit for a sferics counter and field-intensity meter*

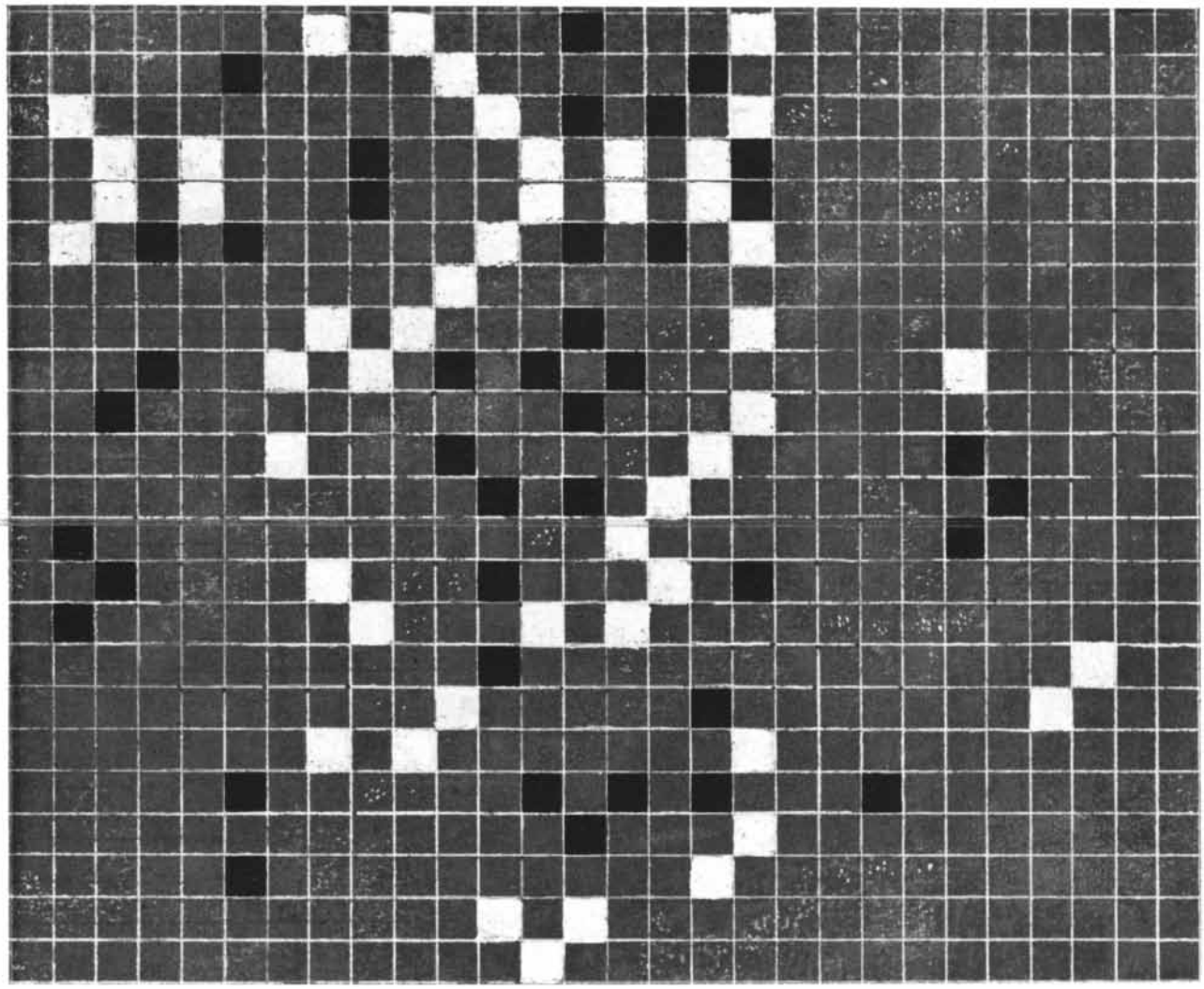
a second. Few strokes are of intermediate duration.

"Although oscillograms show that no two sferics are alike, all cover a broad spectrum of frequencies. Most of the energy is concentrated in the region below 20 kilocycles. The sferics are detected by means of a rudimentary radio receiver; the number picked up during a given interval can be counted automatically by equipping the receiver with a register. In monitoring sferics on three frequencies (430, 2,000 and 5,100 kilocycles) I have observed that the count at each frequency is related both to the distance the sferic is propagated and to the type of discharge from which it is radiated. The ratio of counts among the three frequencies changes characteristically as the storm approaches or recedes. During late-afternoon storms at a distance of 100 to 200 miles, for example, every 100 counts at 430 kilocycles are accompanied, on the average, by 46 counts at 2,000 kilocycles and 13 counts at 5,100 kilocycles. By the time the storm has moved into the local area, the ratio has changed from 100:46:13 to 100:96:50.

"Cold-front advances and storms characterized by a high percentage of cloud-to-ground discharges show considerably less change in ratio. A comparable ratio for long-distance frontal activity would be 100:74:40. Normally one is chiefly interested in the rate of counts at each frequency. It is possible, however, to set up a coincidence-counter to identify sferics that appear simultaneously on two or more frequencies. This counter shows that nearly 90 per cent of those sferics registered on the 5,100-kilocycle channel also appear on the 430-kilocycle channel, thus confirming their common origin.

"Recordings made in the vicinity of Minneapolis are almost as dramatic as the lightning which produces them. The 430-kilocycle channel has provided consistent data up to a radius of 200 miles with counting rates frequently rising as high as 150,000 sferics per minute! The current flowing in a main arc, which may register as a single sferic, can exceed 20,000 amperes. The duration of the arc is of course measured in millionths of a second. But at the rate of 150,000 sferics per minute the average current flowing between the earth and the cloud is on the order of 500 amperes. Other investigators report a mean energy of some 200,000 joules per full-sized lightning discharge. The corresponding energy liberated over the monitored area could thus amount to 30 billion joules per minute, or 500,000 horsepower!

"On clear days the distribution of the electric field between the ground and the ionosphere is relatively uniform. But violent changes are observed when a storm passes overhead, and the build-up in charge which results in a stroke of lightning is easily observed. Many such build-ups occur in less than 30 seconds. Interactions in the field are as fascinating as they are complex. A single discharge can warp a relatively smooth field so that another stroke follows in a matter of seconds. One also observes many polarity reversals in which the normally negative earth swings positive. These changes, like the leaders which initiate lightning, follow a steplike pattern. In most instances the highly stressed field relaxes slowly without evidence of an arc. From this it would seem



## A NEW DIMENSION IN COMPUTER TECHNOLOGY

Never has so vast and complex a project been undertaken in data processing and data communications. Billions of bits to be handled . . . information flowing in from hundreds of electronic sources, processed by digital techniques, displayed, solutions and commands issued . . . in precious seconds.

A very short time ago we were a newly created subsidiary of International Telephone and Telegraph Corporation. Today we are a purposeful engineering management group actively forging ahead with the myriad problems of our challenging project.

As systems manager we are charged with the development and production of a world-wide electronic control system which will transmit, process and display information required in military operations — global, in seconds. This project demands a wealth of engineering imagination. It will result in creation of a wholly new technology in digital computer science.

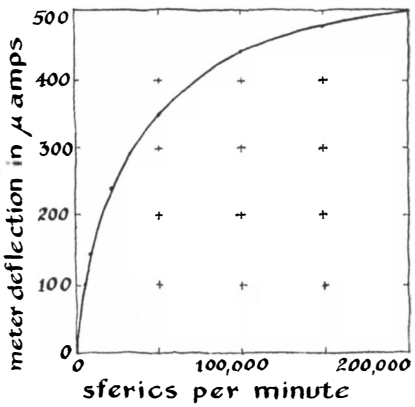
If your interests as an engineer lie in electronic systems engineering, in data processing and communications, you will find in this project unusual opportunity to express imagination and creative competence, in a degree surpassing anything previously undertaken in computer engineering.

*To obtain information on engineer openings write A. J. Crawford, Personnel Manager. A resume of your education and experience is essential. An interview will be arranged at your convenience.*

**INTERNATIONAL ELECTRIC CORPORATION**

Route 17 & Garden State Parkway, Paramus, New Jersey

*A Subsidiary of International Telephone and Telegraph Corporation*




*Calibration curve for sferics counter*

that the potential electrical energy in a widespread storm may be much greater than is indicated by the record of sferics.

"For purposes of weather forecasting, measurements of sferics and field intensity need be combined only with readings from a local barometer and wind-direction indicator. After a reasonable amount of practice in interpreting this information, reliable eight-hour forecasts are easy to make. During the summer of 1947 our method gave only one incorrect eight-hour forecast in 50 attempts. The score of the local Weather Bureau for the same period was less than 50 per cent. The Bureau's forecasts were handicapped, however, by an unusual pattern of weather.

"The effectiveness of sferics and field intensity in forecasting lies in the fact that cumulo-nimbus cloud activity provides a sensitive indication of potentially turbulent air conditions during the summer months. An array of these clouds usually appears in late afternoon. They may either develop into thunderstorms or dissipate with the setting sun. On the basis of visual information alone it is impossible to predict which of these two courses they will follow. In contrast, variations in the strength of the electric field, coupled with a moderate sferics level, nearly always signal the advance of thunderstorm activity into the local scene, even though the visible clouds have not begun the familiar consolidation that marks the first stage of a maturing storm.

"The sferics record at any location constitutes the summation of weather activity throughout the area covered by the recorder. The profile shows the consolidations, growth and maturity of various thunderstorm cells. A typical record made in the late spring of 1956 is reproduced in the illustration on page 155. Weather conditions at that time were reported as a stalled front to the north,

# Frontiers are extended by the practical visionary

It is the practical visionary who has given us much of what we enjoy today. And it will be the visionary—the man with ability to seek concepts beyond the existing limitations of science —who will guide our developments of tomorrow.

The Applied Physics Laboratory (APL) of The Johns Hopkins University seeks men who will be engaged in advanced research problems—who will find solutions to problems yet to be posed. Their findings will provide guidelines for the space and missile hardware research of the future.

Your endeavors will be heightened by the professional atmosphere of APL. This atmosphere, created by men dedicated to the furtherance of science, has earned APL a reputation as a leader in programs vital to the national security.

*Appointments at APL offer exceptional opportunities. For detailed information, address your inquiry to:*

**Professional Staff Appointments**

## The Johns Hopkins University Applied Physics Laboratory

**8641 Georgia Avenue, Silver Spring, Maryland**

with high humidity and temperature carried into the region by several days of southerly winds. The heat of the sun caused thunderstorm activity to begin around noon; the thunderstorms were then dissipated as the atmosphere cooled off at night. Full scale on the graph is 200,000 sferics per minute. The rate varied from 21 counts per minute (9:30 a.m. on May 27) to more than 200,000 per minute (after 6 p.m. on May 28). This 10,000-fold increase was intimately related to the weather disturbance.

"In this as well as in many other periods of activity one or two fairly intense consolidations take place prior to the change of weather in the area. These are noted at about noon on both days. Apparently in the complex interactions within a region close to major weather landmarks—high-pressure ridges, low-pressure cells, fronts and so on—the advent of one or two thunderstorms will either trigger general regional activity or else the cumulo-nimbus formations will quickly dissipate. The sustained activity early in the evening of May 28, shown by the record, persisted as the cold front moved across the area. The southerly flow of air apparently blocked the movement of the front a second time; the temperature drop and northerly winds did not materialize until May 31, after local thunderstorms were observed during the night of May 29. Sferic activity from the region west and north persisted during the entire period.

"As for the forecast that was based on this record, it should be noted that thunderstorms were not visible in the distance until about 5 p.m. on May 28. In spite of strong southerly winds on May 27 the decrease in sferic activity early in the evening led to the correct prediction that no change in weather would occur in the immediate vicinity during the night and following morning. A stronger southeast wind appearing at midafternoon the next day, coupled with the rapid increase in sferic activity, led to the forecast that turbulent weather would enter the vicinity within several hours. The nearest storm was seen and estimated to be 12 miles from the sferics station. A slow decrease in the sferic level, which occurred during the following morning, added to occasional field disturbances beneath passing clouds and resulted in a further prediction that the weather had not cleared and other storms were imminent. These developed on schedule.

"For rapidly moving storm systems the advance indication on the sferic recorder amounts to only a few hours,

ENGINEERS

# *Announcing the formation of*

THE MITRE CORPORATION

A NON-PROFIT CORPORATION ORGANIZED TO PROVIDE SYSTEM ENGINEERING SUPPORT TO THE AIR DEFENSE SYSTEMS INTEGRATION DIVISION (ADSID) OF THE UNITED STATES AIR FORCE

ADSID was formed by the United States Air Force to plan and integrate the elements of the air defense system and to provide management guidance to the agencies responsible for the development, production, and operation of this system as it evolves during the years to come. In this planning MITRE must take into account the threat, defense technology, and the logistics of air defense in such a way as to achieve the best possible defense system, at minimum cost, for any given time period.

All of the components of air defense – communications systems, detection systems, data processing systems, and weapon systems – must be engineered and planned so that they are mutually compatible in both a technical and a scheduling sense.

As technical advisor to ADSID, MITRE will require engineers and scientists with high qualifications in the fields of ground-based and airborne radars; wire and radio communications, including voice, teletype, and data transmission facilities; data processing systems; computer facilities; manned interceptors; and defense missiles.

MITRE will also require the services of operations and analysis engineers and logistics planners for production and system scheduling.

---

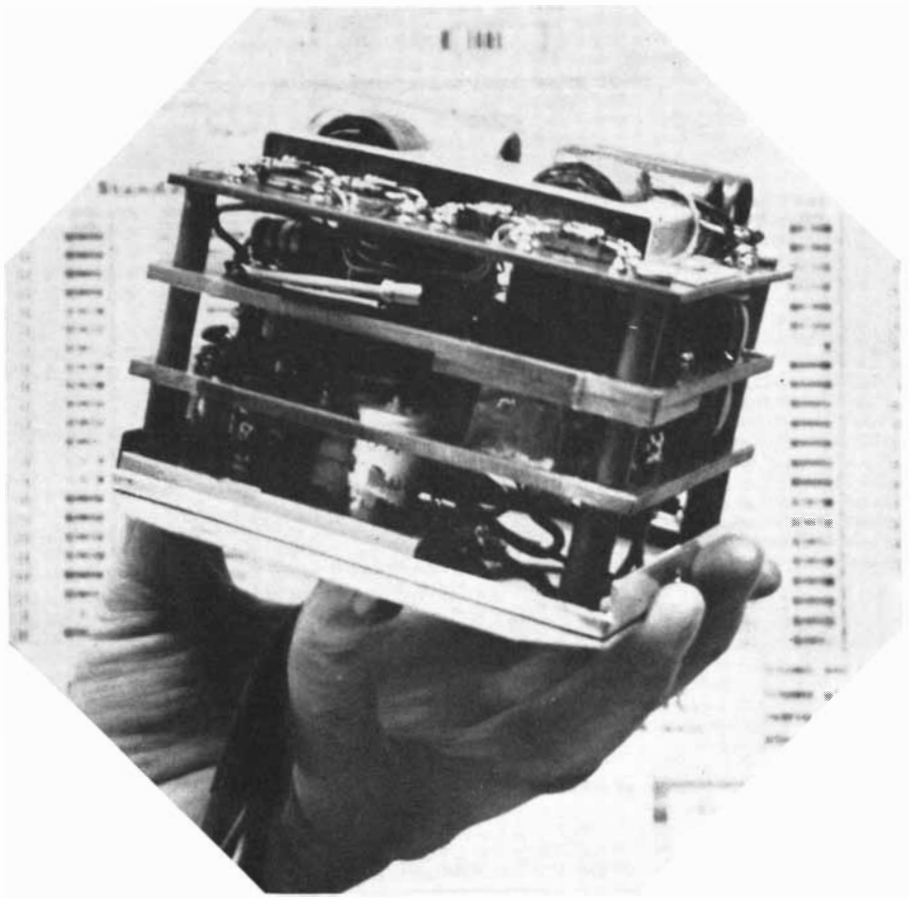
Specialists are invited to make confidential inquiries by contacting the Personnel Director of The MITRE Corporation, 244 Wood Street, Lexington 73, Massachusetts.

and reliable eight-hour forecasts are not difficult. As the observer acquires the knack of interpreting the records, he can also make accurate forecasts under more passive conditions. Observations of the electric field then become particularly useful. Occasionally tremendously impressive cloud formations, including the formidable roll clouds associated with maturing thunderstorms, appear; by conventional standards these would signal foul weather. But when the recorder shows them to be charge-free the observer knows at once that they will be nonviolent. Locally severe storms, on the other hand, are accompanied by violent changes in electric field even though the general sferic level may be fairly low—a clue that the enveloping storm covers a small area.

"With the exception of the electrical-pen recorder, the equipment for measuring field intensity and making sferic counts is relatively inexpensive. The sferic detector is essentially a special radio receiver equipped with a means for counting short pulses of current [*see illustration on page 156*]. The antenna consists of a bare copper wire at least 20 feet long suspended 10 feet or more above the ground between glass insulators. It serves the dual purpose of picking up sferics and sensing field intensity.

"A sferic signal excites the tuned 456-kilocycle transformer, and the resulting oscillations are amplified. The train of amplified oscillations is then rectified and used to trigger a pulse-forming circuit. The output is averaged in a vacuum-tube voltmeter circuit. The antenna should be equipped with a lightning arrester; as a further protection the receiver is equipped with a choke coil designed to block damaging bursts of energy at high frequencies.

"The radio-frequency amplifier consists of two standard 456-kilocycle intermediate-frequency transformers and a high-gain pentode tube. Incoming signals are rectified by a crystal diode that delivers negative pulses at the output. The negative pulses tend to drive the grid of the 6AU6 tube to cutoff, the point at which no current can flow between the cathode and plate. The output of this tube is fed to the 2D21 Thyratron by way of a resistance-capacitor network designed for a pulse duration of 50 microseconds. Most multiple-stroke lightning discharges are thereby registered as a single count. Corresponding pulses generated by the Thyratron tube persist for 100 microseconds. The sensitivity of the circuit to sferics is controlled by adjusting the bias of the Thyratron. Normally this control is set



# The most serious of facts

● "Power when wielded by abnormal energy is the most serious of facts," wrote Henry Adams in *The Dynamo and the Virgin*. One serious fact is the birth of the handful of power above: the early form of a transistor regulated power supply, developed by *tech/ops*, now in production, in sophisticated forms by *tech/ops*' subsidiary, Power Sources, Incorporated.

Best suited for arduous requirements in applications demanding reliability under extreme operating conditions which force rejection of conventional power supply circuitry (such as guided missiles and other military space needs), this handful of power is also presently being used in television stations, as in a host of other applications.

And it is another typical example of *tech/ops*' product capability and broad scientific research and development for business, industry, and government.

**personnel requirements**

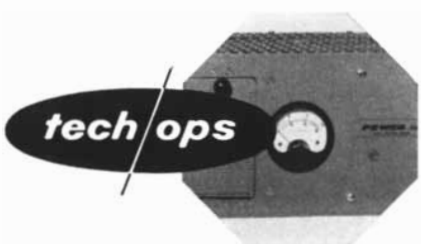
at **Fort Monroe, Virginia, or Burlington, Massachusetts: Operations Analysts** experienced in industrial or military operations research, systems analysis, weapons systems evaluation, computer techniques, or related fields; training should be in mathematics or physical sciences, preferably on graduate level.
at **Washington, D. C.: Programmers** with substantial experience in the development of large digital computer programs; background should include experience with design and application of assembly programs, compilers, and advanced programming concepts.
at **Monterey, California: Communications** engineer or physicist thoroughly familiar with the principles of radio transmission and communications network analysis.

*address: Robert L. Kolker*

## Technical Operations, Incorporated

*Central Research Laboratories / Burlington, Massachusetts*

• WASHINGTON, D.C. • MONTEREY, CALIFORNIA • FORT MONROE, VIRGINIA



to register not more than one pulse per hour during the winter or during fair summer weather.

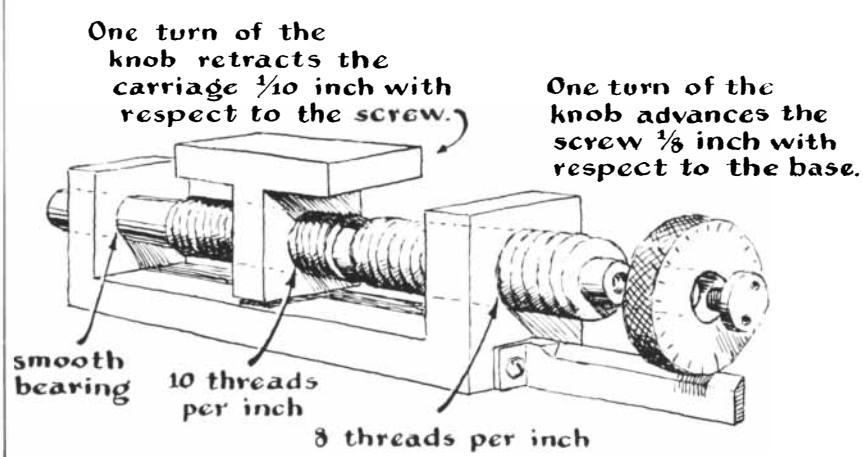
"The output of the Thyratron is coupled to a capacitor-resistance 'averaging' circuit. This smooths out random fluctuations in the sferics counting-rate, and thus gives meaning to recorded values of 50 counts per minute or less.

"As mentioned earlier, the rate at which sferics are detected spans a broad range: from less than 20 sferics per minute to more than 200,000. Hence the scale of the recorder must be compressed as the sferics rate increases to prevent the pen from being carried off the paper. This is accomplished by taking advantage of the grid-cutoff characteristic of the 12AU7 voltmeter tube. As the counting rate increases, progressively higher negative voltage is applied to the grid of the 12AU7, thus reducing the response of the meter.

"The leakage current of the antenna, which varies with the intensity of the electric field, is measured by another averaging voltmeter circuit which utilizes a second 12AU7 tube. One grid is connected to an averaging resistor-capacitor circuit which is connected in turn to the antenna. Some capacity and resistance are inserted to counteract the effects of abrupt changes in the electric field which accompany local lightning discharges. The antenna is so effective that transient changes in the field can induce potential differences in the circuit as high as 10,000 volts! To protect the meter a 22-megohm resistance and a .1-microfarad capacitor are connected in series between the antenna and ground, and the grid of the voltmeter tube is tied to the junction between the two. The capacitor requires an appreciable interval to reach full charge through the resistor. This delay protects the meter against abrupt voltage surges. Sensitivity to local weather is lost by the circuit, however, if transients are suppressed completely. The resistor is therefore bridged by a small neon tube. When the input voltage exceeds the firing potential of the tube (70 to 100 volts), the neon glow short-circuits the resistor and in effect transfers the antenna directly to the capacitor and the grid. The five-millihenry choke and .0002-microfarad capacitor connected between the antenna and ground present a low resistance to slowly varying fields, such as those produced by nearby power lines, and thus prevent these sources of voltage from firing the neon tube."

Amateurs are occasionally faced with the problem of equipping an instrument with a very fine mechanical adjustment. In November, 1956, for example, this department described an interferometer, the accuracy of which in the measurement of short distances depended on the delicacy with which the moving carriage of the apparatus could be positioned. The problem was solved by equipping the instrument with a machinist's micrometer which moved the carriage by depressing a lever.

George O. Smith, an engineer of Highlands, N.J., suggests an alternative device: the differential screw. Two sets of threads, differing in pitch, are cut in separate segments of a rod. One set engages a nut fastened to the bed of the instrument. The other engages a similar nut attached to the movable carriage. When a knob attached to the rod is turned, one set of threads tends to advance the carriage and the other to return it. The difference in pitch produces a net movement of the carriage, as shown




*A differential screw used for a fine-adjustment device*


# The Perfect Solution:

(Forensically Fortified)

"The people want vitamins! All our surveys prove it. *Vitamin C* will improve our sales astronomically," intoned O'Reilly the oratorical marketing manager of Oompah Orange Drink Co.

"That'll get us into orbit, O'R.," shot back Hy Budgett, the hard-sell adman. "And in our commercials we'll have this midget dressed up in a bubble helmet with a big 'C' on his space suit."

" 'Call for vitamin C,' he'll say, and we'll send him around to supermarkets and stores," rejoindered O'Reilly, jumping up and down on his soap box. "And we'll buy our vitamin C from Pfizer. They're veterans in vitamins. With their help we'll fortify all our soft drinks, build a vitamin C program with a platform to please everyone."

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Of course they'll buy their vitamin C from Pfizer. Whether you're interested in vitamin C for fortification of food products or for medicinal products, you can benefit from the years of vitamin experience and the extensive technical service department that make Pfizer the choice in vitamins. In fact for *any* problem which might be solved by a high-quality organic chemical, think of Pfizer first. Chas. Pfizer & Co., Inc., Chemical Sales Div., 630 Flushing Ave., Brooklyn 6, N. Y.

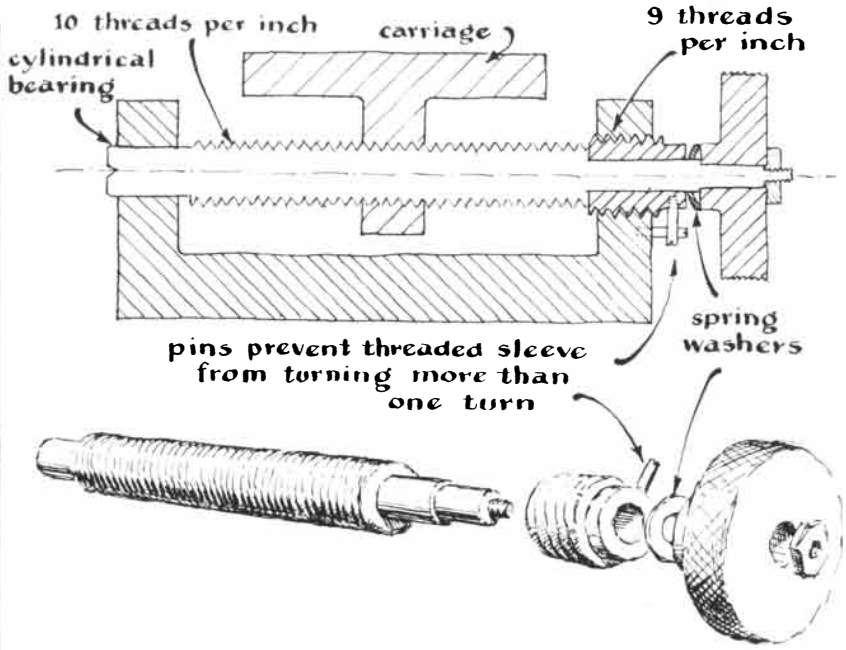
**Pfizer** **CHEMICAL SALES DIVISION**

*. . . 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, $B_{12}$ STABLETS* AND OTHERS**

*TRADEMARK




*Variation of the differential screw providing both fine and coarse adjustments*

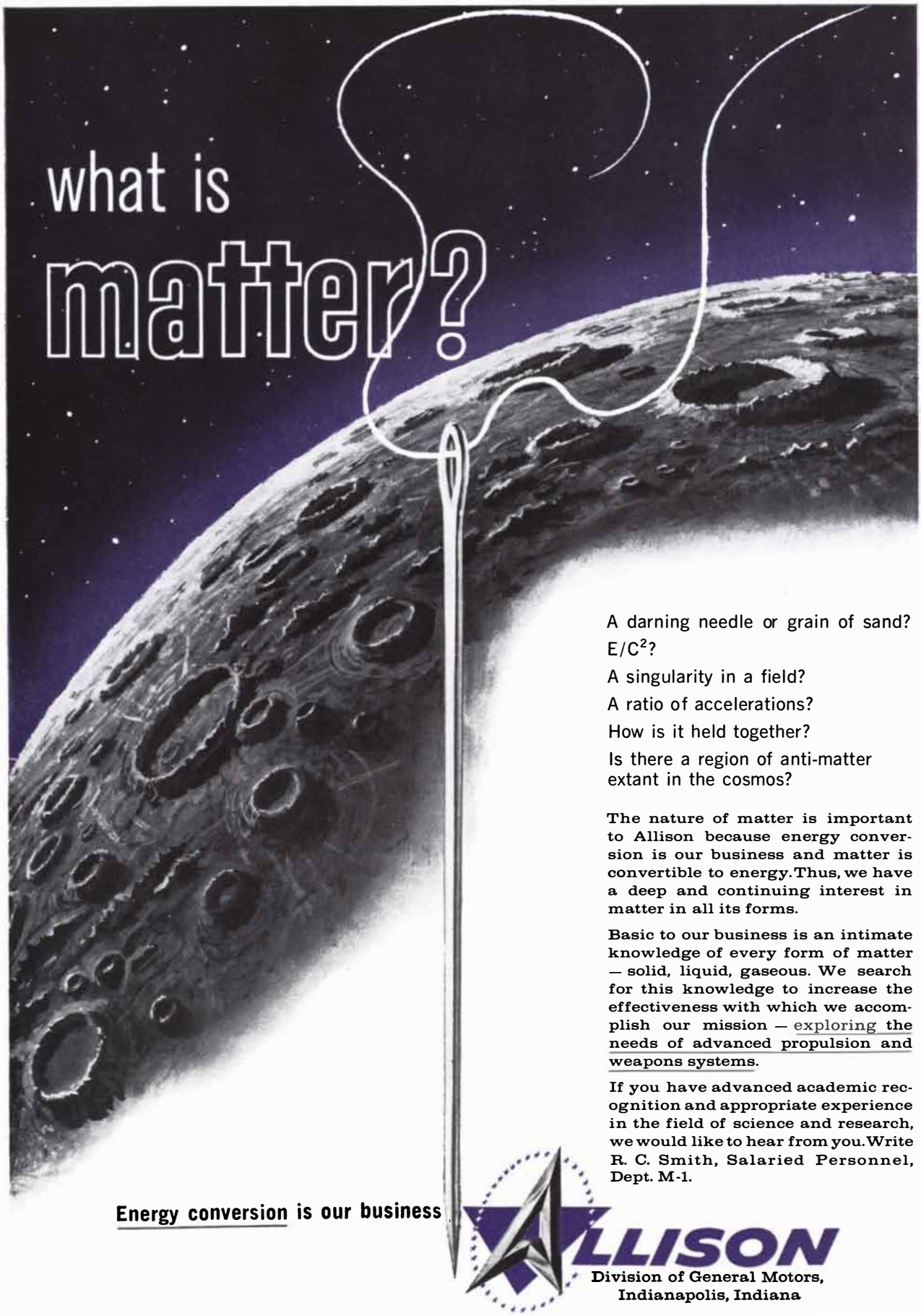
in the drawing on page 164. The threads can be made as coarse as desired and the net movement as fine as desired. Assume that the portion of the rod that engages the bed nut is threaded with 10 turns per inch, and that the portion that engages the carriage nut is threaded with eight. Ten turns of the knob will advance the lead screw one inch. Simultaneously the carriage is returning eight tenths of an inch along its portion of the lead screw; this results in a net movement of only a quarter of an inch. One turn of the knob thus advances the carriage .025 inch.

"The device is not without limitations. For one, it does not lend itself well to long throws of the carriage. The differential screw gains its mechanical advantage at the cost of displacement, which means that quite a lot of lead screw is required to produce a given motion of the carriage. In the case of 10 threads per inch working against eight threads per inch, a carriage translation of one inch requires a total screw length of seven and two tenths inches. Matters worsen as the differential is made less. In the case of 10 threads per inch working against nine, one turn of the knob advances the carriage only a ninetieth of an inch, but requires a total screw length of 19 inches for a carriage translation of one inch!

"All screw-driven devices are subject to errors built into the lead screw, among the worst of which is 'drunkenness,' or variation of pitch within a single turn or fraction of a turn. Drunkenness is present in some amount in the lead screw of the lathe on which the screw is cut, and the error is reproduced in the work. In the case of the differential screw, however, we stand a good chance of averaging out the error because the two portions work against each other."

Roger Hayward, who illustrates this department, has had considerable experience with differential screws. He writes: "Smith's statement that errors due to drunkenness in his screw are as likely to cancel out as to add to each other is in conflict with Murphy's law. (If something can go wrong, it will.) But this is not the only bug in the device. A very real one will show itself in the fit between the screw and the nuts, and in the alignment of the screw with the ways on which the carriage rides. To minimize the effect of drunkenness the lead screw should be lapped against the nuts with which they mate, and the nuts should be supported in gimbals.

"Incidentally, I used a variation of the differential screw in a Michelson interferometer I once designed for the Mount Wilson Observatory. In this scheme the bed nut engaged a sleeve cut with eight threads per inch. The sleeve served as one bearing for the lead screw, in which 10 threads per inch were cut. Rotation of the threaded bearing was limited by a stop to something less than one revolution [*see illustration above*]. This variation enables one to position the carriage roughly at the rate of one inch per 10 turns of the knob. The differential principle is brought into play by permitting both screws to rotate (advancing the carriage at the rate of one inch per 40 turns of the knob) for the desired fine adjustment."




A darning needle or grain of sand?

$E/C^2$?

A singularity in a field?

A ratio of accelerations?

How is it held together?

Is there a region of anti-matter extant in the cosmos?

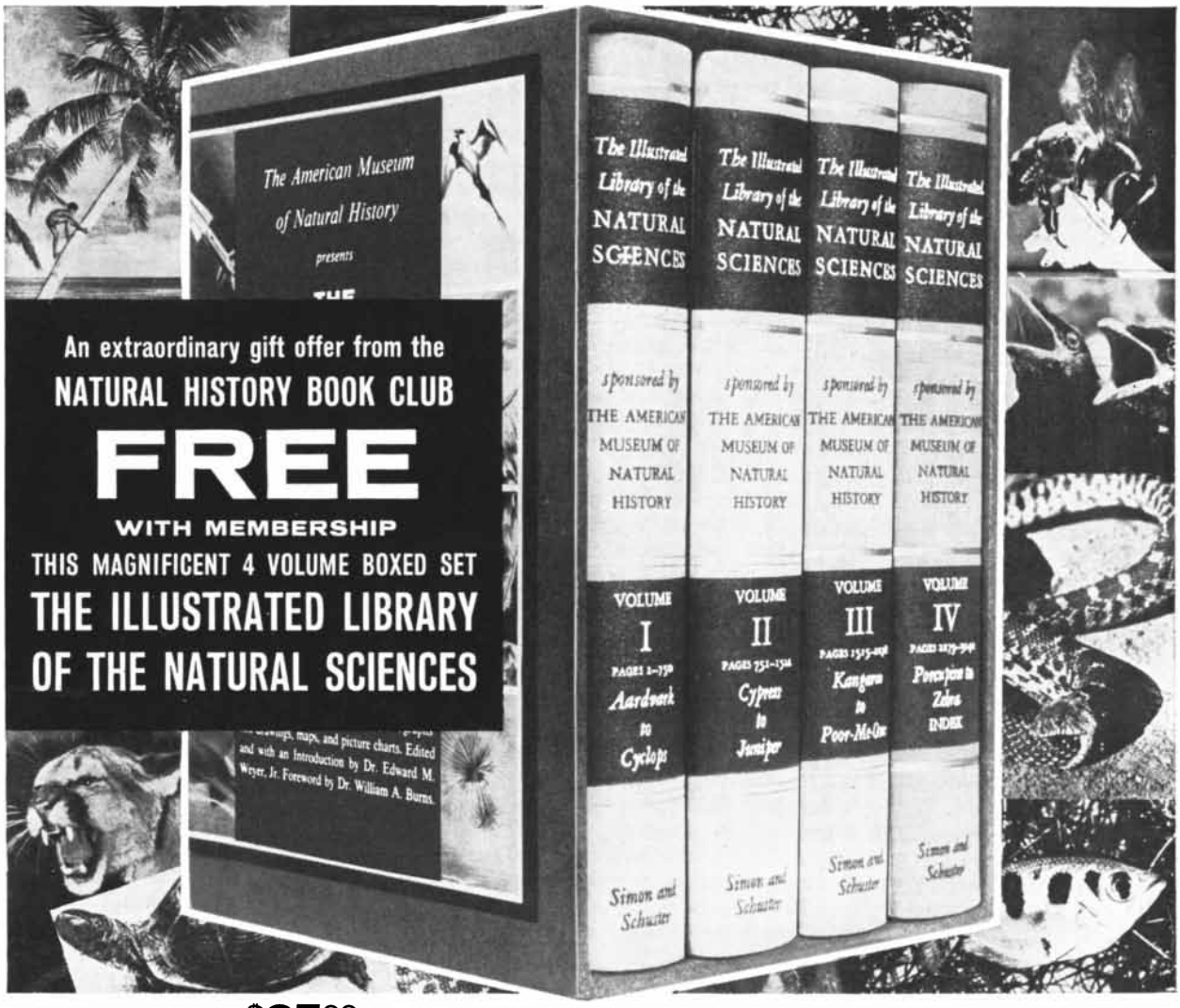
**The nature of matter is important to Allison because energy conversion is our business and matter is convertible to energy. Thus, we have a deep and continuing interest in matter in all its forms.**

**Basic to our business is an intimate knowledge of every form of matter — solid, liquid, gaseous. We search for this knowledge to 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. M-1.**

**Energy conversion is our business**

**ALLISON**
**Division of General Motors,**
**Indianapolis, Indiana**




**Published at $25.00**

*under the sponsorship of*
*The American Museum of Natural History*

- **OVER ONE MILLION WORDS**
- **MORE THAN 3,000 PAGES**
- **OVER 3,000 ILLUSTRATIONS**
- **165 DISTINGUISHED CONTRIBUTORS**

A breathtaking panorama of knowledge in every area of natural science—from anthropology to zoology, from aardvark to zebra. The famous contributors include Marston Bates, William Beebe, Arthur Clarke, J. Frank Dobie, Willy Ley, Donald Culross Peattie, T. C. Schneierla, Edwin Way Teale, and many others.

While rockets and satellites hurtle into outer space to probe the mysteries of the universe, other mysteries — every bit as fascinating — are yielding their secrets to scientists studying the amazing world of nature. New facts are being discovered almost every day about the origin of our Earth and its composition, the vegetation, insects, fishes, reptiles and mammals that have developed on it, and the growth of man himself from primitive savagery to modern civilization. These are facts more and more thinking people want to know today to understand their own relationship to the world of nature, and to the startling scientific accomplishments of our time.

To help you keep abreast of these developments, the NATURAL HISTORY BOOK CLUB invites you to join now, and accept as a Membership Gift the magnificent four-volume boxed set of THE ILLUSTRATED LIBRARY OF NATURAL SCIENCES. Simply choose the volume you want as your first selection from those described below. As a member you need purchase only 3 additional books at reduced Member's Prices during the next 12 months. You will also receive a valuable free bonus book after every fourth purchase — in addition to your Membership Gift of *The Illustrated Library of The Natural Sciences.*

**THE NATURAL HISTORY BOOK CLUB** H-1
**63 Fourth Avenue, New York 3, N. Y.**

Please enroll me as a member and send, as a Membership Gift, THE ILLUSTRATED LIBRARY OF THE NATURAL SCIENCES, along with my first selection at the reduced Member's Price. My only obligation is to take 3 more selections during the next 12 months; I will receive a free Bonus Book after each fourth purchase.

First Selection_____

Additional Selection Desired_____

Name_____

Address_____

City_____ Zone____ State_____

**CHOOSE YOUR FIRST SELECTION FROM AMONG THESE SIX IMPORTANT BOOKS**

**CAN MAN BE MODIFIED?** *by Jean Rostand* & **INSIDE THE LIVING CELL,** *by J. A. V. Butler* **(dual selection).** The basic processes of life and the possibilities of scientific control and alteration, analyzed by two leading authorities. PUBLISHER'S PRICE $6.50 *Member's price* **$5.25**

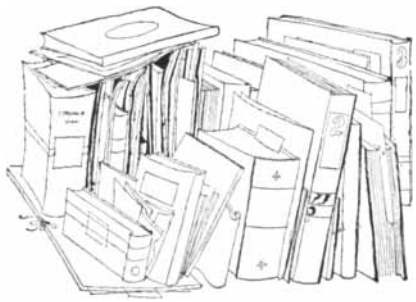
**ELEPHANTS,** *by Richard Carrington.* The complete story of elephants' evolution, history, anatomy, temperament, mating, reproduction, intelligence and usefulness to man. PUBLISHER'S PRICE $5.00 *Member's price* **$3.95**

**THE ANATOMY OF NATURE,** by *Andreas Feininger.* How function shapes the form and design of animate and inanimate structures throughout the universe. 176 photographs. PUBLISHER'S PRICE $5.95 *Member's price* **$4.95**

**RIVERS IN THE DESERT,** *by Nelson Glueck.* Fascinating archeological history of the Negev desert that reconstructs the vanished civilization of the fourth millennium before Christ. PUBLISHER'S PRICE $6.50 *Member's price* **$4.95**

**PATTERNS OF SEXUAL BEHAVIOR,** *by Clellan S. Ford and Frank A. Beach.* A detailed analysis and comparison of the sexual behavior of 90 species of animals, from domestic creatures to the great apes. PUBLISHER'S PRICE $5.00 *Member's price* **$4.25**

**THE EARTH AND ITS ATMOSPHERE,** *edited by D. R. Bates.* Fifteen distinguished scientists present the latest discoveries in understanding weather, circulation of oceans, meteorology, cosmic rays. PUBLISHER'S PRICE $6.00 *Member's price* **$4.95**



# BOOKS

## *Erwin Schrödinger discourses on the problem of mind and matter*

by James R. Newman

MIND AND MATTER, by Erwin Schrödinger. Cambridge University Press ($2.75).

High up in the vault of the head, site of the roof brain, the world comes to light. Sensations, perceptions, memories weave their images. In that tiny tenement all experience comes to focus. Is this moving picture a projection of a real world existing outside, or is the picture itself the whole stuff of the world? The question has for centuries engrossed philosophers, scientists and plain men. Those who are called idealists have asserted that the picture is constructed by mind, and that mind is the reality and matter a mere fiction; those who are called materialists have maintained that matter alone exists and that mind is merely one of its properties. The meaning of the words "mind" and "matter" has itself of course been a subject of vast debate, but on one point at least there has usually been agreement: Between mind and matter lies an impassable gulf.

The debate continues, and here in Schrödinger's latest volume, the Tarner Lectures given at the University of Cambridge in 1956, we have yet another analysis of various aspects of the classical problem. It is not a fresh venture for Schrödinger; he trod the same ground in the epilogue to *What Is Life?*, in *Science and Humanism,* in *Nature and the Greeks* (which I reviewed at length in these columns more than four years ago). For this restless, exquisitely sensitive thinker the mind-matter question has long had a powerful attraction. He has made his mark in physics but his eye scans a wider horizon. He is absorbed in matters which science in its strict definition cannot answer alone. In his search for meaning—of life and the world—he has not been bound by the traditional methods of science. He has not renounced them, but he has supplemented them. Bertrand Russell wrote in a famous essay that men who have sought to conceive the world as a whole by means of thought have felt the need of both science and of mysticism. Schrödinger has felt this need, and has tried to harmonize both impulses. His book is a gem with many facets; one loses oneself easily peering into its depths.

He begins his lectures by considering the physical basis of consciousness. For this purpose it is convenient to adopt the "hypothesis of the real world." Somewhere behind the eyes resides a thinking, sensing, conscious self. This is "inside." We distinguish also an "outside": an external world which consists, as we imagine, of all that has been and is—shapes, sounds, motion, light, matter. This world, we say, exists; yet existence is obviously not enough to make the world manifest. It must communicate itself to us, make itself known. We suppose this is achieved by a complex of signals which the self interprets. How this is done is essentially a mystery, but we conjecture that certain processes taking place in a certain highly specialized piece of matter known as the brain produce certain peculiar occurrences called consciousness. All this may be nonsense, but it is not barren nonsense.

According to our model, consciousness is associated with material processes which take place in nerve cells and brains. It is well established that these biological features, which characterize many different kinds of organisms, serve a unique and valuable purpose. The individual possessing such a mechanism can adapt itself, can choose, can respond to changes in surroundings by changes in its behavior. There are, to be sure, organisms such as plants which can adapt themselves in an entirely different fashion, but a nervous system crowned with a brain is not only the most elaborate and ingenious of all adaptive mechanisms, but confers upon its owner an enormous advantage.

The brain, however, is an accident. It is a special turn of evolution which might never have occurred. Natural selection, as Darwin said, does not necessarily include progressive development, but takes advantage only of variations "beneficial to each creature under its complex relations of life." Are we to assume then that in the absence of that special event consciousness itself would not have arisen, and that the outside world would have remained "a play before empty benches"? Schrödinger finds this a repugnant idea, leading to a "bankruptcy" of the world picture. But he is not disposed to embrace the views of Spinoza and others who held that all natural objects, animate or inanimate, possess a soul. The flashing-up of the world into the light of consciousness would thus not be a privilege reserved for the higher animals, for everything would, in a sense, be aware of itself as part of a universal mind.

To extend the domain of consciousness is to court fantasies, but one can follow another path to firmer ground. Not every nervous process, nor even every cerebral process, as Schrödinger points out, is accompanied by consciousness. Descartes in a famous passage compared the body to a wound-up clock whose wheels and weights simply tell the hours by following the laws of nature. And "so in like manner [he wrote] I regard the human body as a machine so built and put together of bone, nerve, muscle, vein, blood and skin, that still, although it had no mind, it would not fail to move in all the same ways as at present, since it does not move by the direction of its will, nor consequently by means of the mind, but only by the arrangement of its organs." His doctrine has been modified but not abandoned. Mindless motor acts, it is said, constitute a large part of the activities of men and animals. We do not think to breathe, to run, to hold a glass, to swallow. The heart beats, fortunately, without its owner's attentions. Reflex actions are recognized in the vertebrate ganglia, and in

that part of the nervous system under their control, which regulate and time reactions inside the system. Many reflexive processes pass through the brain that do not fall into consciousness or have very nearly ceased to do so. Schrödinger carries the point further. "Any succession of events," he maintains, in which we take part with sensations, perceptions and possibly with actions "gradually drops out of the domain of consciousness when the same string of events repeats itself in the same way very often." The boy recites the poem he has carefully memorized, and for all he is aware of its content it could be T. S. Eliot or Ogden Nash. A well-rehearsed piano sonata can be played "in one's sleep." We drive to work along a familiar route unseeing and lost in thought. There is a story of a noted mathematician whose wife found him lying in bed, the lights off, shortly after evening guests had gathered in his home. What had happened? He had gone to his bedroom to put on a fresh collar. "But the mere action of taking off the old collar had released in the man, deeply entrenched in thought, the string of performances that habitually followed in its wake."

Habit crowds out consciousness. But when something new confronts us, calling for a new response—a detour, say, on the way to work; when we learn an untried action, listen, observe, explore, feel pain or joy, the signal which prods us intrudes into consciousness. Even breathing may become a subject for thought and deliberate action. Consciousness thus appears in the role of a tutor. It "supervises our education," introduces us to new facts and fresh methods, but leaves us to carry on our tried routines alone. The higher vertebrates, having the mechanism that produces consciousness, learn most easily. Their nervous system is the place, in Schrödinger's words, "where our species is still engaged in phylogenetic transformation; metaphorically speaking it is the 'vegetation top' of our stem. Consciousness is associated with the *learning* of the living substance; its *knowing how* is unconscious." Perhaps, then, consciousness is not an "exclusive property of nervous processes," but is associated "with all organic processes inasmuch as they are new." I am not sure I know what this means, but Spinoza might have welcomed it.

Now comes a diversion typical of Schrödinger. Even without the last generalization, he sees in his theory of consciousness a clue toward a scientific theory of ethics. The background of every ethical code is self-denial; an imperative "thou-shalt" opposes our primitive will. Commandments and principles of conduct involve a suppression of "primitive appetites," and our conscious life is necessarily a continued fight against our primitive ego. The organism is ever becoming. Every day of man's life is a small bit of the evolution of the species, as he adapts and transforms himself; and the whole of evolution is the epic of a myriad of tiny transformations—"minute chisel blows," as Schrödinger calls them. We ourselves are both chisel and statue, conquerors and conquered: "it is a true continued self-conquering." Are we asked to believe that this evolutionary process—so ponderous and slow, so imperceptible not only to the individual but to entire historical epochs, so much the creature of chance mutations tested by selection—actually penetrates into consciousness? Schrödinger's answer is an affirmation of faith. It is by learning, by adapting, by solving the problems created by change that we evolve, and in these activities consciousness plays a crucial role. Consciousness is a "phenomenon in the zone of evolution. This world lights up to itself only where or only inasmuch as it develops, procreates new forms." It follows that consciousness and self-discord are inseparably linked. Not the man at peace with himself, dozing like a little rabbit in the sun, but the creature of self-strife, is the hope of society. The wisest and best men of all times confirm this paradox. They suffered to achieve; for them the world was lit in a brilliant light of awareness, and only in this light were they able "to form and transform that work of art which we call humanity."

Lest the reader accuse him of preaching morals instead of expounding science, Schrödinger proffers reassurance. "Do not take it," he says, "that I wish to propose the idea of our species developing towards a higher goal as an effective motive to propagate the moral code. This it cannot be, since it is an unselfish goal, a disinterested motive and thus, to be accepted, already presupposes virtuousness." No, the "shall" of Kant's imperative remains unexplained, and the ethical law—"Be unselfish!"—is simply a fact, agreed upon even by those who do not very often keep it. Schrödinger regards its puzzling existence as an indication "of our being in the beginning of a biological transformation from an egoistic to an altruistic general attitude, of man being about to become an *animal social*." Egoism is a virtue for the solitary animal. It must be primarily self-interested to survive; in evolutionary

**Now** — the world's most distinguished musical artists, in cooperation with the world's largest record club, make it possible for you to systematically acquire their greatest recorded performances on superb high-fidelity records **at far less than the usual cost**

MITROPOULOS BERNSTEIN STERN WALTER SERKIN FRANCESCATTI VAN BEINUM ORMANDY BUDAPEST STRING QUARTET SZELL

# ANY SIX

of these superb **Classical High-Fidelity**

## COLUMBIA and EPIC RECORDS FOR ONLY $3.98

RETAIL VALUE UP TO $29.88

**if you join the Columbia (Lp) Record Club now — and agree to purchase only 5 selections during the coming 12 months**

22.

47.

18.

30.

10.

20.

12.

50.

26.

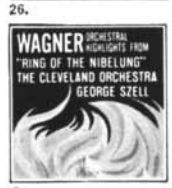
61.

24.

37.

40.

39.



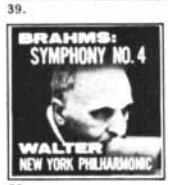
6.

33.

16.

52.

2.



32.

56.

45.

49.

43.

Through the generous cooperation of the world-famous artists shown above, and many others—the Columbia (Lp) Record Club can now help you acquire, regularly and under expert guidance, a distinguished library of the world's finest high-fidelity American and European recordings — at substantial savings!

•

And as a dramatic demonstration of the many benefits you will enjoy as a member, you will receive — at once — ANY 6 of these superb Columbia and Epic records — for less than the list price of one record alone!

•

Read below how the Club operates . . . then select the six records you want and mail the coupon — without money — at once!

### HOW THE CLUB OPERATES:

★ Each month the Club's staff of musical experts selects a classical recording that will be a distinguished addition to your record library. In addition, at least seven other exceptionally fine recordings, both classical and popular, will be available to you as alternate selections. All are fully described in the Club Magazine, which you receive free each month

★ You may accept or reject the regular Classical Selection, take any of the other records offered, or take NO record in any particular month

★ Your only membership obligation is to purchase five selections from the more than 200 high-fidelity Columbia and Epic records to be offered in the coming 12 months. Thus, in your first year of membership, you receive eleven records for the price of six — a saving of more than 43% on your record purchases

★ After purchasing only five records, you receive a Columbia or Epic Bonus record of your choice free for every two additional selections you buy

★ You may discontinue membership at any time after purchasing five records

★ The records you want are mailed and billed to you at the regular list price of $4.98 (Popular Selections are offered at $3.98), plus a small mailing charge

★ Mail coupon today to receive your six records

**COLUMBIA (Lp) RECORD CLUB**
**Terre Haute, Indiana**

**COLUMBIA (Lp) RECORD CLUB, Dept. 256-1**
**Terre Haute, Indiana**

Please send me the 6 records whose numbers I have circled at the right, for which I am to be billed only $3.98 plus small mailing charge — and enroll me in the Classical Division of the Club.

My only obligation is to purchase five selections from the more than 200 to be offered during the coming 12 months, at regular list price plus small mailing charge. For every two *additional* selections I accept, I am to receive a 12" Columbia or Epic Bonus record of my choice FREE.

Name.....
(Please Print)

Address.....

City.....ZONE.....State.....

*FOR CANADIAN MEMBERSHIP:*
*address 11-13 Soho St., Toronto, 2B*
If you wish to have this membership credited to an established Columbia or Epic record dealer, authorized to accept subscriptions, please fill in the following:

Dealer's Name.....

Dealer's Address.....218



**CIRCLE 6 NUMBERS BELOW:**

**2.** Tchaikovsky: Pathetique Symphony
**6.** Wagner: Highlights from the "Ring"
**10.** Schweitzer Plays 3 Bach Organ Works
**12.** Grofe: Grand Canyon Suite
**16.** Mendelssohn: Midsummer Night's Dream; Schubert: Unfinished Symphony
**18.** Beethoven: Emperor Concerto
**20.** Dvorak: New World Symphony
**22.** Mozart: Requiem
**24.** Paganini, Saint-Saens Violin Concertos
**26.** Nutcracker Suite; Bolero; etc.
**30.** Tchaikovsky: Swan Lake Ballet Suite
**32.** Brahms: Symphony No. 4
**33.** Levant Plays Gershwin
**37.** Roumanian Rhapsodies 1, 2; Carnival Overture; Francesca da Rimini
**39.** Firebird Suite; Romeo and Juliet
**40.** Bach and Vivaldi Violin Concertos
**43.** Vivaldi: The Seasons
**45.** Sorcerer's Apprentice; Les Preludes; etc.
**47.** Grieg Concerto; Rachmaninoff Rhapsody
**49.** Waltzes of Tchaikovsky and Strauss
**50.** Beethoven: 3 Piano Sonatas
**52.** Beethoven: Quartets 9 and 11
**56.** Bach: Brandenburg Concertos 1, 2, 3
**61.** Rossini: William Tell Overture, etc. K-38

terms, self-interest is favored by selection. But as communities arise, self-interest must be curtailed; something must be yielded to the commonweal. In certain very ancient societies—of bees, ants, termites—egoism has been entirely relinquished; the state is all that counts, and a kind of ferocious national egoism possesses the citizen. ("A worker bee that goes to the wrong hive is murdered without hesitation.") In the history of man one can discern similar developments. Whether or not we began as Hobbesian brutes, we are still "pretty vigorous egoists"; at the same time many of us are intense national egoists. Yet it has become apparent to many thoughtful persons that nationalism too is a vice. The individual's longing for peace competes with his patriotism; and perhaps the more primitive (and more rational) form of self-interest will save man from destruction. Bluntly: "If we were bees, ants, or Lacedaemonian warriors, to whom personal fear does not exist and cowardice is the most shameful thing in the world, warring would go on forever. But luckily we are only men—and cowards." Unfortunately things are not really that simple.

It may occur to you that these views of Schrödinger involve at least a tacit acceptance of Lamarckism. For if behavior plays a continuing part in evolution, must there not be an inheritance of acquired characteristics? Schrödinger was long troubled, he tells us, by this question, but he is now satisfied that he has found a way out. It consists of the operation of a kind of "feigned Lamarckism," a mechanism suggested by Julian Huxley's treatise on evolution. Lamarck's notion that the improvements or adaptations that an organ acquires through use are transmitted to the offspring is wrong. Chance variations favored by selection are accumulated, or at least accentuated; and this process, easy to describe but of inordinate complexity in its microscopic workings, can be made to account for the gross transformations of species. Yet a striking simulation of Lamarckism occurs, according to Huxley, "when the initial variations that inaugurate the process are not true mutations, not yet of the inheritable type." A specialized skill may lead an animal to change its environment, to migrate to surroundings where this skill is advantageous; thereupon the environment will not only favor those individuals most proficient in the skill but also preferentially select those in whom chance mutations have accentuated the favorable character.

Take this example. The ability to fly enables birds to build their nests high up in the trees or on inaccessible cliffs where the young especially are in less danger of being attacked by predators. Thus the ability to fly *and the use made of it* confer a selective advantage. But now the environment itself takes a hand in smiling upon the better fliers among the young. The behavior of the parents has therefore reinforced and speeded up the process of selective improvement, because when the "right" mutations show up the individuals possessing them are so situated as to make the best use of them. We must of course guard against an animistic interpretation of this process, for it is tempting to lapse into metaphor and say that the species "has found out in which direction its chance in life lies and pursues this path." The fact that certain behavior can be shown to enhance the selective value of certain mutations, to pave the way for the realization of their advantages in a given environment, must not be taken as evidence that this behavior is deliberately adopted for this purpose. To avoid one's enemies if they are stronger, or to seek them out if they are weaker, is doing what comes naturally, without a grand design other than survival in view. But it may happen that just this behavior pattern, which is transmitted to offspring by example, will contribute to the selective process described above. The causal mechanism proposed by Lamarck is enormously suggestive; while it is all wrong, it is merely upside down. Behavior does not change physical organs in an inheritable way; rather physical changes resulting from mutations change behavior. This change, transmitted by example or teaching, acts as a significant evolutionary factor "because it throws the door open to receive future inheritable mutations with a prepared readiness to make the best use of them and thus to subject them to intense selection."

On this hypothesis Schrödinger is able to relate the operations of mind and consciousness to biological development. If behavior has biological consequences among plants and lower animals where trial and error are apt to govern it, how much more important must it be in man, who can make choices —even sensible choices. Political and social events are not thrust upon us; *en masse*, at least, we cause and control them (though we may often act unwisely). Our biological destiny is no different. Nature has not decided it for us in advance. It is possible, to be sure, that man, like the crocodile or the insects, has reached the end of the evolutionary line. Moreover, there is reason to believe

# solution chemistry in fused salts

A novel approach to the study of fused salts, developed at Argonne, is providing new insights into their solution chemistry and structure.

Studies of the absorption spectra of these unique solvents containing actinide, lanthanide, and other transition metal ions are yielding detailed information concerning oxidation states, oxidation-reduction reactions, complex ion formation, coordination numbers, and reaction rates.

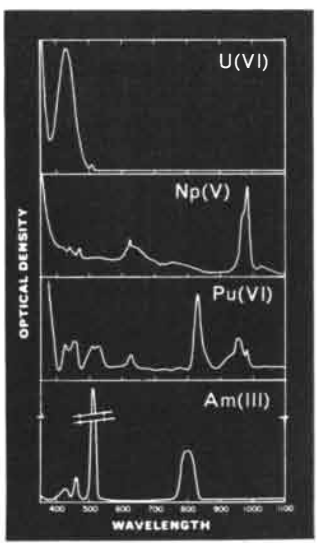
This new knowledge is made possible because of the development of convenient techniques for measuring fused salt spectra at temperatures up to 1500°K. The interpretation of these measurements is greatly facilitated by the key finding that the transition metal ion spectra in fused salts are similar to their spectra in aqueous solutions and in crystals.

Fused salts are already important in many areas of nuclear technology, including high temperature homogeneous reactors, fuel processing systems, and the refining of metals such as thorium, uranium, and plutonium.

Still other areas of application, among them the thermonuclear energy field, are being explored as a result of the continuing fundamental investigations of these versatile materials.

**STAFF POSITIONS AVAILABLE FOR QUALIFIED**

*Physical Metallurgists, Chemical Engineers, Physicists, Mechanical Engineers, Metallurgical Engineers, Chemists, Electrical Engineers, Mathematicians, Technical Writers*




The stable oxidation states of the actinide ions in molten $LiNO_3$-$KNO_3$ eutectic, as revealed through their absorption spectra, are U(VI), Np(V), Pu(VI), and Am(III).

Argonne
NATIONAL LABORATORY
Operated by the University of Chicago under contract with the United States Atomic Energy Commission
PROFESSIONAL PLACEMENT
P. O. BOX 299-K6 • LEMONT, ILLINOIS

we have blocked the Darwinian mechanism in both good and bad directions. We protect the weak, cure the sick, feed the hungry and practice birth control; we also slaughter each other in ever increasing numbers, and permit millions to die of starvation and disease. Humanity and inhumanity alike interfere with natural selection. Nevertheless there remains to us a very broad opportunity to improve our biological future by cultivating the evolution of the intellect. We can hope thereby not only to enlarge our understanding of nature and our control over its forces, but to achieve mastery of ourselves and our destructive impulses.

Schrödinger warns of the serious danger of "a general degeneration of our organ of intelligence [because of] the increasing mechanization and 'stupidization' of most manufacturing processes." There is a constant search for talent and a cry for genius, yet the conditions of industrial society promote the rise of the cheerful robot. Schrödinger notes the controversy over the "welfare state," which is often accused of stifling incentive by leveling chances and providing everyone with economic security. But care for our present welfare need not undermine our evolutionary future. Next to want, says Schrödinger, boredom has become "the worst scourge" in our lives. Ingenious machines steadily encroach upon arts and skills; entertainment is canned and packaged; the popular image of bliss is to rot in feckless leisure, *i. e.*, to "retire," at the earliest possible age. The machine, says Schrödinger, "must take over the toil for which man is too good, not man the work for which the machine is too expensive. . . . This will not tend to make production cheaper but those who are engaged in it happier." We place high value upon competition, but the competition of commerce and manufacture is as uninteresting as it is biologically worthless. "Our aim should be to reinstate in its place the interesting and intelligent competition of single human beings."

I shall discuss only one other of Schrödinger's themes. Two general principles, he contends, form the basis of the scientific method: The first is that nature is comprehensible; the second, that it is possible to "objectify" the world. We are concerned with the second, which the reader will recognize as the "hypothesis of the real world" mentioned earlier in this review.

To make headway in understanding the infinitely intricate problem of nature we pretend to be able to step out of the world, to become observers. It is clear

that this is an artifice, that we are ourselves part of what we are observing, but the device appears to be essential if we are to make sense, let alone science. Yet its illogicality returns to grin at us. With the sentient self removed, we make a tidy model of a system of matter and motion. But this model has a grave flaw: it is "colourless, cold, mute," in short, it is not a model of the world at all. It is like a diagram of a flower. Having eliminated ourselves in order to get closer to the world, we have managed to lose it. Hurriedly we step back into the picture. The result is chaos. Not only is it a picture of ourselves making a picture of ourselves making a picture, but it is full of figments and fictions that came out of our heads. It is a personal world, many features of which cannot be measured and are therefore of no interest to science. My dislike of poached eggs is very real to me: Is it or is it not a proper part of the world picture, and if it is, of whose world picture?

Another difficulty. In the hypothesis of the real world, how does mind act upon matter? To make the picture, the self has been removed. But the self is mind; then how can it work upon that from which it is removed? Is this a mere quibble? Only if science and philosophy are themselves a quibble. "Physical science," Sir Charles Sherrington wrote, "faces us with the impasse that mind *per se* cannot play the piano—mind *per se* cannot move a finger of a hand." What then does what is done? Is the picture of the world of matter made by matter itself? Is there no direction, no design, no discrimination? It can certainly be argued that there is no such thing as mind, that it is a meaningless concept. This leads to one set of antinomies. But if we concede to the concept any meaning whatever we are enmeshed in other antinomies. Mind sits alone in its high perch in a world of shadows. It is a stranger in its own world. In his great book *Man on His Nature* Sherrington epitomizes the dilemma: "Mind, for anything perception can compass, goes therefore in our spatial world more ghostly than a ghost. Invisible, intangible, it is a thing not even of outline; it is not a 'thing.' It remains without sensual confirmation and remains without it forever."

Modern science is in a trap; physics is hopelessly ensnared. Its bizarre model of the world is admittedly a model of nothing; its parts cannot be pictured; it is held together by contradictions. Time, space, matter, motion—even causality itself—have been thrown on the rubbish heap. Limits have been set upon knowl-

edge; the physicists' Eden abounds in forbidden fruits.

All this, in Schrödinger's view, is the result of excluding ourselves from the picture. Whatever science has gained in the past from this "exclusion principle," we are now obliged to assess its consequences. It is too early to say whether science must be made anew, just as it is too early to swallow the fashionable dogma that there are certain properties of an object that cannot be accurately known. (If such boundaries to knowledge exist, we have to abandon at least partially the cardinal principle of the understandability of nature; but we are not yet, Schrödinger feels, forced to this desperate step, because physics may find more plausible models.) It is not too early, however, to criticize the contention, based on recent discoveries in physics, that refined methods of observation have carried us so close to the mysterious boundary between subject and object that the boundary has begun to vanish. Schrödinger's demurrer to this contention is characteristically subtle. Many thinkers have of course made the point that the observer colors the observation, that what we perceive is not the "thing in itself," to use Kant's term. But modern physics goes beyond this in asserting that it is not only our impressions of the outside world which depend on our "sensorium," but the outside world itself which depends upon it and is changed by it. Yet how, asks Schrödinger, can this be? The clumsy finger may tilt the scale, the eyelash may blur the image under the microscope, but how can the subject's mind, the thing that merely senses and thinks, disrupt the physical world? The mind is not matter, nor does it belong to the world's energy. This is the core of the real-world hypothesis, the root of objectivation.

There is, however, another approach to the dilemma. We need not, after all, accept in the first instance the "time-hallowed distinction" between subject and object. It has its practical uses, and in science it serves as an invaluable make-believe; but in philosophy, as Schrödinger believes, it should be abandoned. Scientists do not get into trouble when they act upon the distinction in their own field, but rather when they decide to draw portentous epistemological consequences from their unsolved problems. This does not mean that the scientist should stick to his last; Schrödinger is scarcely in a position to advocate such self-restraint. But it does mean the physicist must clear his thoughts, must recognize that pragmatic assumptions in one sphere do not neces-

sarily yield valid conclusions in another. Let Schrödinger summarize: "It is the same elements that go to compose my mind and the world. This situation is the same for every mind and its world, in spite of the unfathomable abundance of 'cross-references' between them. The world is given to me only once, not one existing and one perceived. Subject and object are only one. The barrier between them cannot be said to have broken down as a result of recent experience in the physical sciences, for this barrier does not exist."

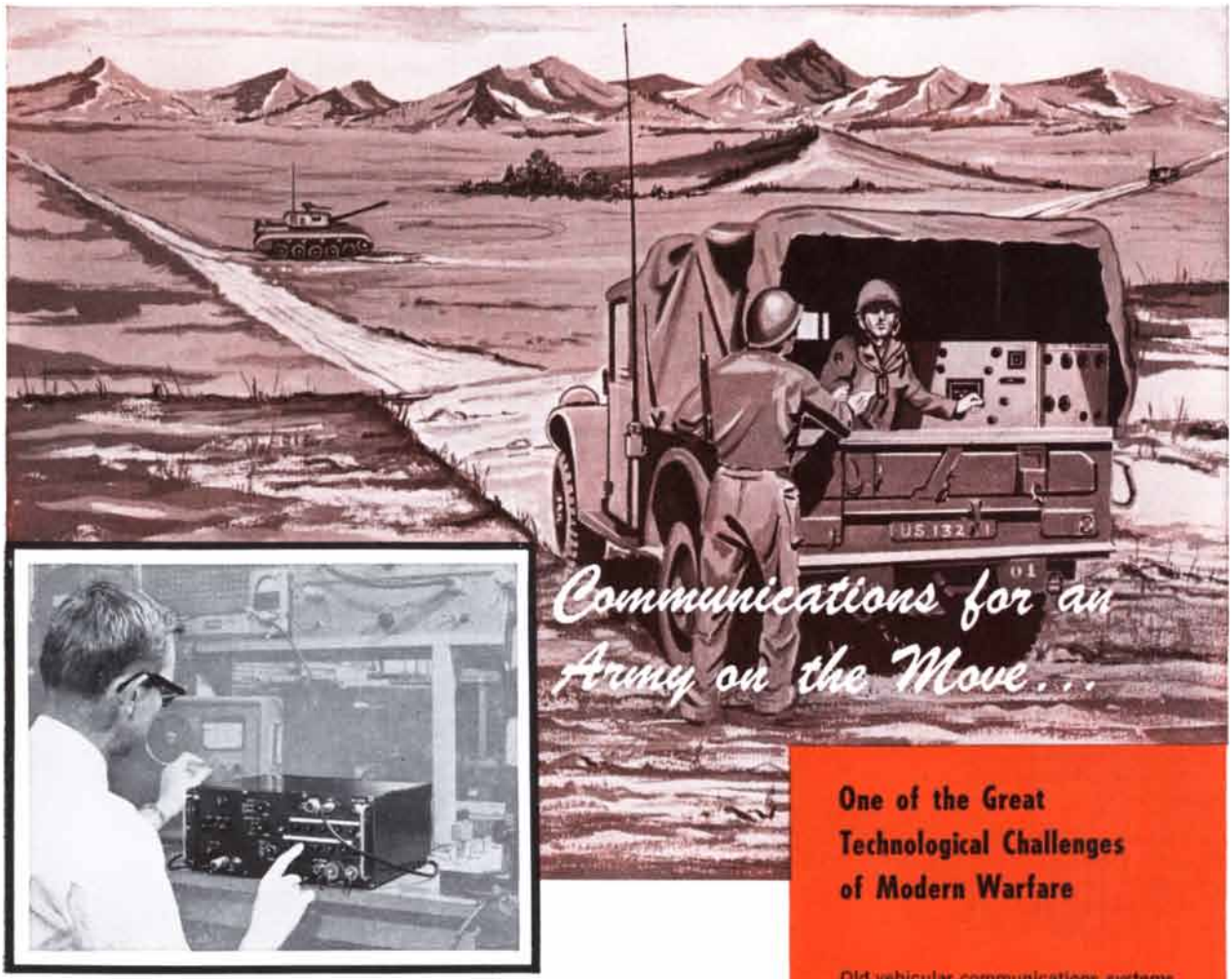
I do not think it can be said that Schrödinger has made a solid contribution to the science of mind; and it would be useless to pretend that a fine linguistic scalpel, of the sort the analytic philosophers have devised and are so mercilessly skillful in wielding, is needed to slice many of his arguments into bits. He is old-fashioned in some of his views; his concepts are apt to leak and flow into one another; he is sometimes, I regret to say, fervid when it would be better to be clear. And yet he has given us something that stands nobly by itself, that can survive the onslaughts of both scientists and philosophers. What he has written is imbued with values that are as compellingly real as they are hard to define. There is not a trace of superficial cleverness about him. To a fine intelligence he joins a passionate heart. He is not ashamed to be human, though he is never sentimental. That the dilemma of objectivation is his primary concern is a reflection of his whole style and outlook: He puts himself into his ideas, he shares his doubts with us, he pierces us with his reflections. For Schrödinger the importance of the questions of science lies in the fact that they are questions about the nature and meaning of life. Because these questions cannot be answered by science alone he has turned elsewhere for light. The Book of Job tells us that the ways of God are inscrutable; that there are questions we must not ask, things too impious to search out, "too wonderful" for man to know. For Schrödinger, if the question can be put, the answer must be sought. One can read his little essay in a few hours; one will not forget it in a lifetime.

### Short Reviews

MOMENTS OF DISCOVERY, edited by George Schwartz and Philip W. Bishop. Basic Books, Inc. ($15). A curious hit-and-miss collection of writings on astronomy, physics, chemistry, biology and medicine. The editors have assembled excerpts from the works of about

80 men of science, from Hippocrates to J. R. Oppenheimer, in the fervent hope that these scraps would somehow coagulate into "the story of the scientists' approach to the universe." It is a vain hope, for the book is stillborn and can tell no story. Many of the excerpts are too short to be either interesting or meaningful; not a few are too difficult to understand without an extensive editorial background and commentary. The editors' introductions do not meet this need; moreover, they contain some astonishing conjectures. For example, it is said that Hipparchus, who lived in the second century B.C., "may still have been living while Ptolemy [who lived in the second century A.D.] was a child." What has been left out of this anthology is more remarkable than what has been included. Mathematics evidently played no part in the moments of discovery, and is therefore not represented. (We are told, however, that Pascal developed the theory of probability, "a type of applied mathematics that was to prove of great importance in such fields as biological statistics.") Physics has a hard time, with Maxwell, Helmholtz, Clausius, Boltzmann, Gibbs, Kelvin, Gauss and Ampère among the absentees—to mention only the leaders of a single century. Geology is not on the compilers' list, nor are modern astronomy and cosmology. The theory of relativity peeps through a single paragraph of a pleasant but insubstantial essay by James Jeans, which, from the vantage point of 1934, also disposes of atomic physics, the quantum theory and other items. That philosophy may have contributed to the growth of science is not a point that this book takes too seriously: Locke and Hume, for example, cannot even find their way into the index. The editors say that their work is the "culmination of twenty years of study of the creative process in science." The reader will not be grateful.

FOSSIL MEN, by Marcellin Boule and Henri V. Vallois. The Dryden Press, Inc. ($9.50). In his introduction Kenneth P. Oakley describes this book, first published in France in 1921, as "the most comprehensive and authoritative general work on human palaeontology." Marcellin Boule, who wrote the original version, was the foremost figure in his field. Later editions were revised by Henri Vallois, best known as the director of the Musée de l'Homme, considered the greatest museum devoted to anthropology in the world. An able English translation by Michael Bullock is presented in this fully illustrated, attractively made volume. Though it is in some




## One of the Great Technological Challenges of Modern Warfare

Old vehicular communications systems suffered serious limitations . . . there weren't enough channels, nor was there sufficient range to keep up with fast-moving mobile warfare.

Then, Avco/Crosley engineering answered the challenge with the AN/VRC-12, a transistorized system developed in collaboration with the U.S. Army Signal Corps. It provides 920 Crystal Control Channels . . . a range up to 30 miles . . . has extremely high sensitivity . . . operates on a standard vehicular battery . . . and weighs only 45 pounds, requiring merely 1500 cubic inches of space. A product of engineering ingenuity and teamwork, it will forge a strong, new chain of command to strengthen the striking power of U.S. Army mobile forces.

What challenge tomorrow? No one knows . . . but you can be sure that Avco/Crosley engineering will be there with an answer.

# OPPORTUNITIES FOR ENGINEERS . . . .

### In Communications and Navigation

*A chance to own a share in America's future security.*

**Communication and Navigation Systems** — Equipment design engineers at all levels required for research and development.

**Telemetry and Guidance**—Design experience on components and sub-systems in advanced military equipment for drone and weapon control.

**Air Traffic Control** — Experience with systems comprising radar search, computers, display and vehicle command. System synthesis, analysis and equipment development experience needed.

**Radar Surveillance** — System and equipment design experience in high power heavy ground radar installations necessary. Acquaintance with associated data handling, computers and decision equipment required.

**Technical Writing** — Maintenance manuals, instruction books, progress reports, technical proposals and presentations.

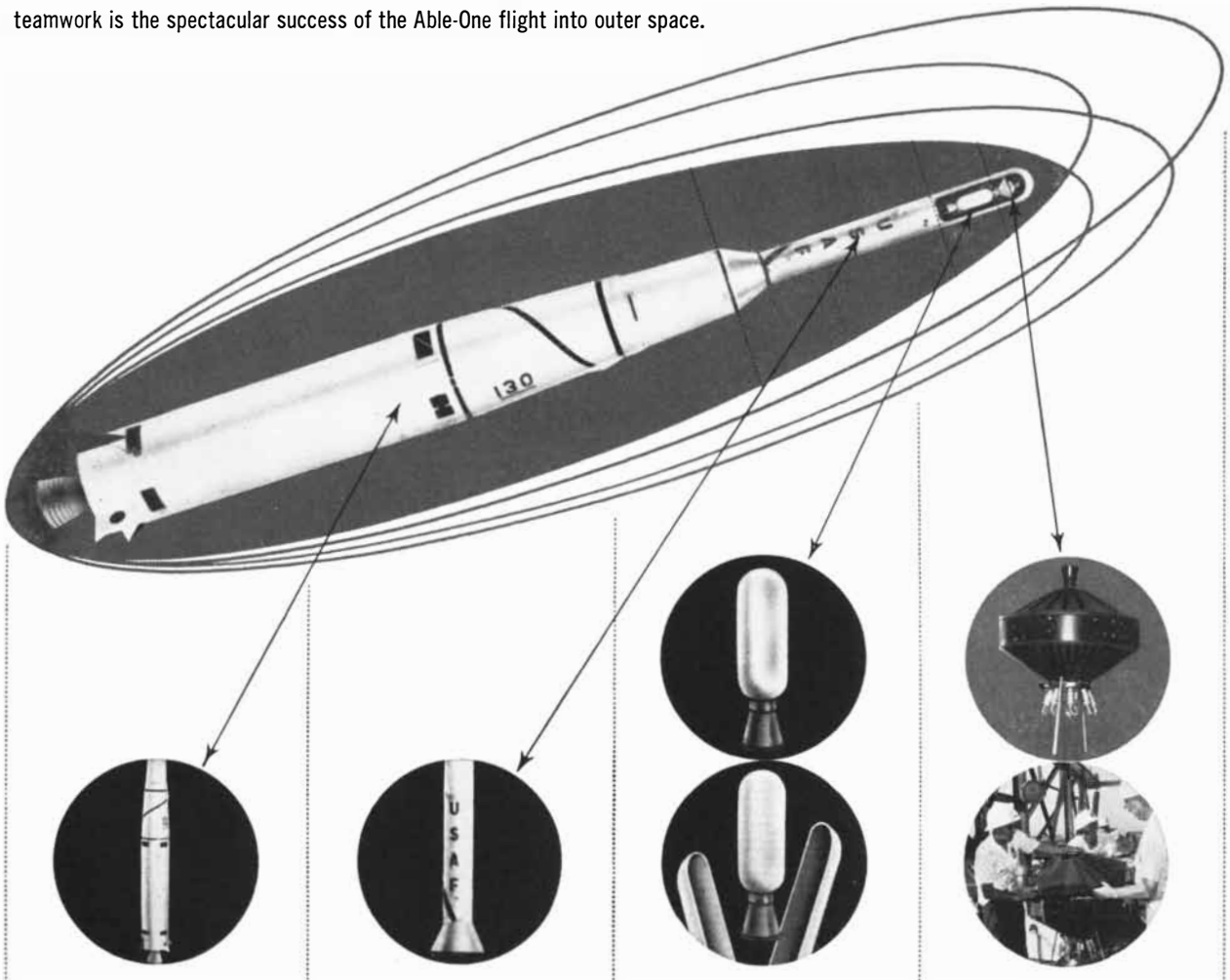
Correspondence regarding these positions should be addressed to:
*Director, Scientific and Technical Personnel*

## CROSLEY DIVISION — AVCO

**1329-B ARLINGTON STREET, CINCINNATI 25, OHIO**

# Able-One... a new apogee in scientific teamwork!

Preparation and execution of an undertaking such as the United States' IGY space probe demanded the participation and exceptional efforts of 52 scientific and industrial firms and the Armed Forces. The Advanced Research Projects Agency and the AFBMD assigned Space Technology Laboratories the responsibility for the project which was carried out under the overall direction of the National Aeronautics and Space Agency. One measure of this teamwork is the spectacular success of the Able-One flight into outer space.






**1st stage:** Vehicle, Douglas Aircraft **Thor** IRBM; propulsion, Rocketdyne; airframe, control, electrical and instrumentation, Douglas Aircraft; assembly, integration, and checkout, Douglas Aircraft.




**2nd stage:** Propulsion system and tanks, Aerojet-General; control, electrical, instrumentation, accelerometer shutoff, and spin rocket systems, STL; assembly integration, and checkout, STL.



**3rd stage:** Rocket motor, U. S. Navy Bureau of Ordnance and Allegheny Ballistic Laboratory; structure and electrical, STL; assembly, integration, and checkout, STL; ground testing, USAF's Arnold Engineering Development Center.



**Payload:** Design and production of **Pioneer,** the payload of the Able-One vehicle, was conducted by STL in addition to its overall technical direction and systems engineering responsibility of the Air Force Ballistic Missile Division project. This highly sophisticated package included a NOTS TV camera and transmitter and Thiokol rocket motor.

Inquiries concerning openings on our staff will be welcomed by

Space Technology Laboratories, Inc.
5730 Arbor Vitae Street, Los Angeles 45, California.

respects out of date, *Fossil Men* can still be recommended to any reader interested in the engrossing and constantly growing study of the ancestry of man.

PERSIA, by L. Lockhart, with photographs by A. Costa. Frederick A. Praeger, Inc. ($10). A book of remarkably fine photographs of Persia. The pictures show different aspects of the landscape, scenes from the towns and cities, famous mosques, gardens and palaces, the grand ruins of Persepolis, the reputed tomb of the prophet Daniel at Susa, the crafts and occupations of the people. Laurence Lockhart, noted orientalist of the University of Cambridge, provides a model introduction dealing with Persian history, literature, art, climate and topography, and a series of admirable notes for Costa's photographs. A delectable volume.

ISAAC NEWTON'S PAPERS & LETTERS ON NATURAL PHILOSOPHY AND RELATED DOCUMENTS, edited by I. Bernard Cohen. Harvard University Press ($12.50). A collection of various Newton papers and letters dealing with physical science, and of a few odds and ends of Newtoniana such as Fontenelle's *éloge* and Edmund Halley's review of the *Principia.* The Newton writings are on light and color, on chemistry, atomism, the ether and heat. Also presented are Newton's four letters to that prodigiously erudite donkey Richard Bentley, who sought to demonstrate in his Boyle Lectures (two of which are included) that the *Principia* made out an irrefutable case for religion. Newton corrected some of Bentley's scientific misconceptions, but he managed not to commit himself on the theological issues. Several specialists contribute prefaces to the separate papers; the editor offers a general introduction that does not help to pull the book together. Facsimiles are used, which is not a happy idea because several are so bad that they cannot be read without considerable strain. The collection will be useful to scholars despite its defects.

THE VOYAGES OF JOSHUA SLOCUM, edited and with commentaries by Walter Magnes Teller. Rutgers University Press ($6). Slocum's reputation keeps growing, and for good reason. *Sailing Alone around the World* is a superb adventure story and a masterpiece of prose. His other writings are little-known but deserve attention. Teller has had the happy thought of bringing together in one volume all of Slocum's works: his first book, *Voyage of the Liberdade;* his

second, *Voyage of the Destroyer from New York to Brazil;* his *Rescue of Some Gilbert Islanders;* his correspondence with the Department of State and with President Cleaveland (*sic*) on the shipwreck of his little clipper bark *Aquidneck* on the coast of Brazil in 1887; and, of course, the classic account of his lone circumnavigation of the globe on the 37-foot sloop *Spray.* An excellent biographical essay and prefaces to each selection add to one's enjoyment of this delightful volume.

## Notes

CASTILLA'S SPANISH AND ENGLISH TECHNICAL DICTIONARY. Philosophical Library ($45). This large work of some 2,700 pages, compiled by a panel of engineers, lexicographers, lawyers and other specialists, deals only with the field of engineering technology, and is intended to provide a compendium of terms in everyday use in industry and technology.

MINERALOGY AND GEOLOGY OF RADIOACTIVE RAW MATERIALS, by E. William Heinrich. McGraw-Hill Book Company, Inc. ($14.50). A summary of the scientific and technical results of the feverish search for uranium which in the last 10 years has resulted in an increase of annual ore production in the U. S. from about 70,000 to 3.5 million tons.

SEMANTICS AND NECESSARY TRUTH, by Arthur Pap. Yale University Press ($6.75). The purpose of this book is to clarify the distinction between *a priori* knowledge and empirical knowledge, a central epistemological problem that in one form or another has long engaged the attention of philosophers—Leibniz, for example, was preoccupied with the distinction between "truths of reason" and "truths of fact"—and to which the members of the modern school of analytic philosophy have indefatigably and even fruitfully applied themselves, without, however, having finally laid the issues to rest.

SPACE RESEARCH AND EXPLORATION, edited by D. R. Bates. William Sloane Associates ($4). A group of writers provides information for the general reader on the main aspects of the exploration of space. Mathematical material, where necessary, has been relegated to appendices. Among the topics discussed are rockets, cosmic radiation, the earth satellite program, manned satellite stations, interplanetary orbits, medical and biological problems. A sound survey.

# INDEX OF ADVERTISERS

*MARCH, 1959*

# BIBLIOGRAPHY

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

## HIGH-ENERGY RADIATION IN SPACE

SPECTRUM OF LOW-RIGIDITY COSMIC RAYS DURING THE SOLAR FLARE OF FEBRUARY 23, 1956. J. A. Van Allen and J. R. Winckler in *The Physical Review*, Vol. 106, No. 5, Second Series, pages 1,072-1,073; June 1, 1957.

THE ARTIFICIAL SATELLITE AS A RESEARCH INSTRUMENT. James A. Van Allen in *Scientific American*, Vol. 195, No. 5; November, 1956.

## DARWIN'S MISSING EVIDENCE

THE CONTRIBUTION OF INDUSTRIAL MELANISM IN THE LEPIDOPTERA TO OUR KNOWLEDGE OF EVOLUTION. H. B. D. Kettlewell in *The Advancement of Science*, Vol. 13, No. 52, pages 245-252; March, 1957.

FURTHER SELECTION EXPERIMENTS ON INDUSTRIAL MELANISM IN THE LEPIDOPTERA. H. B. D. Kettlewell in *Heredity*, Vol. 10, Part 3, pages 287-301; December, 1956.

A RÉSUMÉ OF INVESTIGATIONS ON THE EVOLUTION OF MELANISM IN THE LEPIDOPTERA. H. B. D. Kettlewell in *Proceedings of the Royal Society of London*, Series B, Vol. 145, No. 920, pages 297-303; July 24, 1956.

SELECTION EXPERIMENTS ON INDUSTRIAL MELANISM IN THE LEPIDOPTERA. H. B. D. Kettlewell in *Heredity*, Vol. 9, Part 3, pages 323-342; December, 1955.

A SURVEY OF THE FREQUENCIES OF BISTON BETULARIA (L.) (LEP.) AND ITS MELANIC FORMS IN GREAT BRITAIN. H. B. D. Kettlewell in *Heredity*, Vol. 12, Part 1, pages 51-72; February, 1958.

## ANGIOTENSIN

THE AMINO ACID SEQUENCE IN A HYPERTENSIN. D. F. Elliott and W. S. Peart in *The Biochemical Journal*, Vol. 65, No. 2, pages 246-253; February, 1957.

EXPERIMENTAL RENAL HYPERTENSION. Irvine H. Page and Arthur Curtis Corcoran. Charles C. Thomas, 1948.

PHARMACOLOGIC ASPECTS OF SYNTHETIC ANGIOTONIN. Irvine H. Page, J. W. McCubbin, Hans Schwarz and F. Merlin Bumpus in *Circulation Research*, Vol. 5, No. 5, pages 552-555; September, 1957.

SYNTHESIS AND PHARMACOLOGY OF THE OCTAPEPTIDE ANGIOTONIN. F. M. Bumpus, H. Schwarz and I. H. Page in *Science*, Vol. 125, No. 3,253, pages 886-887; May 3, 1957.

## THE WEAK INTERACTIONS

AN INTRODUCTION TO THE PHYSICS OF THE NEW PARTICLES. C. Franzinetti and G. Morpurgo in *Il Nuovo Cimento*, Supplement VI, Numero 2, pages 469-800; 1957.

K-MESONS AND HYPERONS: THEIR STRONG AND WEAK INTERACTIONS. R. H. Dalitz in *Reports on Progress in Physics*, Vol. 20, pages 163-303. The Physical Society of London, 1957.

THE PHYSICS OF ELEMENTARY PARTICLES. J. D. Jackson. Princeton University Press, 1958.

## THE FIRST HEARTBEATS

THE FIRST HEARTBEATS AND THE BEGINNING OF THE EMBRYONIC CIRCULATION. Bradley M. Patten in *American Scientist*, Vol. 39, No. 2, pages 225-243; April, 1951.

HEART, BLOOD VESSELS, BLOOD, AND ENTODERMAL DERIVATIVES. W. M. Copenhaver in *Analysis of Development*, pages 440-461. W. B. Saunders Company, 1955.

INITIATION AND EARLY CHANGES IN THE CHARACTER OF THE HEART BEAT IN VERTEBRATE EMBRYOS. Bradley M. Patten in *Physiological Reviews*, Vol. 29, No. 1, pages 31-47; January, 1949.

THE MOLECULAR BASIS OF THE FIRST HEART BEATS. James D. Ebert, R. A. Tolman, A. M. Mun and J. F. Albright in *Annals of the New York Academy of Sciences*, Vol. 60, Art. 7, pages 968-985; 1955.

## UNDERWATER ARCHAEOLOGY IN THE MAYA HIGHLANDS

ANTIQUITIES OF GUATEMALA. Eduard Seler in *Bureau of American Ethnology Bulletin*, No. 28, pages 75-121; 1904.

LIMNOLOGICAL STUDIES ON SOME LAKES IN CENTRAL AMERICA. Chancey Juday in *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters*, Vol. 18, pages 214-250; 1916.

LUGARES ARQUEOLOGICOS DEL ALTIPLANO MERIDIONAL CENTRAL DE

GUATEMALA. Edwin M. Shook in *Antropologia e Historia de Guatemala*, Vol. 4, No. 2, pages 3-40; Junio, 1952.

A NEW SURVEY OF THE WEST INDIES, 1648. THE ENGLISH-AMERICAN. Thomas Gage. Robert M. McBride & Company, 1929.

THE SILENT WORLD. Captain J. Y. Cousteau with Frédéric Dumas. Harper & Brothers, Publishers, 1953.

JOEY, A "MECHANICAL BOY"

LOVE IS NOT ENOUGH. Bruno Bettelheim. The Free Press, 1950.

TRUANTS FROM LIFE. Bruno Bettelheim. The Free Press, 1955.

LONG EARTHQUAKE WAVES

ELASTIC WAVES IN LAYERED MEDIA. W. Maurice Ewing, Wencelas S. Jardetzky and Frank Press. McGraw-Hill Book Company, 1957.

AN INTRODUCTION TO THE THEORY OF SEISMOLOGY. K. E. Bullen. Cambridge University Press, 1953.

SEISMOLOGY. Keith Edward Bullen. Methuen & Co., Ltd., 1954.

SEISMOLOGY. Perry Byerly. Prentice-Hall, Inc., 1942.

MATHEMATICAL GAMES

"MELENCOLIA I." Erwin Panofsky in *Albrecht Dürer*, Vol. I, pages 156-171. Princeton University Press, 1943.

THE ALGEBRAIC THEORY OF DIABOLIC MAGIC SQUARES. Barkley Rosser and R. J. Walker in *Duke Mathematical Journal*, Vol. 5, No. 4, pages 705-728; December, 1939.

MAGIC LINES IN MAGIC SQUARES. Claude Bragdon in *The Frozen Fountain*, pages 74-85. Alfred A. Knopf, Inc., 1932.

MAGIC SQUARES AND CUBES. W. S. Andrews. The Open Court Publishing Company, 1917.

ON THE TRANSFORMATION GROUP FOR DIABOLIC MAGIC SQUARES OF ORDER FOUR. Barkley Rosser and R. J. Walker in *Bulletin of the American Mathematical Society*, Vol. 44, No. 6, pages 416-420; June, 1938.

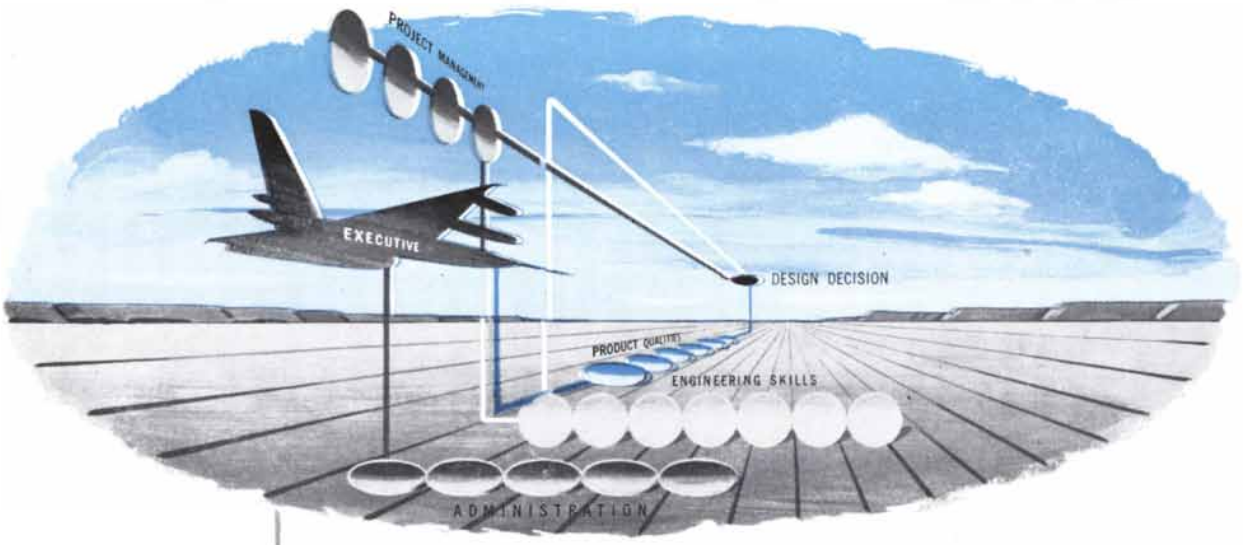
THE AMATEUR SCIENTIST

ATMOSPHERIC ELECTRICITY. J. Alan Chalmers. Clarendon Press, 1949.

PHYSICAL METEOROLOGY. John C. Johnson. John Wiley & Sons, Inc., 1954.

PRINCIPLES OF MECHANISM. F. Dyson. Oxford University Press, 1939.

# *a new perspective...*




## Convair's Engineering Organization

To develop the best and most creative abilities from the individual, and to coordinate thinking and activity in a manner that is efficient and rewarding — a new perspective in engineering organization at Convair-Fort Worth. The effectiveness of the plan is being demonstrated daily, and is best exemplified by the all-new B-58, America's first and fastest supersonic bomber . . . brought from concept to reality in record time.

Men of training and experience, seeking a more stimulating call on their creative ability, are invited to investigate Convair-Fort Worth. A card or letter will bring greater detail, or send a complete résumé of your background for evaluation by other engineers in the areas best suited to your qualifications.

*ALL INQUIRIES STRICTLY CONFIDENTIAL*

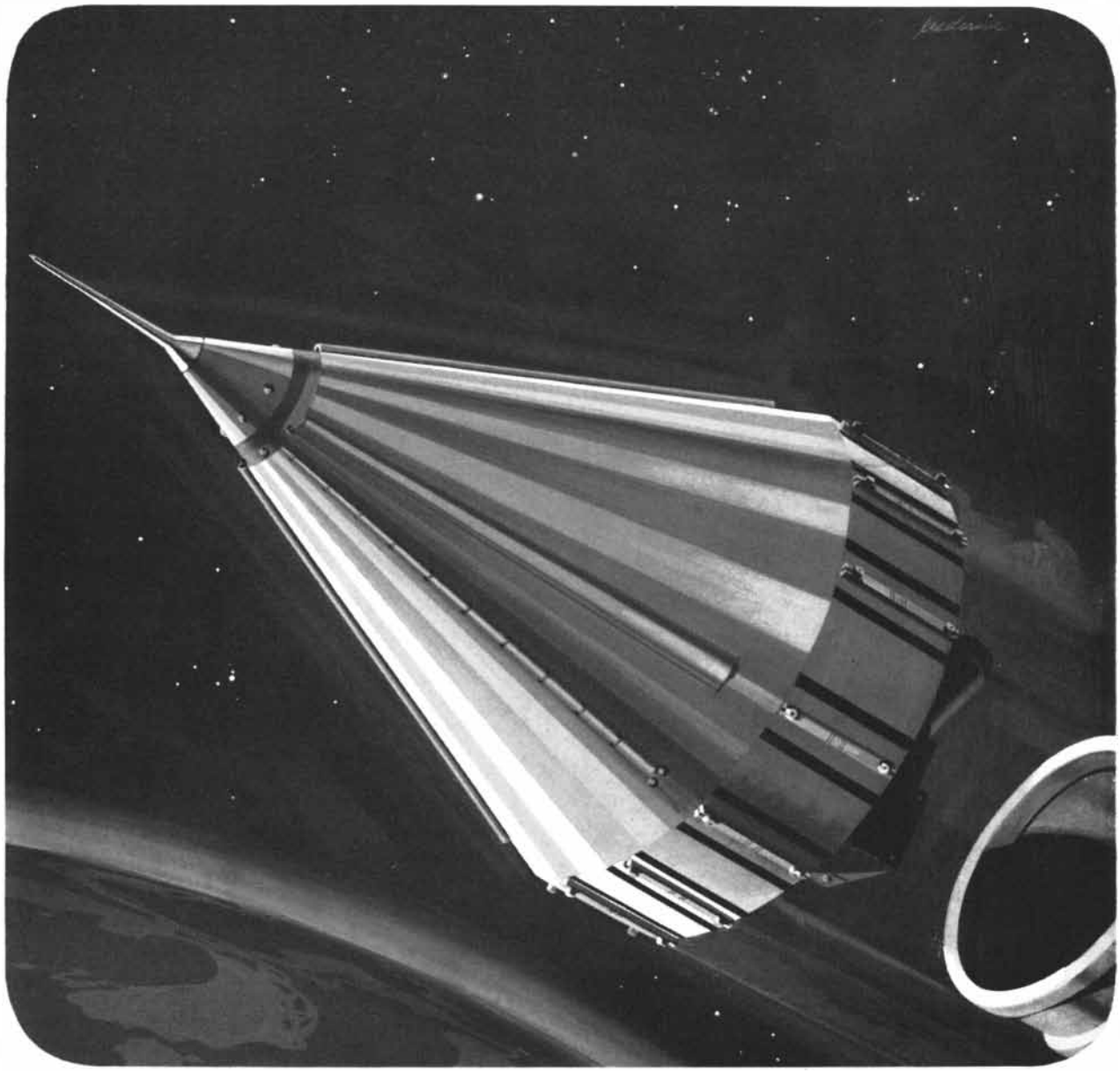
Please address P. O. Box 7485

**CONVAIR FORT WORTH**

FORT WORTH, TEXAS

CONVAIR IS A DIVISION OF GENERAL DYNAMICS CORPORATION

## NOTABLE ACHIEVEMENTS AT JPL . . .



## PIONEERING IN SPACE RESEARCH

Another important advance in man's knowledge of outer space was provided by Pioneer III. This, like many others of a continuing series of space probes, was designed and launched by Jet Propulsion Laboratory for the National Aeronautics and Space Administration. JPL is administered by the California Institute of Technology for NASA.

During its flight of 38 hours, Pioneer III was tracked by JPL tracking stations for 25 hours, the maximum time it was above the horizon for these stations.

The primary scientific experiment was the measurement of the radiation environment at distances far from the Earth and telemetering data of fundamental scientific value was recorded for 22 hours. Analysis of this data revealed, at 10,000 miles from the Earth, the existence of a belt of high radiation intensity greater than that observed by the Explorer satellites.

This discovery is of vital importance as it poses new problems affecting the dispatch of future vehicles into space. The study and solution of such problems compose a large part of the research and development programs now in extensive operation at the Laboratory.

jpl

CALIFORNIA INSTITUTE OF TECHNOLOGY

**JET PROPULSION LABORATORY**

A Research Facility operated for the National Aeronautics and Space Administration

**PASADENA, CALIFORNIA**

OPPORTUNITIES NOW OPEN IN THESE CLASSIFICATIONS

APPLIED MATHEMATICIANS . ENGINEERING PHYSICISTS . COMPUTER ANALYSTS . IBM-704 PROGRAMMERS
AERONAUTICAL ENGINEERS . RESEARCH ANALYSTS . DESIGN ENGINEERS . STRUCTURES AND DEVELOPMENT ENGINEERS

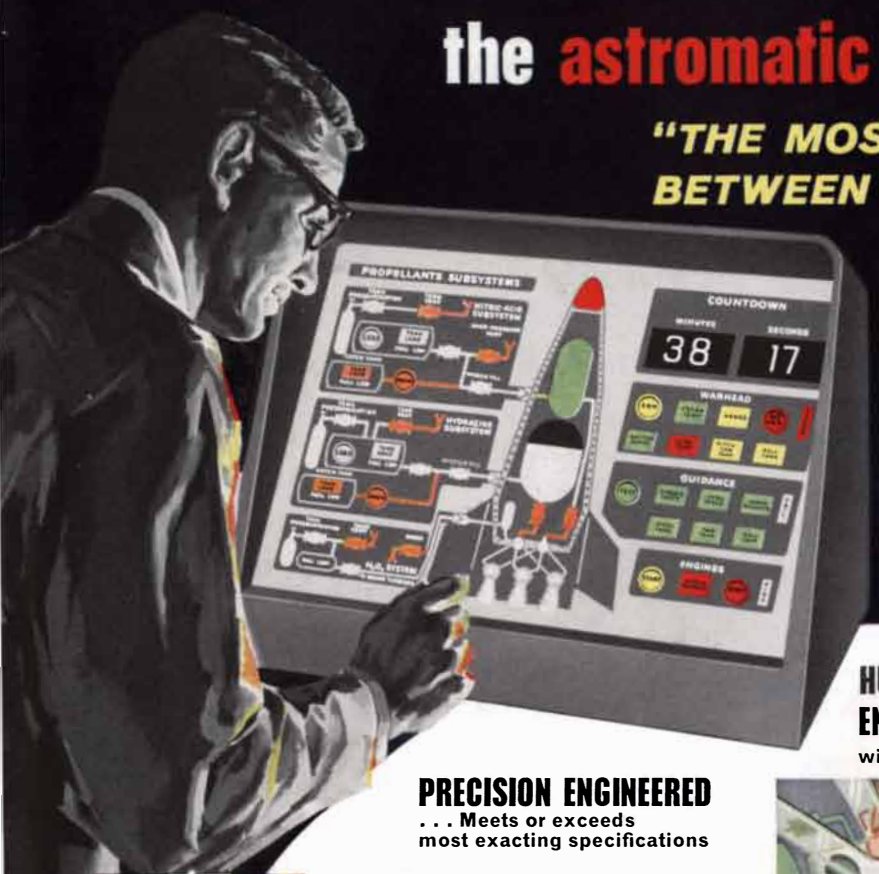
ELECTRO SNAP

Creators of over 6,000 Precision Switches and Controls

*presents . . .* A new panel concept that promises to revolutionize monitoring or control of Missiles and Rockets

# the astromatic panel concept

## "THE MOST EFFICIENT LINK BETWEEN MAN AND MACHINES"




### Consider These Obvious Advantages in Your Designing

- OFFERS INSTANT VISUAL CONTROL WITH EXTREME ACCURACY
- REDUCES HUMAN ERROR TO AN IMPROBABILITY
- PROVIDES SIMPLIFICATION OF THE MOST COMPLEX OPERATION
- ALLOWS REMARKABLE CONSERVATION OF VITAL SPACE
- WITHSTANDS EXTREME LIMITS OF TESTING SPECIFICATIONS
- APPLICATION POSSIBILITIES AS UNLIMITED AS THE IMAGINATION

## PRECISION ENGINEERED

**. . . Meets or exceeds most exacting specifications**


**SHOCK AND ABUSE TOLERANT** . . . Laminated Fiberglas and aluminum eggcrate construction of front panel very rugged.

**LASTING LEGIBILITY** . . . Vivid colors actually photoprinted. Legend and diagrams will not chip or scratch off . . . meets all requirements of MIL-P-7788.

**EASY TO ALTER** . . . Legend and diagramming can be changed to visualize any new findings.

**QUICK LAMP REPLACEMENT** . . . Panel hinged for access to subpanel components permitting 10-sec. lamp change.

**CONCENTRATED GROUPING OF CONTROLS** . . . Multiplefunction of TRILITE controls saves two to four times space required by ordinary panel.

**VERSATILITY OF DESIGN** . . . The module concept of construction makes the Astromatic panel technique extremely versatile. WHATEVER ACTION YOU DESIRE TO VISUALIZE, ASTROMATIC CAN SUBMIT A PANEL DESIGN TO SURPASS YOUR EXPECTATIONS.

## HUMAN FACTOR ENGINEERED for highest efficiency with extreme accuracy



**100% FLUSH PANEL** . . . Eliminates protruding hardware . . . unless specified by human engineering requirements. Switching functions may be recessed, flush, or overflush.

**TRI-COLOR LIGHTS** . . . Each light module contains separate bulbs and circuits to permit three distinct color indications.

**VERSATILE SWITCHING** . . . Momentary, positive feel and alternate action switching is available.

**LIMITLESS COLOR COMBINATIONS** . . . Versatile TRILITES plus multi-color photo printing of panel allows unlimited color guidance.

**SCHEMATIC DIAGRAMMING** . . . Eliminates the written word. Increases speed and efficiency of operators and recognition of indications.

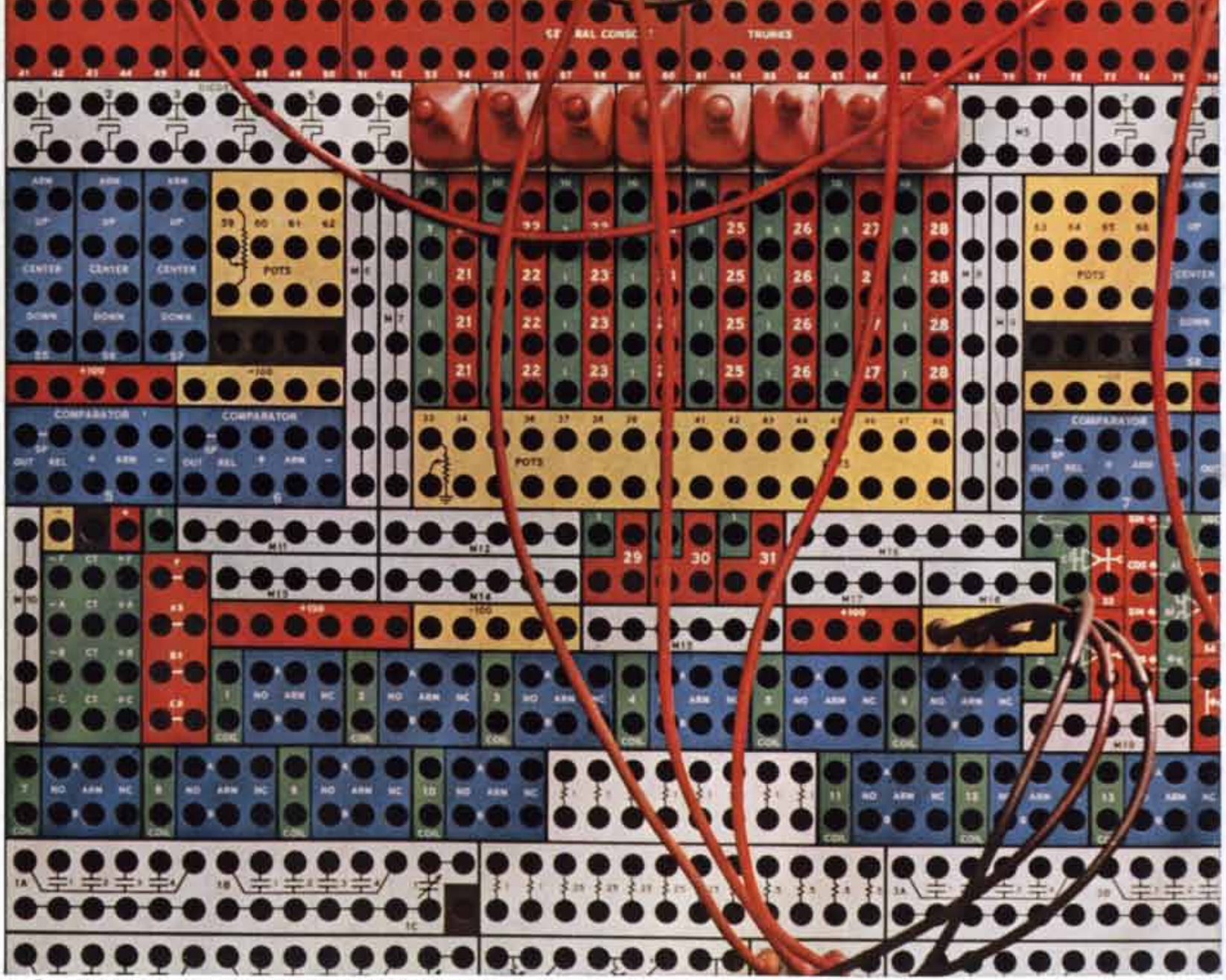
WRITE FOR ADDITIONAL TECHNICAL INFORMATION OR PHONE ROBERT PROVART, TECHNICAL DIRECTOR "COLLECT" . . . VAN BUREN 6-3100

**ASTROMATIC DIVISION**

**Electrosnap Corporation**

4220 W. Lake Street, Chicago 24, Illinois

VAn Buren 6-3100, TWX CG-1400




*Problems of Space: Will intelligent life forms be encountered; will they be ho*



*General Dynamics Corporation · 445 Park Avenue, New York 22, N. Y.*

**GENERAL DYNAMICS**