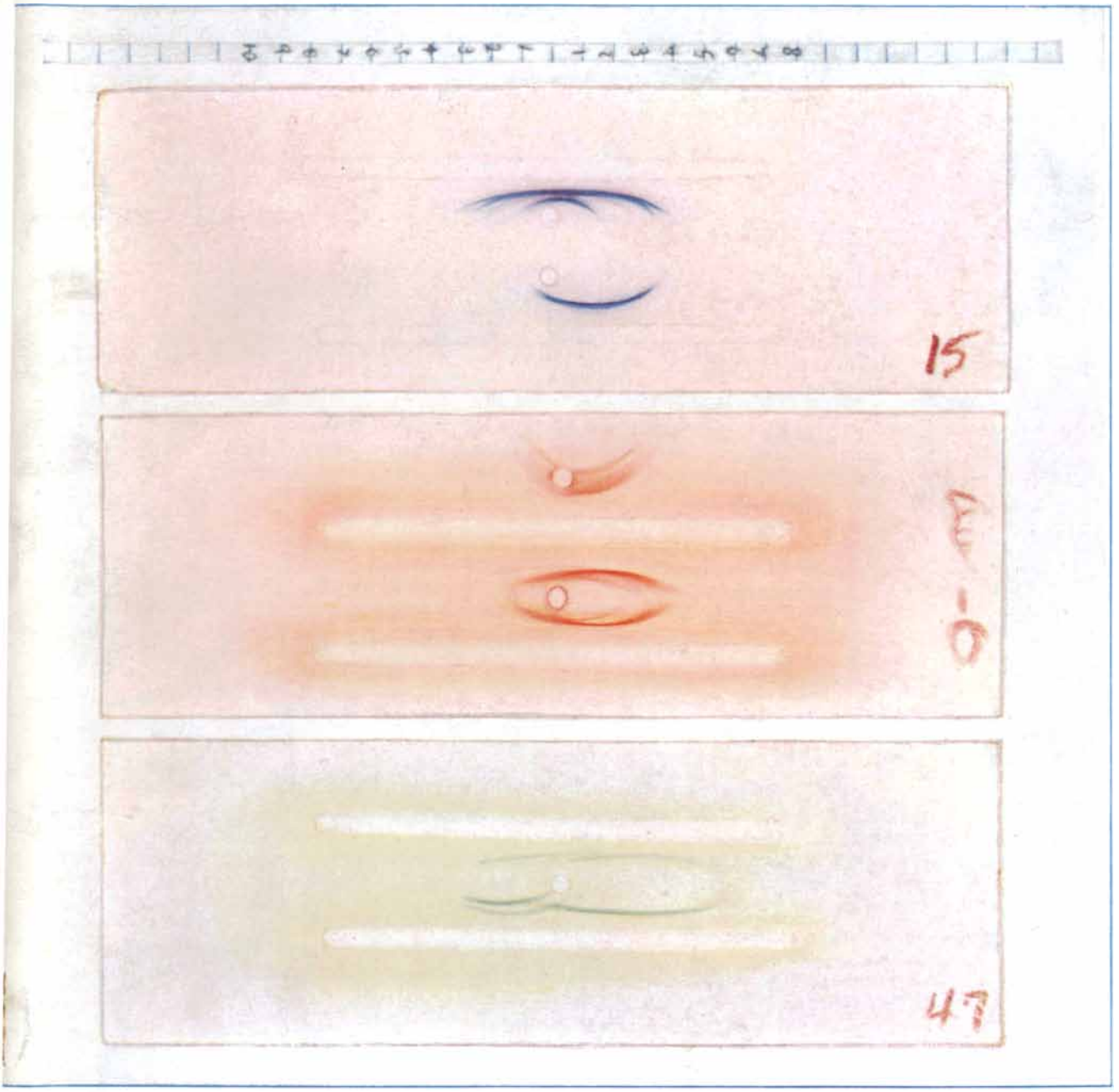
SCIENTIFIC AMERICAN



IMMUNOELECTROPHORESIS

FIFTY CENTS

March 1960

Who will pick up the gauntlet?

"How will we use it?" scientists ask as they strive to meet the challenge of an unusual molecule with extraordinary properties. Will it lead to a new plastic? Better rocket fuel? A cure for the common cold?

Now Shell Chemical offers a molecule (in commercial quantities) with a myriad of uses—*acrolein.* Pronounced ah-crow′-lee-in, it links to many other molecules to create whole new families of chemical derivatives. Some venturesome spirit with an eye to the future will accept the challenge presented by acrolein. In picking up the gauntlet, he may well trigger the most successful new product of 1965.

* * *

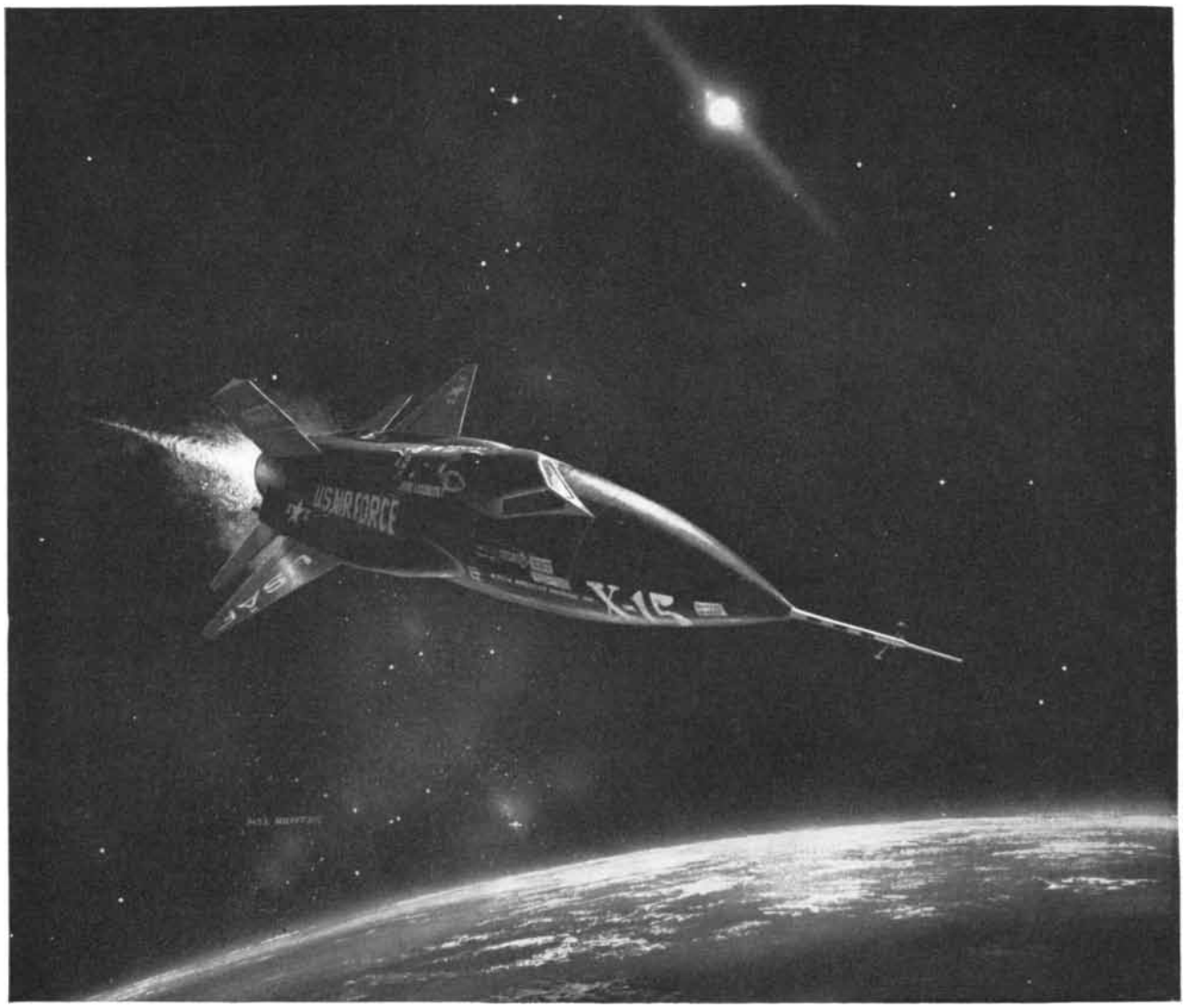
With a promising steppingstone to new materials, Shell Chemical helps American ingenuity set the future in motion.

SHELL

Shell Chemical Company

Chemical Partner of Industry and Agriculture

NEW YORK



MISSION: MAN IN SPACE
FILTER APPLICATION: PROTECT HYDRAULIC CONTROLS
FILTER: PUROLATOR

A malfunction in the lines of the hydraulic and pneumatic controls of the X-15 could send it off its programmed trajectory—alter the angle of re-entry—cause deviation from the ballistic arc.

So North American Aviation engineers took advantage of Purolator's know-how and assistance. The ultimate result is that new and unique designs to meet the wide range of operating temperatures, high capacity requirements and exacting space and weight restrictions are being supplied.

The filters designed for the X-15 are just one example of the kind of imaginative engineering that's a specialty at Purolator. Purolator engineers have developed filters, in every known medium, to handle temperatures from —420°F to 1,200°F—pressures from 0.000 to 6,000 psi—flow rates from a few drops to thousands of gallons per minute—filtration from submicronic to 700 microns.

Filtration conditions like these have been met by Purolator filters in scores of industries, including food and chemical processing, metalworking, transportation, petrochemicals, uranium processing, plastics manufacturing and liquid oxygen production.

And the engineers who solved these filtration problems are ready to solve yours. A phone call, or a descriptive letter with blueprints, will receive their prompt attention.

Filtration For Every Known Fluid

PUROLATOR
PRODUCTS, INC.
RAHWAY, NEW JERSEY. AND TORONTO ONTARIO. CANADA

Antoine Lavoisier...on algebra as a language

"Languages are not only intended, as is commonly supposed, to express ideas and images by signs, but also are real analytical systems by which we advance from the known to the unknown, and to a certain extent in the manner of mathematicians: let us try to expound this idea.

"Algebra is the analytical method *par excellence:* it has been contrived to facilitate the operations of the understanding, to make reasoning more concise, and to contract into a few lines what would have needed many pages of discussion; in short, to lead by a more convenient, rapid, and unerring method, to the solution of the most complicated questions. But a moment's reflection readily shows us that algebra is a real language: like all languages it has its representative signs, its methods, its grammar, if I may use this expression. Thus an analytical method is a language and a language is an analytical method; and these two expressions are, in some sense, synonymous."

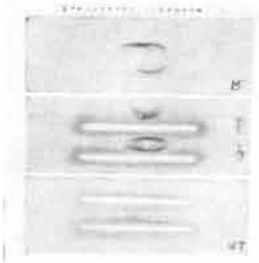
— *Méthode de nomenclature chimique,* 1787.

Established 1845 **SCIENTIFIC AMERICAN** March, 1960 Volume 202 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 $6 PER YEAR.



THE COVER

The three glass plates on the cover were made by immunoelectrophoresis (*see page 130*), a technique used to study proteins and other biological substances. To prepare the plates Leonhard Korngold of the Sloan-Kettering Institute in New York first coated them with a thin layer of agar gel and impregnated it with an electrically conductive solution. A few drops of the protein solution to be studied were then placed in a hole cut in the agar; the slide was connected to an electrophoresis apparatus that separated the proteins according to their respective mobilities in an electric field. A trough was cut in the agar and filled with an antibody solution prepared previously by injecting the proteins to be studied into an animal. The antibodies diffused into the agar, each reacting with its protein counterpart to form an arc of precipitate. The arcs on the bottom plate, for example, were produced by reacting normal human blood serum (a complex mixture of proteins) with anti-macroglobulin (*in upper trough*) and anti-euglobulin (*lower trough*) from a rabbit. Similarly the plates at top and center show the reactions of serum proteins with various other antisera. The precipitates are stained with various protein-specific dyes to produce a permanent record. The scale at top is used to measure the distance the proteins moved through the agar.

THE ILLUSTRATIONS

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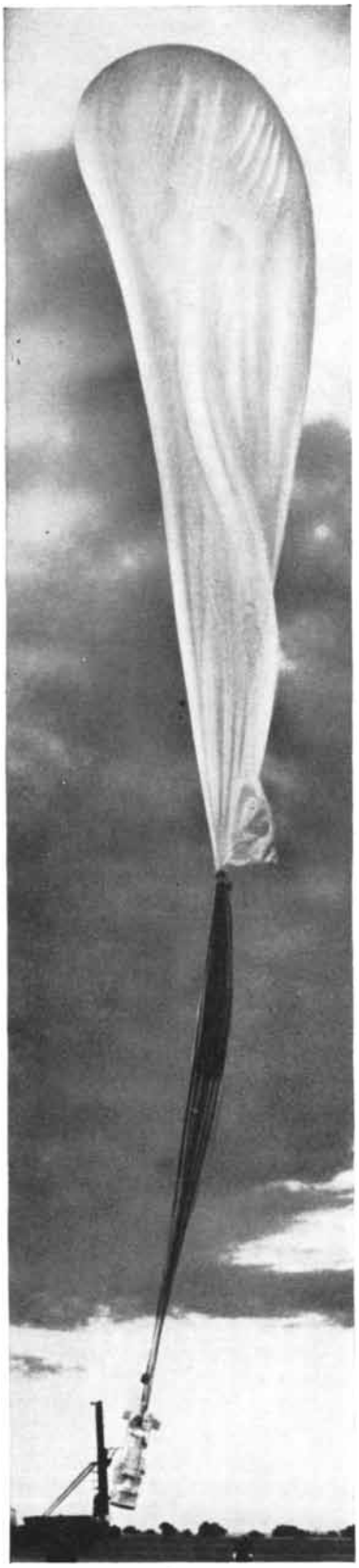
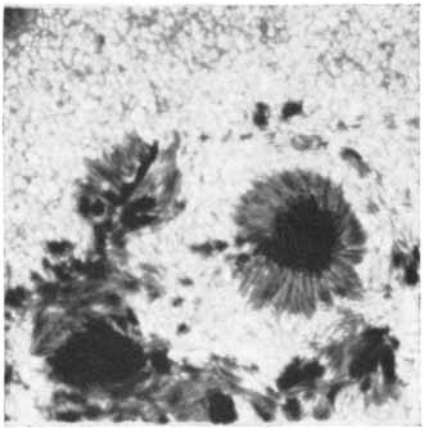
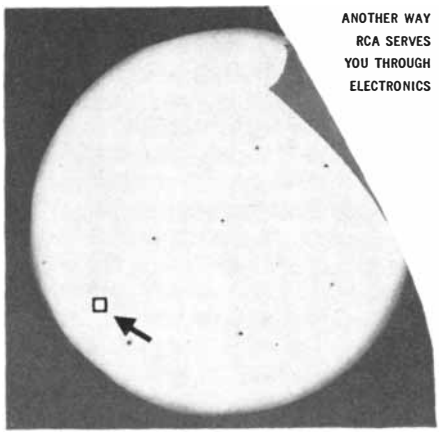


Going up for "good seeing." Unmanned balloon-observatory starts its ascent to take sunspot photos. "Project Stratoscope" is a continuing program of the Office of Naval Research and the National Science Foundation.



One of the sharpest photos ever taken of sun's surface. It, and hundreds of others taken by stratoscope, may answer mystery of violent magnetic disturbances on earth.



Exact position of photograph in relation to the total sun surface is shown here. Plotting and photography of precise areas was made possible by airborne RCA television.

ANOTHER WAY
RCA SERVES
YOU THROUGH
ELECTRONICS

RCA REPORTS TO THE NATION:

REMARKABLE NEW PHOTOS UNLOCK MYSTERIES OF SUN'S SURFACE

Special RCA Television, operating from stratosphere, helps get sharpest photos of sun's surface ever taken

Scientists recently took the first, sharp, searching look into the center of our solar system. It was achieved not by a missile, but by a balloon posted in quiet reaches of the stratosphere.

The idea was conceived by astronomers at the Princeton University Observatory. They decided that a floating observatory—equipped with a telescope-camera—would offer a stable "work platform" from which sunspots could be photographed free of the distortion caused by the earth's atmosphere.

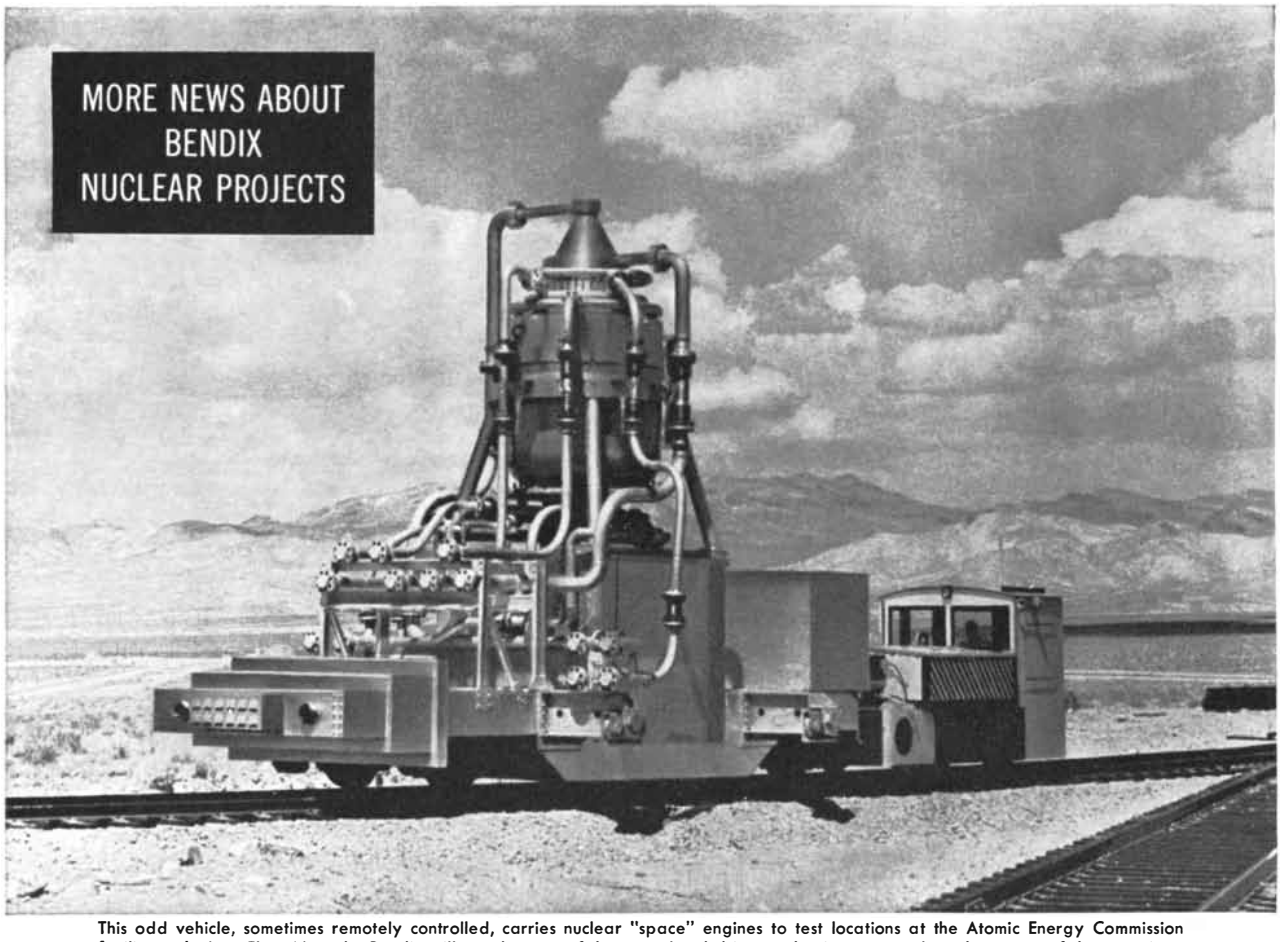
But "Project Stratoscope" encountered an unforeseen and major obstacle on its initial flight. A foolproof method was needed for aiming and focusing the telescope of the unmanned observatory. Princeton asked RCA to help.

A special RCA television system was devised which enabled observers on the ground to view exactly what the telescope was seeing aloft. This accomplished, it was a simple matter to achieve precise photography—directed from the ground by means of a separate RCA radio control system.

The resulting pictures reveal sunspot activities in unprecedented detail. They provide the world with important information regarding the magnetic disturbances which affect navigation and long-range communications.

The success of "Project Stratoscope" is another example of RCA leadership in advanced electronics. This leadership, achieved through quality and dependability in performance, has already made RCA Victor the most trusted name in television. Today, RCA Victor television sets are in far more homes than any other make.

RADIO CORPORATION OF AMERICA
THE MOST TRUSTED NAME IN ELECTRONICS



This odd vehicle, sometimes remotely controlled, carries nuclear "space" engines to test locations at the Atomic Energy Commission facility at Jackass Flats, Nevada. Bendix will supply some of the control rod drive mechanisms to regulate the power of these engines.

THREE NUCLEAR ENGINES IN RACE FOR AIR-SPACE SUPREMACY

In the all-out race for space and air supremacy the United States is developing three mighty nuclear engines—a nuclear aircraft engine, a nuclear ramjet and a nuclear rocket engine. They are for use in planes, missiles and space vehicles.

Today's missiles gulp gigantic fuel loads in seconds. By comparison, the ramjet and aircraft engines, powered with atomic fuel, will have tremendously increased range just as nuclear power has greatly increased the range of submarines. The nuclear rocket engine will also deliver far greater thrust per pound of fuel.

Bendix® is playing a significant part in the development of all of these engines. A Bendix nuclear research reactor is being used by the Atomic Energy Commission in connection with the nuclear aircraft engine.

For the nuclear ramjet and rocket engines, Bendix supplies control rod drive mechanisms, which regulate the power generated in the atom-splitting, heat-producing process. In this case we are applying experience gained in building control rod drive mechanisms for Navy submarines and for the prototype engine for the Navy's first nuclear-powered surface ship.

Similar Bendix control mechanisms also regulate the Shippingport reactor, the first full-scale industrial atom power plant in the United States. It is operated by the Duquesne Light and Power Company of Pittsburgh.

To warn of trouble and automatically shut down reactors when safety requires, Bendix developed a transistorized "cut-off" switch for the large research reactor being built for the National Aeronautics and Space Administration. Radiation damage tests are being performed for the Air Force. Transistorized nuclear instrumentation is being supplied to the Army Package Power Reactor at Fort Belvoir. This project deals with reactors to supply power in remote locations, such as the Arctic, where fuel is lacking.

To help train nuclear engineers, a Bendix research reactor is being built for the University of Kansas. Bendix is also associated in the development of the reactor which will supply industrial power to the Detroit Edison System.

As a further indication of long experience in this new field, Bendix has operated the Kansas City Division for the past ten years. It is a large AEC facility covering 1,300,000 square feet, employing nearly 8,000 people, and is devoted to the atomic weapons program.

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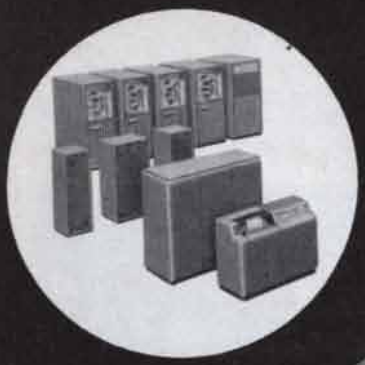

DATA PROCESSING

AVIATION CONTROLS

MISSILES AND ROCKETS

RADAR SYSTEMS

SPACE EXPLORATION

MEDICAL INSTRUMENTS

DEFENSE WEAPONS

EDUCATIONAL DEVICES

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there's Transitron

Manufacturers from all parts of the free world depend on Transitron for germanium and silicon semiconductors used in thousands of electronic applications: industrial, commercial, military. At Transitron more than 4500 skilled employees work exclusively developing and producing semiconductors of the highest quality and utmost reliability. That's why — *wherever there's electronics, there's Transitron.*

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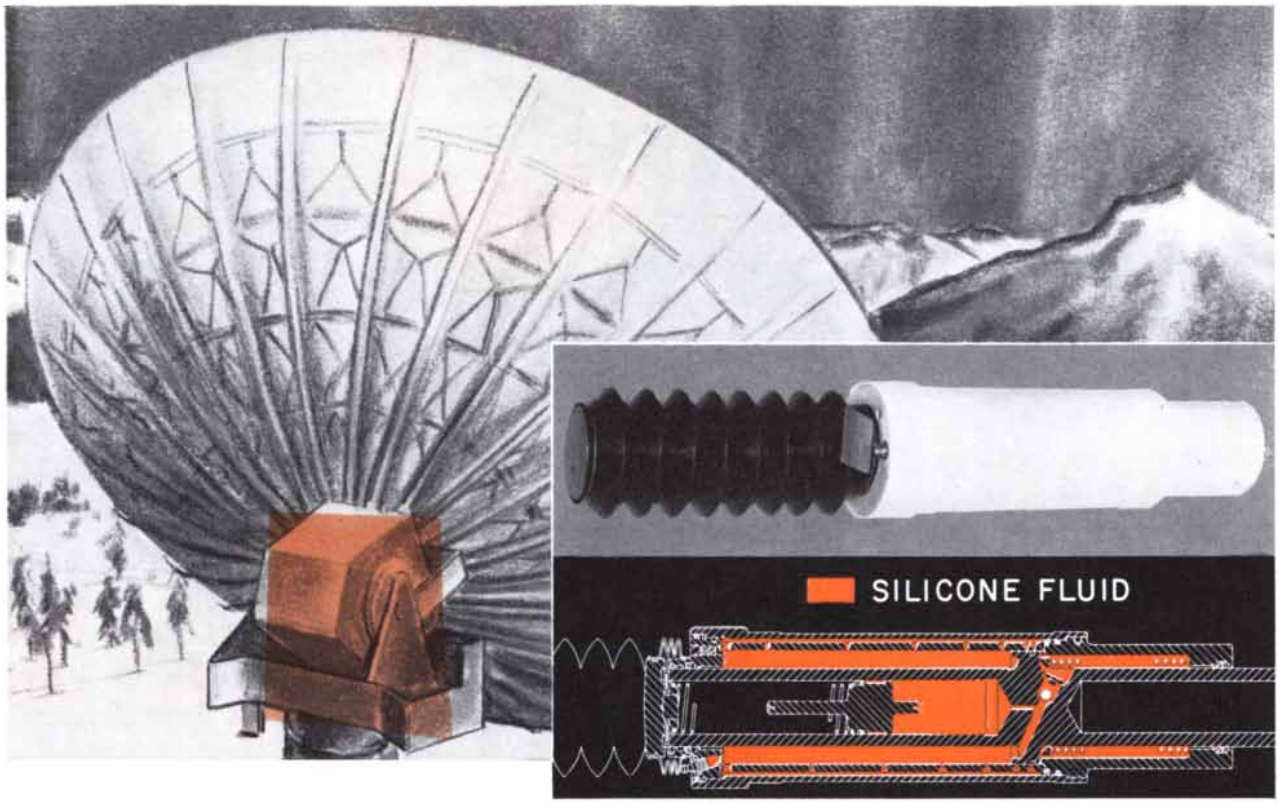
Silicones Soak Up Shock



Dow Corning Damping Fluids Unaffected by Cold, Heat, Time

"Steady-state" fluids — that's what some engineers call these exceptionally stable damping media. And steady they are. Their useful range extends from as low as —100 F on the cold side to over 400 F on the hot side! Within these extremes, viscosity varies but little. They're resistant to oxidation and to breakdown under shear; won't sludge; won't corrode metals. Because of such properties, silicone fluids are highly effective media for damping, springing and torque converting.

Illustrated above is one example. It's a Radar Antenna Buffer, designed and built by Houdaille Industries, Buffalo, N. Y. Radar equipped with this unit, "Has silicone; won't over-travel." For that's where the buffering comes in. When the antenna swings to its travel limit, something must give, or the structure may be shock-damaged. What "gives" is the Buffer, and the working medium is Dow Corning silicone fluid. Because the damping fluid's viscosity is unaltered by temperature changes, performance of the Buffer varies less than 1% per 100 Fahrenheit degrees. That's important, because installations of ballistic missile early warning radar, which use the Buffer, may vary from tropic to Arctic.

This is but one of many designs where silicone fluids have aided the product engineer. Others include auto fan drives, aircraft oleo struts, missile accelerometers, and truck scales. If in your design you require a high performance damping or coupling fluid, investigate Dow Corning Silicones . . . the fluids with "steady-state" viscosity. Write to Dept. 9803 for more detailed information.

TYPICAL PROPERTIES OF DOW CORNING 200 FLUID*

Centi-stokes at 25 C	Pour Point, °F	Visc/temp.[1] Coefficient	Coeff. of Expansion cc/cc/°C
10	—85	0.57	0.00108
50	—67	0.59	0.00104
100	—67	0.60	0.00096
500	—58	0.62	0.00096
1,000	—58	0.62	0.00096
12,500	—51	0.58	0.00096

*Available in a range of viscosities to over a million centistokes.

[1] $1 - \frac{\text{Viscosity at 210 F}}{\text{Viscosity at 100 F}}$

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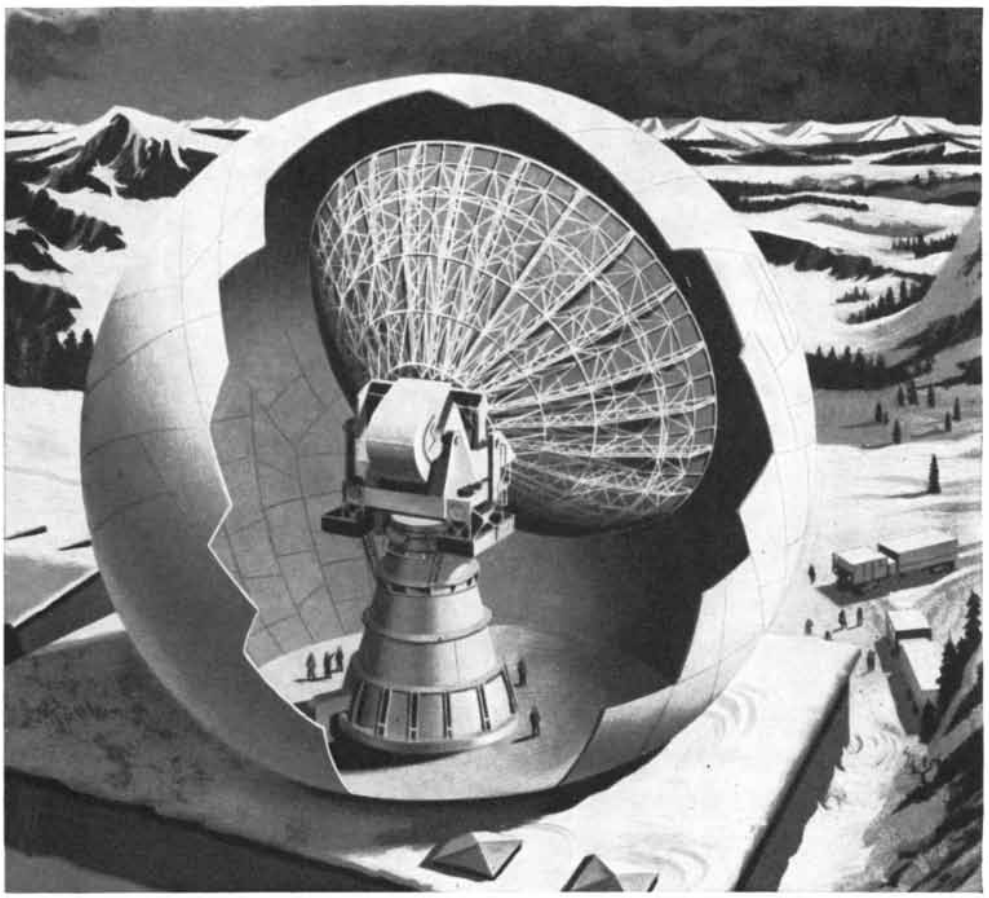
wary watchman for



BMEWS

This giant early warning "watchman" is a prototype model—designed and built by Goodyear Aircraft under contract to the Radio Corporation of America for the U.S. Air Force. The project: BMEWS—Ballistic Missile Early Warning System.

You get some idea of the size and capability of the Goodyear Aircraft components when you consider these facts:

—The concave tracking "dish" and rotating components weigh more than 200,000 pounds, *yet* it rotates and maneuvers with fluid ease and perfect balance.

—The supporting pedestal is three stories high, structured for the immense load it must carry, *yet* it is one of the most accurate mechanisms of its type ever made.

—The 140-foot-diameter radome can withstand gale-force winds and arctic storms, *yet* it offers almost complete electromagnetic transparency and requires no internal framework.

These achievements stem from Goodyear Aircraft's long experience in radar and radome design, development, fabrication and testing. Such experience provides an invaluable background *for virtually any radar system assignment*—from farseeing radar structures of unprecedented accuracy to massive radomes of advanced architecture.

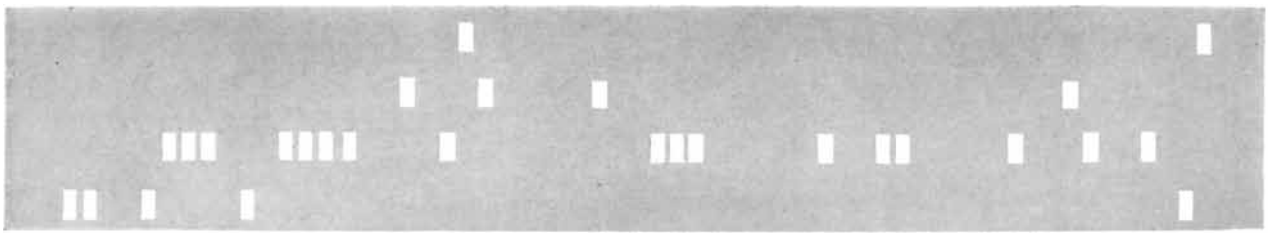
Where can this experience solve a problem for you? WRITE for complete information to:

Goodyear Aircraft Corporation,
Dept. 916OO, Akron 15, Ohio

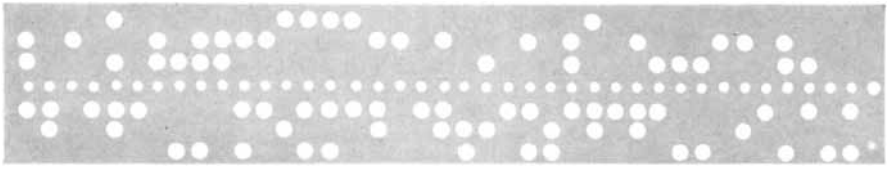
RADAR STRUCTURES AND RADOMES—PRIME CAPABILITIES OF

GOODYEAR AIRCRAFT

Plants in Akron, Ohio, and Litchfield Park, Arizona



a new development of vital importance—*to users of punch cards and tape*



The Dobeckmun Company is now successfully laminating foil, Mylar* and paper in varying combinations to produce tape and card stocks of extremely high dimensional stability and strength. They have proven to be particularly valuable in complex control and programming systems that demand absolute fidelity of every component part.

If you have special tape or card stock requirements, we shall be delighted to work with your development people in producing a special material. We feel confident that somewhere within the framework of our skills and diversified products we can be of service to you. Write for brochure of complete details.

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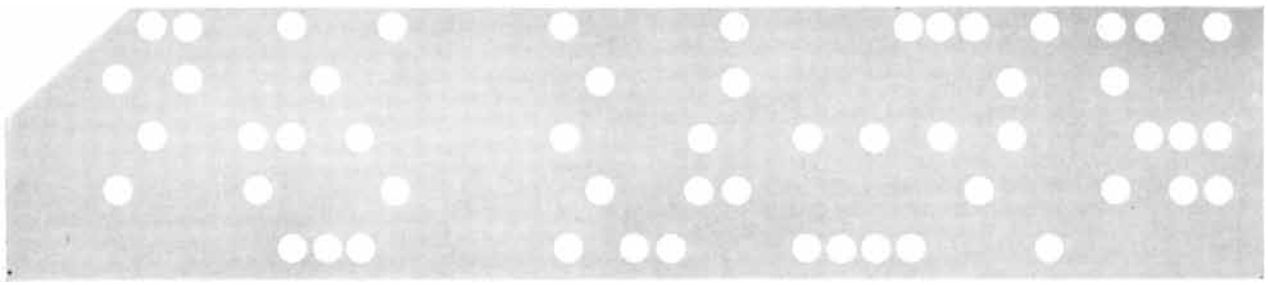
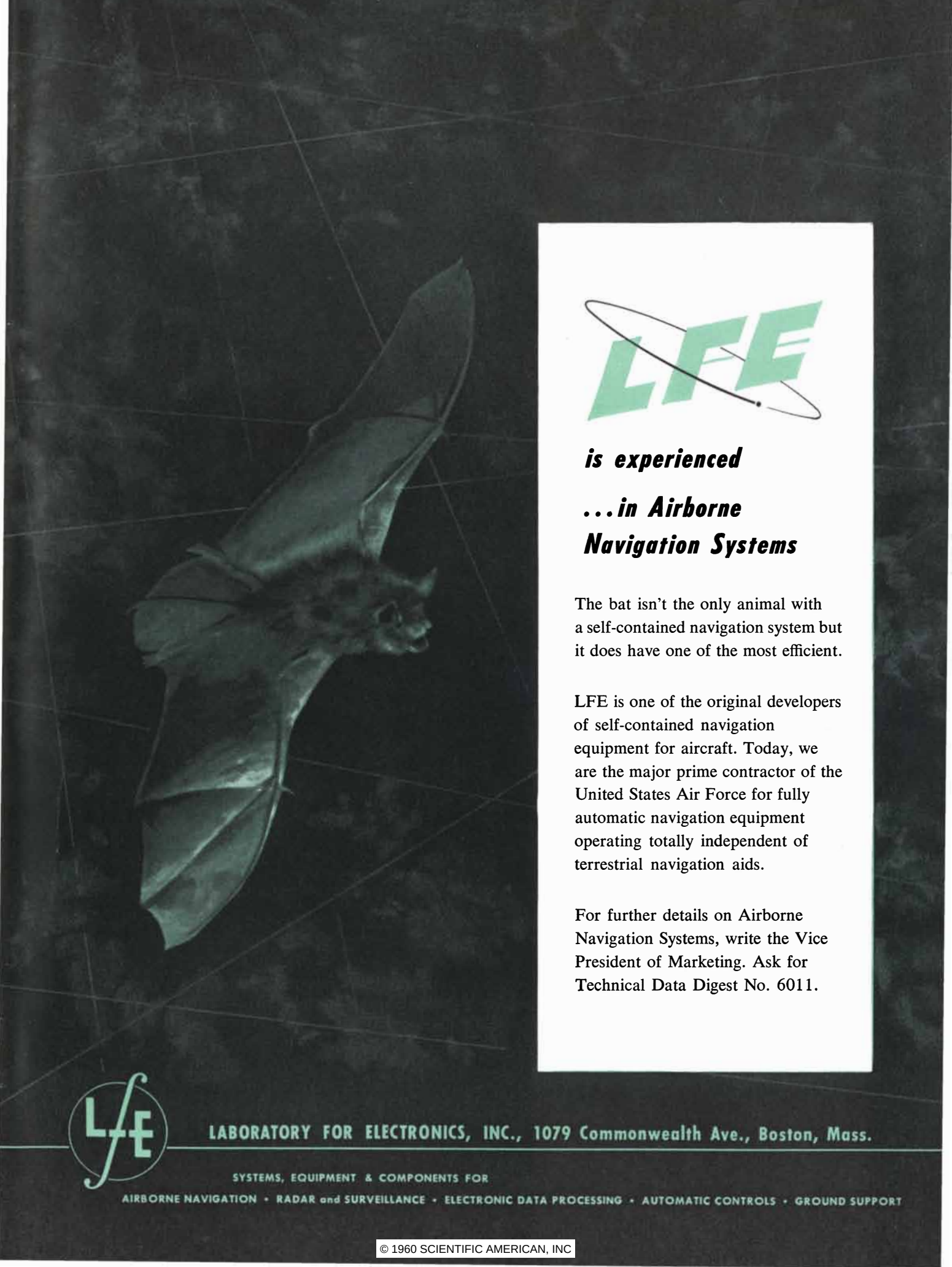
*MYLAR IS A REGISTERED DUPONT TRADEMARK





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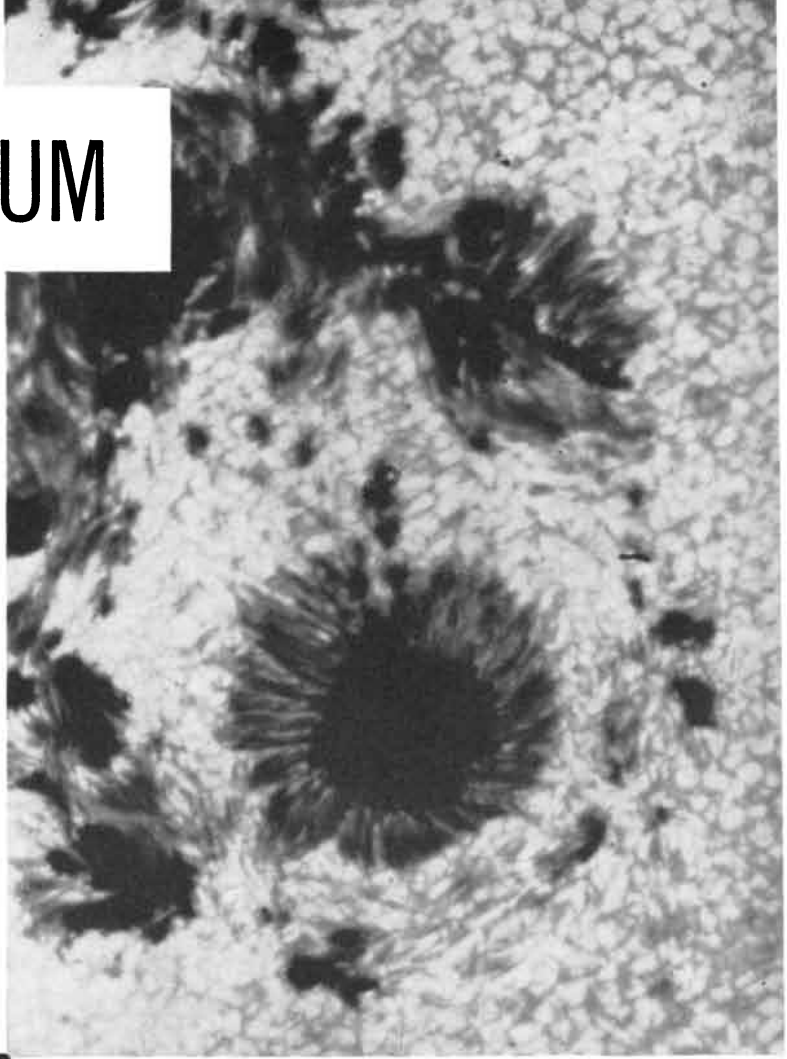

TV-EQUIPPED SOLAR TELESCOPE TAKES SHARPEST-EVER SUN SPOT PHOTOGRAPHS

This past summer's Stratoscope I flights employed a closed-circuit television hook-up for ground-based aim, control and focus of a sun telescope borne 80,000 feet high in an unmanned balloon. Result: sun spots were photographed with unprecedented sharpness, as the accompanying photo shows.

This is an active group of sun spots that caused a magnetic storm on earth the day before the flight. The spots are dark cores of relatively cool gases imbedded in a strong magnetic field. Enveloping them are wispy filaments of outward moving warmer gases.

These balloon telescope experiments—sponsored jointly by the Office of Naval Research and the National Science Foundation, and under the direction of Dr. Martin Schwarzschild of Princeton University — are providing fundamental data of value in such fields as communications, thermo-nuclear reactions and space travel. In this year's flights, the same basic 12-inch telescope-camera system designed and built by Perkin-Elmer for the first successful high-altitude telescope flights in 1957 was used. Perkin-Elmer now is designing a much larger 36-inch balloon telescope, known as Project Stratoscope II, to be flown in 1961 for the study of planets, galaxies and nebulae.

"NEW CONCEPT" POTENTIOMETER HELPS CHECK OUT B-58 AUTOMATIC FLIGHT CONTROL SYSTEM

A mobile test set, built by Eclipse-Pioneer Division of Bendix Aviation Corp. to check out the complex automatic flight control system of the Air Force's Convair-built B-58 Hustler bomber, utilizes a unique type of a.c. potentiometer developed by Perkin-Elmer. The Vernistat* is based on a new concept in relating shaft rotation to voltage. In the B-58 test set, several Vernistats provide accurate sources of test voltages used to simulate control system signals. An alternative method of supplying voltage levels would have necessitated several additional components and would have cost four times as much as the Vernistat system.

CAREER OPPORTUNITIES

Perkin-Elmer's continuing growth has created need for additional engineers and physicists experienced in optomechanical systems, reliability standards and transistorized electronic circuits at both East and West Coast locations.

You will be happy with the opportunities for individual recognition, professional growth, and advancement in responsibility and salary these positions offer. To investigate, forward resumé to R. H. Byles, Electro-Optical Division, Perkin-Elmer Corporation, 915c Main Avenue, Norwalk, Conn., or J. Armitage, Perkin-Elmer Corporation, 5670 East Washington Blvd., Los Angeles 22, Calif.

Vernistat is a registered trademark of The Perkin-Elmer Corporation.

Perkin-Elmer *Corporation*
NORWALK, CONNECTICUT

ANALYTICAL INSTRUMENTS • MILITARY SYSTEMS
FINE OPTICS • PRECISION ELECTRONIC COMPONENTS

Perkin-Elmer will be happy to send you an 8 x 10 glossy print of the sun spot photograph. Forward your request to P-E's Public Relations Department at the above address

Making the incredible commonplace is our job. From fertilizers to fuels, from papers to proteins…everywhere in production and processing, Beckman Instrumentation makes the unheard-of not only possible but profitable ● In the laboratory,

Beckman electrophoresis apparatus measures a molecule…a Beckman ultracentrifuge isolates a virus — to speed medical and pharmaceutical research. And without fanfare, Beckman computers and data processing systems steadily shape the development of entire space programs ● Scientists, manufacturers and processors throughout the world meet endless problems of accurate analysis, difficult measurement and critical control with Beckman instruments…performing minor miracles on a regular schedule ● Where ever electronics has application, it is our job to reduce the impossible to the routine… to make the incredible commonplace ● We do it every day.

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LETTERS

Sirs:

The note "Radiation Compromise" in your department "Science and the Citizen" for December suggests that there has been a difference between the recommendations of the International Commission on Radiological Protection and the National Committee on Radiation Protection and Measurements. It would appear that considerable confusion with regard to the relative positions of these two bodies has arisen because of some slightly inaccurate reporting of this complicated question by the daily press.

First, I should like to point out with emphasis that there is not, nor has there ever been, any substantial disagreement between the recommendations of the two bodies. In fact, it would be very difficult for disagreement to arise, as there is so much overlap of membership between the two groups.

For several years both groups have recommended a *maximum* permissible dose for the population outside of controlled areas resulting from operations within controlled areas, at one tenth the occupational level. The same *maximum* values more recently have been extended either formally or informally by both groups to apply to individuals in the population at large. It is expected that by the use of such *maximum* values the average would be substantially less.

The I.C.R.P. in its report issued last spring also suggested *average* permissible population doses for long-range planning purposes. These were set at a 30th of the occupational level for somatic damage and a 100th for genetic damage. The same figures would derive from the 1957 recommendations of the N.C.R.P., although the N.C.R.P. has never stated these figures in such a specific manner.

I believe that the I.C.R.P. position will be made clear in a statement that is expected to appear in the January issue of *Radiology*. It is unfortunate that some of the press articles have given the appearance of accenting differences between the recommendations of these two bodies, when in fact there has been none of consequence since both were organized over 30 years ago.

LAURISTON S. TAYLOR

Chairman
National Committee on Radiation
Protection and Measurements
Washington, D. C.

Sirs:

I should like to raise a question concerning a most interesting and important point made by Knut Schmidt-Nielsen in his informative article "The Physiology of the Camel" [SCIENTIFIC AMERICAN, December].

It is one of the fairly well-established facts of desert experience that men are prostrated after about 10-per-cent weight loss due to dehydration and that a 20-per-cent loss is almost certainly lethal, apparently due to inability of the heart to continue to pump blood after the viscosity increases as a result of the plasma water loss. Schmidt-Nielsen's work reveals, by contrast, that the camel is not in serious danger even after 25-per-cent loss of total body-water.

To understand the marked differences in physiological response to dehydration in camel and in man is clearly important for the study of both animals. Hence I wish to suggest that some revision of Dr. Schmidt-Nielsen's osmotic interpretations seems to be necessary. If, as is apparently implied, both man and camel lose water via evaporative processes at the immediate expense of plasma water, then osmotic flow of water from nonplasma sources into the thickening plasma can, at most, bring the plasma's osmotic pressure back down to that of the rest of the body solutions. The author suggests that man's osmotic response is anomalous and that the camel's is that which is to be expected, but the opposite seems true. How can a camel

Scientific American, March, 1960; Vol. 202, 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.

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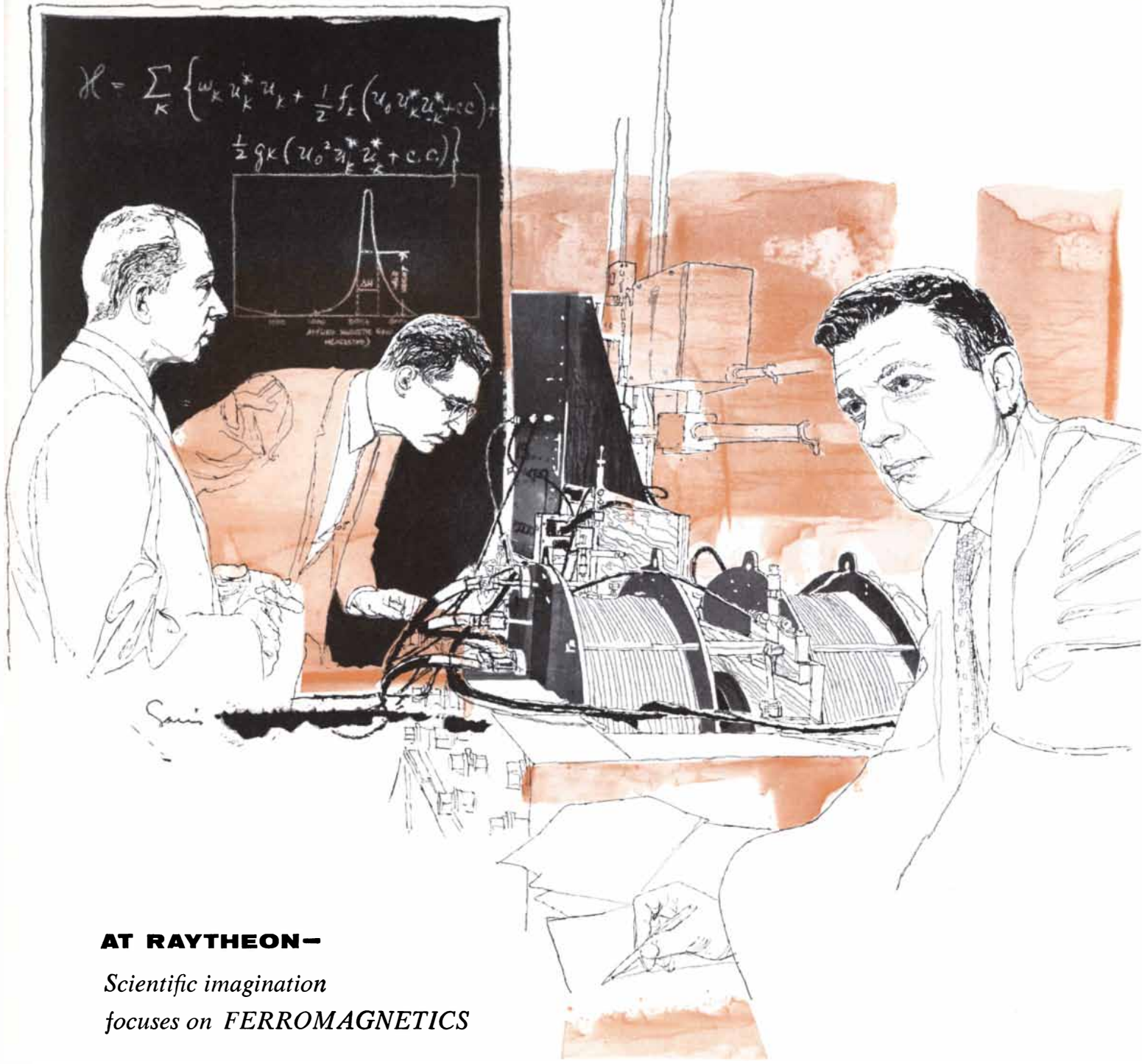

AT RAYTHEON—

Scientific imagination
focuses on FERROMAGNETICS

Ferrites, ceramic materials derived mainly from magnetite, combine high electrical resistivity with ferromagnetic properties. These characteristics make possible microwave devices such as isolators—units which conduct radio waves in one direction, but not the other—modulators, phase shifters and microwave switches. Unlike conventional microwave hardware, ferrites are simple, highly efficient solid-state devices.

New types of microwave tubes require ferrites capable of operating at multi-megawatt levels. However, at high power, heat generated within the ferrite may cause a gradual loss of magnetic properties. And at low frequencies, interaction among microwave, external and ferrite magnetic fields may seriously attenuate the transmitted signal.

Through design innovations, new material formulations and special ceramic production techniques, Raytheon scientists and engineers have successfully minimized these effects in developing the first commercially-available UHF (350 to 400 mc) isolator for high-power—10 megawatt peak—radar.

Out of the combined efforts of many professional disciplines—mathematical physics, metallurgy, physical chemistry—have come major contributions to fundamental understanding of ferromagnetics and microwave behavior.

Dr. M. H. Sirvetz of the Research Division, Dr. H. Scharfman, head of the Special Microwave Devices Operations, and Dr. S. L. Blum also of Research are among the many Raytheon personnel contributing to these fields.

Excellence in Electronics RAYTHEON **RAYTHEON COMPANY, Waltham, Mass.**

that has undergone 25-per-cent loss of total body-water exhibit only about a 10-per-cent loss of plasma water without defying thermodynamic laws—unless its total body-water loss involves some form of immediate drain on nonplasma solvent rather than plasma solvent? If the latter were the case, this would be a point of great physiological interest.

JAMES E. MCDONALD

University of Arizona
Tucson, Ariz.

Sirs:

James E. McDonald's letter correctly states: "If, . . . both man and camel lose water . . . at the . . . expense of plasma water, then osmotic flow of water . . . into the thickening plasma can, at most, bring the plasma's osmotic pressure back down to that of the rest of the body solutions." McDonald's contention, that plasma volume should therefore be reduced in dehydration, is a widely held opinion, and I am happy to have this opportunity to explain that this is not necessarily so.

The capillary wall is permeable to water and salt, but not to proteins, and therefore plasma proteins osmotically attract water from the extravascular space. The influx of water is opposed by the hydrostatic pressure in the capillary. The net flux of water is zero when hydrostatic pressure and colloidal osmotic concentration are equal. In general, if water is lost from the plasma, the resulting increase in protein concentration (in the absence of changes in hydrostatic pressure) causes an increased influx of water, diluting the protein until equilibrium is reached at the original protein concentration, *i.e.*, the plasma volume is restored. In the specific case of 25-per-cent dehydration, salt concentration in plasma and tissue water is increased by one third, but since the capillary wall is freely permeable to salt and water, this increase has no effect on the equilibrium between hydrostatic pressure and osmotic concentration of proteins. Hence plasma volume, which is determined by this equilibrium, should be maintained without "defying thermodynamic laws." As I briefly stated in the article, the camel approaches this situation, and the real problem is why man does not.

KNUT SCHMIDT-NIELSEN

Department of Zoology
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Durham, N. C.

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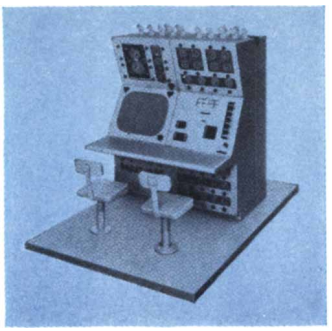
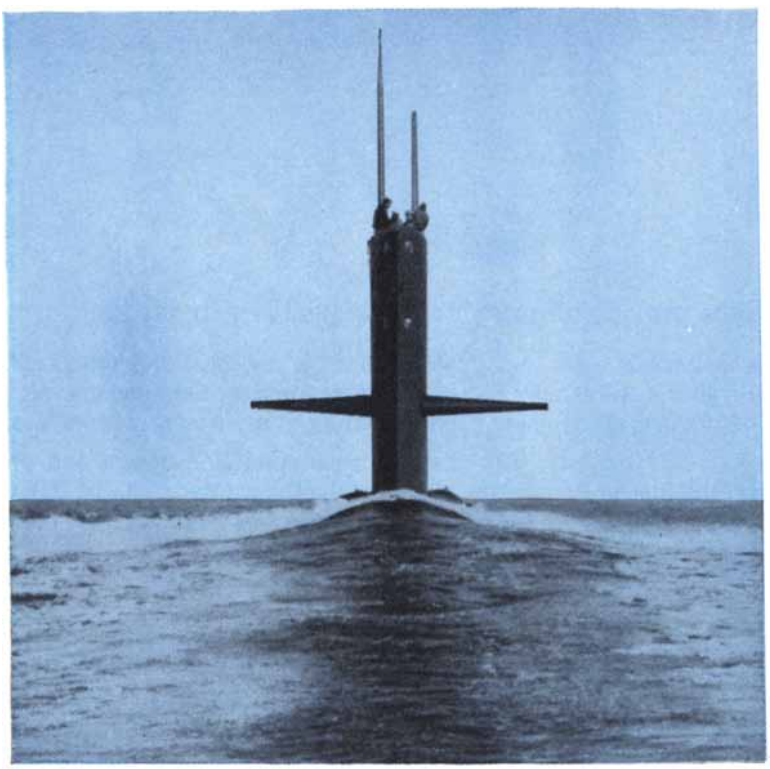


computers that pace man's expanding mind



GP LI-03

WHEN YOU WANT TO TOUCH THE UNTOUCHABLE

You may design manipulators for radioactive materials . . . control devices for corrosive chemicals . . . laboratory equipment for research on deadly viruses. *Whatever* you design, if it calls for precision instrument ball bearings, Fafnir can help you. Low torque, for example, is insured through Fafnir's balanced bearing and retainer design, extreme accuracy in geometry of parts, superior finishes, and "clean room" assembly. Let Fafnir's uniformly high standards of quality plus diversity of types, sizes, and materials help *you* "touch the untouchable" in meeting exacting requirements. The Fafnir Bearing Company, New Britain, Connecticut.

Fafnir precision instrument ball bearings are available in four tolerance classes—ABEC 1, 3, 7, and Modified 7—to meet specific needs.

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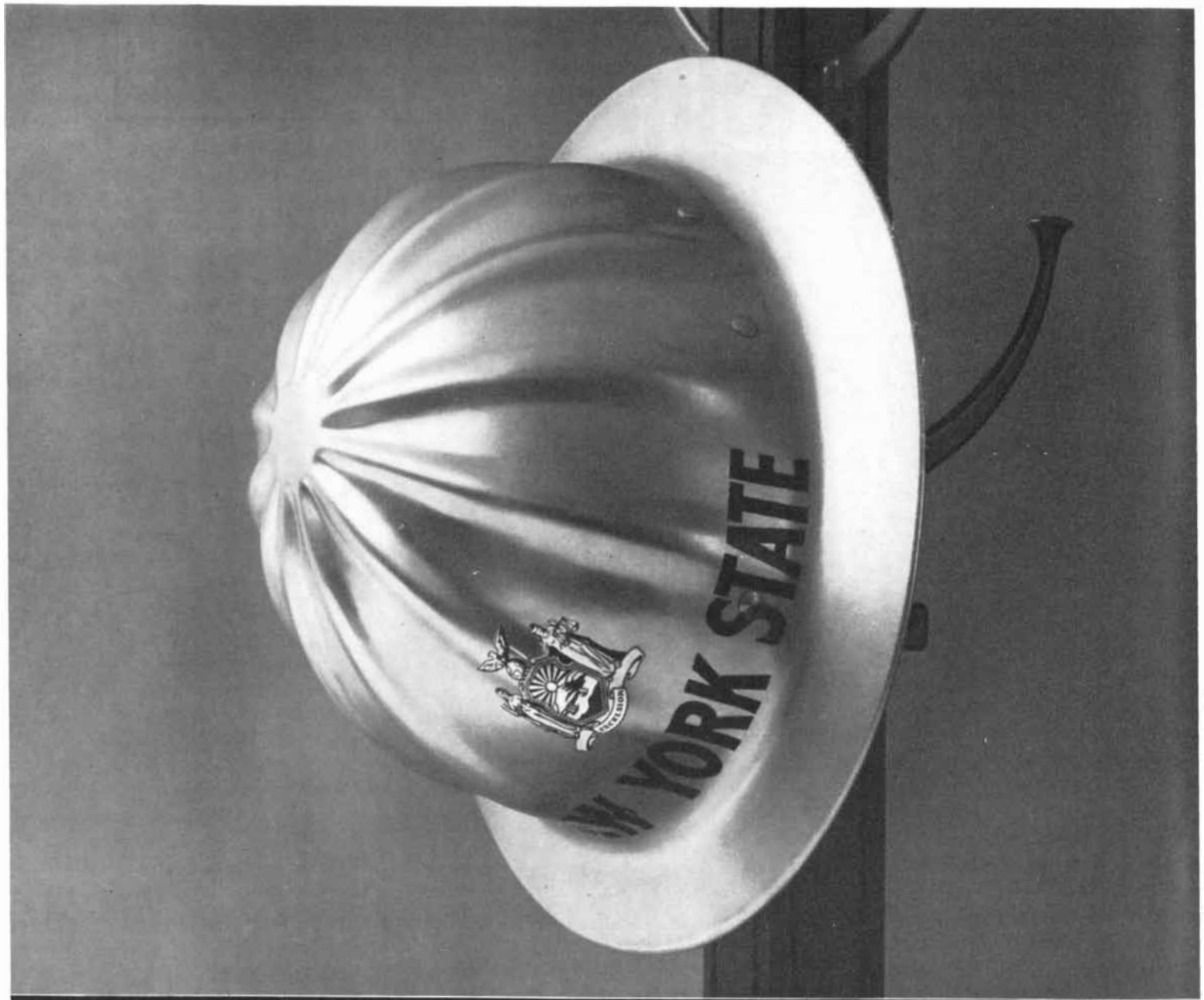
THIS IS A HARD HAT. It's worn by men who get things done. It's the perfect symbol for the new spirit in New York State . . . a spirit that's working to create more and better job opportunities for everyone by encouraging business to grow.

Focal point of this new spirit is the capital city of Albany. The city is alive with "doers." Successful business and professional men who gave up positions of responsibility to help Governor Nelson Rockefeller make New York State an even better area for companies to locate and grow . . . an even more rewarding place to live and work.

You'll see and feel the work of the hard-hat "doers" in many ways. In the interest in streamlining the administration of laws affecting business . . . in the new survey of New York's business climate . . . in the new study of taxation . . . in new approaches to plant financing and in many other new developments.

If you agree that your company could grow and prosper in this hard-hat businessman's climate, get in touch with the Commissioner of Commerce, Keith S. McHugh. He will send you, free, confidential, up-to-date reports on sites, labor, transportation, markets, raw materials, water. Write Keith S. McHugh, New York State Department of Commerce, Room 375, 112 State Street, Albany, N. Y., or phone HObart 2-7511.



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cooler... less cloudy... better going

Formaldehyde in water solution has always presented problems. It must be heated and then kept warm in transit and storage, otherwise the chemical tends to cloud the solution and fall to the bottom as a precipitate. Celanese research has recently discovered a better way to stabilize formaldehyde—a new process which permits shipment of formaldehyde at a full 15 to 20 degrees F. less than before! The savings in steam and heating plant at storage points is considerable. Higher concentrations can be shipped, with resultant economies in chemical processing. Celanese is headquarters for formaldehyde in all its variants. A leader in high-volume basic chemicals, Celanese has pioneered many advances in chemical industry—several in formaldehyde. We'd be glad to help you find answers to your chemical problems and requirements. For a listing of the chemicals we produce, write to: Celanese Chemical Company, a Division of Celanese Corporation of America, Dept. 582-C, 180 Madison Avenue, New York 16, N. Y.

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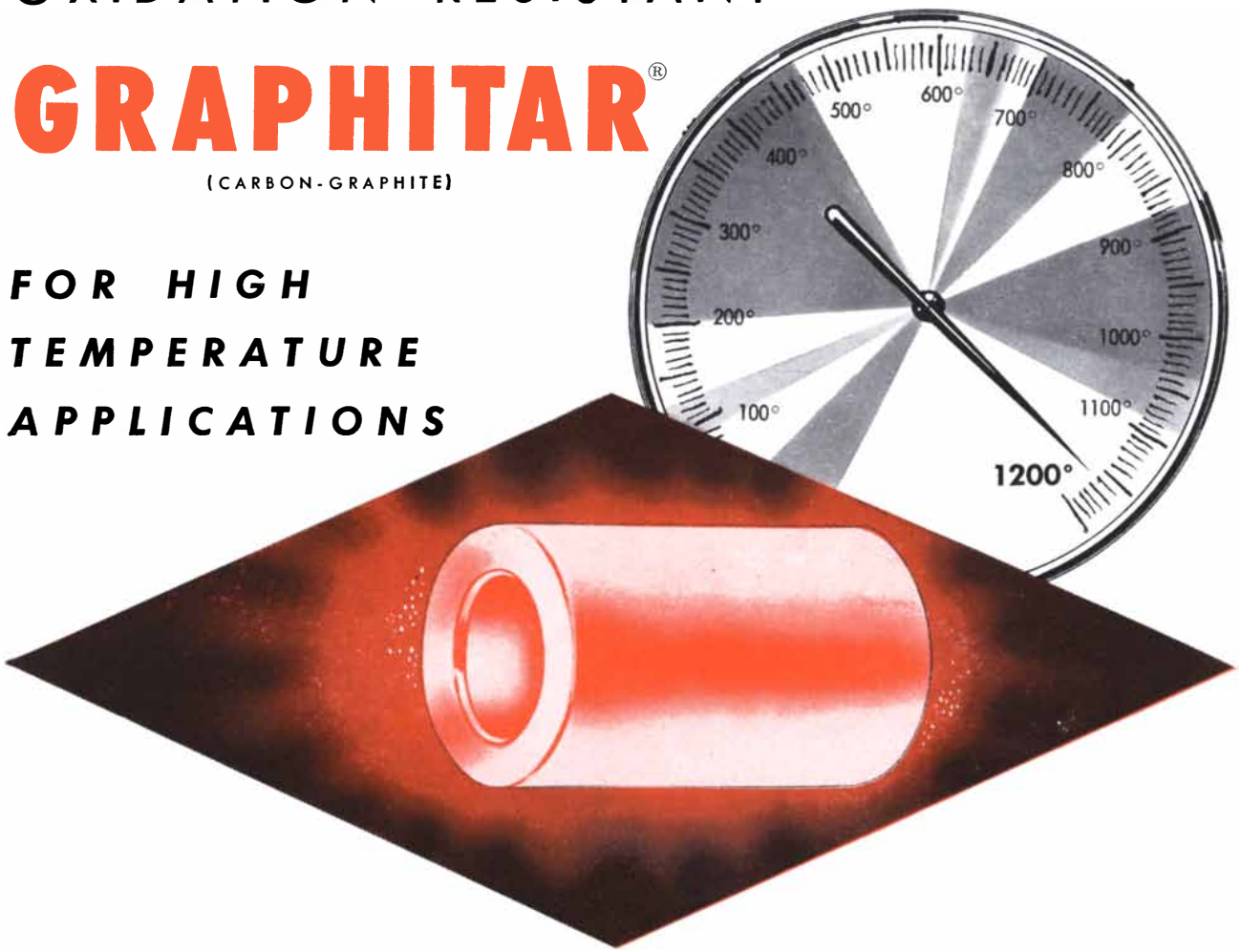
FOR HIGH TEMPERATURE APPLICATIONS



Culminating five years of intensive research, engineers of The United States Graphite Company have developed a new oxidation resistant GRAPHITAR. In exhaustive tests, GRAPHITAR parts were exposed in an oxidizing atmosphere (air) at 1200 degrees F and after 200 hours, the GRAPHITAR showed a weight loss of less than six percent!

GRAPHITAR, which is available in many grades, is a versatile engineering material with unusual and outstanding properties that make it ideal for tough applications. It is non-metallic, resists chemical attack, has self-lubricating properties and a low coefficient of friction. It is mechanically strong, lighter than magnesium and is the perfect material for packing rings, pressure joint seals, clutch release bearings, fluid coupling seals, piston rings, pump liners and vanes.

For more information on this new oxidation resistant GRAPHITAR and its applications, write the GRAPHITAR product manager on your company letterhead.

R-279-1

THE UNITED STATES GRAPHITE COMPANY

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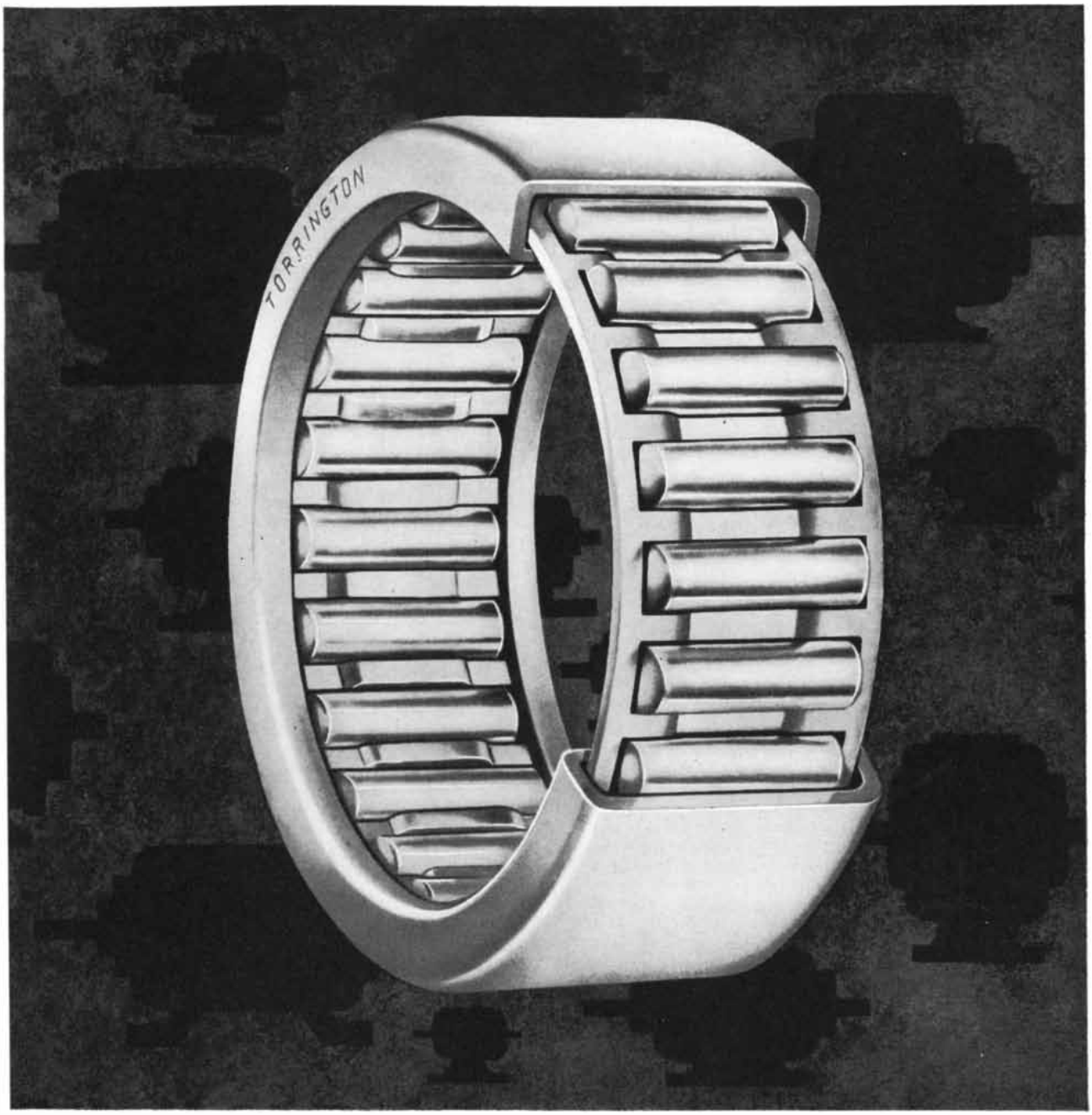


ADVANCED DESIGN CONCEPTS . . . WITH BEARINGS FOR MOTORS

A major advance in electrical motor design has been made possible with the introduction of Torrington Drawn Cup Roller Bearings.

The advantages of drawn cup outer race construction are now available in a compact, low-cost, precision roller bearing. Design restrictions imposed by the need for in-service lubrication are eliminated. These bearings can be pregreased *for life*. They insure highly efficient anti-friction performance, yet are compact and exceptionally light in weight. They offer extreme design simplicity in housing and installation. Their cost is low. In many cases, armature bearing costs have been reduced by as much as 50%.

Torrington Drawn Cup Roller Bearings have a field of application ranging from advanced servo-motors to domestic appliances. Their development is one more example of Torrington's continuing effort to improve bearings in design, material and performance.

THE TORRINGTON COMPANY

Torrington, Conn. • South Bend 21, Ind.

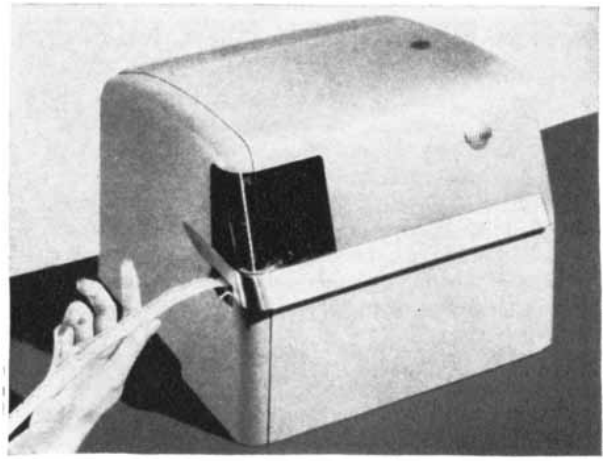
RESEARCH FOR PROGRESS IN BEARING DESIGN AND PERFORMANCE

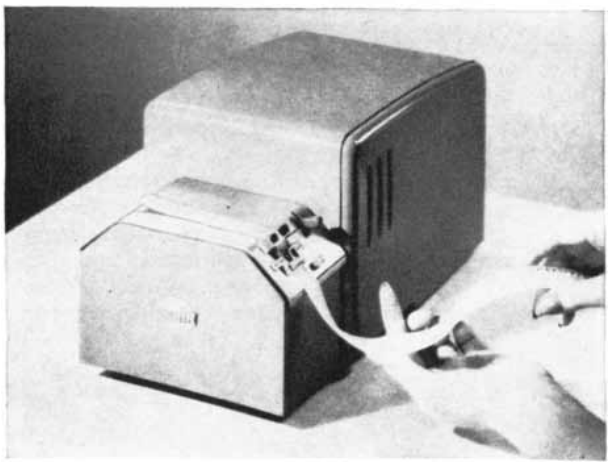
Teletype Model 28 Automatic Send-Receive Set A "complete station" in one console—with facilities for sending and receiving on message paper or sprocket-fed business forms . . . tape punching . . . sending or receiving with tape . . . integrating tape and manual keyboarding . . . producing tape automatically, as a by-product of send-receive operations.

Teletype Model 28 Receive-Only Page Printer A message receiving unit (without keyboard). This is "terminal" equipment, for use where two-way communication is not necessary. No attendant is needed. Produces a printed record on plain paper or multipart business forms. Table models of this unit and the send-receive set at the right are also available.

Teletype Model 28 Tape Punch Receives incoming electrical signals, punches a 5-level "common language" tape, and prints data right on the tape, for easy identification and handling. Unit is used for message relaying . . . for integrating data from several sources into a single tape . . . for providing punched tape as a by-product of send-receive operations.

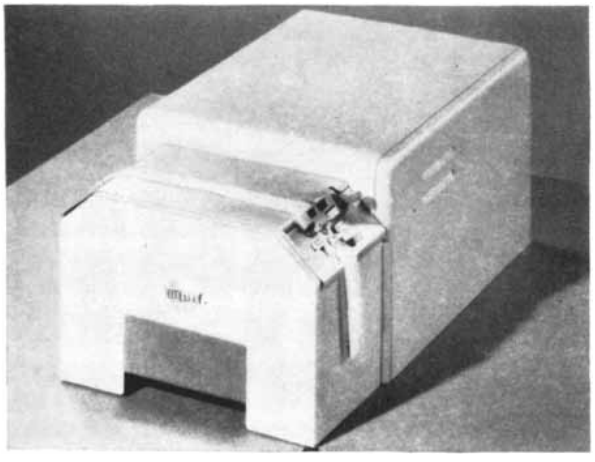
Teletype Model 28 Tape Reader This is a sending unit. Reads punched tape and instantaneously transmits data to local or remote receiving equipment. As with all Teletype transmitting units, data may go to one destination or a number of destinations simultaneously—either nearby or thousands of miles away.





Teletype Model 28 Send-Receive Page Printer Message originating unit, for sending and receiving. Model 28 page units, including the Automatic Send-Receive Set, feature a built-in "stunt box" control system for automatic station selection and electrical control of remote equipment. Horizontal tabulation and form positioning arrangement available.

Teletype Model 28 Tape Reader—Twin Shaft Besides reading punched tape for on-line transmission, twin-shaft reader-distributor design offers facilities for simultaneous output on a multi-wire basis and direct translation (without tape) of signals from an external parallel-wire source for on-line transmission.



For your communications system . . .

TELETYPE Model 28 Line

Presented here are the principal units of the Teletype Model 28 line. "Model 28" stands for an entirely new concept in record communications. It is an integrated line, designed on the modular principle, permitting a wide choice and ready interchange of components and providing accommodations for expansion. Typebox printing on page units makes possible quick interchange of alpha-numeric characters. Speed is 600 characters per minute with printing, up to 1,200 characters per minute on tape units where printing is not required.

These new machines are manufactured to Teletype's precision standards for continuous day-in and day-out service. All-steel clutches and simple harmonic-design elements greatly reduce and simplify maintenance requirements.

Exclusive with the Model 28 printer line is the versatile stunt box, which is actually a "robot brain." It responds to keyboard or line signals, and may be used for internal control of extra functions in the Teletype printer, as well as for external controls.

More information. If you would like more information on Model 28 equipment, please write to Teletype Corporation, Dept. 18C, 4100 Fullerton Ave., Chicago 39, Illinois.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MARCH, 1910: "A recent test of wireless telephony was made to show its value for transmitting music. Several selections were sung into a transmitter at Park Avenue and Fortieth Street, New York, and were listened to by a group of newspaper men at the Metropolitan Tower. At times the singing was very clear, but frequently it was impossible to hear anything but a confused blur of sound."

"Guglielmo Marconi writes: 'With regard to the utility of wireless telegraphy, there is no doubt that its use has become a necessity for the safety of shipping, all the principal liners and warships being already equipped, its extension to less important ships being only a matter of time, in view of the assistance it has provided in cases of danger. Its application is also increasing as a means of communicating between outlying islands, and also for the ordinary purposes of telegraphic communication between villages and towns, especially in the colonies and in newly developed countries. However great may be the importance of wireless telegraphy to ships and shipping, I believe it is destined to a position of equal importance in furnishing efficient and economical communication between distant parts of the world, and in connecting European countries with their colonies and with America.'"

"Prof. E. E. Barnard of Yerkes Observatory informs us that on February 27th last he obtained with a one-hour exposure a photograph of Halley's comet, showing a faint tail of two degrees, equivalent to a length of about 14,000,000 miles. This is rather important in relation to the question as to whether the tail will reach the earth on May 18th. From these photographs, taken so far from perihelion, it seems that the tail will be amply long to reach the earth."

"The Royal Geographical Society of Italy, at a largely attended meeting, ratified the recommendations of the committee relative to the bestowal of medals and other distinctions for the year 1909. These include a gold medal to Robert E. Peary, for the discovery of the North Pole; silver medal to Captain Robert A. Bartlett, who commanded the steamship *Roosevelt* on the Peary expedition; gold medal to Lieutenant Sir Ernest H. Shackleton, for his 'nearest South Pole'; silver tablet to the Duke of the Abruzzi, for his expedition to the Himalayas, where he made a record ascent."

"Every day some four or five million persons attend the 13,000 moving-picture shows of the United States. The pictures which flicker on the screen before the spectators are projected by means of apparatus the basic patents of which were taken out by Thomas A. Edison. These four or five million persons, therefore, unwittingly pay royalty to Mr. Edison whenever they hand in their nickels or dimes at the box office. It is stated that about 1,440,000 feet of film are made by the members of the Motion Pictures Patents Company. On this production a royalty of half a cent per foot is paid to Mr. Edison, so that his revenue from the moving-picture-loving public amounts to $7,200 per week."

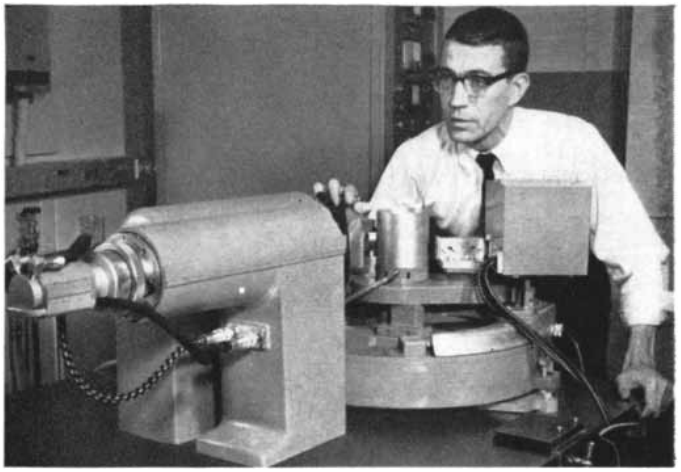
Scientific American.

MARCH, 1860: "The continued yield of the Pennsylvania oil springs is creating much excitement in their vicinity and elsewhere, being calculated, as they are, to render that region of our country one of the richest in the Union. One gentleman commenced boring, and at the depth of 58 feet struck a vein, which is yielding him 12 barrels of oil per day. Others, from a greater depth, are securing 30 barrels. It now becomes a question as to what the effect of these discoveries will be upon the whale fishery."

"The Homestead Bill passed the House of Representatives in Washington, on the 12th inst. by a vote of 114 to 66. It provides that every person who is the head of a family and 21 years of age may enter one quarter section (160 acres) of land, subject to pre-emption, and at the expiration of five years, if then a citizen, shall be entitled to a patent for it on payment of $10. We hope this bill will also pass the Senate at an early date. We have no doubt but much good will ultimately result from it to

HE X-RAYS WOOD...

to help make telephone poles last longer



Chemist Jack Wright developed the use of this X-ray fluorescence machine for testing the concentration of preservatives in wood. Here he bombards a boring from a test telephone pole with X-rays.

This Bell Labs chemist is using a fast, new technique for measuring the concentration of fungus-killing preservative in telephone poles.

A boring from a test pole is bombarded with X-rays. The preservative—pentachlorophenol—converts some of the incoming X-rays to new ones of different and characteristic wave length. These new rays are isolated and sent into a radiation counter which registers their intensity. The intensity in turn reveals the concentration of preservative.

Bell Laboratories chemists must test thousands of wood specimens annually in their research to make telephone poles last longer. Seeking a faster test, they explored the possibility of X-ray fluorescence—a technique developed originally for metallurgy. For the first time, this technique was applied to wood. Result: A wood specimen check in just two minutes—at least 15 times faster than before possible with the conventional microchemical analysis.

Bell Labs scientists must remain alert to *all* ways of improving telephone service. They must create radically new technology or improve what already exists. Here, they devised a way to speed research in one of telephony's oldest and most important arts—that of wood preservation.

Nature still grows the best telephone poles. There are over 21 million wooden poles in the Bell System. They require no painting, scraping or cleaning; can be nailed, drilled, cut, sawed and climbed like no other material. Scientific wood preservation cuts telephone costs, conserves valuable timber acres.

BELL TELEPHONE LABORATORIES

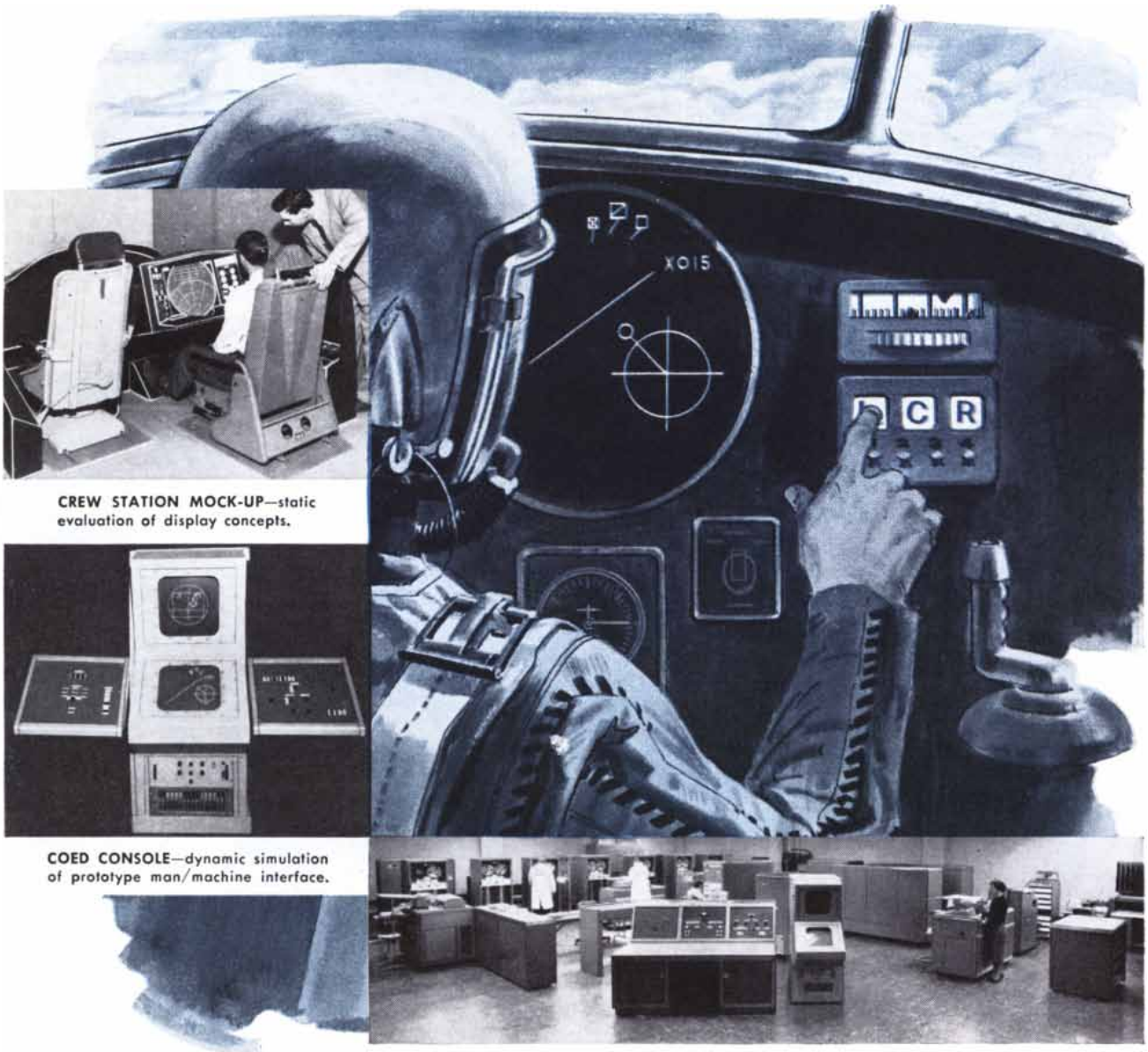
World Center of Communications Research and Development

many workmen in our cities. The success of this measure is due to the 'Land Reformers'—an organization of mechanics which was formed in New York City about 15 years ago, and which has ever since continued to labor for this object with much zeal."

"The large submarine cables which have been laid down in Europe, as well as a new one connecting Australia with Tasmania, are said to be operating badly. The Channel Islands cable, the one in the Mediterranean between Malta and Cagliari and the one between England and the Isle of Man, are all failures to a certain extent. Some have attributed this to defective insulation in the first place; while others affirm that it is all owing to the rocky bottom on which they were laid, and the undercurrents to which they have been subjected. It is asserted that every submarine cable laid down in a muddy bottom has been successful, while those laid in shallow sea and on hard, rocky bottoms, without being made enormously thick to prevent abrasion, have all failed. In all likelihood the truth lies between the two opinions."

"They do things up in grand style in London. The tunnel under the river Thames, and the *Great Eastern*, are world's wonders, and nowhere out of London could such projects be carried out at the present day. But something more magnificent still than the Thames tunnel is about to be achieved in London, and the work has already commenced; this is the tunneling of the city itself for a grand 'trunk' underground railway, intersected by several lines, to get rid of the crowded thoroughfares."

"The workers in stone and marble in our cities are subject to lung diseases by inhaling dust. Their average age is 38 years, and they are very frequently sick. We have known several who had to quit the business in New York on account of threatened consumption, who were otherwise of powerful frames and naturally robust. Those who grind the knives and forks with which we eat our food are very short-lived. The dust which is inhaled by the lungs soon coats them with stone. Wet grinding, such as that of saws, axes, knives, is not so unhealthy, but the dry polishing of every tool greatly shortens the lives of those engaged at the business. An exhaust fan to draw off the dry dust should be applied to every emery wheel in factories under a penalty, and all those engaged in these operations should never permit a razor to be drawn across the upper lip."



CREW STATION MOCK-UP—static evaluation of display concepts.

COED CONSOLE—dynamic simulation of prototype man/machine interface.

COED/IBM 704 FACILITY—speed and flexibility for real-time simulation of man/machine systems.

COED . . . computer operated electronic display

The airborne data processing system for the EAGLE missile concept uses advanced digital data handling complemented by the intelligence of the human operator. Coordinated transfer of data between man and machine is implemented with human-factored electronic display and control devices.

Balanced man and computer functions are assured in the development of the EAGLE electronic system through analysis and experimentation with realistic operational missions using the COED (Computer Operated Electronic Display) simulator. This simulation involves real-time programs for a large-scale digital computer which are integrated with cathode-ray-tube alpha-numeric displays and operator controls.

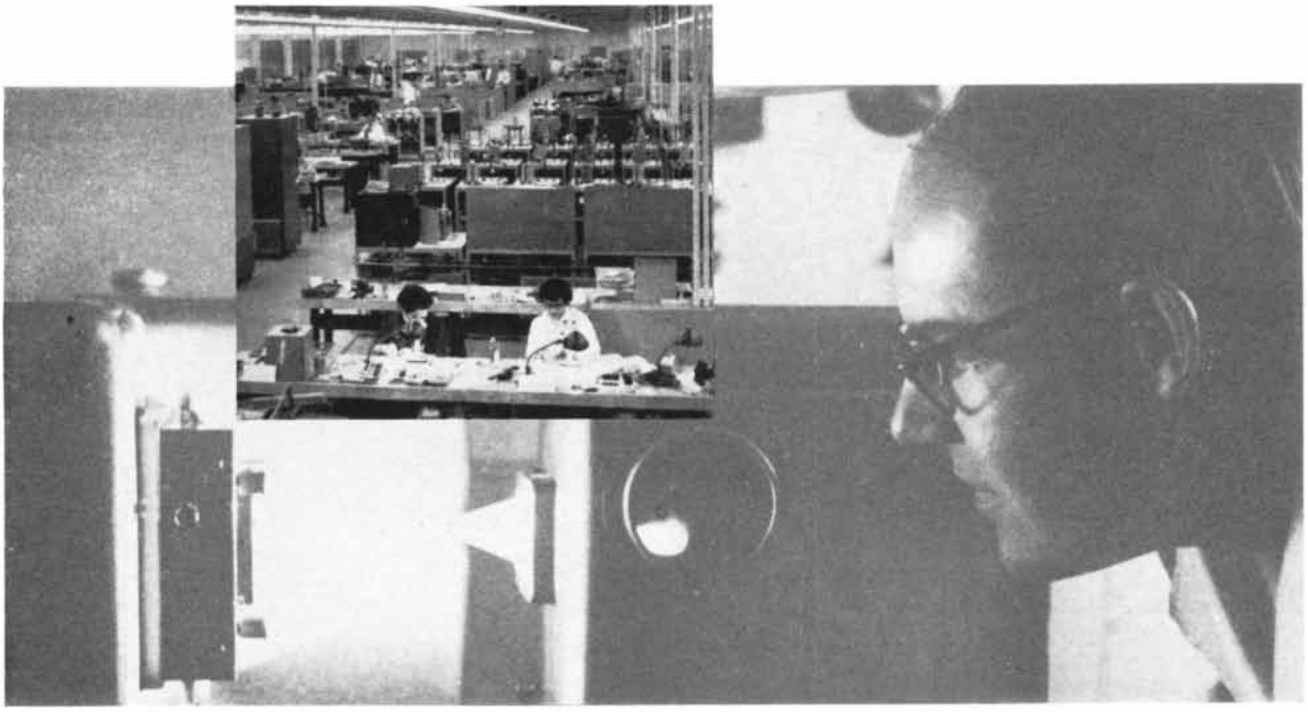
The COED system has been developed to provide a special facility for versatile and realistic simulations of the man-machine interface. It is a stepping stone in the Bendix program of *Intellectronics* where the ultimate goal is the machine synthesis of man's unique perceptual and intellectual faculties.

Opportunities are available to better engineers and scientists who would like to participate in this and other systems programs of the highest technical integrity.

Bendix Systems Division
ANN ARBOR, MICHIGAN

Bendix AVIATION CORPORATION

THE SCIENCE OF PRACTICALITY



The ability to move a highly complex prototype product from the research laboratory into economical **quantity production** is an important reason for the rapid growth of Varian Associates—major producer of microwave tubes, instruments, electronic components and scientific equipment.

And with the recent acquisition of Bomac Laboratories by Varian Associates, depth and versatility have been added to the volume production capacity of microwave tubes and other Varian products.

Advance production techniques are the "science of practicality" at Varian, and in large measure account for the extraordinary performance standards of Varian products... the frequency stability of Varian Klystrons, high resolution of the NMR Spectrometers, the high order of vacuum achieved by the Vaclon® pumps and the field homogeneity of Varian laboratory magnets. The maintenance of highest standards while at the same time achieving volume production, is an example of Varian creativity at work for science, industry and the military establishment.

VARIAN associates

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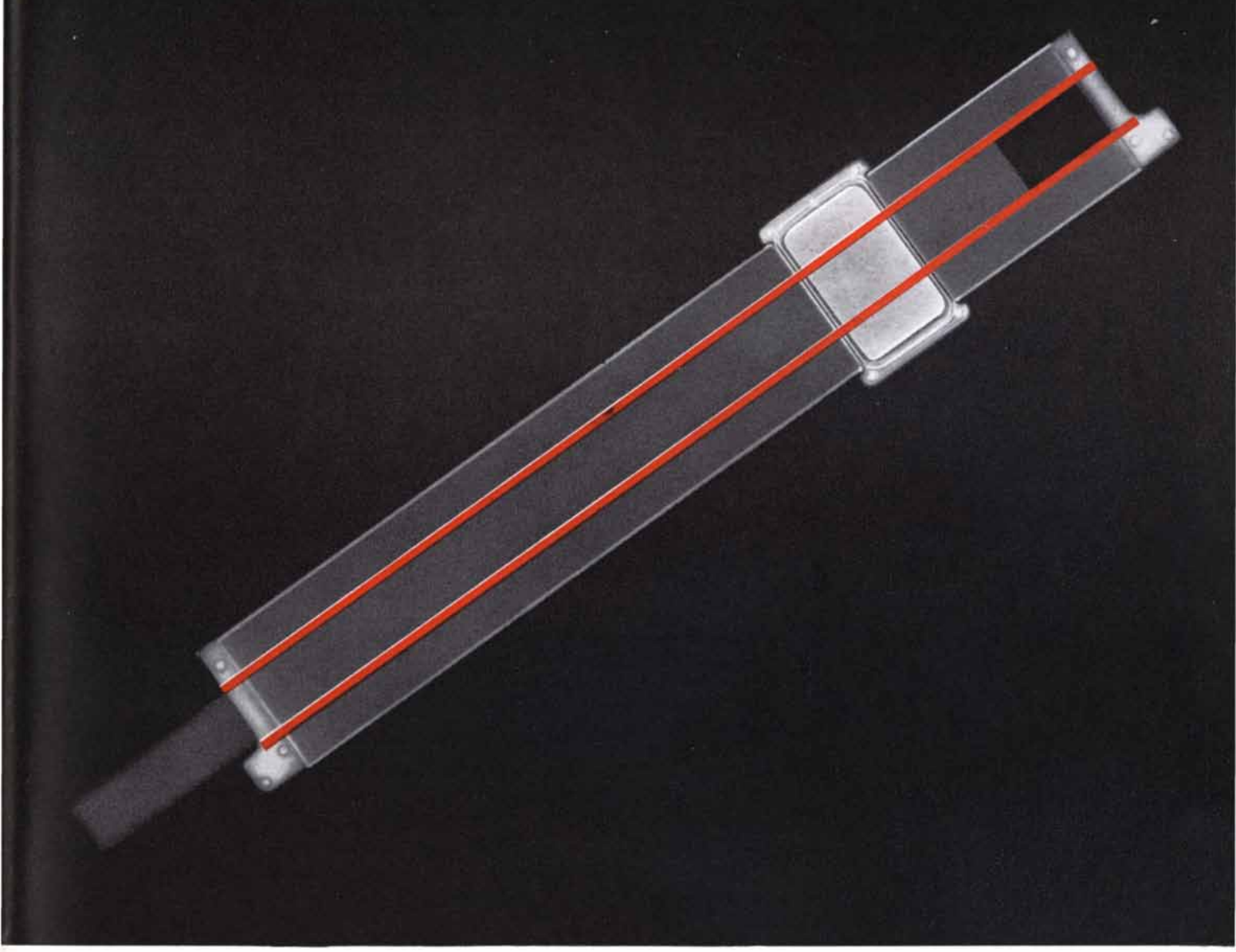
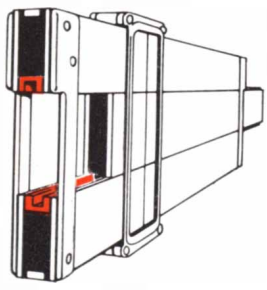


Microglide* slide-rule by Eugene Dietzgen Co., Chicago, Ill.

THE INSIDE STORY: taking the stick-slip out of slip-sticks



The sliding scale of this slide rule runs in grooves of a TEFLON TFE-fluorocarbon resin. Smooth operation is assured by the very low static and dynamic coefficients of friction of the TFE resin, which eliminate any stick-slip type of motion.

Remarkable frictional properties are only one of the many design advantages offered by TFE resins. These tough materials have almost universal chemical inertness, resist heat and exhibit excellent dielectric strength . . . in short, they offer a combination of properties unmatched by any other single material.

If you would like to find out more about how TFE-fluorocarbon resins make possible improved design, send for your copy of a booklet describing in detail the unique mechanical properties of these resins. Write to: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept. T-393, Room 2526, Du Pont Building, Wilmington 98, Delaware.

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

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

METALGRAMS

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MARCH - APRIL, 1960

Sub-micron Tungsten Powder -- Ultra-fine tungsten powder with particle size in the 0.015 to 0.030 micron range is a recent product of UCM research. Uses are proposed in powder metallurgy, dispersion hardening, and catalysis. This highly flowable powder has closely dimensioned, spherical particles; measured surface area is in the range of 10 to 20 sq. m. per gm. UCM's field representatives are available to discuss new applications. For properties request WP1-S6.

* * *

Columbium Alloy Readily Fabricated -- A new medium-strength columbium-base alloy -- CB-65 -- which has an ultimate tensile strength of 37,000 psi at 1800°F. was announced by UCM. This alloy, containing titanium and zirconium, can be cold rolled extensively and also retains a high degree of notch-toughness at sub-zero temperatures. These properties indicate that the alloy is ductile and should exhibit good formability. The material is now available on a development scale. Properties of CB-65 are given in data sheet CBA1-S6, free on request.

* * *

40,000 psi at 2200 F -- Tensile strengths in excess of 40,000 psi at 2200°F are indicated by preliminary data on CB-7, a member of UCM's family of columbium-base alloys. Recent tests also indicate that CB-7 has a high degree of oxidation resistance when compared to other columbium alloys presently known. The alloy has been developed for applications in the 2000°F plus range for both sheet and forgings. The Company anticipates that limited quantities of the CB-7 alloy will be available for test purposes. For properties data request CBA2-S6.

* * *

Higher Yield Indicated With Activated Catalyst -- High yield, high isotactic crystallinity, and a clear polymer are indicated by laboratory test of UCM's activated titanium trichloride. Delving into the problem of activation, the Company's researchers are designing this modified form of titanium trichloride -- designated $TiCl_3$-1A -- especially for polypropylene catalysis. The unactivated product, $TiCl_3$-1, is also being evaluated in catalysis as well as in several other uses -- organometallic synthesis, reducing agent for organic nitro compounds, and special pigment. Data on titanium trichlorides are available in Bulletin TT2-S6.

* * *

Vanadium Mill Products Growing -- One of the largest vanadium shape orders to date -- 300 lbs. of bar, sheet, and plate -- was delivered by UCM in February. The material, earmarked for Government use, represents another important stride toward commercial availability of vanadium mill products. UCM has made bar and wire in sizes down to 0.005 in. diam. and plate and sheet down to 0.005 in. thick in widths up to 18 in. Bulletin VM1-S6 gives general information on vanadium.

* * *

Hard, Oxidation-Resistant Coatings -- UCM's chromium carbide, titanium carbide, tungsten carbide, and chromium boride are being used or evaluated in coating applications. Applied by metallizing or flame spraying methods, pure or combined with metal binders, these compounds provide coatings which have high hardness and oxidation resistance. UCM sales representatives are exploring coating requirements with potential users. Data packet IM1-S6 gives properties of materials.

* * *

Union Carbide Metals Company, Division of Union Carbide Corporation, 30-20 Thomson Avenue, Long Island City 1, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

Stafoam CONTROLS TEMPERATURES

Above: New successful environmental fuel and missile component test chamber constructed with *poured in place* Stafoam.

From temperature controls to cryogenics, the Freedlander R & D Laboratories can provide new dimensions in material technology.

Hot or cold—inside or out!

STAFOAM, the miracle urethane insulator, has achieved its place in space, protecting men and intricate machinery against the fury of unearthly temperature ranges. Reentry capsules, like the one pictured above, are being insulated with *poured-in-place* rigid STAFOAM. Arctic shelters, missile *defrosting* mantles, refrigerator trucks, environmental fuel chambers, and airline food containers are only a few of the hundreds of new STAFOAM structural insulating applications.

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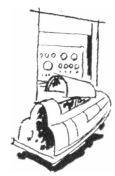
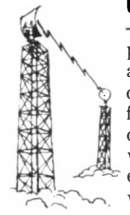
MELPAR APPLIES ELECTRONIC CREATIVITY TO SEVEN PRINCIPAL AREAS OF ACTIVITY

DETECTION & IDENTIFICATION—Melpar has exceptionally broad experience in data analysis. Melpar designs and develops special equipments and systems for early detection and identification. A large engineering capability has been assembled in these areas. New detection-identification methods and techniques are constantly being developed.

ANTENNAS AND RADIATION—Equipped with the best research and development facilities, Melpar is able to reduce customers' requirements to physical equipments. Melpar, supporting its leadership in advanced concepts, has established 19 antenna test ranges for proof of performance. Also, Melpar provides a unique quick reaction facility through its "follow on" production. The Company's experience in new ordnance and electronic countermeasures systems is currently being applied to the nation's newer missile and satellite programs.



FLIGHT SIMULATION & TRAINING—Concurrent design and development of simulation and training equipment that matches the exacting demands of new aircraft schedules gives Melpar proved ability to design and develop complete mission-type simulators for fixed and rotary-wing aircraft, radar and fire control, and missiles. Melpar excels in the ability to derive and reproduce system analogs rapidly while accurately preserving all of the original equipment's tolerances.



COMMUNICATION & NAVIGATION—Leading in the application of novel printed circuit techniques to achieve a new order of miniaturization and compact design, Melpar is responsible for many innovations and new concepts in data transmission links, microwave receivers, communication terminal equipment, secure communications devices, and remote control systems. Melpar maintains extensive field operations, including a facility at Tucson, Arizona, where avionic equipment and systems are studied, installed, and tested for the Army's Electronic Proving Ground (Fort Huachuca).

PHYSICAL SCIENCES—Recognizing the need for a partnership between electronics and physical sciences, Melpar has established a materials research laboratory within its electronics complex. Research on the structure and application of new materials to support electronics is advancing at Melpar. Experienced research staffs are now evolving practicable, workable designs in such areas as high temperature effects on materials and molecular electronics.

...proved ability, experience assure electronic achievement

MELPAR'S ENGINEERING DIVISION makes a continuing creative contribution to electronic development. And a number of significant electronic achievements have resulted from Melpar's imaginative approach to project and system engineering.

Electronic achievement at Melpar resulted in the conception, design, and production of one of the largest airborne electronic systems ever developed—the first integrated electromagnetic reconnaissance system . . . and two of the largest ground electronic systems—a ground based reconnaissance data handling system, and the F-101B weapon system simulator.

MELPAR EQUIPMENTS form an integral part of many advanced weapons systems, and equipment developed at Melpar will comprise a part of the first manned-satellite launched into orbital flight.

DATA HANDLING—Melpar designs, develops, and produces fully automatic data handling systems with both tremendous data gathering capacity and the ability to process results in a relatively short time. New approach philosophies have been applied to the development of special purpose computers, tactical displays for weapons systems, and systems for both data reduction and data processing. Melpar has full data handling resources, with a broad range of customer services—from problem analysis to complete system design.

RECONNAISSANCE—Early design and development experience with reconnaissance systems led Melpar to recognition of the possibilities inherent in new reconnaissance techniques. Now, Melpar leads the industry in the development, design, and production of reconnaissance systems that incorporate new and sophisticated techniques. One example of Melpar's leadership in this area is the conception, design, and production of one of the largest airborne electronic systems ever developed.

For details on provocative job openings in advanced scientific, engineering areas, write to: **Department I-8, Professional Employment Supervisor, 3607 Arlington Blvd., Falls Church, Virginia,** in historic Fairfax County, 10 miles from Washington, D. C.

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AiResearch is now in production on two greatly simplified hot gas steering control systems: a reaction control system for outer space flight stabilization and a hot gas actuator control system for terrestrial steering (in the atmosphere and under water).

Both systems eliminate any need for pumps, heat exchangers, accumulators and other apparatus required in earlier control systems. And both systems utilize hot gas, operating off either the main engine or a separate fuel source.

The gas in the outer space reaction control system is fed into a set of nozzles which imparts spin to the missile to stabilize its flight through space.

In the terrestrial hot gas actuator control system the gas is fed into an on-off controlled linear actuator which moves the fins controlling the missile's attitude in the atmosphere or under water. This system also utilizes a concept developed from the AiResearch hydraulic "printed circuit." This approach eliminates complicated plumbing, thereby decreasing the weight and increasing the reliability of the system.

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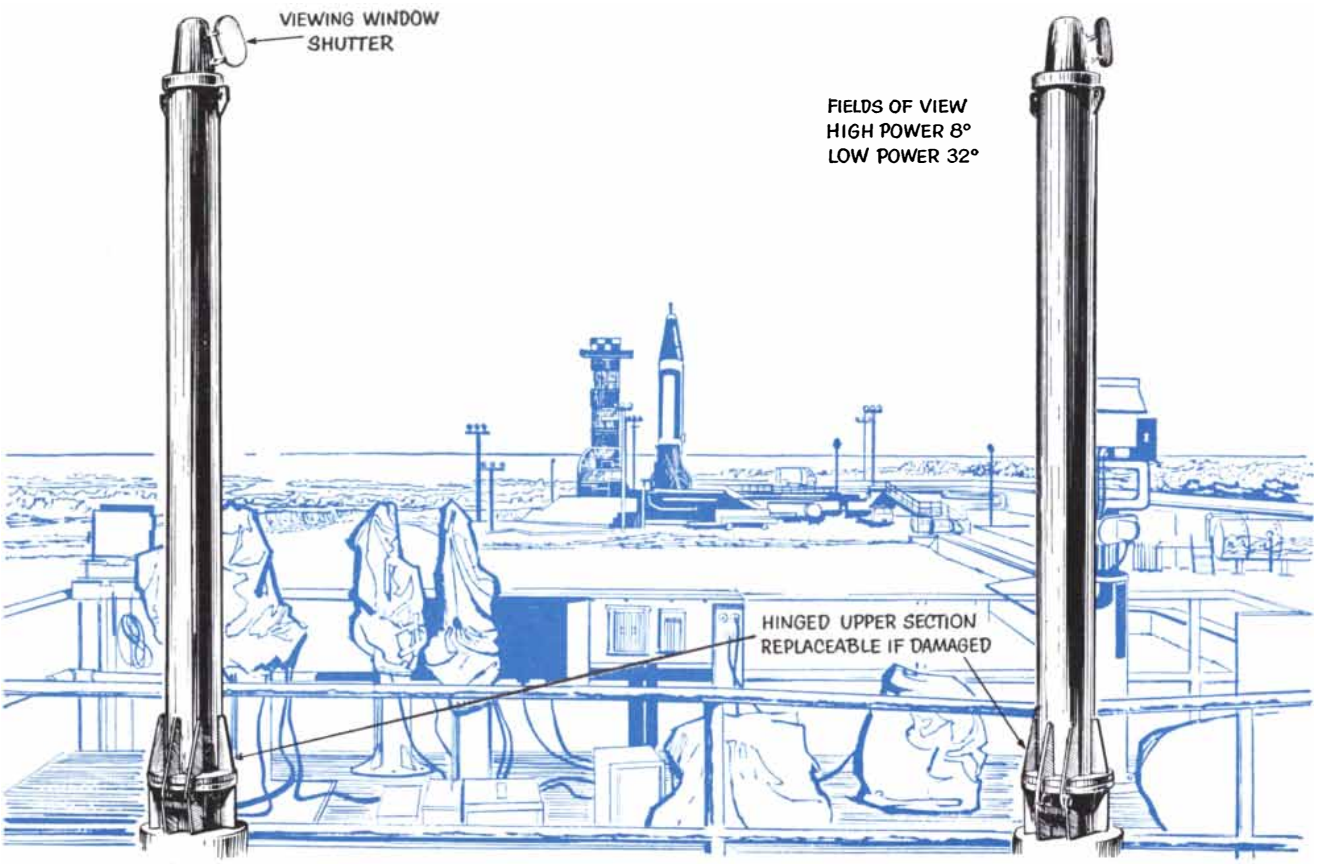

Cape Canaveral count-downs get Kollmorgen close-ups

What happens on the pads at Cape Canaveral is subject to the continuous close scrutiny of experts thanks to Kollmorgen bunkerscopes. During launching operations and static tests the trained observer sees exact detail in his choice of two magnifications and in true color, with complete safety even in cases of power failure.

Bunkerscopes by Kollmorgen require virtually no maintenance and are built to withstand blast forces such as may be expected around missile launching sites. They are easy to operate, even by untrained personnel, and can quickly be adapted to photography and television use.

These instruments are typical of Kollmorgen experience with remote viewing and inspection equipment, wall periscopes, underwater periscopes, micro-photo periscopes, continuous strip fuel-inspection cameras and other optical systems employing mechanical and electronic skills. In this field Kollmorgen is foremost, having served both industry and defense for nearly half a century.

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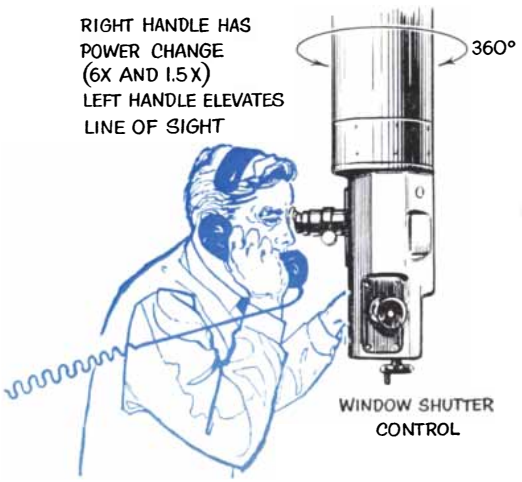

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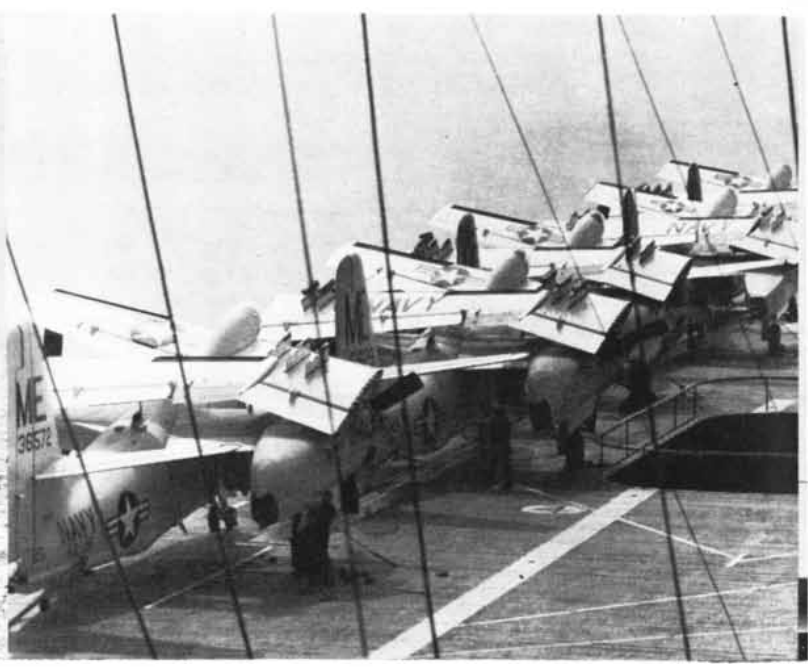
The story of Alfa and the Skunks—

An enemy might be able to hit any point in the United States with a missile fired from a submarine. To protect us, the Navy must patrol millions of square miles of open sea. Task Group ALFA trains for the task. Ships and planes probe the bottom of the seas in an eerie game of cat and mouse with sonar sets so delicate they must tell a school of snapping shrimp from a pack of enemy "skunks," as unknown submarines are called. Our anti-submariners depend on steel—carbon steel, high-strength low-alloy steel, ultra high-strength alloy steels, Stainless Steel,

With deadly patience, a helicopter hovers above a suspected submarine and lowers a sonobuoy into the water. Little larger than a football, the sonobuoy transmits any sound impulses from sub back to the helicopter, which can drop depth charges. The cable is specially designed multi-control electrical cable of steel and copper strands manufactured by the American Steel & Wire Division of U. S. Steel. It is the main artery of $1,000,000 worth of detection gear in the helicopter.



These S2F "Guardians" are ideal for long-range, all-weather operations. Engine pods hold sonobuoys; on the wings are seven-million-candlepower JULIE searchlights. It takes 78,000 tons of steel, counting the carrier and her supporting destroyers, to keep the task group's aircraft operating.

electrical cable, or wire rope. And United States Steel maintains the technical service to guide users in the proper use of these many steels and provide even better steels for the future. Before a program is ready for the drawing board consult with UNITED STATES STEEL.

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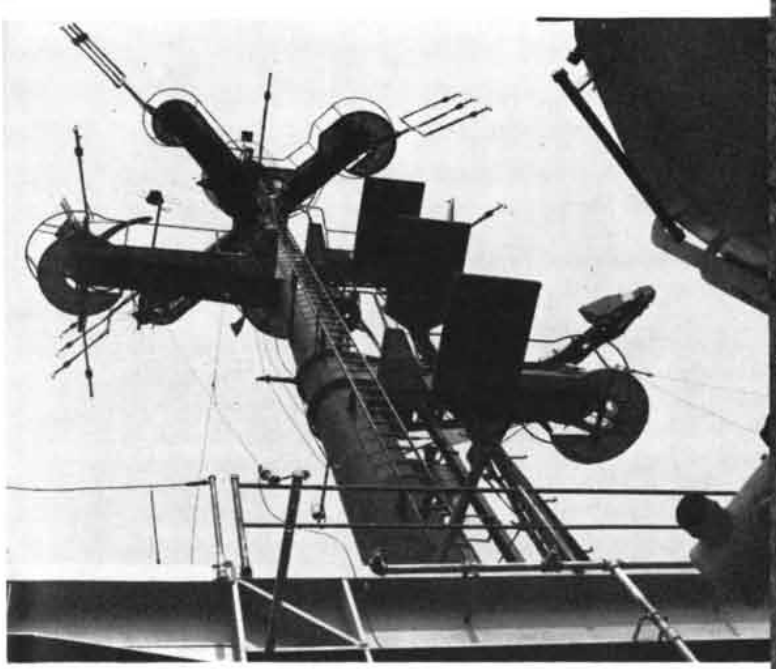


CARRIER VALLEY FORGE's steel mainmast is a maze of electronic devices, including steel radar and radio antennas that keep her in constant touch with all elements of the task group. Her radio can reach around the world. She coordinates all attacks, and has been modified to handle anti-sub helicopters, S2F "Guardian" and AD "Skyraider" hunter-killer aircraft. Although not suited to handle modern Navy jets, VALLEY FORGE's life has been extended by modification to anti-sub work.

THE AUTHORS

WALTER C. LOWDERMILK ("The Reclamation of a Man-Made Desert") is a leading conservationist who was associate chief of the Soil Conservation Service in the U. S. Department of Agriculture from 1933 until he retired in 1947. He was also chief of research for the Service from 1937 until 1947. Born in North Carolina in 1888, Lowdermilk acquired his B.A. at the University of Arizona in 1912 and then attended the University of Oxford as a Rhodes scholar. He was in forestry work for many years in this country and in China, where he was associated with the University of Nanking. In 1929 he took his Ph.D. at the University of California. Since 1943 Lowdermilk has been serving as consultant on conservation to many foreign governments as well as to presidential commissions and the Supreme Allied Command of Japan. From 1955 to 1957 he was visiting professor of agricultural engineering at Technion, the Israeli technological institute of Haifa.

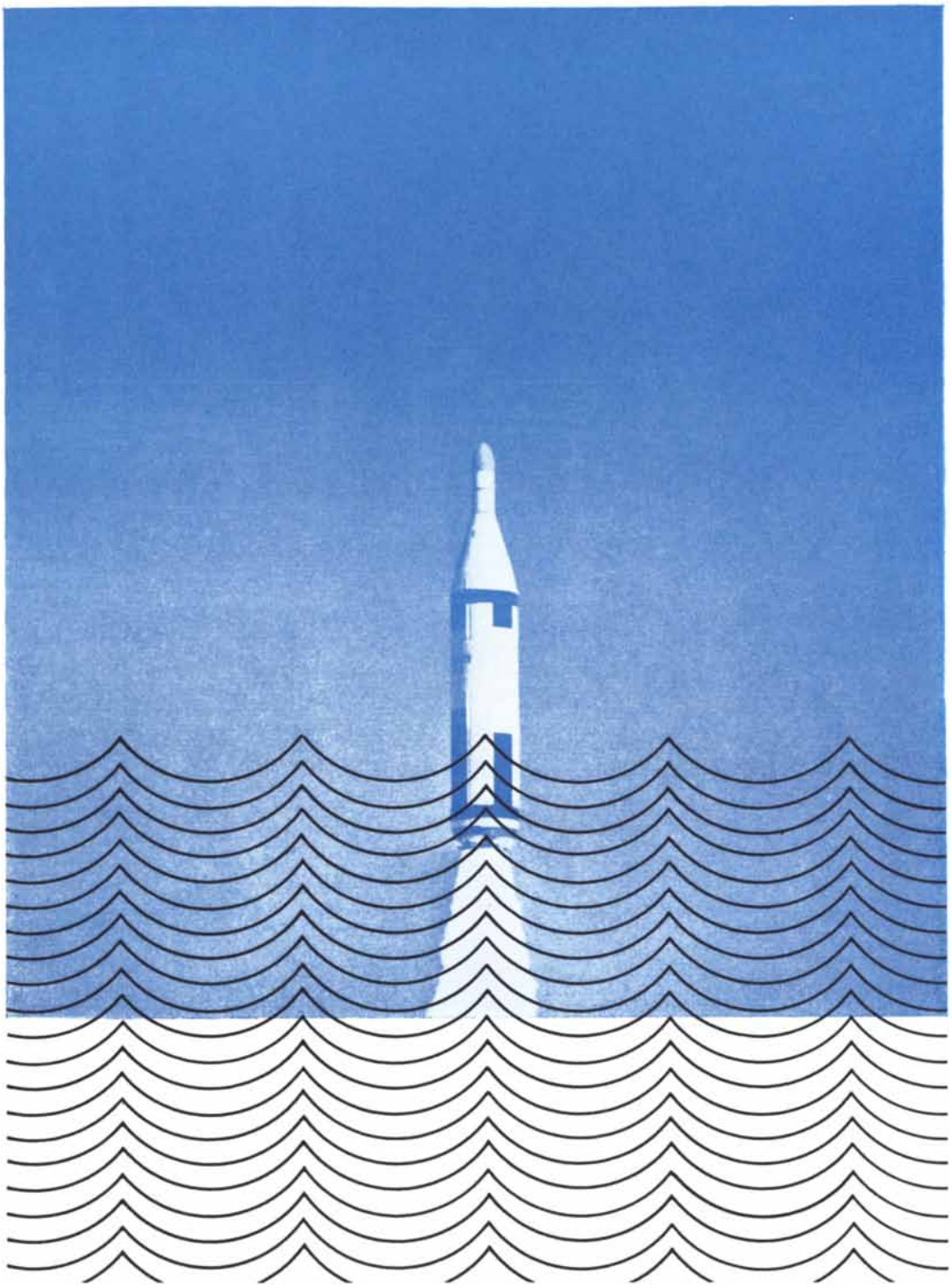
AUBREY B. MICKELWAIT, EDWIN H. TOMPKINS, JR., and ROBERT A. PARK ("Interplanetary Navigation") are two scientists and a writer-lawyer on the staff of the Space Technology Laboratories in Los Angeles. Mickelwait was born in Honolulu in 1925 and took his degrees in physics at the Carnegie Institute of Technology. A theoretical physicist, he has been especially interested in quantum-field theory and meson theory. He joined the Space Technology Laboratories in 1955 and is associate manager of the guidance and navigation department, doing theoretical and design work on trajectories, payloads and guidance systems for space vehicles such as the *Pioneer* moon flights. Tompkins was born in Charlottesville, Va., in 1928 and took his degrees in electrical engineering at the Virginia Polytechnic Institute and at North Carolina State College. From 1951 to 1957 he worked with the Rocket Research Group at North Carolina State and in 1957 and 1958 he taught mathematics and electrical engineering there. He went to Los Angeles in 1958 and is now head of the navigation section in Mickelwait's department. Park, born in Stockholm in 1923, acquired an M.A. in English in 1949 and a Doctor of Laws degree in 1955, both at the University of Chicago. He has taught English there and at the University of Illinois and Wilson Junior College. From 1955 to 1957 he was an assistant attorney general for the State of Oregon.

THEODORE A. BUCHHOLD ("Applications of Superconductivity") is a consulting electrical engineer in the General Engineering Laboratory of the General Electric Company in Schenectady, N. Y. A native of Germany, he acquired his master's and doctor's degrees in electrical engineering at the Darmstadt Technical University. After working in private industry he became a professor at Darmstadt in 1934. During World War II Buchhold developed a very accurate accelerometer for V-2 rocket guidance and pioneered in work on magnetic amplifiers which were used in the V-2. In 1946 he joined the Guided Missile Development Division at Fort Bliss, Tex., as chief of the control and guidance branch, which was later moved to the Redstone Arsenal in Huntsville, Ala. He developed the basic concept of a new inertial-guidance system for the Redstone missile. Buchhold became consultant to the vice president of engineering of the Ford Instrument Company in New York City in 1954, and a year later joined the G.E. laboratory.

ROBERT E. MARSHAK ("The Nuclear Force") is Harris Professor of Physics and chairman of the physics department at the University of Rochester. He was born in New York City in 1916 and attended Columbia University as a Pulitzer scholar. He graduated at the age of 19 and three years later took a Ph.D. in theoretical physics under Hans A. Bethe at Cornell University. Later he was associated with Victor F. Weisskopf at Rochester, and during the war he worked for the Manhattan District. He has written three other articles for SCIENTIFIC AMERICAN.

LAWSON WILKINS ("The Thyroid Gland") is professor of pediatrics at the Johns Hopkins University School of Medicine, and a leading authority on pediatric endocrinology. He was born in Baltimore and educated at Johns Hopkins University and the Johns Hopkins Medical School, taking his M.D. in 1918. The son of a general practitioner, he spent 25 years in the private practice of pediatrics, from which he retired in 1946. In 1935 he set up the Pediatric Endocrine Clinic at Johns Hopkins, and has been its chief ever since.

CURTIS A. WILLIAMS, JR. ("Immunoelectrophoresis") has since 1957



Avco "primes" America's newest peacemaker — Newest weapon in America's atomic defense is the Navy's submarine-launched missile, Polaris. The critical job of making sure the Polaris detonates on time and on target was handled by Avco's Crosley Division. Arming and fuzzing for the Polaris—like the recent development of the Air Force's Titan nose cone—is typical of Avco's role in U. S. missilery.

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been a guest investigator at the Rockefeller Institute from the National Institute of Allergy and Infectious Diseases. He was born in Moorestown, N. J., in 1927, attended Swarthmore College and took his B.S. at Pennsylvania State University. This was followed by a period as a teaching assistant at Rutgers University, where he acquired his Ph.D. in 1954. He worked briefly at the Carnegie Institution of Washington as a research fellow in biophysics, and from 1952 to 1954 held fellowships at the Pasteur Institute in Paris. In 1954 and 1955 he worked as a fellow at the Carlsberg Laboratory in Copenhagen, and in 1955 came to the Rockefeller Institute as a research associate.

LAWRENCE ZELIC FREEDMAN (" 'Truth' Drugs") is a research associate in psychiatry at the Yale University School of Medicine, but is presently on leave at the Center for Advanced Study in the Behavioral Sciences in Stanford, Calif. Born in 1919 in Gardner, Mass., he is a graduate of Tufts College, and acquired his M.D. there in 1944. After service in the Navy he became a resident in psychiatry at Yale and remained there to become an associate professor in 1957. He has also been a co-operating faculty member of the Yale Law School and chairman of the Yale Study Unit in Psychiatry and Law. He is a permanent nongovernmental delegate to the United Nations from the International Society of Criminology.

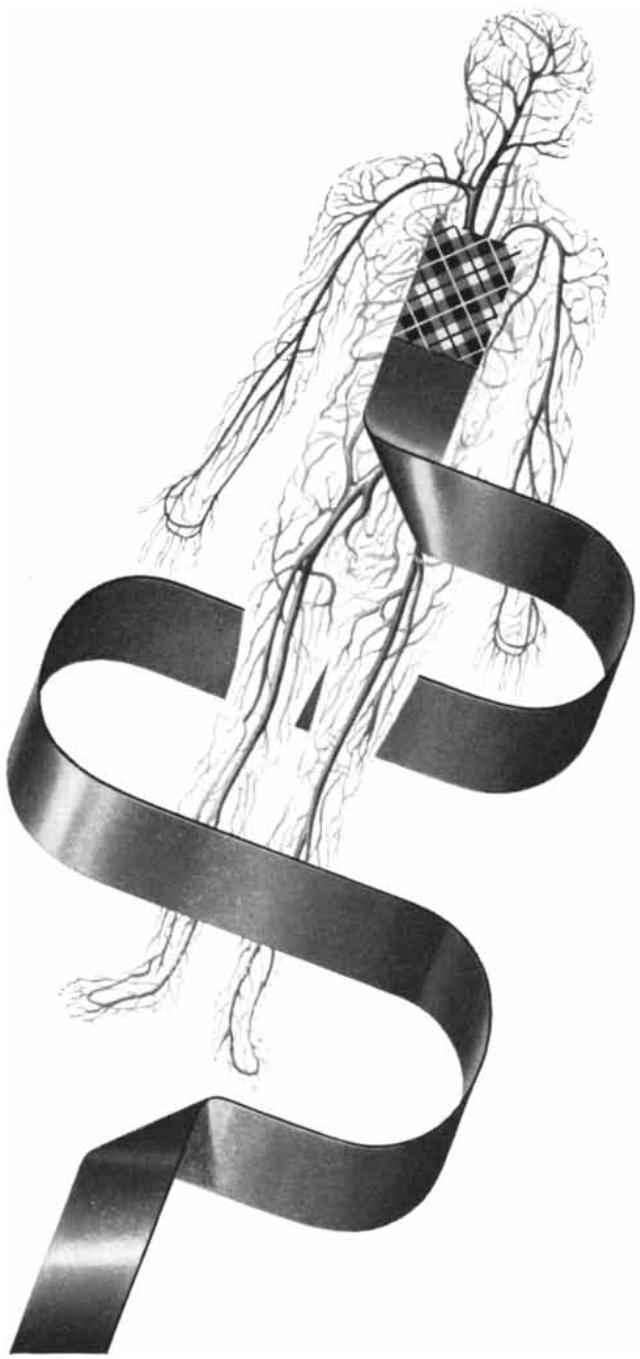
CHARLES E. LANE ("The Portuguese Man-of-War") is professor of marine biology at the University of Miami. He took his Ph.D. degree at the University of Wisconsin in 1935 and has taught at the University of Wichita and at Stanford University. After serving for four years in the Army Air Force in World War II, he worked until 1949 in the special products division of the Borden Company, studying the synthesis of various substances produced by marine organisms. During the past decade at the University of Miami Marine Laboratory he has investigated the general biology of wood-boring animals, the natural history of the local land crab, and the Portuguese man-of-war.

MORTON WHITE, who reviews Ernest Gellner's book *Words and Things* in this issue, is professor of philosophy at Harvard University, the editor of *The Age of Analysis,* and the author of *Toward Reunion in Philosophy, Religion, Politics and the Higher Learning* and other books.

The voice, the pulse, the environment of

THE ASTRONAUT

—on one vital half-inch magnetic tape



WHEN THE PROJECT MERCURY ASTRONAUT first probes the mysteries of space, 12 precious pounds of the capsule payload will be allotted to the task of collecting data. It is significant that the medium selected to take this vital record is magnetic tape.

While man himself is the most complex component in the capsule, he is yet unequal to tape in keeping a perfect record of the historic flight. Because of its peculiarly versatile character, magnetic tape can simultaneously take the astronaut's voice and compress discrete information about his reactions and the environment into one narrow half-inch—a record of perfect accuracy which can later be sifted and analyzed.

The miniaturized recorder, measuring only 11 x 13 x 3⅝″, will carry a 3 pound, 4800 ft. reel of "SCOTCH" BRAND Magnetic Tape which will record not only the astronaut's comments but six channels of multi-plexed data containing hundreds of facts received by sensitive pick-ups on his body and the capsule.

Telemetry, of which this experiment is but one example, is just one of the ways "SCOTCH" BRAND Magnetic Tape for instrumentation can serve the future. The first practical magnetic tape devised, "SCOTCH" BRAND controls industrial automation, helps the scientist explore sea, earth and space — remains the leader as new, more sensitive tapes are developed for science, business and industry. For details on tape constructions that can serve you, write Magnetic Products Division, 3M Co., 900 Bush Avenue, St. Paul 6, Minnesota.

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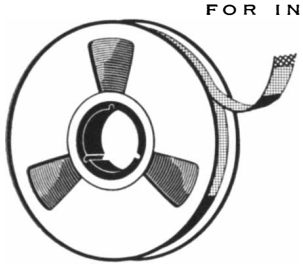

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3M COMPANY

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Who stands still, falls behind. Fairchild Semiconductor Corporation is devoting considerable effort to building the lead it has achieved in advanced silicon semiconductor devices. We are not unique in our technological abilities; we do have a head start. It is an opportunity and a challenge based in Time.

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Our facilities and working atmosphere have attracted engineers and scientists of the highest caliber. Their work, combined with creatively oriented management policies and the abilities of the entire staff, has resulted in a whole series of product innovations.

We are still moving on in transistors, and have now branched into diodes of similarly advanced technologies. Current programs include integrated solid-state circuitry and investigations of semiconductor films and III-V compounds. If yours is a relevant background, and if you would like to move ahead with us, we would very much like to hear from you.

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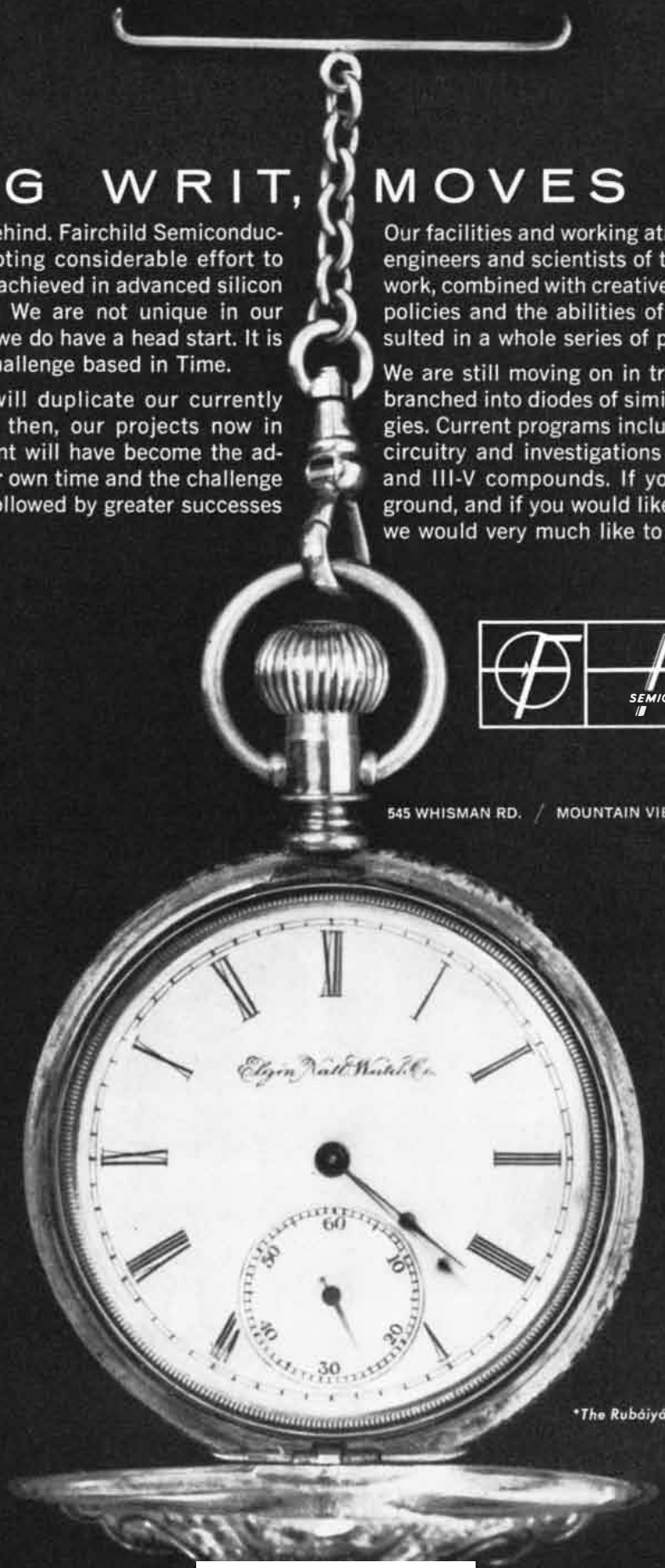
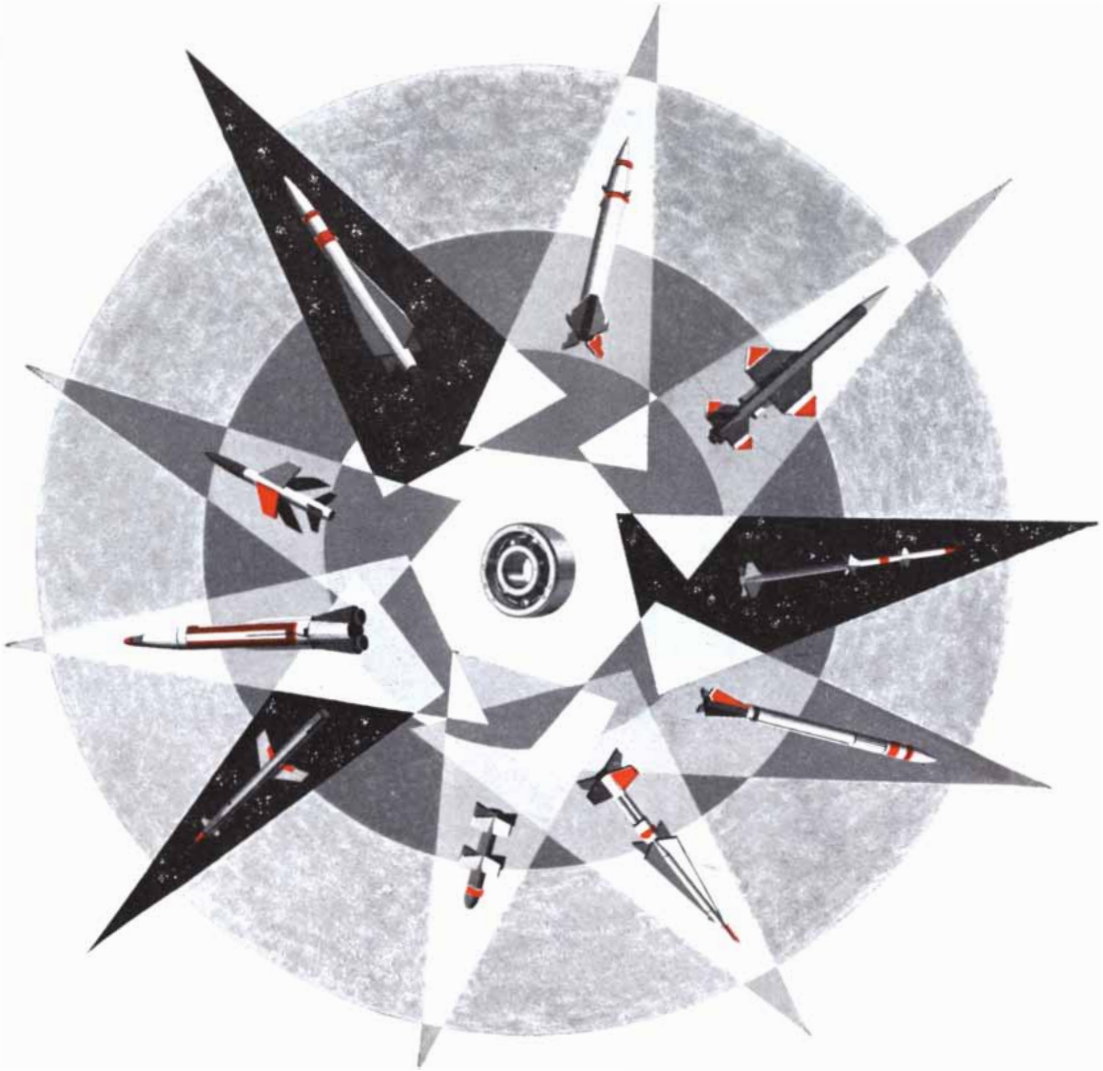


*The Rubáiyát of Omar Khayyám



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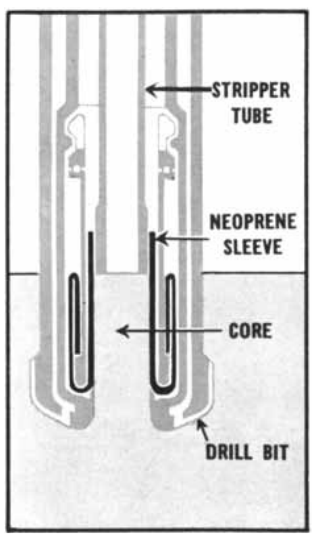

As shown here, a neoprene sleeve is folded within the core barrel, with one end attached to the stripper tube. Both the stripper tube and the bit rest on top of the formation to be cored. As the bit cuts downward, the level of the stripper tube remains fixed. The descending barrel thus draws the sleeve around the core to hold it in the exact position it occupies in the formation. The neoprene sleeve also protects the core from damage by drilling fluid, and makes an ideal package for safe delivery to the laboratory. During coring, the neoprene sleeve, 2⅜ inches in diameter, is expanded to 4 inches, then contracts to 3 inches to firmly hold the unconsolidated sand in position. Cores, like the small sample shown above, are extracted in lengths up to 20 feet.

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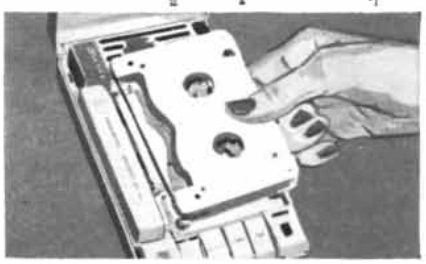

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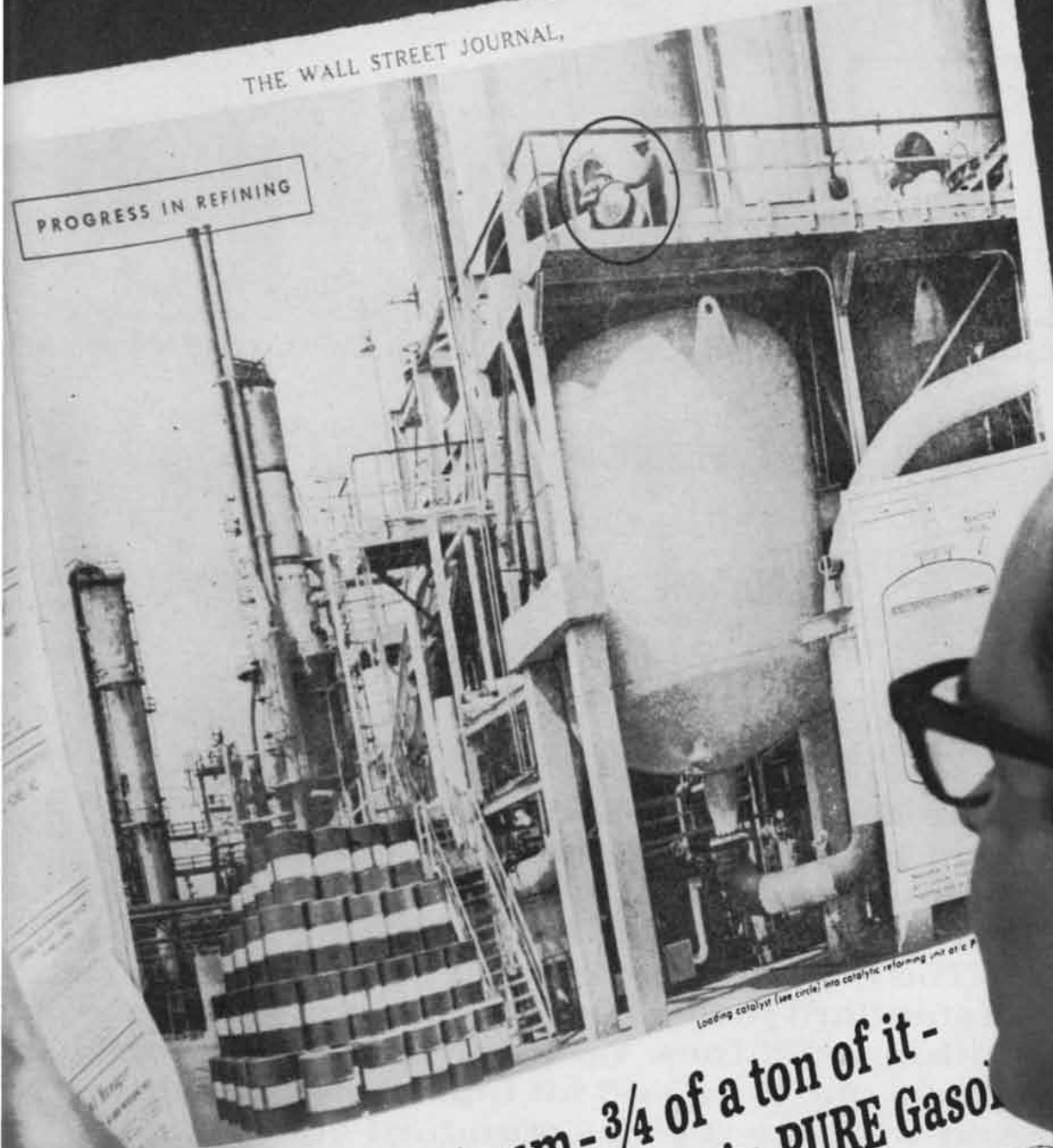

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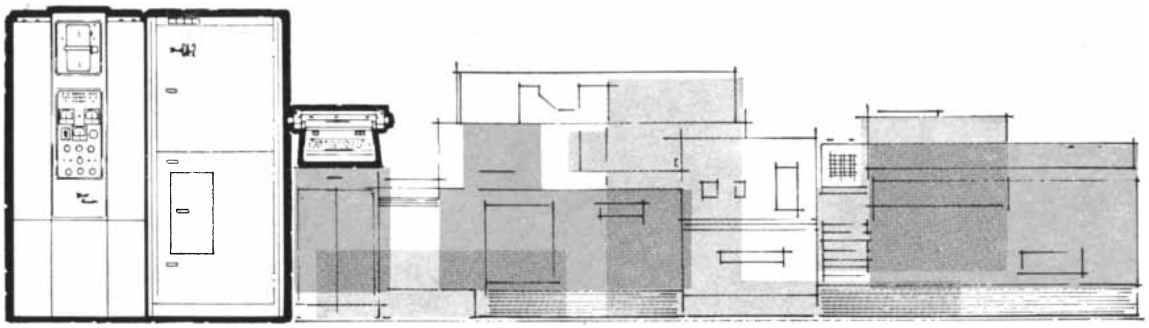

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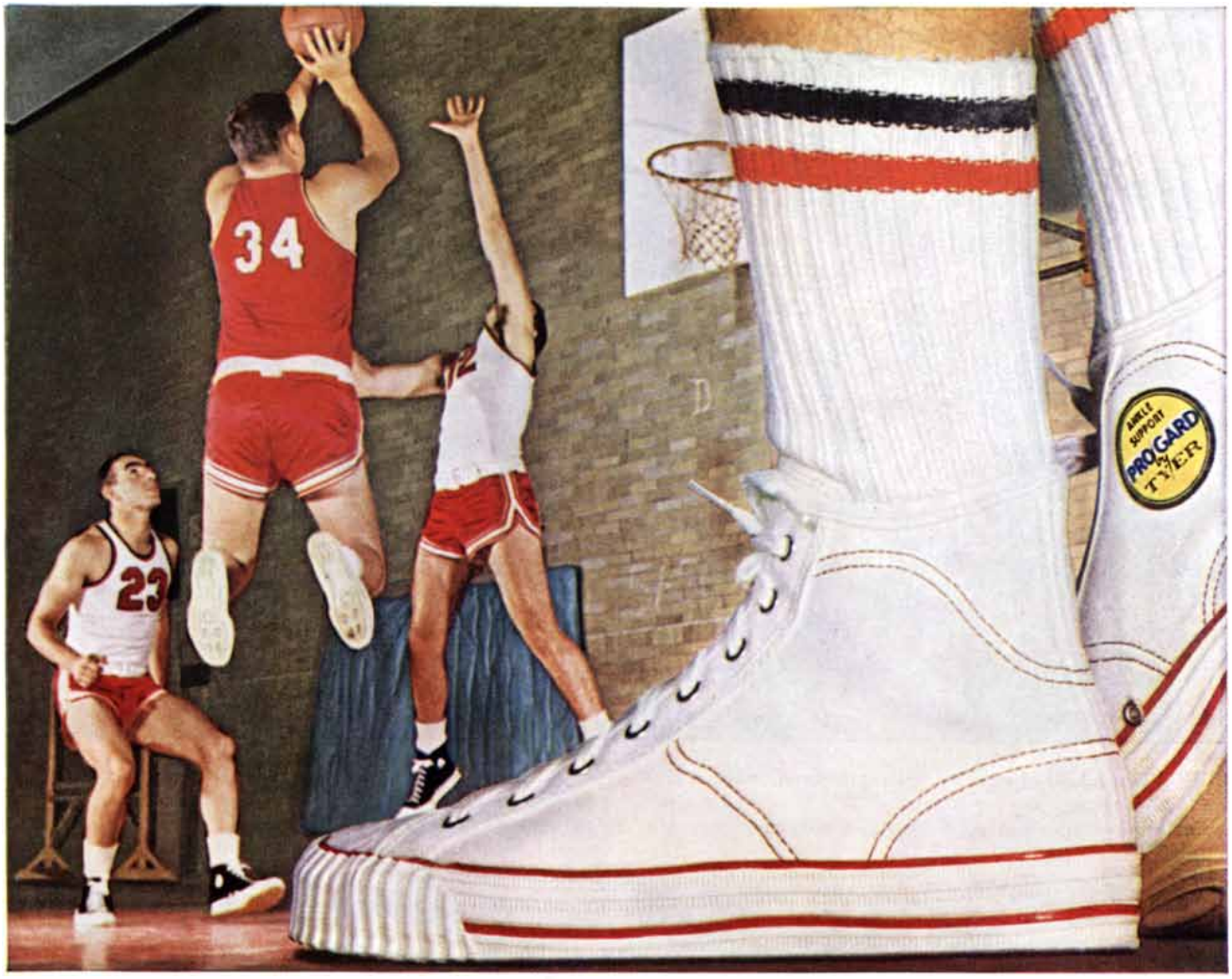

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IRRIGATED LAND of small-holders' settlement near Sea of Galilee (*visible through gap in background*) is watered by aluminum sprinkler pipes supplied from wells. Fields are planted to garden crops and to forage for dairy cattle. On slope in foreground, still green from winter rains, is an old olive grove. Land is rented from the state on 49-year leases with rental at 2 per cent of land value.

DESERT LAND in the Negev is made to support forage crops by diversion of flash-flood water, after methods employed by ancient Nabataeans. Water is trapped in basin fields, held long enough to soak the ground and then passed on to the field below over concrete spillways such as that under construction here. Agricultural engineering students inspecting site are armed against border raids.

Established 1845 SCIENTIFIC AMERICAN March, 1960 Volume 202 Number 3

The Reclamation of a Man-Made Desert

Israel is restoring to cultivation a land damaged by a millennium of abuse. The achievement is an example to a world that must face the task of increasing food supplies to feed a rising population

by Walter C. Lowdermilk

The State of Israel has undertaken to create a new agriculture in an old and damaged land. The 20th-century Israelites did not find their promised land "flowing with milk and honey," as their forebears did 3,300 years ago. They came to a land of encroaching sand dunes along a once-verdant coast, of malarial swamps and naked limestone hills from which an estimated three feet of topsoil had been scoured, sorted and spread as sterile overwash upon the plains or swept out to sea in flood waters that time after time turned the beautiful blue of the Mediterranean to a dirty brown as far as the horizon. The land of Israel had shared the fate of land throughout the Middle East. A decline in productivity, in population and in culture had set in with the fading of the Byzantine Empire some 1,300 years ago. The markers of former forest boundaries on treeless slopes and the ruins of dams, aqueducts and terraced irrigation works, of cities, bridges and paved highways—all bore witness that the land had once supported a great civilization with a much larger population in a higher state of well-being.

Last year, as a finale to the celebration of the 10th anniversary of the founding of the State of Israel, an international convention brought 485 farmers from 37 countries to see what had been accomplished. They found a nation of two million people, whose numbers had doubled in the decade, principally by immigration. Yet Israel was already an exporter of agricultural produce and had nearly achieved the goal of agricultural self-sufficiency, with an export-import balance in foodstuffs. It had more than doubled its cultivated land, to a million acres. It had drained 44,000 acres of marshland and extended irrigation to 325,000 acres; it had increased many-fold the supply of underground water from wells and was far along on the work of diverting and utilizing the scant surface waters. On vast stretches of uncultivable land it had established new range-cover to support a growing livestock industry and planted 37 million trees in new forests and shelter belts. All this had been accomplished under a national plan that enlisted the devotion of the citizens and the best understanding and technique provided by modern agricultural science. Israel is not simply restoring the past but seeking full utilization of the land, including realization of potentialities that were unknown to the ancients.

For the visiting farmers, many of whom came from the newer and less developed nations of the world, the example of Israel was a proof and a promise. Civilization is in a race with famine. The doubt as to the outcome is due not so much to the limitations of the earth's resources, plundered as they are, but to a lag in the uptake of progressive agricultural practices and failure in the distribution of the present output of food. More than two thirds of the people of the world are undernourished. Most of them live in the lands where mankind has lived longest in organized societies. There, with few exceptions, the soil is in the worst condition. The example of Israel shows that the land can be reclaimed and that increase in the food supply can overtake the population increase that will double the 2,800-million world population before the end of this century. Israel is a pilot area for the arid lands of the world, especially those of her Arab neighbors, who persist in their destitution in the same landscape that Israel has brought into blossom.

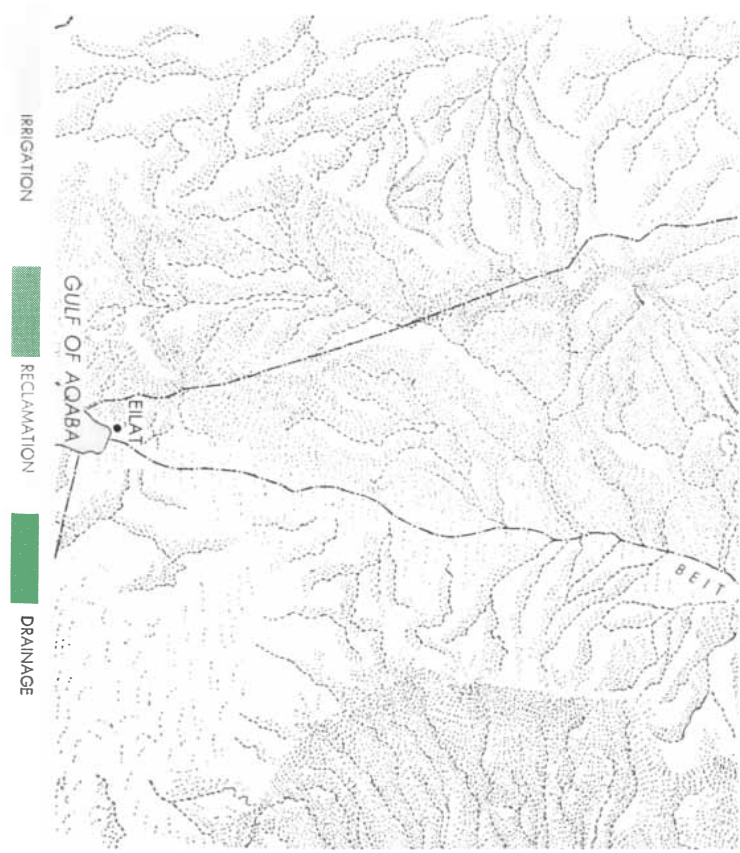
The achievement of Israel is the more remarkable for the fact that politics showed little regard for the logic of terrain and watershed in setting the boundaries of the state. The 7,815 square miles allocated to Israel in the 1948 partition of Palestine make a narrow strip of land along the eastern shore of the Mediterranean, roughly 265 miles long and 12 to 70 miles wide. It comprises only part of the Jordan River Valley, the principal watercourse of the region, with its three lakes: Lake Huleh, 230 feet above sea level at the northern end; the Sea of Galilee, nine miles to the south and 680 feet below sea level; and the Dead Sea, 65 miles farther south and 1,290 feet below sea level. More than half of Israel's territory is occupied by

true desert or near desert, and the principal agricultural acreage lies on the narrow coastal plain, on the northern uplands and on the western slope of the Jordan Valley from Lake Huleh downstream to 25 miles below the Sea of Galilee, where Israel's boundary comes down to the river. This division of territory and the persistent hostility of Israel's Arab neighbors continue to frustrate programs to realize the full benefits of the water supply to all concerned in a region where water is scarce.

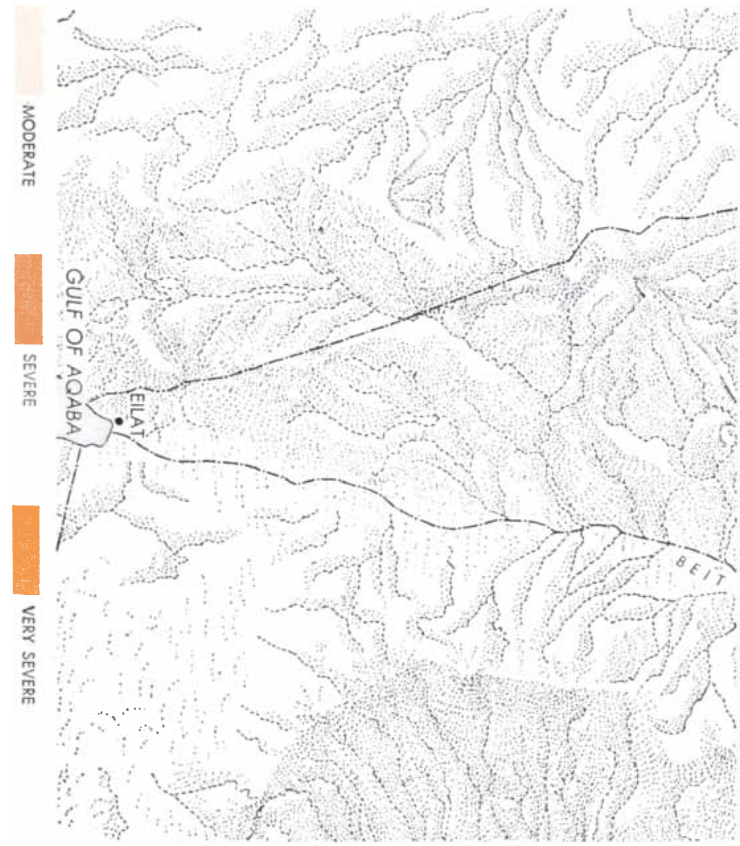
Climatically Israel much resembles California. Rains come in winter, and the summers are long and dry. Moreover, the erratic rainfall varies considerably from one end of the country to the other, from an average of 42 inches in the north, to 26 inches at Jerusalem, to less than two inches at Eilat on the Gulf of Aqaba at the foot of the desert of the Negev. Temperatures range to similar extremes over short distances, being cool at high elevations and hot and tropical in the Jordan Valley. In the spring a hot, dry wind, called the khamsin, may blow for days at a time out of the desert to the east, with calamitous effect upon unprotected crops. Harsh as these conditions are, there has been no significant deterioration in climate since Roman times. The same plants still thrive in protected places, and springs recorded in the Bible still bubble from the ground. The "desert" that took over the once-flourishing land was the work of man, not of nature.

Fortunately one geologic feature operates in favor of the conservation of rainfall; the porous limestone of the landscape absorbs a high percentage of the rain and distributes the water widely from the regions of heaviest fall through labyrinthine aquifers underground. The total discharge from springs exceeds the flow of the Jordan: a single great spring near the foothills of Judea gives rise to the Yarkon River. Another important source of water, the heavy summer dew, helps crops to grow in the uplands.

The agricultural restoration of Israel began in the 1880's, with the arrival of the first immigrants brought by the emergent Zionist movement as refugees from the pogroms of Eastern Europe. They were able to buy "useless" marshland on the coastal plain. These marshes had been created by the shoaling of erosion-laden streams and by the damming effect of the inland march of sand dunes. With heroic labor the early settlers succeeded in draining the marshes and farming them successfully. But until



LAND-USE SURVEY shows measures to be taken to achieve maximum productivity. Extensive "drainage" areas reflect problem of salinity as well as of standing water in lowlands after winter rains. Marshes along coast were created by inland drift of sand dunes and erosion outwash from uplands which shoaled stream beds. "Irrigation" areas can be cultivated when watered; "reclamation" areas require repair as well as irrigation.



SOIL-RESOURCES SURVEY, covering those areas where water is or can be made available for agriculture, shows the effects of 1,300 years of misuse of the land. Most "very severe" erosion areas are beyond reclamation for cultivation and have been downgraded to forest and pasture or to wasteland. "Severe" erosion areas are reclaimable when watered; "moderate" areas can be restored by using elementary measures of soil management.

CONTOUR FARMING in Jezreel Valley is being extended to all slopes that exceed the safe gradient for "safe-line" farming. Steeper slopes are terraced and crops are rotated on contour strips. These practices prevent erosion and conserve the rainfall on fields.

the State of Israel was established, the effort was on a "first aid" basis.

When the new government set out to frame a comprehensive program for the development of the country's soil and water resources, it could call upon a number of outstanding authorities among its own citizens: specialists in forestry, horticulture, soil science, plant breeding and civil engineering who had come as refugees from Germany and Central Europe. But with a major portion of its expanding population coming from the Arab countries of North Africa and the Near East, Israel did not have enough experts in the many disciplines needed to establish a modern agriculture in short order. The government therefore was among the first to draw upon the technical assistance offered by the specialized agencies of the United Nations and by the "Point Four" program of the U. S. I had the rewarding experience of sharing in this work as a member of missions that served in Israel under the Food and Agriculture Organization of the U.N. from 1951 to 1953, consulting in the establishment of a national program of land development and in building up a staff of men to carry it out; and again from 1955 to 1957 helping to build a department of agricultural engineering at Technion, the Israeli institute of technology.

The first order of business, begun in 1951 and completed in 1953, was the

OLD SETTLEMENT of small-holders at Nahalal is laid out on the eastern European pattern with the village at center, surrounded by individual truck-garden farms, each seven acres in extent.

CITRUS GROVES, managed on a cooperative basis, support a com-

SOIL RECLAMATION has halted gully erosion and brought a limited area of heavily eroded soil under cultivation in the northern Negev. The soils in this region developed a "bad land" topography during centuries in which they were stripped of grass cover.

taking of a comprehensive inventory of the land. This comprises the 2.38 million acres north of the 60th parallel, about half the territory of Israel, where major agricultural development is possible. One of the most thorough inventories of its kind in the world, it furnished a secure foundation for land-use policy and for the immense task of reclamation and water development that has followed. Classification of the inventoried land by end-use shows that, given adequate water supply, about 40 per cent, or a million acres, can be made suitable for general cultivation; about 15 per cent for orchard, vineyard, pasture and other use that will keep a permanent plant cover on the soil; 20 per cent for natural pasture without irrigation; and 25 per cent for forests, parks and wasteland. Outside the area of detailed survey, in the Negev, an extensive reconnaissance has projected a program for range development and for the cultivation of forage crops in those areas where the scant winter run-off can be diverted or impounded to support irrigation.

A major feature of the land inventory was the classification of the lands according to their relative exposure to erosion by wind and water. In the hands of the Israeli Soil Conservation Service this has served as a blueprint for measures to preserve the best soils and ultimately to reclaim land now

munity on the Sharon Plain. Taller eucalyptus trees shelter groves.

NEW SETTLEMENT has begun to farm land opened up to cultivation by irrigation and soil-conservation measures. Open center of the village is eventually to be occupied by service buildings.

IRRIGATION BY SPRINKLING is the method that has proved most economical in bringing water to the field in Israel. Aluminum pipes are moved from field to field as needed.

unusable. The hazard of erosion increases in geometrical ratio with increase in the gradient of the soil. The first line of defense is directed against the dynamics of the falling raindrop and includes measures of soil management that are also required for sustained crop yields such as the build-up of organic matter to increase the water-holding capacity of the soil and the use of crop litter to absorb the energy and reduce the splash-erosion of the raindrop. Contour plowing and the planting of crops in strips along the contour provide the second line of defense and usually suffice against the hazards of moderate storms. These defenses can be set up by the individual farmer or farm cooperative and are everywhere encouraged through education and demonstration by the Soil Conservation Service. But rains in Israel characteristically come in downpours, in a few heavy storms during the rainy season and in extreme storms every few years. Where such rains overtax the first two lines of defense, more elaborate and costly measures must be designed and laid out by soil-conservation engineers of the Soil Conservation Service. Slopes must be broken by broad-base terraces to pick up and slow storm runoff and the terraces must be interconnected by waterways to keep the accumulated water from cutting gullies through the fields. Storm waters are then available for storage in surface ponds and reservoirs or to recharge ground waters. This line of defense must be accurately and adequately engineered, for running waters do not forgive a mistake or oversight in design.

One of the effects of man-induced erosion in the past was the creation of marshes on the narrow coastal plain, notably at Hadera, Kabri and in the Jezreel Valley. Carrying through the work started by the early settlers, Israel has now fully reclaimed these lands, draining and planting them to eucalyptus trees in the lowest spots and to citrus groves and crops on the higher ground.

A more substantial engineering challenge was presented by the marshlands of the Huleh basin at the head of the Jordan Valley. In Roman times and before, this region was fertile and thickly populated, but it had become a dismal swamp and a focus of malarial infection to the country at large. Sediments from the uplands to the north had progressively filled in the northern end of Lake Huleh, thus creating a marsh that was overgrown with papyrus. The marshes have now been drained by widening and deepening the mouth of the lake to bring down its water level and by a system of drainage canals. With the papyrus cleared away, the deep deposit of peat beneath yields richly to cultivation, much as do the delta peat-lands at the head of San Francisco Bay. The Huleh Reclamation Authority estimates that this little Garden of Eden will support a population of 100,000 in an intensive agricultural economy, cultivating vegetables, grapes, fruits, peanuts, grains, sugar cane, rice—even fish (in ponds impounded on the old lake bed). The yield of fruits and vegetables will soon require the installation of processing and canning plants on the spot. Another gain achieved by the reclamation of this land is the conservation of water; the reduction of the evaporation surface of the lake and surrounding marshes will save enough water to irrigate 17,000 to 25,000 acres of land, depending on the rainfall of the district to which these waters will be delivered. The Huleh Drainage and Irrigation Project is not great in size, but it symbolizes the determination of Israel to make the most of its resources.

The development of water supplies and irrigation constitutes the most significant achievement of the new nation and differentiates its agriculture most sharply from that which prevails in all but a few areas in the surrounding Arab countries. Since the time of Abraham, when "there was famine in the land," agriculture in this region has been at the mercy of the variable winter rainfall. In ancient Palestine irrigation was limited to small areas that could be fed by gravity from perennial springs. These works had long since fallen into disuse, and at the beginning of this century very little of the Holy Land was irrigated. In 10 years the State of Israel has quadrupled the acreage under irrigation, from 72,500 to 325,000 acres. It was this achievement that made possible the absorption of the great influx of immigrants. Irrigation has increased yields per acre from three to six times and more over those achieved by dry farming in the region and has secured dependable yields from year to year.

With most of the water coming from wells, irrigation in Israel is accomplished by sprinkling, rather than by furrow or border ditch. The grid of pumps and pipes delivers the water under pressure but at low rates of flow. Irrigation engineers soon found that sprinkling was best adapted to this mode of delivery and for application of the water to sandy soils and to rougher, stony land unsuited for leveling. The high investment in pumps and piping has been more than offset by the intensive year-round cultivation made possible by irrigation and by the urgent need to settle immigrants in self-supporting activity on the lands. Each year from 25,000 to 30,000 additional acres are being brought under irrigation, and the prospect is that this will continue until the limit of water supply is reached.

Meanwhile extensive field research

is devoted to achieving the most efficient use of water. In the northern Negev, for example, it has been found that about six inches of irrigation water, applied just before the winter rains to soak the soil to its water-holding capacity down to a depth of about four feet, will make up the equivalent of 20 inches of rainfall, sufficient for winter grain. In many soils irrigation raises a serious drainage problem. Evaporation from the soil and transpiration by crops in the "consumptive" use of the water leave behind the salts it carries in solution. After a few years the accumulation of salts may reach toxic proportions. Certain crops, such as sugar beets, take up some salts and may be planted in rotation to reduce this accumulation. But whatever the crop, drainage must be provided in time to leach away the salts, and the chemical composition of the soil must be kept under surveillance.

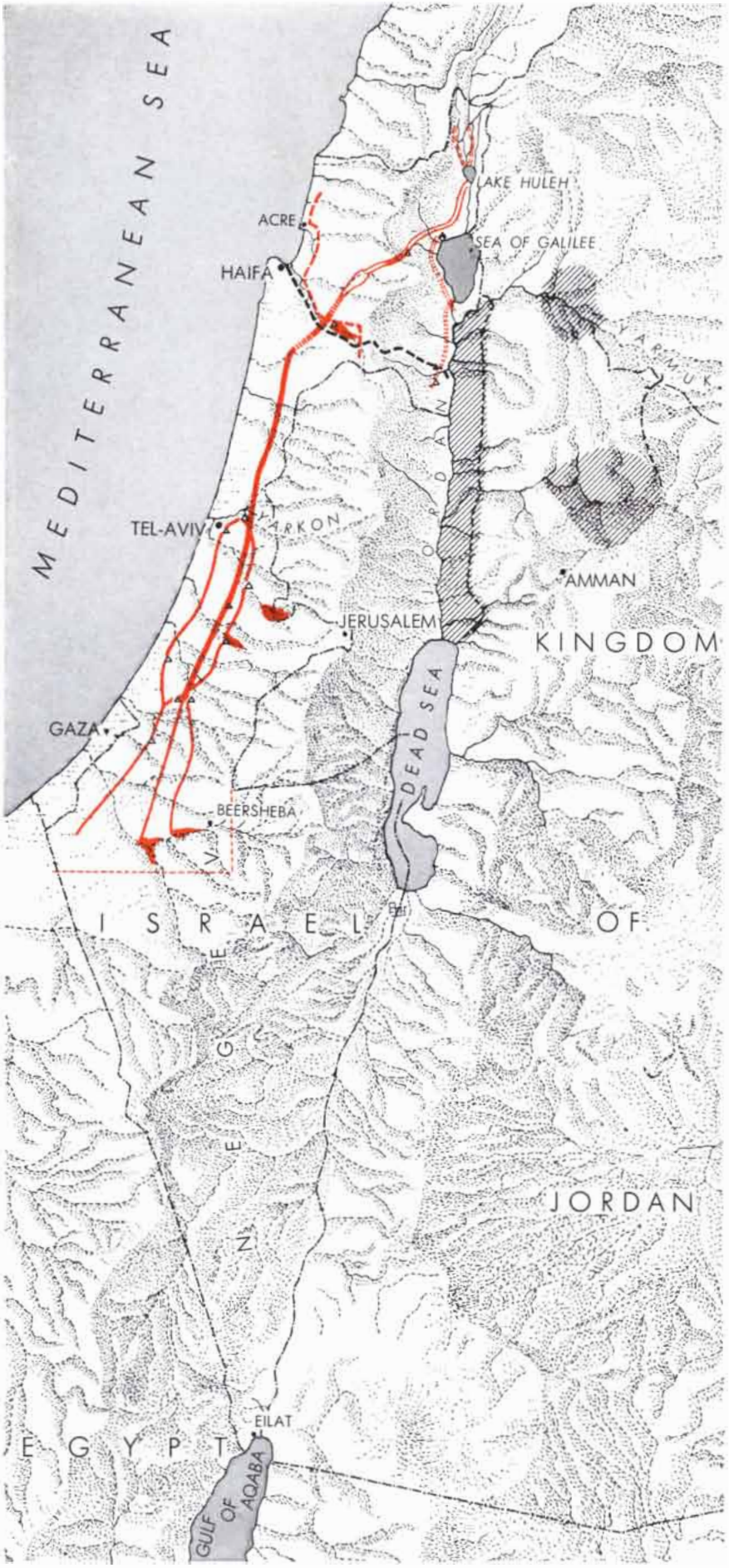
To bring much of the land under irrigation and cultivation has required strenuous repair of the damage done by centuries of erosion. The slopes in stony soils are typically covered by an "erosion pavement" made up of stones too heavy to be moved by rain splash and by the sheet flow of the storm runoff that carried away the topsoil. In some parts of the country, farmers have raked these stones from the fields and piled them into great heaps. Where erosion has exposed the rock or gullied the deep soils beyond plowing, the land has been put to some lower use, such as rough pasture or woodlot. In many parts of the highlands modern farmers have been able to take advantage of the soil-conservation works of the ancient Phoenicians. My own investigations indicate that the Phoenicians, 3,000 to 4,000 years ago, were the first people in the Middle East to clear and cultivate mountain slopes under rainfall agriculture and so were the first to encounter soil erosion. They were also the first to control soil erosion by using the principle of the contour and by building stone walls to convert a slope into a series of level benches. Most of these ancient terraces had been allowed to fall in ruins. Today they are being reconstructed and redesigned. Since the terraces are narrow and so suited only to hand labor, the practice is to collect the stones from old terrace walls and to pile them into ridges spaced more widely apart on the contour, creating terraces with gentle gradients for cultivation by tractor-drawn farm implements. Under sprinkler irrigation the new terraces are proving to be favorable sites for vineyards and orchards.

Over the large stretches of the coun-

SAND DUNES carried inland from coast have been encroaching for centuries upon arable land. Dunes are now being held in place by planting and even reclaimed for cultivation.

FLASH FLOOD from winter downpour rushes over ruins of ancient desert irrigation works in northern Negev. Waterfall in foreground demonstrates gully-cutting action of floods.

PLOWING BY CAMEL in Gaza Strip on Israeli border reflects survival of primitive agricultural practices that over the past millennium have wasted the soil resources of the region.



MASTER WATER PLAN of Israel (*color*) is based upon plan originally designed to maximize water resources for entire Jordan River Valley, including both Israel and what is now the Kingdom of Jordan. Basic scheme calls for diversion of water from the head of the Valley, where rainfall is heaviest, to arid lands in the south. Via the Jordan-Negev canal, a tunnel and a 108-inch pipeline now under construction, water from Lake Huleh region is to be carried to the Negev, with additional water from the Yarkon River being carried by the Yarkon-Negev pipelines. The Mediterranean-Jordan Power Project and Yarmuk-Yaboq scheme await cooperation and action by Jordan.

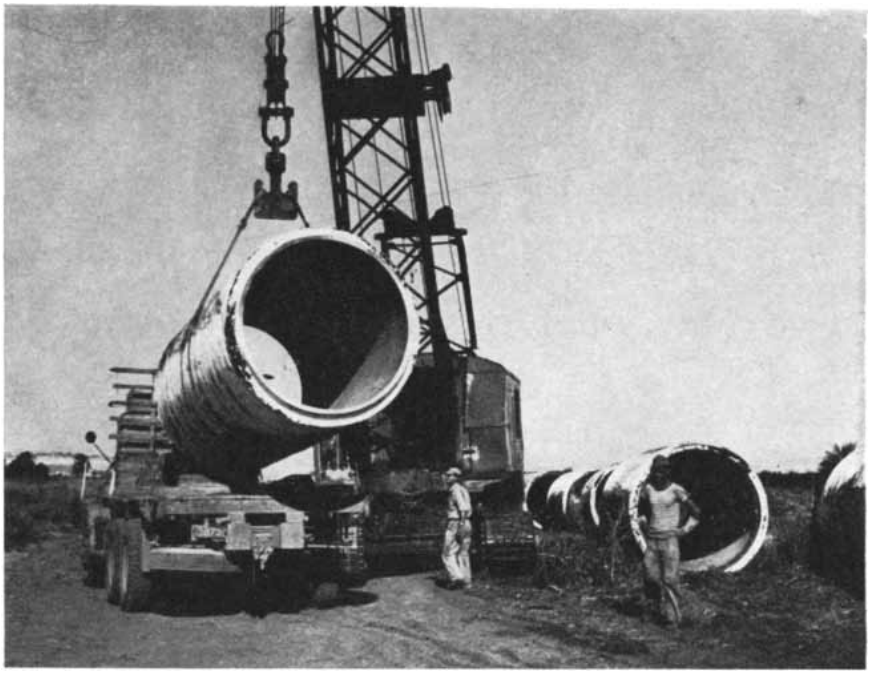
try that are beyond such reclamation and are too dry for forests, the effort is to develop the land for pasture. Throughout the Near and Middle East and North Africa the land has been overgrazed for more than 1,000 years. What sheep will not eat, goats will, and what the goats leave, camels will graze. By the time these hardy animals have ranged over the land through the long, hot, rainless summer, there is little plant cover left to protect the soil from the winter rains. But if one may judge by the relict species of forage grasses and plants that survive in rocky places and thorn thickets beyond the reach of goats and camels, it may be surmised that this land was once a pastoral paradise. The prompt return of a good cover of grasses and herbs after the goats were removed from the land by the Israeli Government in 1948 confirms this appraisal. The Soil Conservation Service has since been reseeding the range with native plants and with species imported from the U. S. and South Africa. In addition, certain woody bushes and low trees are being planted to hold the soil and furnish browse for livestock; the rich beans of the hardy carob tree, for example, yield as much

feed as an equal planting of barley. Measures to divert and spread the storm waters over the pastures are further increasing the yield. Herds of beef and dairy cattle are now beginning to multiply on the restored range.

Early in the Jewish immigration to Israel the planting of trees came to be a symbol of faith in the future. Afforestation now plays a central role in the control of erosion, in reclamation of stony hills and in sheltering orchards and garden plots from the winds, whether from the sea or the desert. Some 250 million trees, both native and imported species selected by the Israeli Forest Experiment Station, are to be planted in the next 10 years. The growing of stock in the nurseries and the planting of trees on uncultivated hillsides, on roadsides, in shelter belts and on sand dunes provides interim employment for new immigrants until they become established. Already the new stands are yielding timber, poles and fuel products—valuable commodities in a deforested land.

The land inventory has served to protect the best agricultural lands from being engulfed by the growing cities and towns of Israel. Along the coast, for example, the communities have been encouraged to expand their boundaries into the sand dunes rather than into surrounding cultivable land. The dunes comprise 10 per cent of the coastal land and, under the drag of the prevailing westerly winds, are overwhelming good land, orchards and even houses. Experiments are under way to hold the shifting dunes by stabilizing the sand surface and by aggregating sand grains into crumb structures. This is accomplished by plantings of hardy shrubs and sand grasses, and of such fibrous-rooted plants as alfalfa, with water supplied to some tracts by sewage effluent and partially rectified sewage water. The rapid growth of the plants where this has been tried converts the sand in a few years into a stable soil-like material suited to the planting of trees and even some crops. But the full reclamation of the dunes to agricultural use is still in the research stage.

Ultimately the expansion of agriculture is limited by the availability of water. The Israeli Water Planning Agency is seeking to double the 1956 water supply by 1966, giving the country a total of 14.5 million acre feet (an acre foot is 12 inches of water per acre) per year. A central feature of the plan derives from a survey that I conducted in 1938 and 1939 for the U. S. Department of Agriculture and from the proposal, growing out of that survey, of a Jordan Valley Authority to achieve the fullest development of the surface and underground waters of the valley for the entire original Mandate under the League of Nations, including what is now the Kingdom of Jordan as well as Israel. That proposal called for the development of ground waters and diversion of the upper Jordan waters within Israel to the dry lands in the south and for the diversion of the waters of the Yarmuk River to the eastern side of the Jordan Valley for irrigation of a promising subtropical region in Transjordan. In order to replace the flow of these rivers into the Dead Sea, salt water was to be brought in from the Mediterranean Sea through canals and tunnels to drop through two sets of hydropower stations nearly 1,300 feet below sea level to the Dead Sea. This salt water would not only produce electric power but also would maintain the level of the Dead Sea for the extraction of the minerals and chemicals that are there in fabulous amounts. The plan was declared feasible by an international consulting board of engineers. All parts of the plan that do not require the collaboration of the adjoining Arab states are now being carried out by the Israeli Government. The prestressed-concrete sections of the main 108-inch pipeline that will carry upper Jordan water down as far as the Negev are now being fabricated and set in place in a great trench, and the tunnels to carry it through intervening hills are under construction.



CONCRETE PIPE 70 inches in diameter for Yarkon-Negev pipeline is delivered to location where it is to be set in place in a great trench and buried. This line will carry water from the Yarkon River in the north to the arid lands of the Negev (*see map on opposite page*).

Beyond this major undertaking the country is conserving for use and reuse such minor flows of water as are represented by the sewage of its cities and the runoff of intermittent streams along the coast. In the southern Negev, where the annual rainfall is less than six inches, the Soil Conservation Service is adopting the methods of ancient Nabataeans to impound the waters of flash floods for the irrigation of forage crops.

Prospects for the future have recently been brightened by progress in the desalting of sea water. A new method developed in the laboratories of the Government is about to be tested in two pilot plants, each with an output of 250,000 gallons per day. Success in this undertaking would be a major victory not only for Israel but also for all the other arid-land countries of the world.

On the anvil of adversity the State and people of Israel have been hammering out solutions to problems that other nations must sooner or later face up to. There are no more continents left to explore or to exploit. The best lands of the earth are occupied and in use. All of them, to a greater or lesser extent, need the same measures of reclamation and conservation that have succeeded so well in Israel. The frontiers of today are the lands under our feet.

Interplanetary Navigation

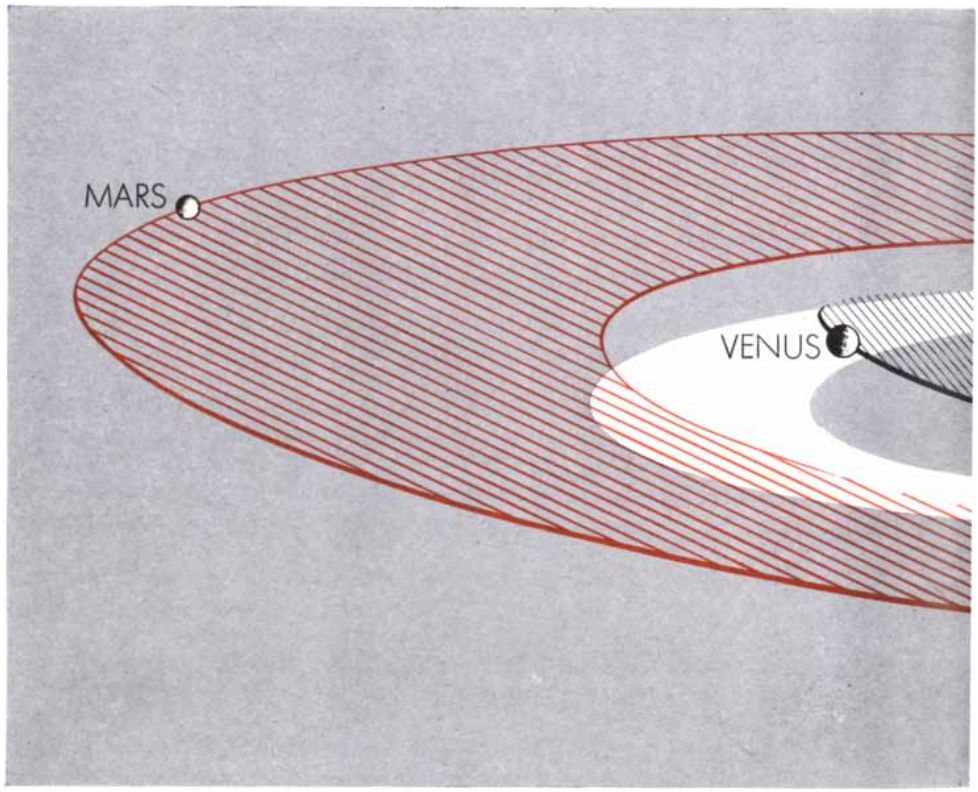
To bring a rocket to a precise rendezvous with another planet requires difficult compromises among the conflicting demands of payload, radio communication, guidance and available power

by Aubrey B. Mickelwait, Edwin H. Tompkins, Jr., and Robert A. Park

Within the next year or two interplanetary flight should be a reality. *Lunik I* and *Pioneer IV* have demonstrated that existing rockets can carry a package of scientific instruments away from the earth's gravitational field and on toward the orbits of Venus and Mars; in fact, *Lunik I* is assumed to have come fairly close to the orbit of Mars. But achieving the necessary distance is only the first step. In the next class of flights the rockets must bring the instruments close to—or even land them upon—another planet while transmitting information back to earth. To accomplish this objective with available propulsion and control systems and to secure a sufficient return of scientific information to justify the effort places a premium on the new art of interplanetary navigation.

If interplanetary vehicles could travel under continuous power they could be navigated continuously to their destinations. For the time being, however, the vehicle must be a rocket that travels under power principally during the first few minutes of flight, when it is lifted from the surface of the earth. The navigation that is to bring the rocket to its destination must be accomplished during those few minutes. Through the long journey to a rendezvous with its far-off moving target, the vehicle travels as a satellite of the sun. It was already in motion around the sun before it started from the earth, and its velocity on its own orbit is now only weakly modified by the escape velocity that carried it free. The task of the trajectory designer is to place the vehicle on an optimum orbit: one that will minimize the requirements of propulsion and control and maximize the payload and yield of information back to earth. He must reckon that the earth and the target planet are moving at different speeds, albeit in the same direction, on orbits inclined to each other and are thus constantly changing their positions with respect to each other in space. His primary decision is to choose a launching year, day and hour that will find the earth and target planet in the most favorable relative positions to bring the vehicle and target together with a minimum expenditure of energy and within transmitting distance of the earth months later, when all three have traveled around the sun on their courses.

The practical prospect of interplanetary flight has awakened fresh interest in celestial mechanics, the branch of astronomy that deals with the motion of bodies in a gravitational field. Celestial mechanics was the first branch of physics to attain scientific maturity. By 1687 Isaac Newton had published in his *Principia* the complete equations of motion in a gravitational field and had shown that Johannes Kepler's three empirical laws of planetary motion followed from these equations. Despite the great names as-



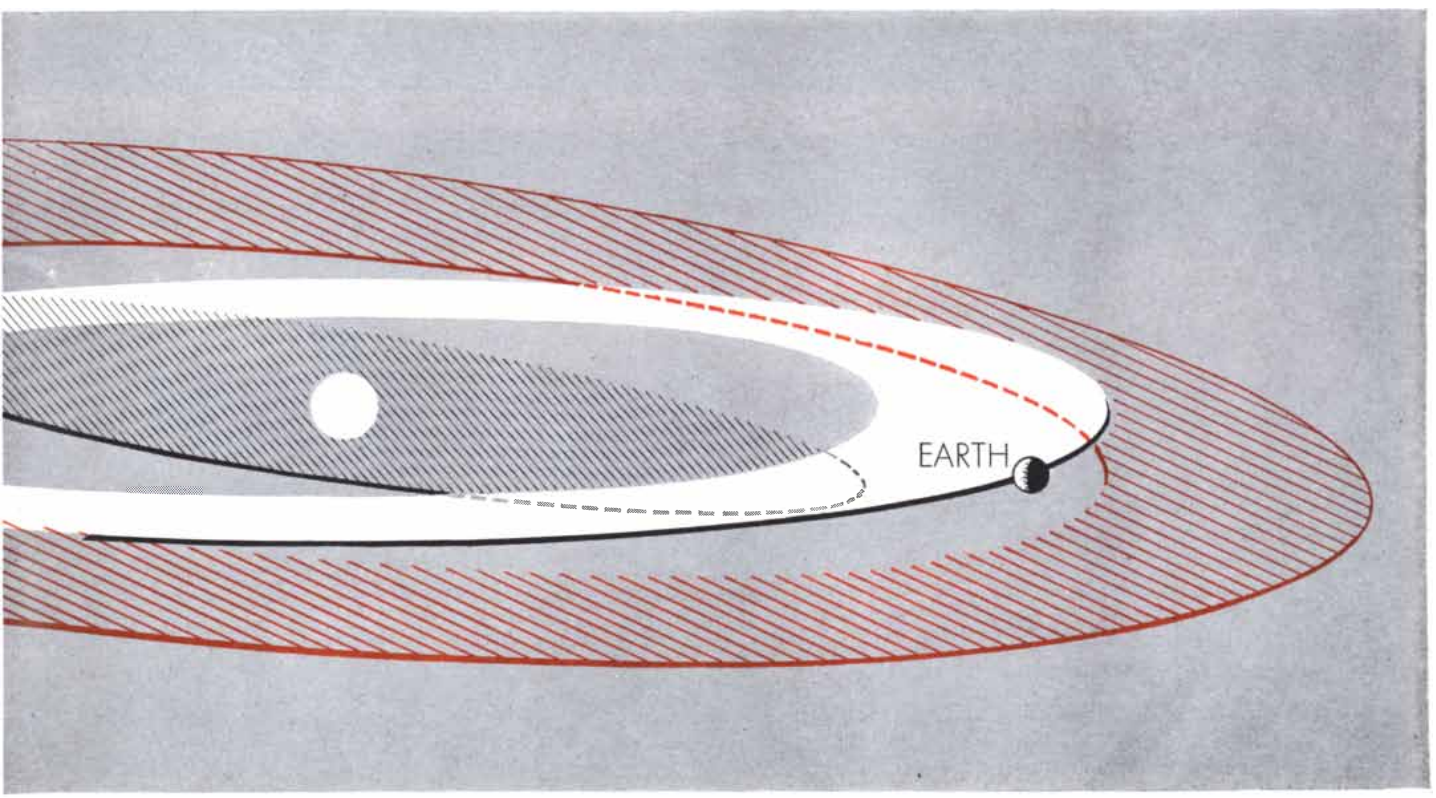
TILT OF PLANETARY ORBITS with respect to the orbital plane of earth, or ecliptic *(white)*, is the chief complicating factor in interplanetary navigation. For most flights the

sociated with this branch of physics, one unsolved theoretical problem remains to confront the trajectory designer: that of predicting the motion of a body through two or more simultaneously acting gravitational fields. A century after Newton, Joseph Louis Lagrange developed an approximate method for handling such motion. By 1845 calculations by similar approximations had been sufficiently refined to reveal a discrepancy of about .01 degree of arc per century between the predicted and the observed motion of Mercury. That tiny discrepancy served, a century later, to provide partial verification for Albert Einstein's general theory of relativity. The application of celestial mechanics to interplanetary navigation requires equally refined methods, though the laborious computations can now be handled by computer.

The problems involved in designing a trajectory for an interplanetary vehicle may be elucidated, however, by means of a much simpler approximation of reality. Since it is difficult to handle the analysis of more than one gravitational field acting simultaneously, the solar system may be divided into three regions, each governed by a single gravitational field. In the first region, which surrounds the earth out to a distance of about a million miles, only the earth's gravitational field is assumed to affect the motion of the vehicle. In the second region, through which the vehicle passes on most of its flight, only the sun's gravitational field is considered; in the third region, only the field of the target planet [*see top illustration on page 68*].

According to the equations of Newton the trajectory of an object moving through any one of the regions will assume the form of one of the familiar conic sections when viewed from the central gravitational body in each region: a hyperbola if the object is moving fast enough to escape from the region, an ellipse if it is not. For example, the several man-made satellites now in orbit about the earth, lacking the energy to escape the earth's gravitational field, move on elliptical paths. The interplanetary vehicle, with much greater energy, will leave the earth's gravitational field on an "escape" hyperbola. Viewed from the sun, it will then proceed along an ellipse. When, and if, it is caught by the gravitational field of the target planet, the vehicle appears to move on a hyperbolic course as it makes a swing around the planet and returns to its elliptical path around the sun. Braking rockets may be fired at this juncture to remove energy from the vehicle and place it on a permanent elliptical orbit around the target planet. Or, if the trajectory was successfully designed for "impact," the hyperbola will intersect the target [*see bottom illustration on page 68*].

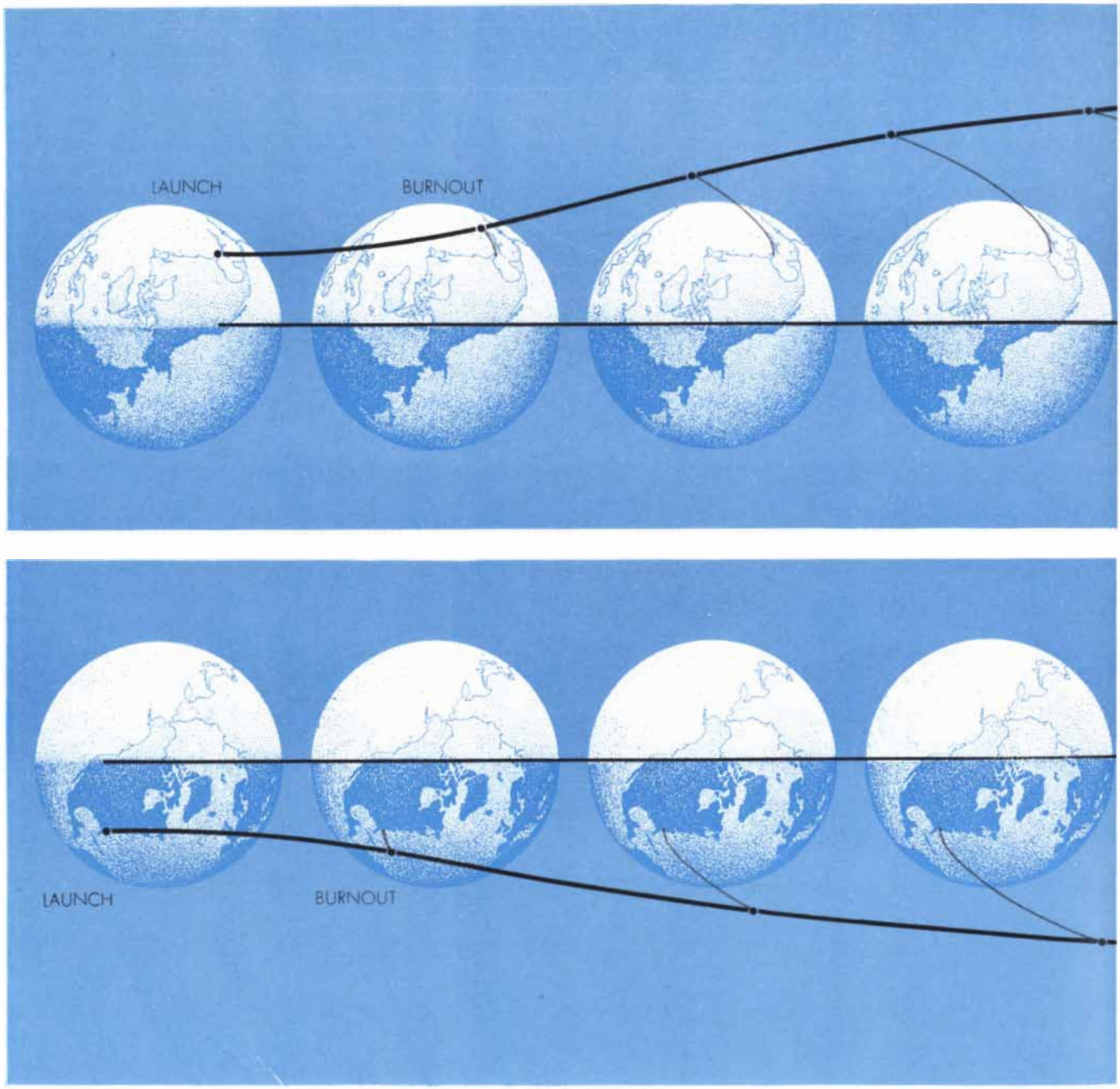
To achieve an escape hyperbola from the earth on a course that will reach the orbit of Venus or Mars, the vehicle must attain a velocity at burnout (the moment when its rocket motor ceases firing) in excess of 36,000 feet per second with respect to the earth, assuming that its altitude at burnout is at least 200 miles. By the time it has coasted "uphill" out of the earth's gravitational field it has lost about three fourths of this velocity. It is therefore traveling at about 10,000 feet per second with respect to the earth when it enters the sun's sphere of influence. But even before the vehicle left the earth it was traveling on the earth's orbit at 97,000 feet per second with respect to the sun. The residual escape-velocity is small compared to this figure, but it can modify the solar velocity of the vehicle sufficiently to carry it on to a new orbit around the sun. If all or part of the residual velocity is added to the 97,000-foot-per-second solar velocity by launching the vehicle in the direction of the earth's motion, the vehicle will move



vehicle must be aimed above or below the ecliptic, a procedure that raises fuel requirements and may increase the necessary accuracy of aim and velocity. The actual tilt, here somewhat exaggerated, is about 2 degrees for Mars and 3.4 degrees for Venus.

ahead of the earth and out on an elliptical course toward Mars. If residual velocity is subtracted, by launching the vehicle against the direction of the earth's motion, it will fall behind the earth on an elliptical course toward Venus [*see illustration on these two pages*]. There is no chance that the vehicle will fall into the sun. Such a trajectory—one that would also bring the vehicle to rendezvous with Venus when Venus is closest to the earth—would require cancellation of all of the velocity imparted by the earth. This would require more energy than a voyage designed to escape from the solar system entirely. Either trip is beyond present technology.

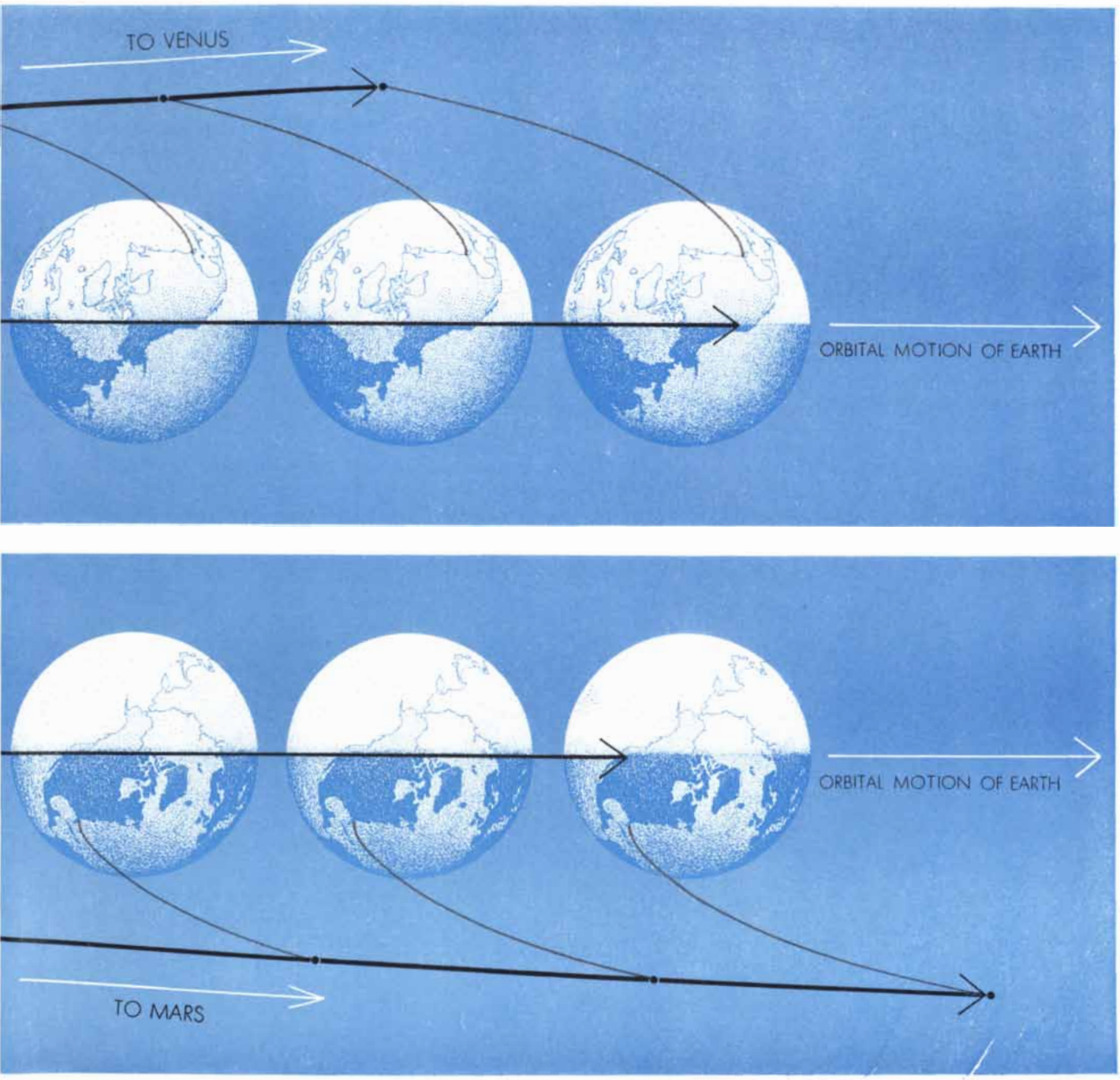
Since the trajectory designer's objective is to transport a maximum payload to the target planet, he seeks at the outset a trajectory that can be achieved with minimum expenditure of energy. To secure the maximum modification of the original 97,000-foot-per-second velocity by addition or subtraction of the residual escape-velocity, it is clear that the designer should seek to launch the vehicle straight along the line of the earth's motion. All of the vehicle's escape velocity will then be added to, or subtracted from, the earth's velocity. If the solar system were two-dimensional, that is, if all of the planets moved in the same plane, the "ideal" minimum-energy tra-



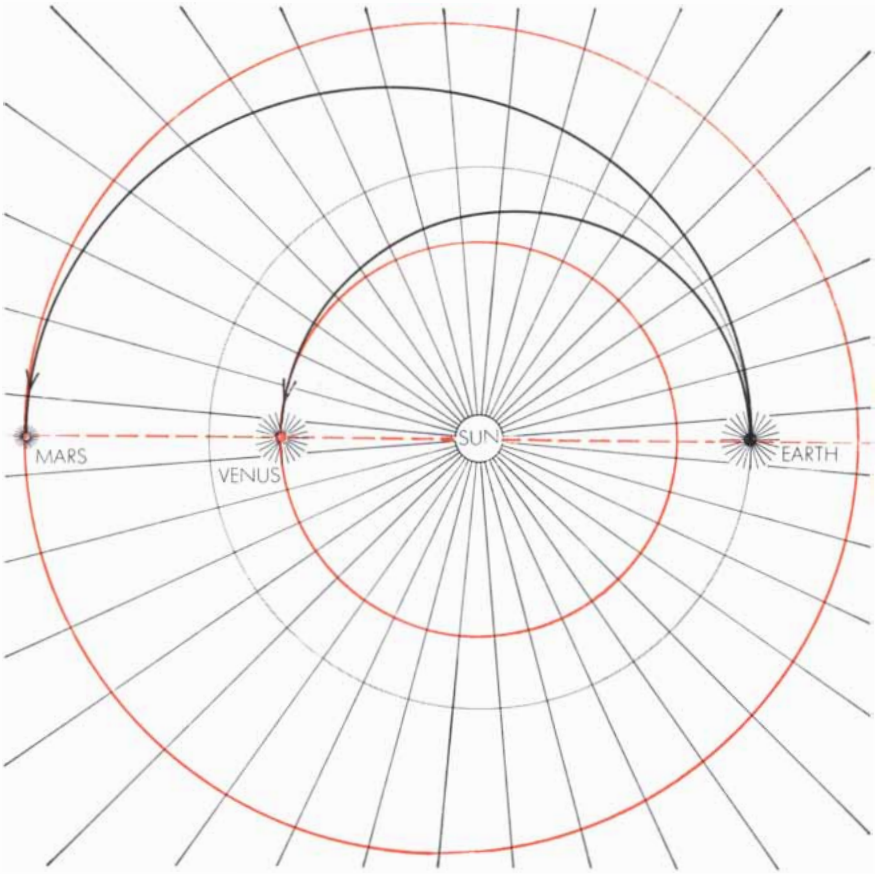
"ESCAPE" TRAJECTORY of a space vehicle leaving earth is depicted in these drawings, which show the positions of the vehicle and the earth at intervals of about eight minutes. In relation to earth the vehicle takes off along a hyperbolic path (*gray lines*). For a flight to Venus (*top*) the vehicle is aimed backward along the orbit of the earth so that it moves more slowly than the

jectory would bring the vehicle into rendezvous with the target planet just 180 degrees around the sun from the starting point, and the orbit of the vehicle would lie tangent to that of the planet. Any other trajectory requires that the vehicle cross the orbit of the target planet, traveling farther outward or inward, and so consumes more energy. The two-dimensional minimum-energy trajectory has the additional advantage of bringing the vehicle to its target at the lowest possible "approach velocity." This allows the instruments more time to do their work and, if the vehicle is to go into orbit around the planet or make a landing on it, reduces the fuel needed for braking.

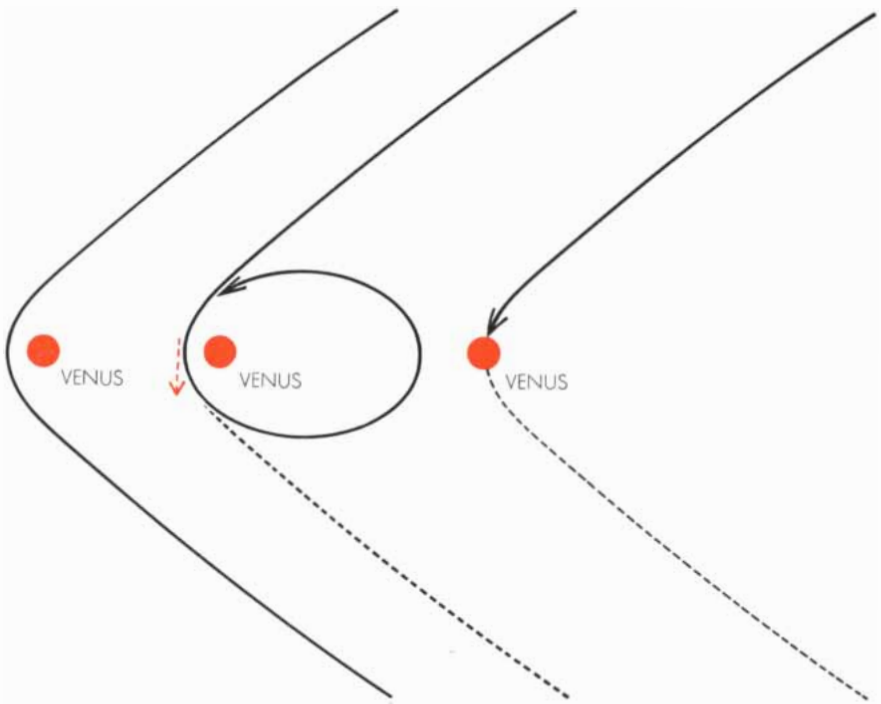
Plainly the achievement of the minimum-energy orbit, even in the two-dimensional model, calls for a happy coincidence in the relative positions of the earth and the target planet. At launching time the earth must be just 180 degrees around the sun from where the target planet will be at rendezvous. Since the planets move at different speeds around the sun, the proper orientation of earth and target occurs at comparatively long time intervals: about 584 days for Venus and 780 days for Mars. An almost ideal minimum energy launching day for Venus was June 8, 1959. By increasing the launching velocity and thereby increasing or decreasing both the flight time and the angle turned in space



earth, as suggested by the lengths of the heavy black lines that plot the trajectories of the earth and the vehicle as seen from space. As a result the sun's gravitation pulls the vehicle inward toward Venus. For a flight to Mars (*bottom*) the vehicle is fired in the direction that the earth is moving. Since it is now traveling more rapidly than earth, it moves outward toward the orbit of Mars.



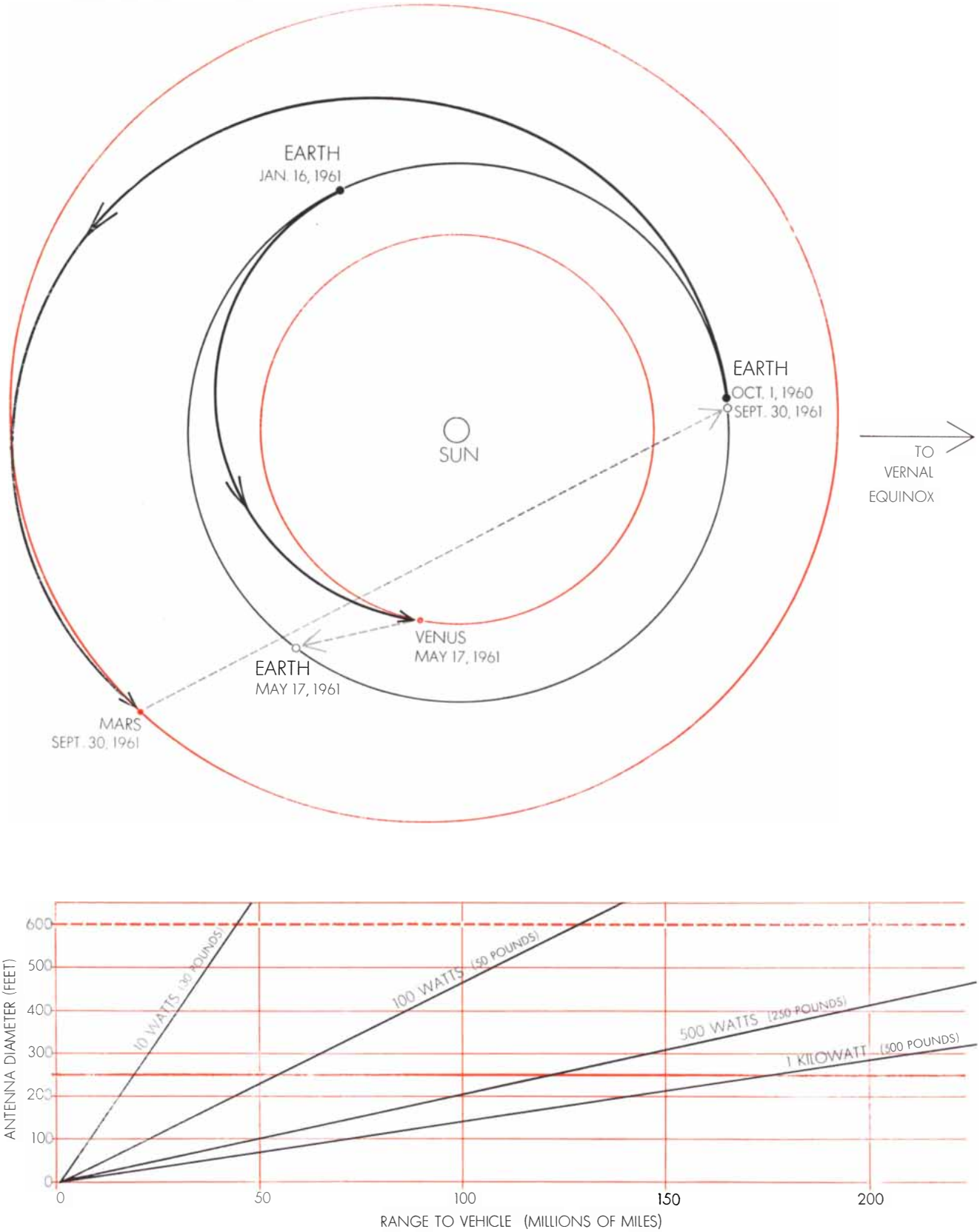
IDEALIZED TWO-DIMENSIONAL TRAJECTORIES requiring a minimum of power are semi-ellipses (*heavy black lines*) tangent to the orbit of earth at one end and to that of the target planet at the other. Rendezvous with the target is exactly 180 degrees around the sun from the take-off point. Radial lines give a very simplified picture of the gravitational fields of the sun and the planets. The size of the planetary fields is exaggerated 10 times.



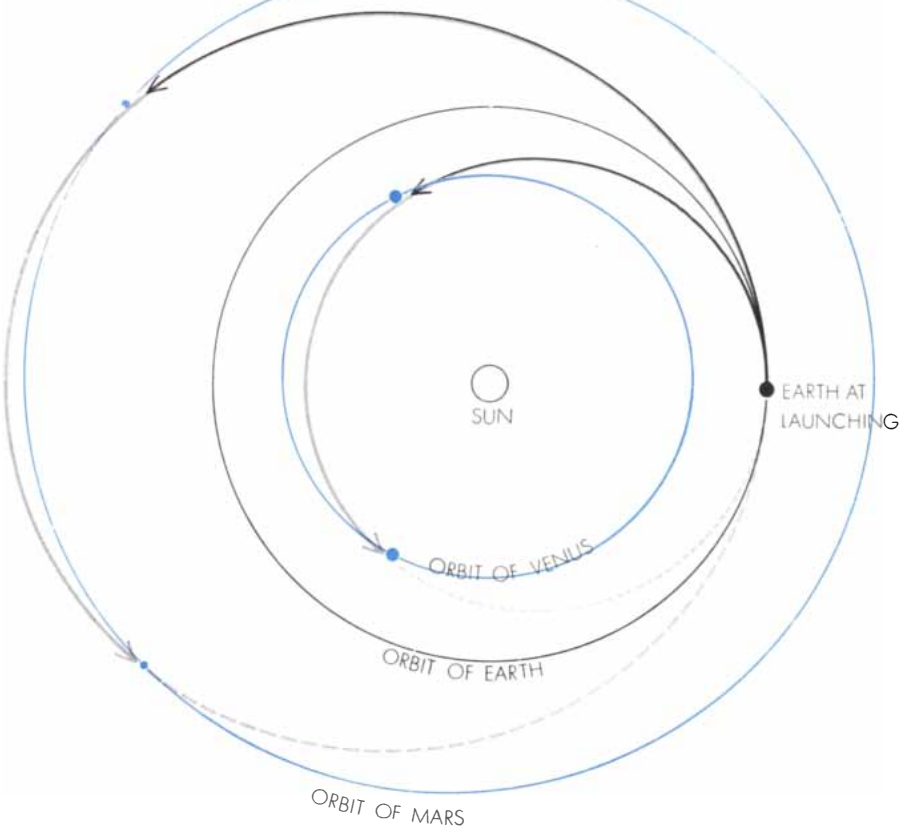
"APPROACH" TRAJECTORY to a planet, such as Venus, follows a hyperbola, as does the escape trajectory. The vehicle may swing around the target (*left*) or, by applying a braking thrust (*colored arrow*), go into orbit about it (*center*). At right is an "impact" trajectory.

around the sun before rendezvous, the launching date may be set with some flexibility. But the feasible dates will still group roughly around a minimum-energy date. The higher-energy orbit will not simply graze the target orbit but will cross and recross it on the outbound and inbound legs of the flight. An earlier or later launching date will thus permit rendezvous at either intersection [*see illustration on page 70*]. Necessarily, however, the vehicle will make its crossing at a larger angle and thus at a much higher velocity with respect to the target. This is undesirable both for simple probes that will sample the properties of the target planet as they pass by, as well as for the more complicated vehicles that are intended to make "soft" landings or enter satellite orbits around the target and so must slow themselves down.

The designing of a trajectory and the selection of a launching date are raised to another order of complexity by the third dimension of the solar system. The orbit of Venus is inclined at an angle of about 3.4 degrees to the plane of the earth's orbit (the ecliptic) and that of Mars is inclined at about two degrees. These angles are small, but they introduce considerable error into a trajectory or an optimum launching date calculated from a simplified two-dimensional picture of the solar system. In its motion around the sun Venus is at times as much as three million miles out of the earth's orbital plane. To make a successful rendezvous with Venus the vehicle must approach to within 10,000 miles of the planet. Since Venus spends only about one day in 112 within this critical range of the ecliptic, there is little chance that the day will also correspond with the rendezvous date of a minimum-energy flight wholly within the plane of the ecliptic. Even on such a day the geometry of the situation would bring the vehicle into rendezvous with Venus at an angle of 3.4 degrees and so at an unfavorable speed for effective observation or for placing the vehicle in orbit around the planet. One way out of this three-dimensional dilemma is to launch the vehicle in the plane of the target planet's orbit, that is, on a day when the earth is crossing the plane. Such an orbit has many features of the two-dimensional model. However, there is again no assurance that such a day will coincide with a minimum-energy day. On June 8, 1959, the last minimum-energy day for a Venus flight, it happens that the earth was also crossing Venus's orbital plane. An equally favorable opportunity will



RADIO RECEPTION OF DATA from a space vehicle may force alterations in its trajectory. Graph at bottom shows estimated range at which nondirectional signals of different power can be received by radio telescopes of various sizes. Heavy colored line shows the range of the largest present telescope, at Jodrell Bank in England; broken colored line, that of the 600-foot telescope now under construction. Diagram at top shows minimum-energy flights to Mars and Venus during 1960 and 1961. For Mars rendezvous is over 200 million miles from earth, beyond reception range; to reduce range to 90 million miles will require an additional 1,000 feet per second velocity at take-off. For Venus rendezvous is only about 40 million miles from earth, well within radio range.



TWO CLASSES OF TRAJECTORY are possible if the orbit of the vehicle crosses the target orbit twice. Class I trajectory (*black*) places the rendezvous at the first intersection of the orbits; Class II (*solid gray*), at the second. As shown here the two trajectories are schematic. In practice each of them would require a different take-off date from the earth.

not occur again for many centuries, though 1967 will bring a close approximation.

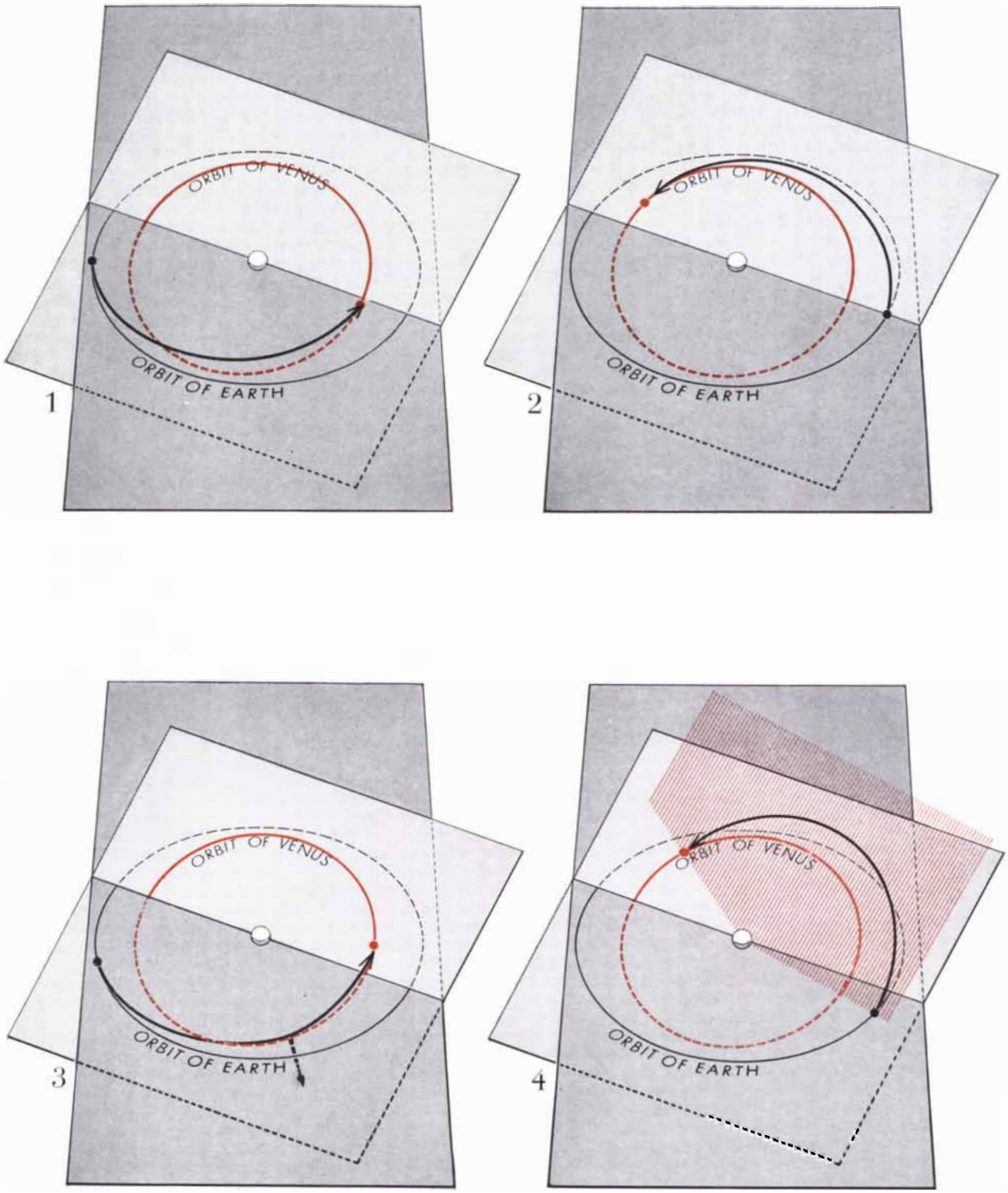
Until then the only solution is to design a trajectory that will be canted at a small angle to both the ecliptic and the orbital plane of Venus. While this method will work on any otherwise favorable day, it will require somewhat higher take-off energies than the two-dimensional model predicts. Approach velocities will generally also be higher because the vehicle approaches the orbital plane of the target at an angle. When the designer sets out to plot such a three-dimensional trajectory, he faces tricky compromises between take-off and approach velocities. For example, the next minimum-energy day for a flight to Venus, early in 1961, will require a burnout velocity fairly close to the 1959 ideal. But to hold the approach velocity down to a reasonable value the actual launching day must be advanced about a month to a time when the earth is closer to the plane of Venus. A successful launching on this day will call for an additional 1,000-feet-per-second of burnout velocity. This is one of the paradoxes of three-dimensional flight: a higher take-off velocity can mean a lower approach velocity.

The blessing of nature that set all of the planets traveling in the same direction around the sun now becomes apparent. With the "chase" approach that this makes possible, the vehicle can spend a reasonable time in the vicinity of the target planet. If the two objects were traveling in opposite directions, their courses would add, not subtract, their respective velocities.

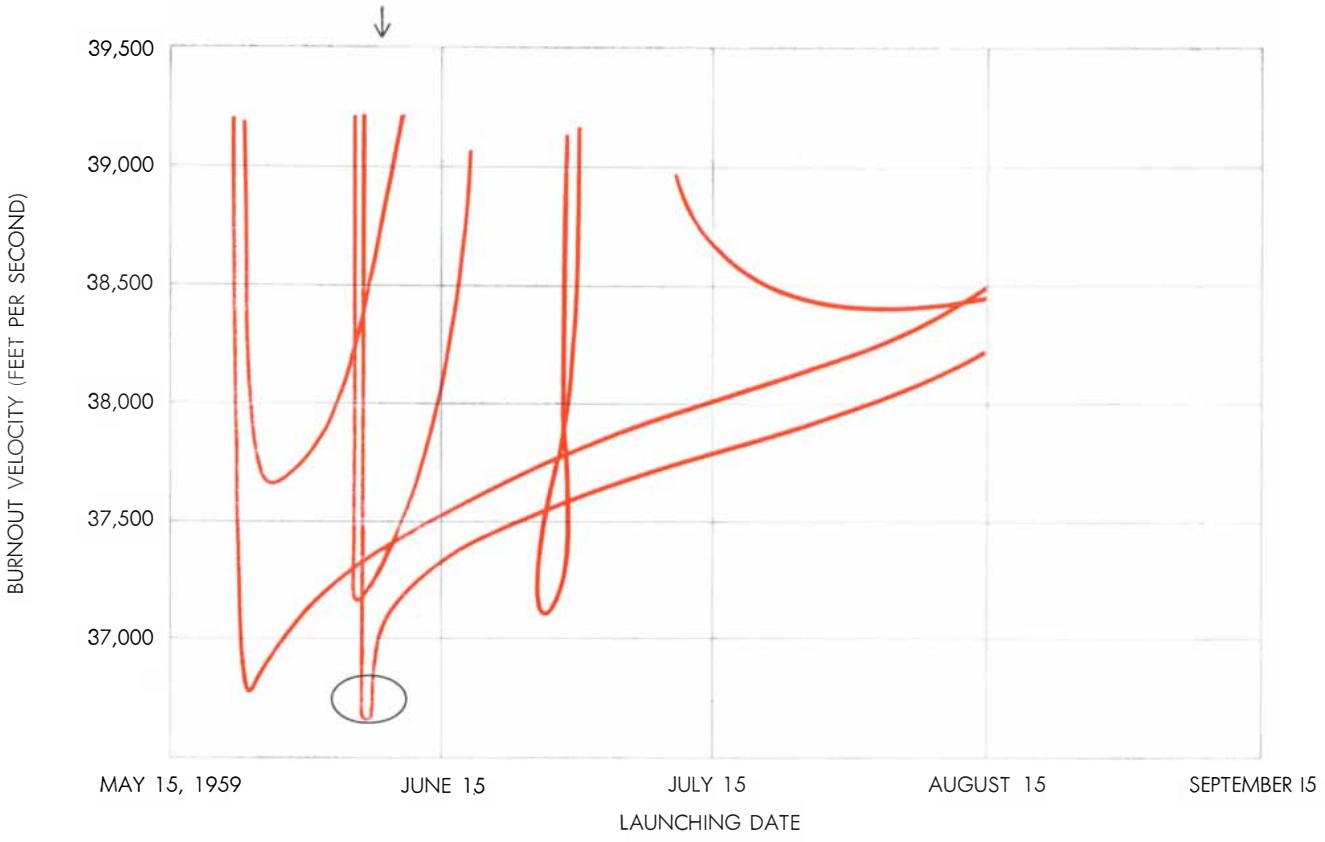
Since the purpose of the flight is to deliver information back to earth, the designer has to take account of still another problem. The vehicle must make its rendezvous within the range of radio communication. That range depends in part upon the power of the transmitter. But greater power means greater weight. The weight of the transmitter can be of course reduced by equipping the vehicle with a focusing antenna to beam its signal energy. But this requires that the vehicle also be equipped with instruments to sense its orientation in space and with stabilizing rockets to point the beam at the earth. Some of the burden on the vehicle can be removed on earth. The 250-foot paraboloid reflector of the Jodrell Bank radio telescope in England has already served this purpose in the *Pioneer I* and *II* flights. The 600-foot radio telescope now being built in West Virginia will extend the range even farther. On the other hand, the designer can solve this problem by choosing a launching day that will bring the rendezvous point closer to earth. A minimum-energy flight to Mars might establish rendezvous at 200 million miles from the earth, close to the operating limits of present transmitters and receivers. To reduce the distance to the more reasonable figure of 90 million miles the trajectory designer may set the launching on another day at a cost of an extra 1,000 feet per second in burnout velocity. Fortunately the most useful trajectories for a flight to Venus in 1961 will bring the rendezvous to a point about 40 million miles from the earth, well within the range of transmission. But the ideal date of June 8, 1959, would also have produced the same favorable transmitting distance. Man's conquest of space has come just too late to exploit the advantages of that day!

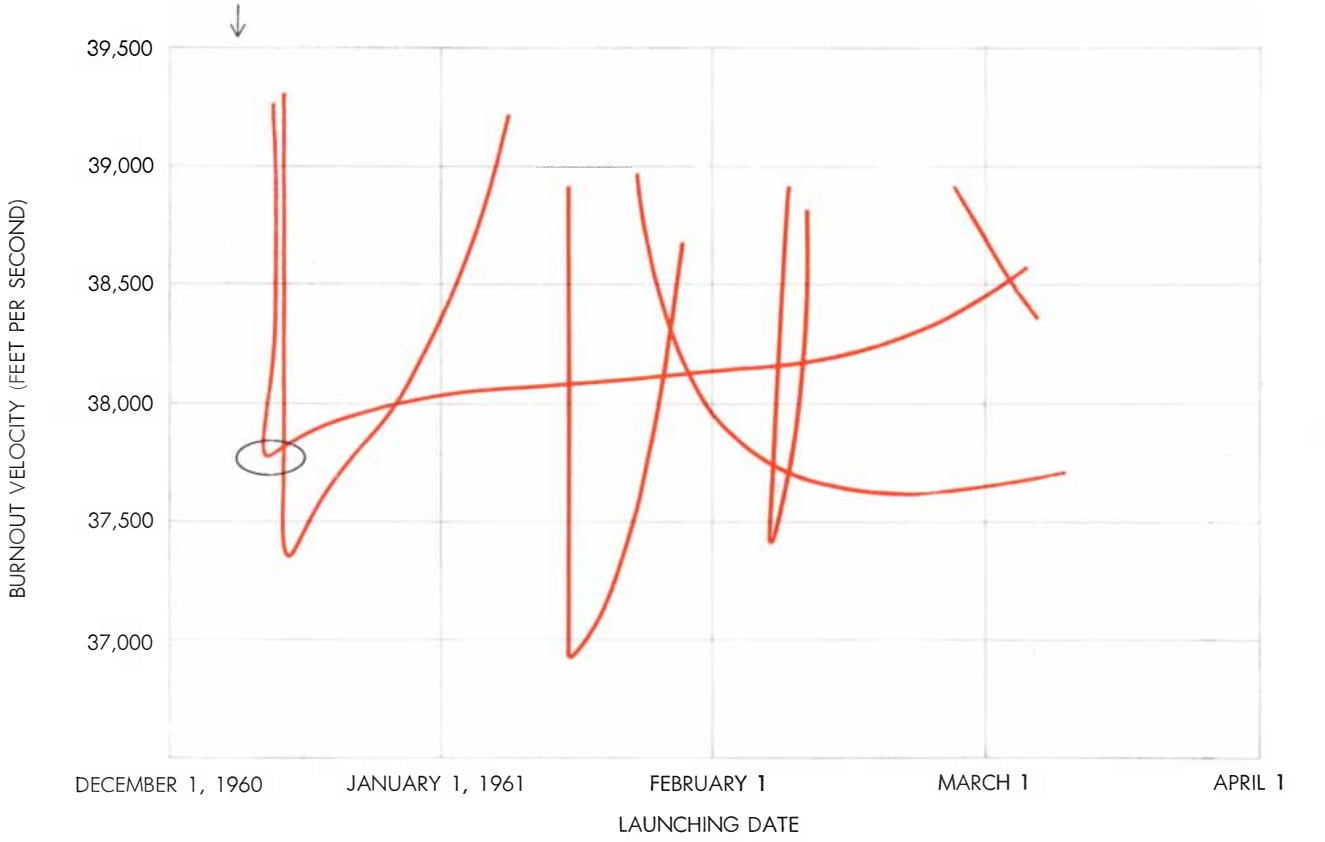
The interplanetary navigator's most difficult problems all derive from the fact that present vehicles are ballistic and so can be significantly guided only during the first few minutes of flight. The immense distances to be traveled will many times magnify any initial errors in aim or velocity. Although a Mars-bound vehicle can miss the planet by as much as 6,000 miles and still fall within its gravitational influence, even this near miss requires, for certain trajectories, a burnout velocity accurate to within one foot per second and an aim accurate to .001 degree. This is equivalent to shooting a duck at a distance of 11 miles.

Not all orbits require this degree of accuracy in both aim and velocity. In orbits approximating the two-dimensional case—for example, the lost opportunity of June 8, 1959—the vehicle makes a more nearly ideal chase approach to the target planet. As a result, minor alterations may be made in the take-off velocity in order to reduce the sensitivity of the orbit to small launching errors. In three-dimensional flight, inclination of the orbit to the orbital plane of the target planet diminishes the chase aspect of the approach. At an inclination of 90 degrees the chase aspect disappears altogether. For this reason three-dimensional flight sets much more severe guidance requirements than the two-dimensional model would suggest. In a flight to Venus during 1960 and 1961 the demands on the guidance system will be



FOUR TYPES OF FLIGHT PATH which take account of the inclination of the orbit of Venus to that of earth are shown here schematically; the angle between the orbits is greatly exaggerated. A vehicle launched in the orbital plane of earth (1) must reach Venus at a time when Venus is crossing that plane; the relative positions of the planets rarely permit such a flight. The same objection applies to a flight launched into the orbital plane of Venus when earth is crossing that plane (2). The vehicle might be shifted toward the orbital plane of Venus (3) by a strong corrective thrust (*broken arrow*), but would have to carry much fuel for this sole purpose. The most practical flight path (4) lies in a plane (*hatched*) that intersects the orbital planes of the two planets.





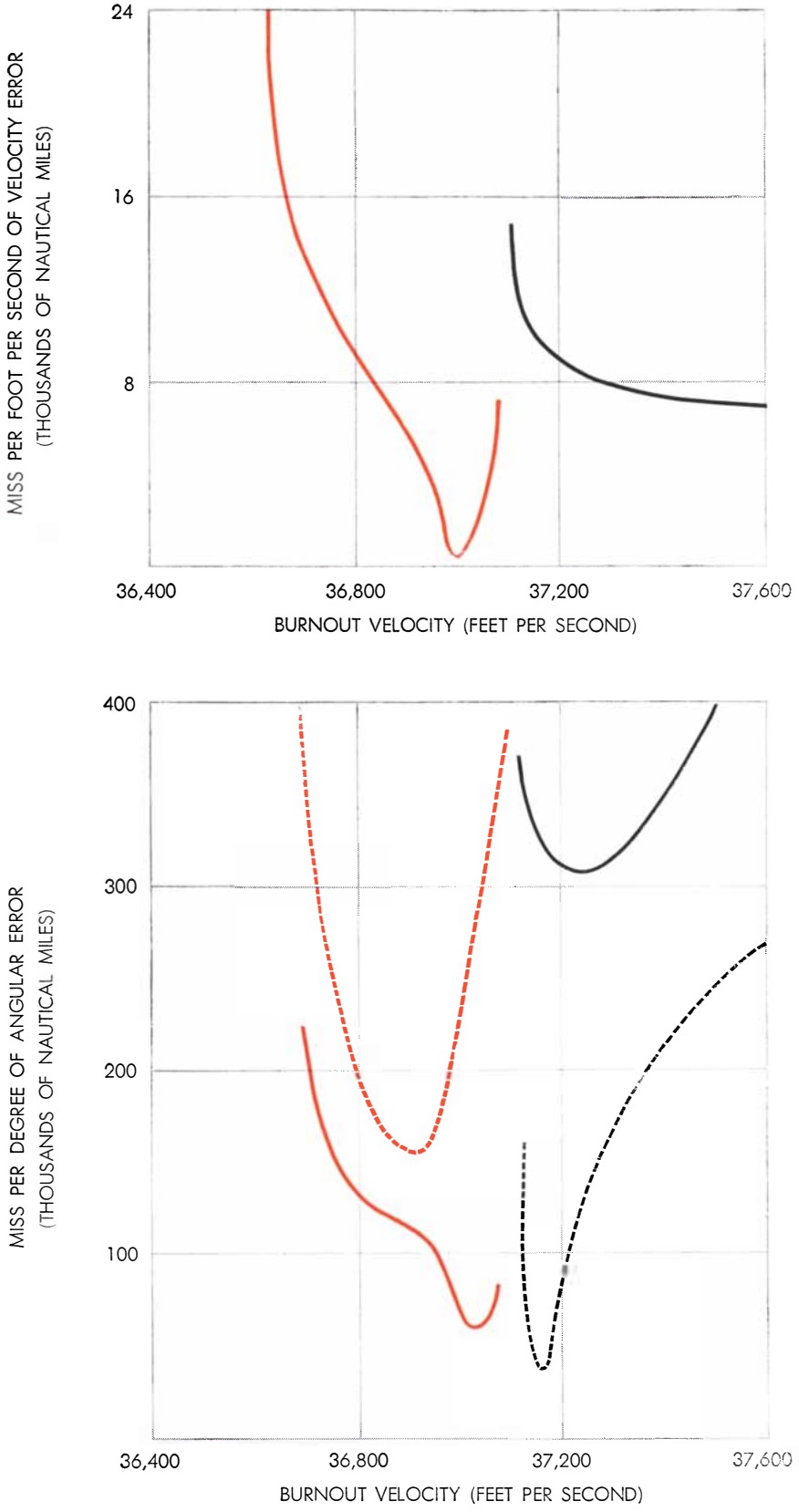
ENERGY REQUIREMENTS of flights to Venus during the 1959 (*top*) and 1960-61 (*bottom*) launching seasons are shown for selected orbits of widely differing characteristics. The "best" flight in February, 1961, would require little more energy than the "ideal" flight of June, 1959, but would approach Venus at an undesirably high velocity. Ellipses suggest the area within which minimum-approach velocities are possible; arrows indicate the dates when earth crosses the orbital plane of Venus. For a reasonably low-approach velocity during the 1960-61 season, the take-off date would have to be advanced and energy requirement raised considerably.

10 times as stringent as those that held in 1959. To design a three-dimensional trajectory requires the analysis of simultaneously acting gravitational fields, the very theoretical problem that has defied physicists and mathematicians for nearly three centuries. The present empirical solution is to run the equations of motion for many alternative trajectories on a large digital computer and plot sensitivity curves for the results. Such curves reveal the surprising fact that changes in the burnout velocity amounting to only a few feet per second can increase or decrease the sensitivity by a factor of 100.

At some sacrifice in payload, launching errors can be corrected by small rockets installed in the vehicle and fired on radio command from the earth. But a corrective thrust in the right direction implies control over the orientation of the vehicle in space. This can presently be achieved by imparting a spin to the vehicle at take-off; gyroscopic action then holds the axis of the vehicle stable with respect to any fixed point in space. As the vehicle proceeds on its elliptical orbit the axis goes through a slow but predictable shift with respect to the orbital direction of the vehicle. At some moment it will be pointing in the right direction for firing the corrective thrust.

More powerful rockets, now in the offing, will extend the range of possible launching velocities. But speed is no solution to the problem of error. Burnout velocities of double the minimum-energy value would multiply aiming and approach problems 10-fold. Any increase in power will therefore be employed to increase the mass of the vehicle, making it possible to install more sophisticated course-correction devices and observing instruments. A larger vehicle might carry a computer and instruments to sense the position of the sun or certain bright stars. Small rocket jets, turning the vehicle in response to these instruments, could point the vehicle in the right direction for a corrective thrust.

Ultimately, still more powerful rockets will lift continuous-propulsion space vehicles free of the earth's gravitational field. These vehicles will be driven by small engines, perhaps powered by nuclear reactors [see "Nuclear Rockets," by John J. Newgard and Myron Levoy; SCIENTIFIC AMERICAN, May, 1959]. Such vehicles can be continuously navigated by automatic or even human pilots. But all the important aspects of their trajectories will still be designed in advance by earth-bound trajectory analysts.



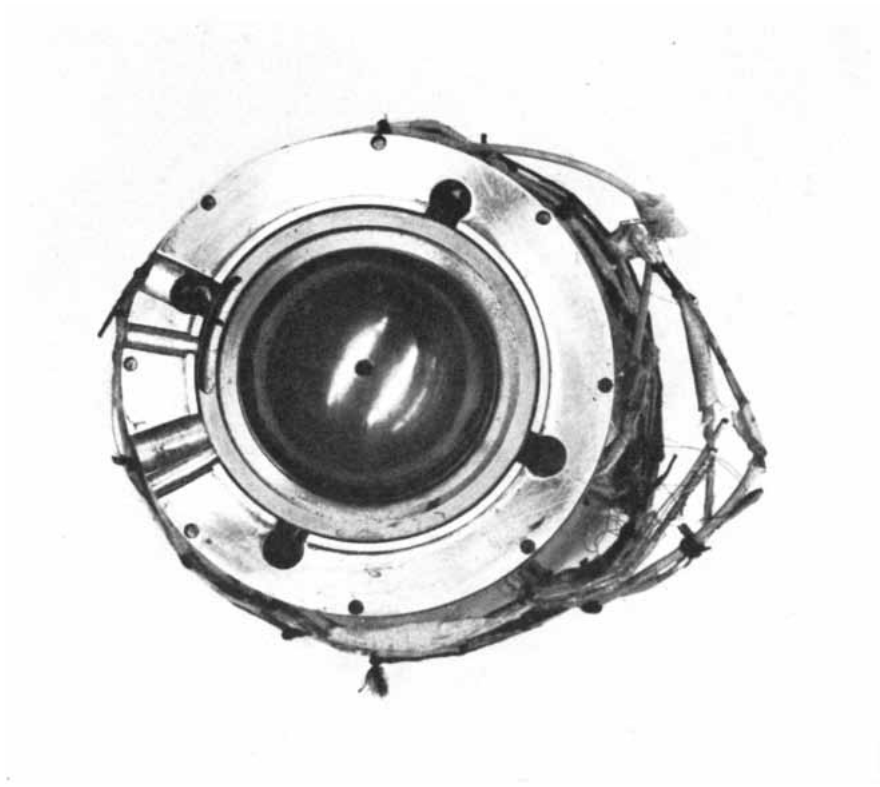
GUIDANCE REQUIREMENTS of a Venus flight on June 9, 1959, are shown here for Class I (*color*) and Class II (*black*) orbits. Graph at top gives the effect of velocity errors; graph at bottom shows the result of errors in the two aiming components: azimuth (*solid lines*) and flight-path angle (*broken line*). Evidently no burnout velocity can simultaneously minimize the effect of all three types of error. June 9, 1959, was an almost "ideal" launching date; the guidance requirements for 1960-61 flights to Venus will be 10 times as stringent.

Applications of Superconductivity

When certain metals are cooled almost to absolute zero, they become superconductive, that is, their electrical resistance disappears. This remarkable phenomenon is now being turned to technological purposes

by Theodore A. Buchhold

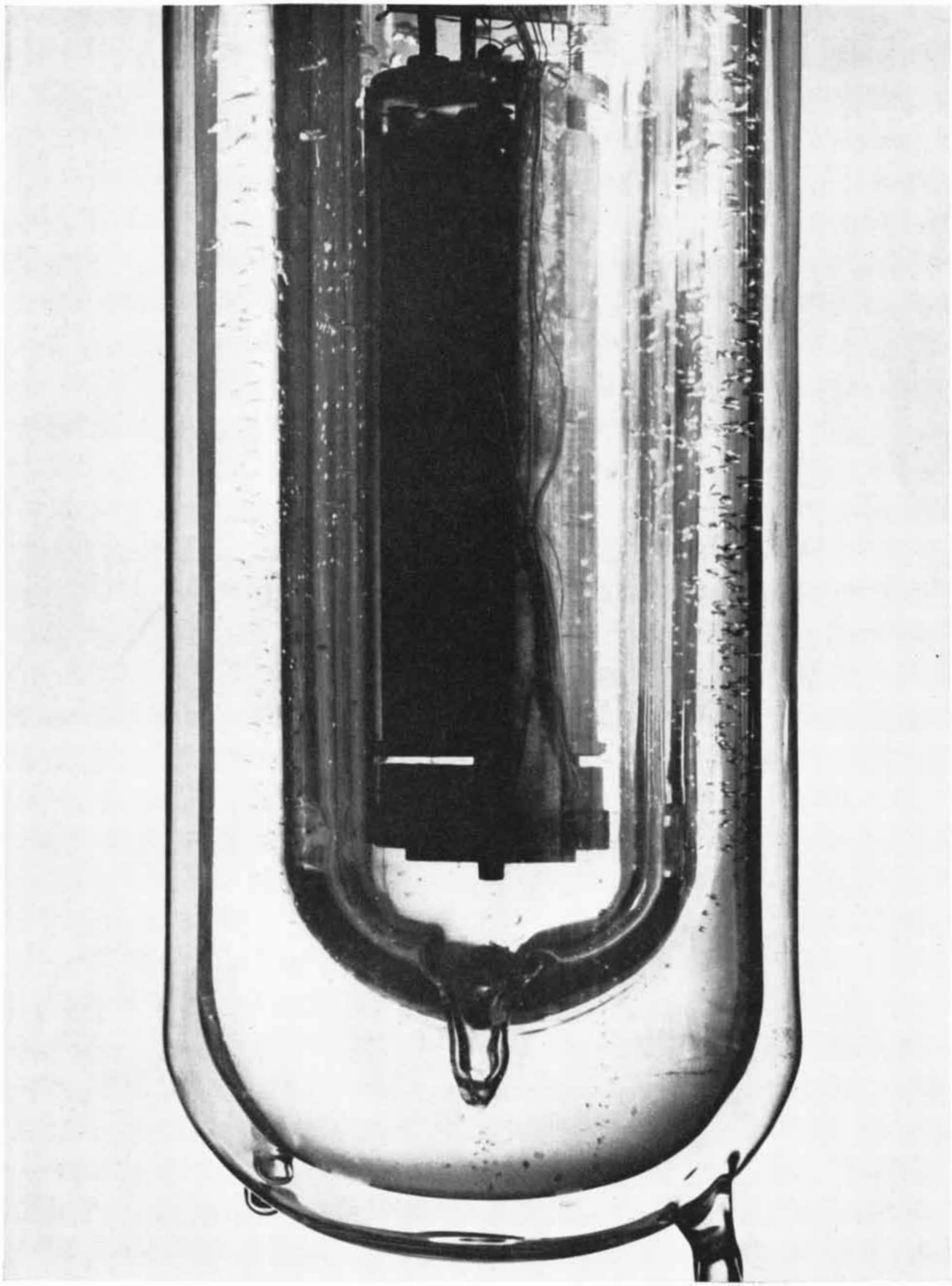
Superconductivity—the total disappearance of electrical resistance—is a strange property of matter that makes its appearance in the remote realm of temperatures close to absolute zero. It confounded the classical theory of electromagnetism when it was discovered some 50 years ago. It remained until four years ago an intractable riddle to the new quantum physics. Yet in a very few years from now superconductivity is going to prove to be a windfall to technology. Engineers are engaged in the design of superconductive bearings distinguished by the absence of friction, electric motors with extraordinary efficiency, tiny and reliable switching elements for computer circuits, magnetic lenses with unprecedented resolving power for electron microscopes, noiseless amplifiers and other devices with characteristics that approach ideal standards. In the future workers in other fields of engineering are sure to find that superconductors, insulated from their immediate environment in cold chambers, will provide unexpected solutions for an increasing variety of design problems.



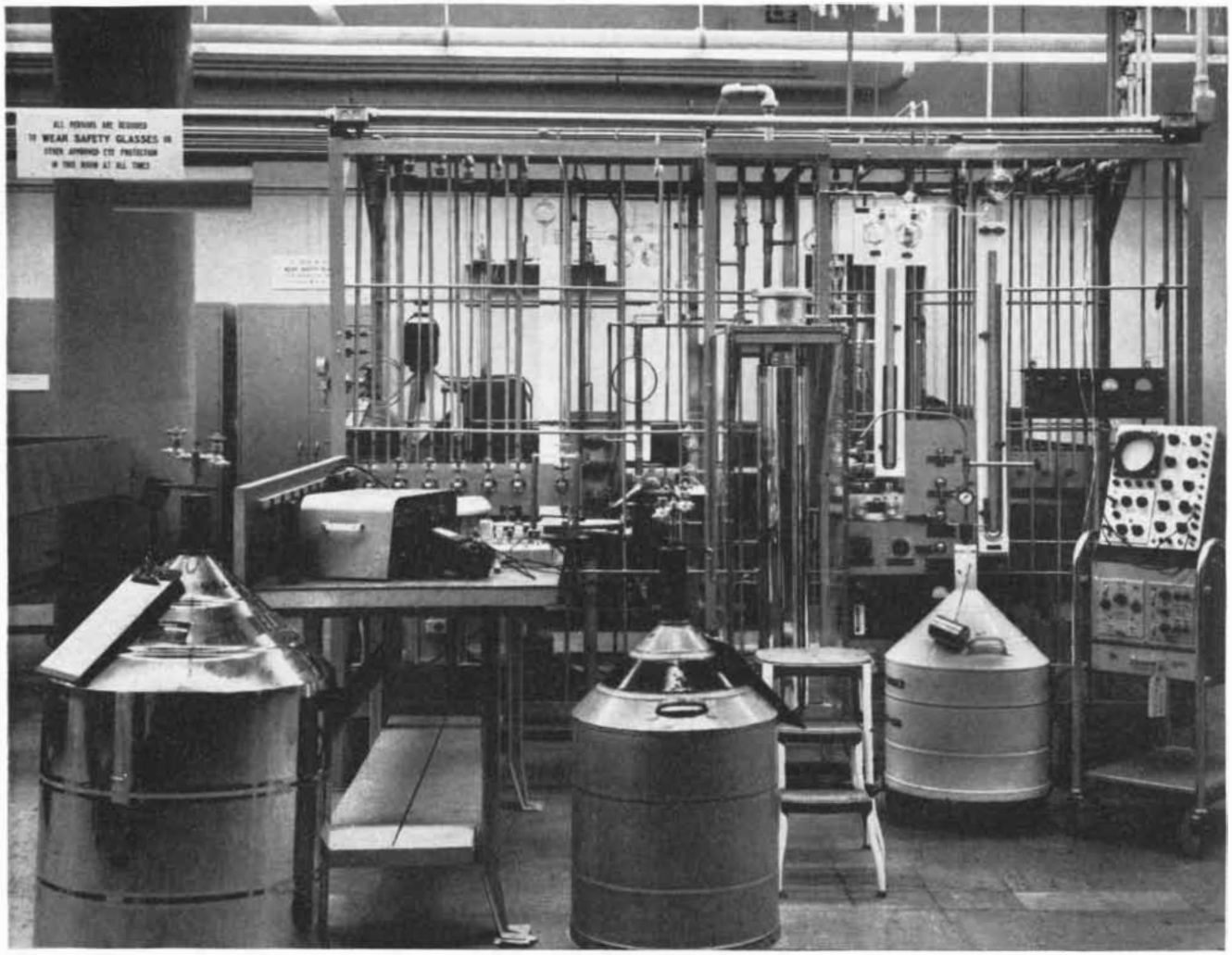
SUPERCONDUCTIVE GYROSCOPE, shown here in pilot model, is being developed by the General Electric Company. The spherical rotor floats without friction in an "atmosphere" of magnetic flux. Upper housing has been removed to show interior structure.

It was well understood in classical electromagnetism that the resistance of an electrical conductor should fall with temperature. The explanation could be pictured quite graphically. An electric current consists in the flow of free electrons through the crystal lattice of the conductor. At room temperature the thermal vibration of the atoms in the lattice increases the probability that the electrons will collide with them; this impedes the flow of electrons and sets up resistance to the current. At lower temperature, with the vibration of the atoms reduced in amplitude, the electrons collide with the atoms less frequently, and the current encounters less resistance. At absolute zero the atoms were supposed to cease vibrating entirely. But there would remain some resistance to the flow of current because a few electrons would still collide with the now-stationary lattice and with the defects and impurities that distort the lattice structure in all but perfect crystals.

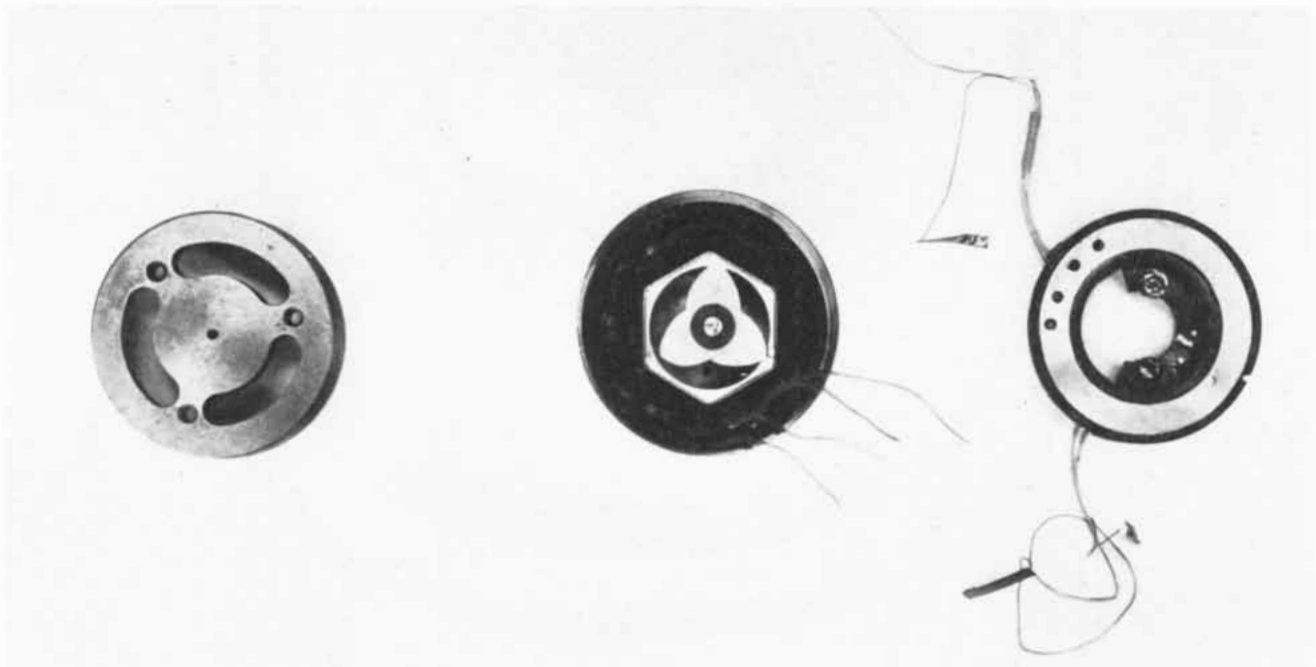
This model worked with complete satisfaction down the temperature scale as investigators approached closer and closer to absolute zero. Then, in 1911, it failed completely when the Dutch physicist Heike Kamerlingh Onnes froze mercury in a bath of liquid helium. He ran a current through the mercury and watched as his instruments showed resistance declining with temperature. The familiar relationship between the two properties held until the temperature reached 4.2 degrees absolute (degrees centigrade above absolute zero). Suddenly the electrical resistance of the mercury vanished; there was not even the residual resistance betokening collisions between electrons and defects and



LOW-TEMPERATURE ENVIRONMENT is maintained in this Dewar flask within a Dewar flask. Outer double-walled flask holds liquid nitrogen (at 77.3 degrees absolute), which insulates liquid helium (at 4.2 degrees) in the inner double-walled flask. Tall cylinder, weighing 12 pounds, is supported by magnetic flux of small cylinder at bottom. Bubbles are due to boiling of liquids.



LOW-TEMPERATURE INSTALLATION at the General Engineering Laboratory of the General Electric Company is the site of the experimental apparatus depicted on the preceding page. The large Dewar flask is at right center. Cans contain liquefied gases.

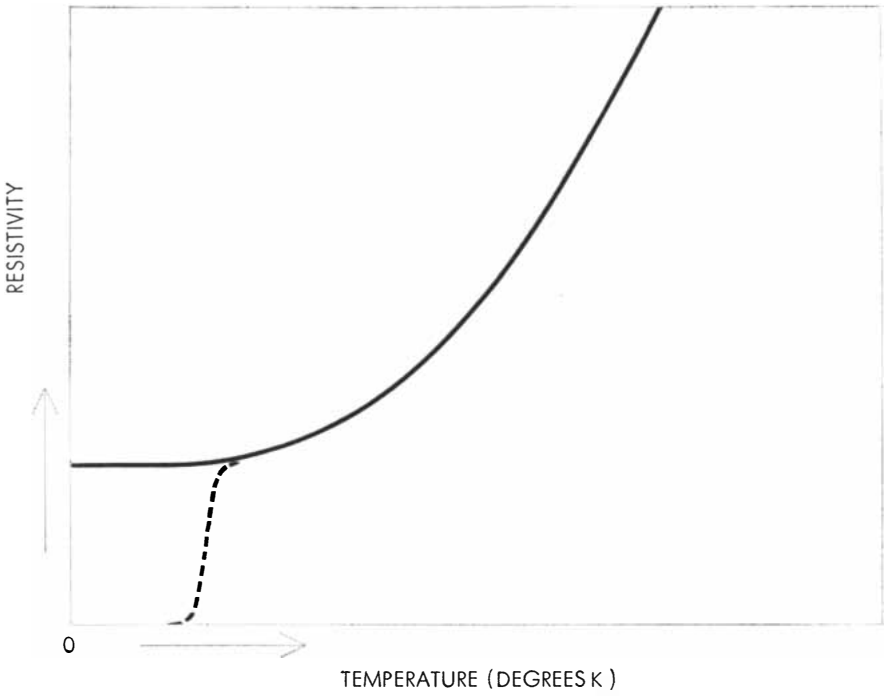


PROTOTYPE OF SUPERCONDUCTIVE MOTOR includes supporting elements (*left and right*) and stator housing (*middle*). Hexagonal structure in stator housing is the rotor, an aluminum core wrapped in niobium foil, which turns at 700 revolutions per minute in a bath of liquid helium. Its hexagonal shape, necessary for it to develop torque, is explained in top illustration on page 81.

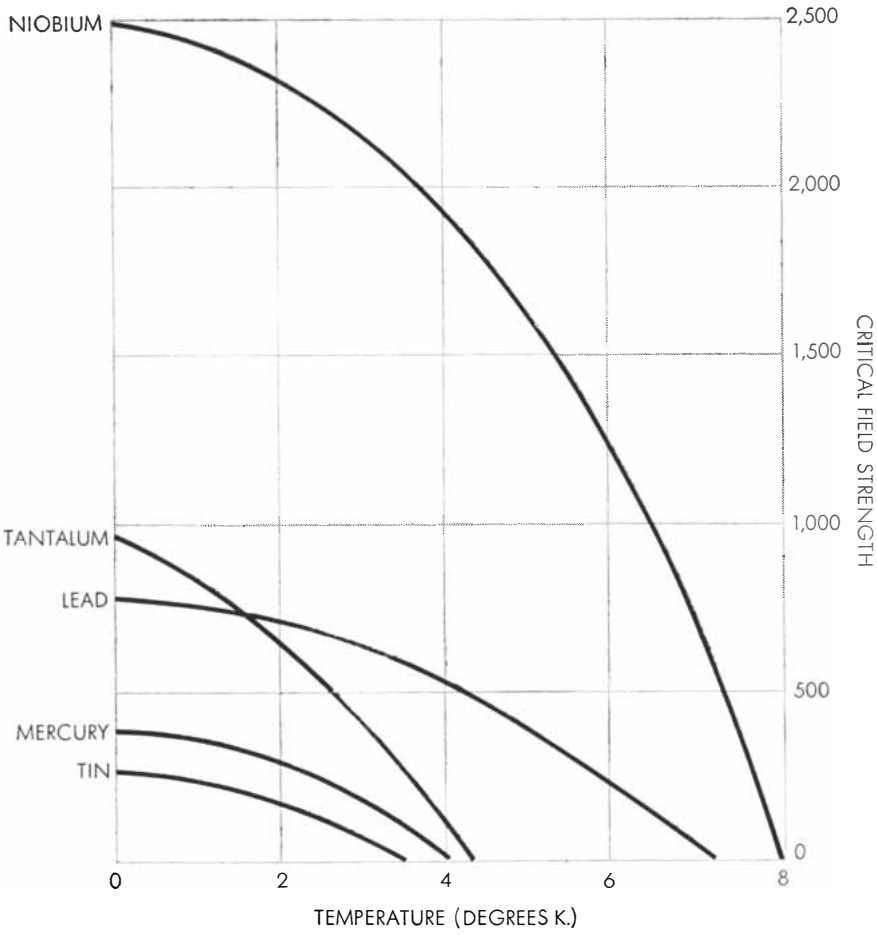
impurities in the lattice predicted by the classical model.

Kamerlingh Onnes found that other metals, among them tin, lead, tantalum and niobium display the same abrupt disappearance of resistance near absolute zero. It does not occur in all metals; strangely, the best electrical conductors, copper and silver, do not become superconductive. But certain alloys and compounds, as well as pure metals, become excellent superconductors under the right conditions. The property puts in its appearance and disappearance just as suddenly in each material but at a different "transition" temperature—generally only a few degrees above absolute zero. Superconductivity can also be destroyed if the metal or alloy is exposed to a magnetic field of sufficient strength, whether the field is applied externally or set up by the current flowing through the superconductor itself. In each material the field strength required to erase superconductivity varies with temperature within the range in which the material is superconductive. The metal niobium, for example, has a transition temperature of 8 degrees; its critical field-strength is 2,000 oersteds at 4.2 degrees and rises to 2,400 oersteds at 1 degree. Critical field-strength varies not only with temperature, but also with the purity of the material, with mechanical stress and with the configuration of the specimen in question. Depending upon these factors, niobium has shown field-strengths as high as 4,000 oersteds. An alloy of niobium and tin has so far shown the highest transition temperature, 18 degrees, and may have a critical field-strength as high as 16,000 oersteds at 4.2 degrees.

Experimental findings of this kind troubled theoretical physicists for more than 40 years. Superconductivity was the one phenomenon in the domain of quantum physics which that powerful system could not explain. Some six years ago B. T. Matthias of Bell Telephone Laboratories set out to discover by empirical methods the order underlying the appearance of superconductivity in elements and compounds. He made systematic measurements on a great variety of materials, and in the course of his investigation developed many promising new superconductors. He also found a pattern of results that sometimes helps in predicting which materials will become superconductive. In general it appears that elements with three, five or seven electrons in their outer electron-shells become superconductive most easily,



ABRUPT DISAPPEARANCE OF RESISTANCE in superconductors as they approach absolute zero (–273 degrees centigrade) is indicated by the broken line in this graph. The resistance of nonsuperconductive metals falls to a minimum value (*solid curve*).



CRITICAL FIELD STRENGTH of superconductors rises as temperature falls. Niobium (*top curve*) becomes superconductive at about 8 degrees absolute, but at that temperature even the weakest magnetic field renders it resistive again. At 5 degrees niobium withstands a field strength of some 1,600 oersteds; at 1 degree, a field strength of almost 2,500 oersteds.

while those with only one or with more than eight do not become superconductive at all [see "Superconductivity," by B. T. Matthias; SCIENTIFIC AMERICAN, November, 1957].

As Matthias proceeded on this line of investigation, John Bardeen and his colleagues at the University of Illinois succeeded in bringing superconductivity within the equations of quantum theory. They found that some fraction of the total population of current-carrying electrons in a superconductor are "paired" in the sense that the resistance set up by the collision of one electron is precisely offset by the rebound of its partner from a simultaneous collision, so that no net resistance to the current is set up. At temperatures above the transition point, or in magnetic fields of greater than critical strength, these electrons are "unpaired." Their collisions are no longer self-canceling but additive, and electrical resistance is restored.

The first practical applications of superconductors arise not so much from the currents they conduct so easily as from the magnetic fields these currents set up. Once a current has been started in a superconductor it continues to flow without variation or decay—theoretically forever—after the power source has been disconnected [*see top illustration on page 80*]. The superconductor thus becomes a kind of perpetual-motion machine. But it is the magnetic flux, frozen into the superconductor with the current, that makes this curious phenomenon useful. The frozen-in flux makes it possible to use the current to calibrate other currents. The current to be calibrated is simply conducted through the cold environment, and its magnetic flux is compared with that of the superconductor.

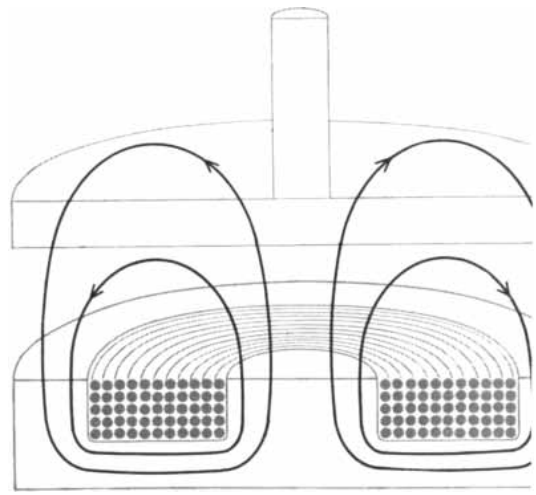
The same relationship between electricity and magnetism accounts for another remarkable property of superconductors: they act as insulators against magnetic fields. When an external magnetic field is brought near a superconductor, or any conductor for that matter, it sets up eddy currents in a surface layer of the material. In an ordinary conductor this surface layer may be relatively deep, and the resistance of the material quickly suppresses the eddy currents. In a superconductor, on the other hand, the eddy currents are confined to a layer only about .0001 millimeter deep, and they continue to flow without deterioration. The magnetic flux associated with the eddy currents is oriented in a sign parallel to that of the external field. In effect the surface of the superconductor becomes a magnetic mirror, reflecting the lines of force of the impinging field.

The magnetic-mirror effect suggests a variety of useful applications of superconductivity. In an electron microscope, for example, magnetic fields focus the image formed by the beam of electrons. These fields are shaped to act as "lenses" by the doughnut shape of the magnet that produces them, the lines of force being concentrated in the hole in the middle. Since the magnetic-mirror effect involves only the outer surface of materials, a superconducting foil shielding the contours of the center hole and employed as shielding elsewhere in the instrument will perfect the shape of the magnetic lens. The improvement in resolution may make it possible to produce an electron microscope in which atoms can be seen. For certain biological and chemical investigations (for example, studies of free chemical radicals) which require low temperatures in any case, the necessary refrigeration will create no serious complications.

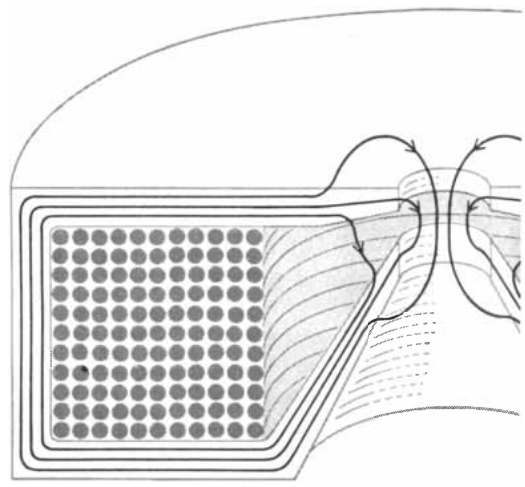
Superconductive surfaces might also improve the performance of the resonant cavities of the oscillators that generate microwaves. Because superconductors offer little resistance to high-frequency electric currents, they would greatly enhance the efficiency of these cavities and stabilize the oscillator on its frequency with an accuracy approaching that of an atomic clock. In the low-temperature environment necessary for superconductivity, moreover, metals neither expand nor contract; the enhanced structural stability would hold the geometry of the resonating cavity constant.

The magnetic-mirror effect inevitably suggests the idea of a frictionless magnetic bearing, one that would ride upon a cushion of magnetic flux. At the General Engineering Laboratory of the General Electric Company we have made a model of such a bearing. It consists of a superconductive coil of niobium wire above which we mount a superconductive disk in such a way that it can move vertically but not laterally. A current passing through the coil creates a magnetic flux that repels the disk and pushes it upward. With the flux trapped in the coil [*see top illustration at right*], the disk remains suspended on the flux. Pushing the disk downward toward the coil compresses the flux, raising its density, thereby increasing the current in the coil and amplifying the repelling force of the flux; the upward force of the flux increases, in fact, as the square of the increase in the flux density. Tests have shown that the model bearing can produce an upward push of 300 grams per square centimeter of coil surface. With small gaps between disk and coil, good bearing stiffness can be obtained. Conventional magnetic and electrostatic devices cannot match this performance without the aid of complicated feedback circuitry.

It is only a small leap of the imagination from a simple bearing such as this, which sustains a vertical load, to a



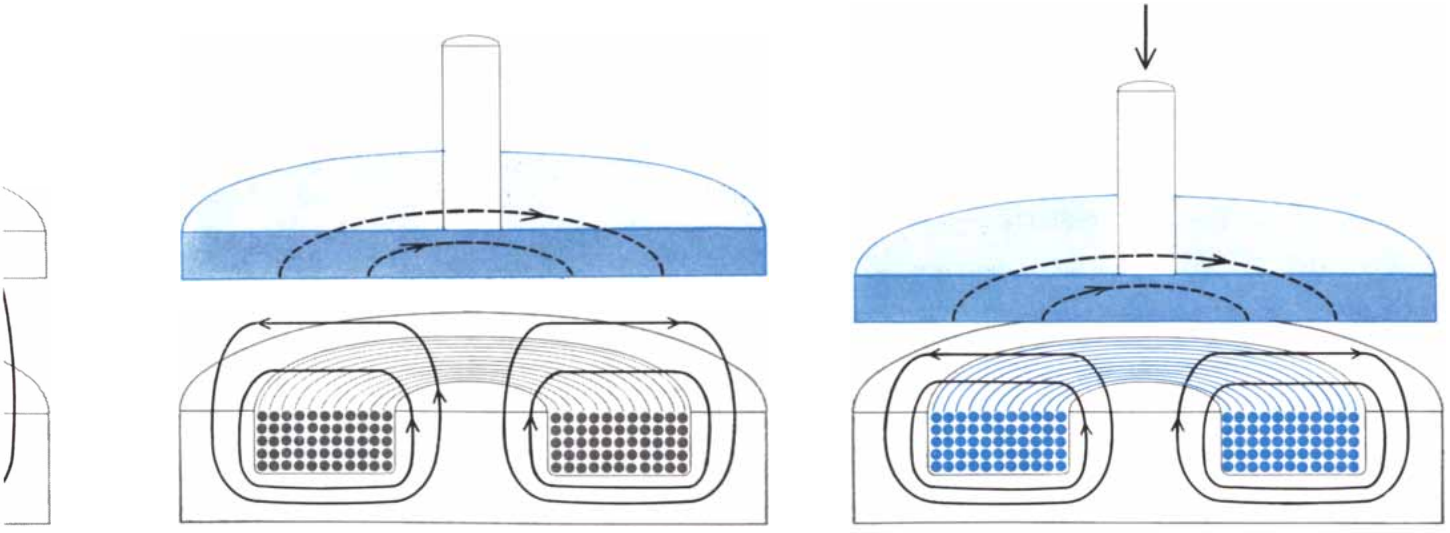
MAGNETIC BEARING is based upon the ability of superconductors to insulate magnetic fluxes. In the illustration at left the magnetic flux (*black lines*) generated by



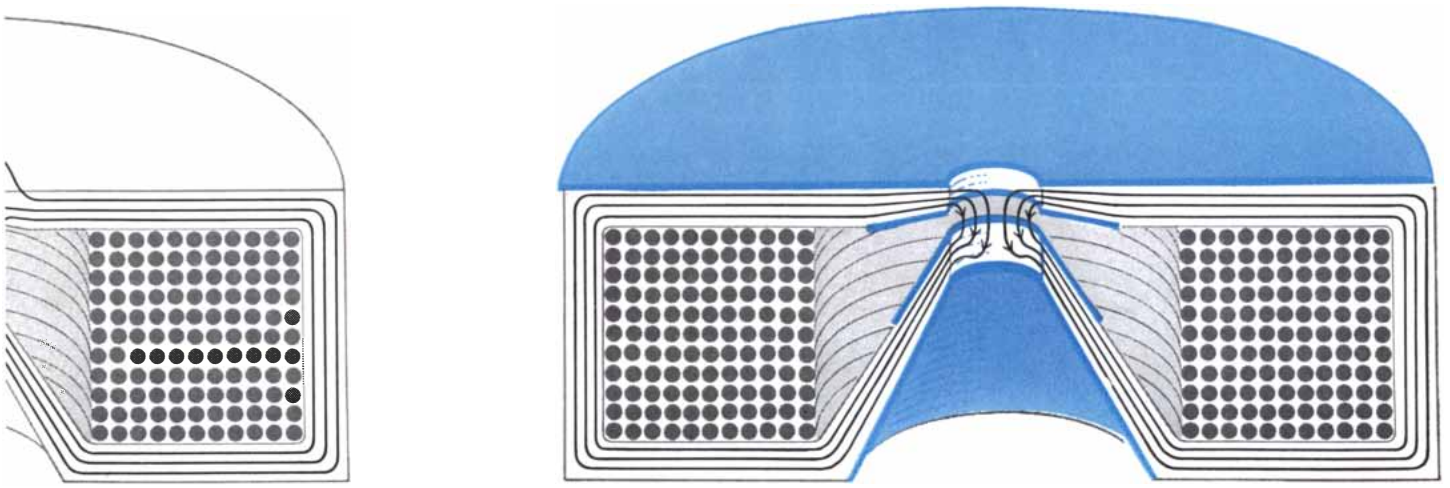
MAGNETIC-INSULATING SHIELDS may so greatly enhance the resolving power of electron-microscope lenses that they could

pair of magnetic bearings to support a rotating shaft [*see bottom illustration on page 80*]. In another small leap one can conceive of a three-dimensional arrangement of six such bearings to float a body in a magnetic "atmosphere." If the floating body is now rotated, it becomes in effect a gyroscope in which the superconductive magnetic bearings replace the conventional gimbals. To make it spin, the body would of course become the rotor of an electric motor.

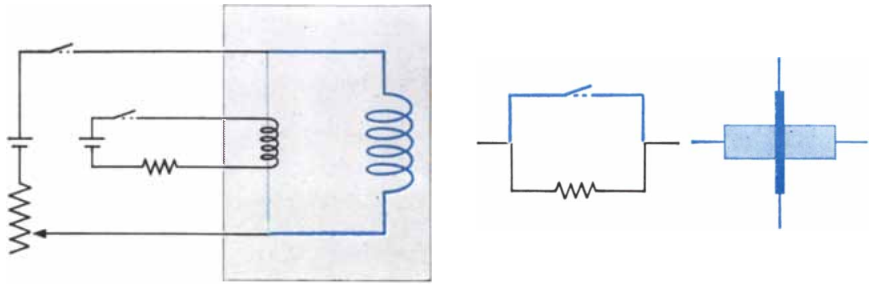
The superconductive electric motor is a topic in itself. Superconductive bearings would eliminate the major source of friction. If the stator coils as well as the rotor are made superconductive, the motor should have an efficiency of nearly 100 per cent. The rotor, however, cannot have the conventional cylindrical shape. Since the lines of force set up by the stator coils are perpendicular to the surface of the rotor, they produce no torque, and the rotor will not turn on its bearings. If the rotor is given the shape of a polygon, the lines of force exert the desired torque [*see top illustration on page 81*]. A rotating flux, produced as in any alternating-current polyphase winding motor, will turn the rotor; increase in the frequency of the coil currents will turn the rotor faster. We have built a model motor on these principles and driven it up to 20,000 revolutions per minute, the speed being limited only because the rotor was not built to withstand higher centrifugal forces. The low temperature in which the motor must operate to maintain superconductivity limits its usefulness to special applications; for example, a high-precision gyroscope.



the electromagnetic coil passes unhindered through a disk which is not superconductive. The magnetic insulating ability of a superconductive disk (*middle illustration*) arises from its ability to repulse the magnetic flux. In the illustration at right this ability to insulate against magnetic flux is applied in design of a bearing that has extremely low friction. As the superconductive disk descends under a load (*arrow*), it compresses the flux lines of the superconductive coil. Their increased density repels the disk more forcefully.



make atoms visible. Illustration at left shows unwanted stray lines of magnetic flux (*black lines*), which are among factors that limit ability of conventional lens to focus image-carrying electron beam. Superconductive shields (*colored areas*) on the lens at right eliminate stray flux lines and shape the magnetic field, thereby improving its ability to focus the electrons and form a sharp image.



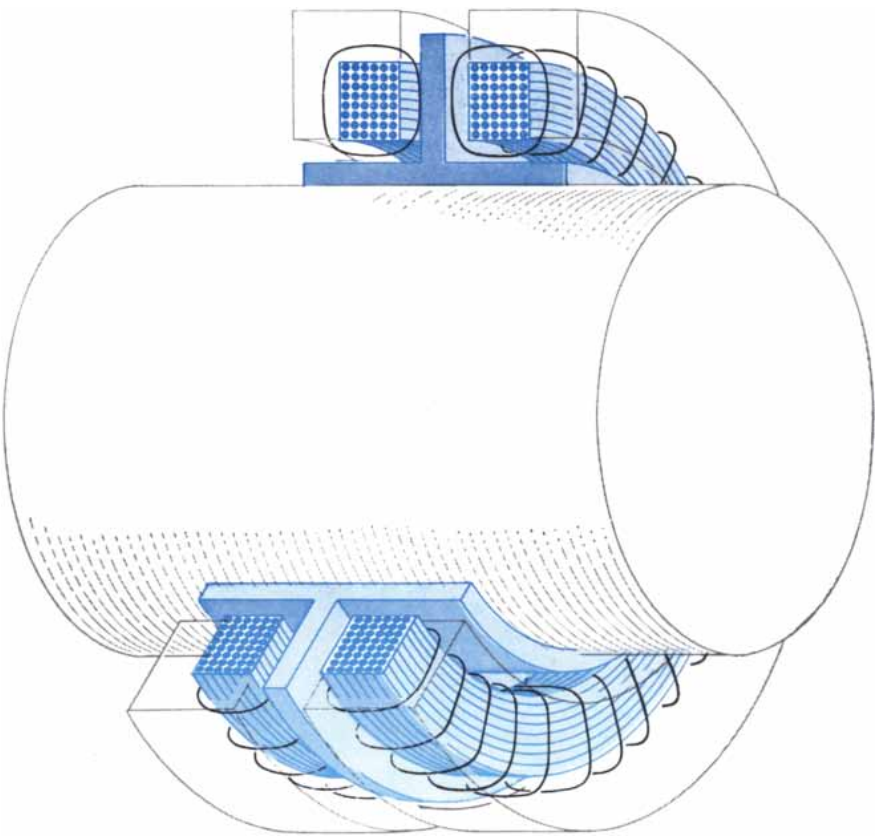
FLUX TRAP (*left*) is basis of several superconductive devices. Superconductive circuit (*color*) in low-temperature environment (*gray*) conducts current from source at left. Small heating coil keeps shunt (*light color*) resistive when switch is closed; when switch is open, coil cools and shunt becomes superconductive. Opening switch in nonsuperconducting part of superconductive circuit then cuts circuit from power source, trapping current and its flux indefinitely. Middle drawing shows analogy between resistive and superconductive states of shunt. When resistive, it is in effect an open switch; when superconductive, it is a closed one. Drawing at right shows a printed cryotron. When flux of vertical element exceeds the critical field strength of the horizontal element, the latter becomes resistive.

Superconductive amplifiers comprise another branch of the family of devices that derive from the basic magnetic bearing. In the bearing the vertical motion of the disk acts on the magnetic flux of the coil and converts its steady, or direct, current to a changing one. In the case of the amplifier the flux, instead of being trapped, will be produced by a current fed in from a signal source. The up-and-down motion of the disk will now vary the density of the flux. With an insulated second coil wound around the first one the changing flux will induce an alternating voltage in the second coil. As the current in the first coil is increased or decreased the output voltage of the second coil is increased or decreased proportionately. Here is the working principle of an amplifier that would convert direct current to alternating current. Since the superconductive coils offer no resistance to electrical current, regardless of the number of turns of wire in their construction, the amplifier would have infinitely high gain, or amplification.

To increase the operating frequency of such an amplifier, the disk can be segmented like a Maltese cross and, instead of moving vertically, can be made to rotate between four opposed pairs of fixed superconductive coils [*see top illustration on page 82*]. The flux of an encircling direct-current coil would be alternately repelled and passed by the blades and spaces of the rotating disk. The intermittent flux would induce an alternating current in the coils with a frequency dependent upon the speed at which the disk rotates. Such an amplifier would have zero drift, that is, perfect stability; and since it is always superconductive it would also be noiseless.

The responsiveness of superconductors to small changes in temperature and field strength qualifies them for service in high-precision switching and sensing devices. A superconductive heat-detector will operate in the narrow area within which resistance very rapidly declines to zero [*broken line in top graph on page 77*]. In this area very slight changes of temperature cause sharply defined changes in the resistance of the superconductor. The change in resistance thus provides an accurate measurement of change in temperature.

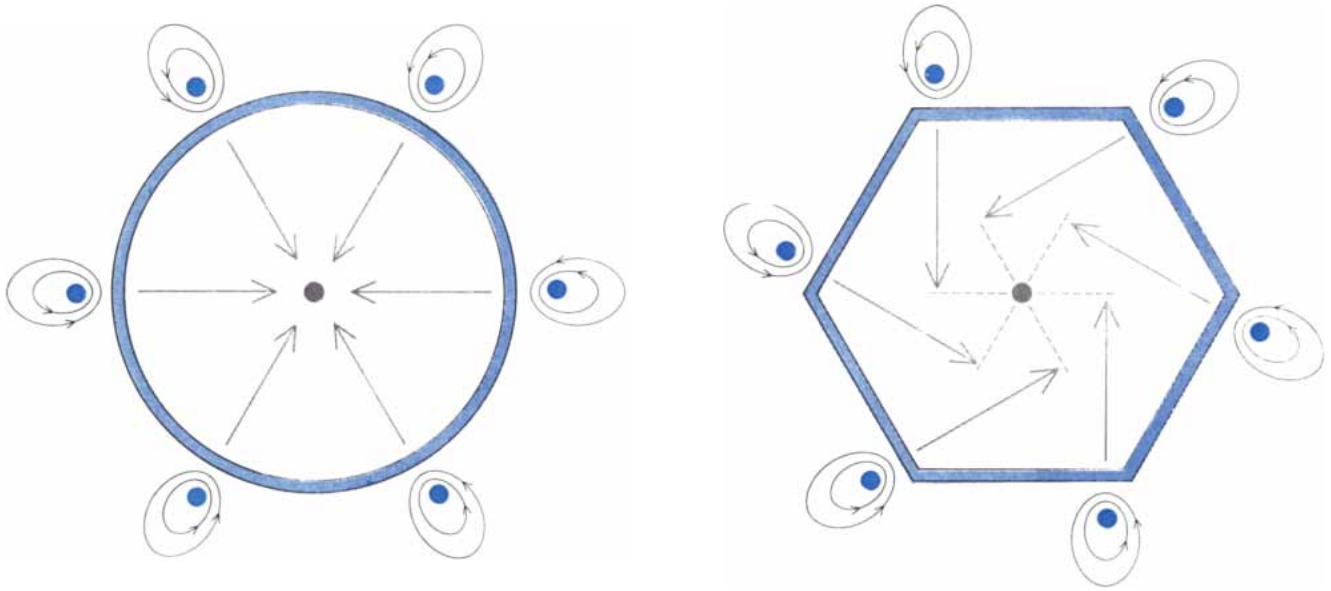
Superconductors are as sensitive to changes in magnetic-field strength as they are to changes of temperature. The cryotron, a relatively simple switching device, operates on the principle that a superconductor is rendered resistive by a magnetic field that exceeds its critical field strength. One element of a cryotron, a superconductive coil having a high critical field strength, surrounds the other element, a wire having a lower critical field strength. A slight increase in the coil current, and hence in its flux, renders the wire resistive; a decrease of coil current weakens its flux and allows the wire to become superconductive. The superconductive-resistive states of the cryotron correspond to the binary "on" and "off" states of ordinary computer elements. Since superconductivity is a surface phenomenon, very small cryotrons can be made with printed-circuit techniques. One element simply



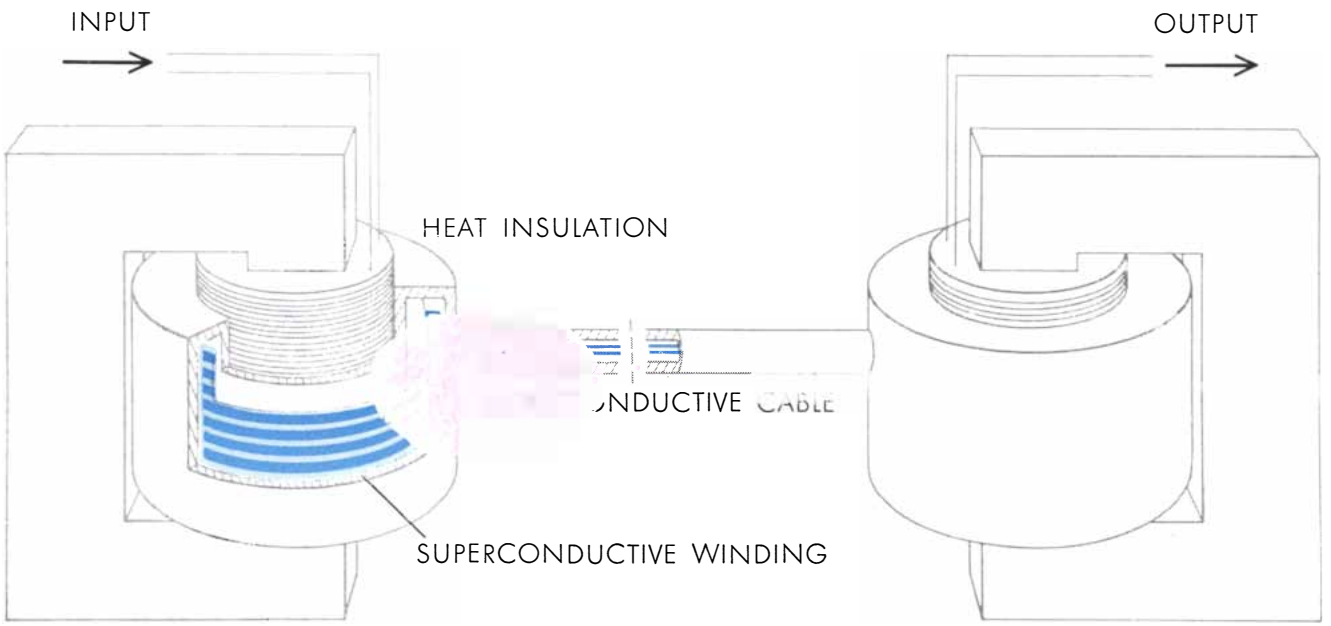
SUPERCONDUCTIVE BEARING supports a rotating shaft without friction. The T-shaped structure affixed to the shaft is superconductive. It rests on opposed magnetic fields (*black loops*), which are generated by concentric but noncontiguous coils, by repelling them.

intersects the other in the circuit [*see top illustration on opposite page*]. Printed cryotrons could reduce the bulk and the power requirements of present computers and enhance their reliability and versatility.

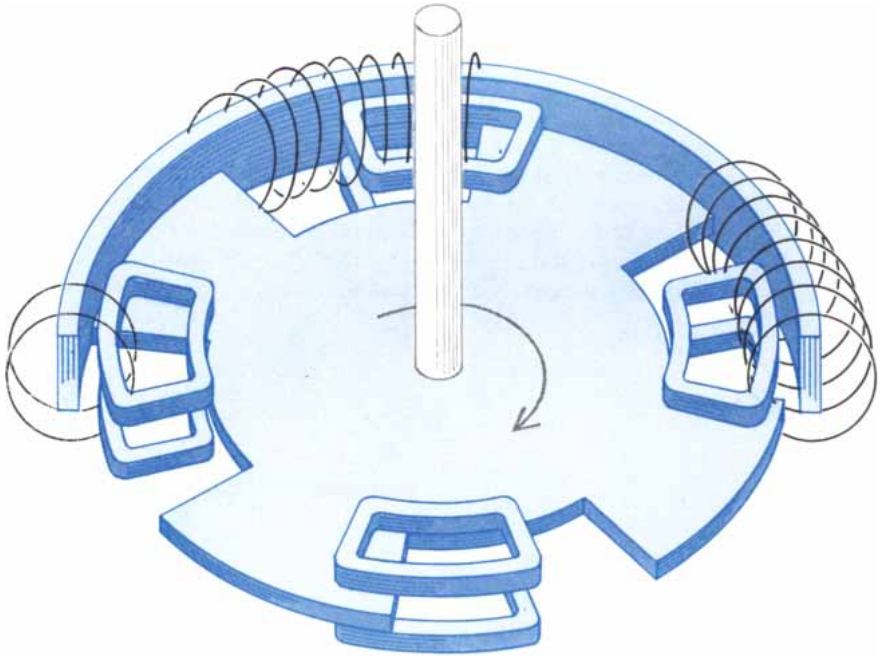
In the more distant future superconductivity promises improvements for special power-generating and transmission equipment. If the hollow conductors in the stators of a generator could be cooled sufficiently to make them superconductive, the generator could produce much more power. Liquid helium seems prohibitively expensive for this use. But materials might be found that become superconductive at the higher temperatures of liquid hydrogen (20.4 degrees) or, better still, of liquid nitrogen (77.3 degrees). Due to heat transfer through the driving shaft it does not seem possible to cool the rotor down to superconductive temperatures. The large currents produced by superconductive generators might be carried great distances with low losses to resistance by means of coaxial transmission



ROTOR OF SUPERCONDUCTIVE MOTOR would not rotate if it had conventional circular cross-section (*left*), because forces (*arrows*) exerted by magnetic flux (*ellipses*) of stator coil (*colored dots*), being perpendicular to rotor surface, could not develop torque. Rotor with polygonal cross-section (*right*) would in effect have lever arms (*broken lines*) that would introduce torque.



PRINTED TRANSFORMER COILS, made feasible by superconductive metals, could replace the massive coils of present transformers. Printed on an insulating base, the superconductive coils (*shown in color*) would be immersed in a low-temperature bath of liquid hydrogen or nitrogen and insulated against ambient heat. Superconductive cables would be used to complete power circuits.



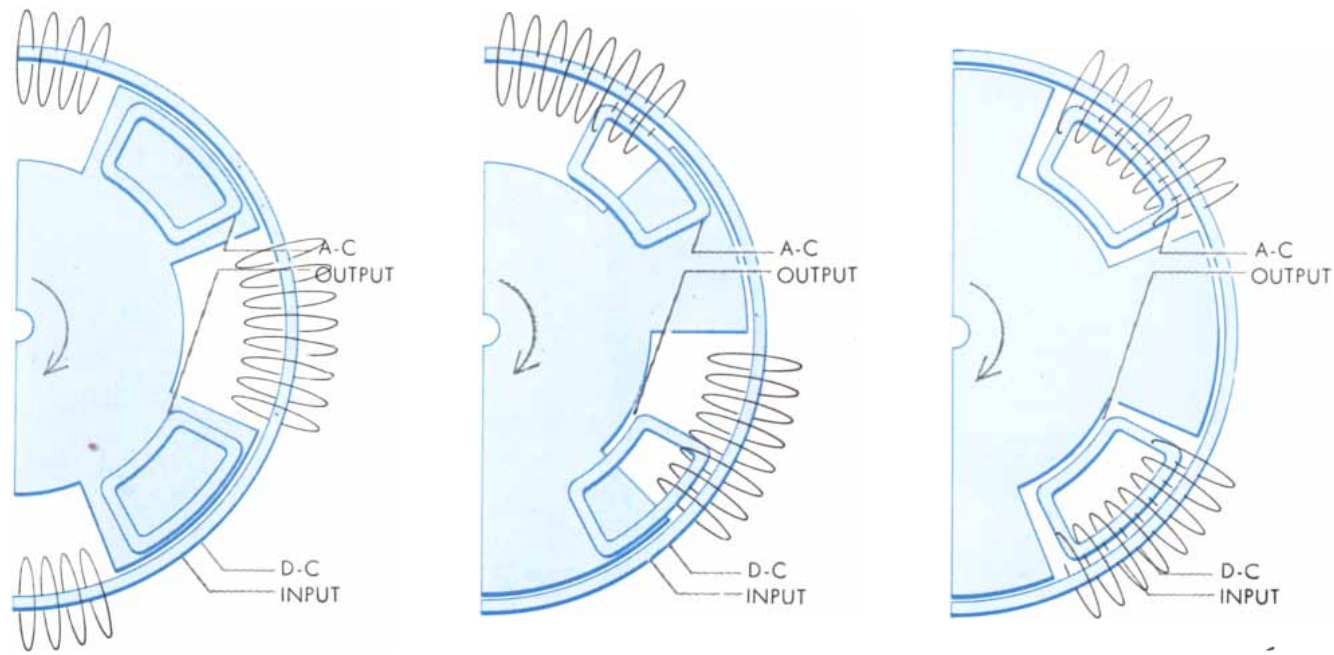
SUPERCONDUCTIVE AMPLIFIER converts direct current, in fixed outer coil, to alternating current in fixed coil pairs. As the superconductive disk rotates, its blades block the lines of magnetic flux (*black loops*) generated by outer coil, and its spaces pass the flux. Alternate blocking and passing of the constant flux make the current induced in the coil pairs an alternating one. The shaft, which rotates the disk, is powered by external source.

lines whose center conductors would be superconductive.

Such superconductive cables could feed power to superconductive transformers. But the usual power-loss in a transformer can be reduced by making only one of its windings superconductive. This would provide a further significant advantage. Instead of massive quantities of metal in huge coils, the superconductive winding would consist of a cylinder bearing a printed coil [*see bottom illustration on preceding page*]. In installations requiring two transformers, one coil of each transformer might be installed in a low-temperature environment; the other coils would be outside this environment.

The particle accelerators employed in nuclear physics might gain immediate advantage from progress in the technology of superconductivity. Their magnetic coils consume great quantities of power, much of which is lost to resistance. As superconductive alloys with higher critical field strengths are developed and fashioned into coils for accelerators, they will quite possibly eliminate all losses. By applying the principle of the flux trap, magnetic energy may be stored indefinitely in the magnetic coils and, under appropriate control, released in short pulses as is now done with banks of capacitors.

Applied superconductivity is a young technology, now at a stage of development similar to that of electricity after Michael Faraday made his discoveries a century ago. Much that is envisioned is not yet technologically feasible, or where it is feasible, it is not yet economically competitive. Though prototypes of superconductive bearings, motors, switches and resonant cavities have been built, they await improved refrigerating systems to become more attractive. Meanwhile more research should be devoted to attaining higher critical field strengths and higher transition temperatures. With adequate enterprise along both lines, the meeting of the two technologies may occur sooner than we can now foresee.



OPERATION OF SUPERCONDUCTIVE AMPLIFIER is based upon rotation of superconductive disk. At left spaces of disk pass constant flux (*black loops*) set up by peripheral coil. As disk rotates, flux reaches small coils (*drawings in middle and at right*), where it induces a current. Induced current alternates between positive and negative values as the flux is blocked and passed.

Kodak reports on:

the question of whether or not instrumentation people really need ultra-fast film . . . the profit viewpoint on nondestructive testing . . . a gimmick the committee needn't resist . . . a new gravimetric reagent for potassium

1600—no waiting

How come after all those promises we have made to innumerable instrumentation people over the years that some day there would be 16mm, 35mm, and 70mm film as fast as *Kodak Royal-X Pan Recording Film* now is—Index 1600—how come we now find ourselves in the ridiculous position of being able to make it at a greater rate than they're buying it? How come?

Don't they know that a note or phone call to Eastman Kodak Company, Photo Recording Methods Division, Rochester 4, N. Y., will set up the channel to supply it through a local dealer?

Not too good, not too bad

One lady and 106 gentlemen, all materialists by profession whatever their private spiritual views, have labored long and brought forth two volumes of material philosophy that weigh in about average for newborn babes.

Title: *Nondestructive Testing Handbook*. Editor: Robert C. McMaster, The Ohio State University. Publisher: The Ronald Press Company, New York. Price: $24. No charge for the applause rendered the work here. What's good for nondestructive testing is good enough for Kodak.

Nondestructive testing seems to be analytical physics, counterpart to analytical chemistry. The public pictures the "purpose" of chemistry as mostly analyzing things, just as the physicist fashions atom bombs out of cosmic rays. This book shows that physics, too, can have a "purpose" in better, safer, more profitable living. However, the book is not written for the public. Deeply concerned with profit it is indeed.

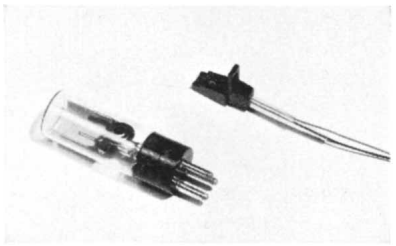
Too much control of product characteristics squanders resources. Too little squanders reputation. Profit perfumes the happy valley in the middle.

The first section develops these thoughts in a manner to interest and please the management, whether the product is bathtubs or Venus probes. The remaining 53 sections pursue the theme down every crevice of technical detail, not only in our own specialties of film radiography and optical gaging but in such others as liquid penetrants, magnetic particle tests, electrified particle tests, eddy currents, ultrasonics, brittle coatings, photoelastic coatings, strain gaging, radiation sources, fluoroscopy and x-ray image devices, x-ray diffraction and fluorescence, and even vision itself, properly aided.

Silicon over the sound track

Quietly, Kodak Pageant Sound Projectors have stolen a march, scored a scoop in their field. You have heard of the "solar battery" which generates useful electrical power when light falls on silicon? The power source for communication from satellites and interplanetary space? Here it is, in over-the-counter civilian hardware, doing a product-improvement job that is apparent even to those who can resist the temptation of a gimmick. If you are on a committee to select a sound movie projector for audio-visual instruction, the facts to lay before your fellow committeemen are these:

Early attempts at sound movies through a variable light pattern on the film employed selenium cells. They foundered. An EMF-generating selenium cell (not to be confused with a device that changes resistance in response to light) has an inherently slow time constant for adequate frequency response. The movies had to wait for the evacuated phototube to give them a good voice.



At left is a phototube such as employed today in most sound projectors. Being a little bulky, light that has passed through the sound track of the film must be somehow transmitted to it. At right is the new silicon "solar" cell. It holds 0.014 square inch of silicon directly above the sound track. It therefore requires a less critical optical arrangement. More important, it generates a varying EMF instead of valving from a constant EMF that must be supplied to it. This considerably simplifies the circuitry. There is less to get out of whack. Also, a solid-state generator happens to generate less random fluctuation than a photocathode system that must be kept under electrical tension. Less "white noise" shows up at the speaker. The old trouble from inadequate frequency response with selenium is gone.

If the old boys had known enough solid-state physics to place their bets on silicon instead of selenium, people with vivid memories of the silent movie queens would be even older, on the average, than they feel as it is.

We are talking about Kodak Pageant Sound Projectors, Models 8K5, AV-085, *and* AV-255-S. *Your local audio-visual dealer will take it from here.*

Made in U.S.A. under hygienic conditions

The Japanese have developed a new gravimetric reagent for potassium which we now offer as *N-(2,4-Dinitro-1-naphthyl)benzenesulfonamide* (Eastman 7828). And regardless of how scarce are good gravimetric reagents for potassium that can be used even in the presence of one-third as much sodium and magnesium as potassium, if that numeral in front of the "naphthyl" in the name had been 2 instead of 1, we would not offer it as Eastman 7828 or Eastman anything else. Our medical director feels so strongly about the carcinogenic properties of β-naphthylamine that it would seem wiser to let the science of chemistry go shift for itself than to observe the safety precautions he demands before he will let it into the plant. Pure α-naphthylamine is OK, as far as we know.

You dissolve the new reagent in lithium chloride solution and use it for the precipitation and conductometric titration of potassium. The precipitated potassium salt of the reagent is washed with the saturated solution of potassium salt and dried at 100°C for an hour. As for the fine details of the procedure, you can either buy 10 grams of Eastman 7828 from us for $4.45 and work them out for yourself, or you can first read up on them in *Nippon Kagaku Zasshi*, *79*, 598 (1958).

We expect no flood of $4.45 checks for potassium reagent. We merely make the point that some 3800 Eastman Organic Chemicals with a multitude of uses are stocked by Distillation Products Industries, *Rochester 3, N. Y. (Division of Eastman Kodak Company).*

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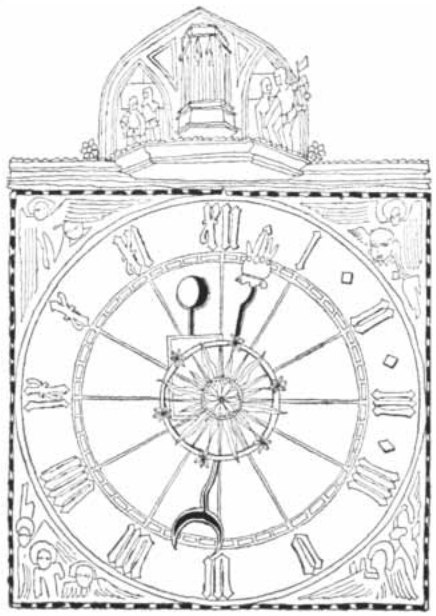
SCIENCE AND



General-Relativity Test

The first terrestrial experiments to test the gravitational red-shift effect predicted by the general theory of relativity were announced at the New York Meeting of the American Physical Society in January. A group from the British Atomic Energy Research Establishment reported that electromagnetic waves falling in the earth's gravitational field undergo a change in frequency approximately equal to the amount called for by the theory. Physicists at Harvard University, who had performed a similar experiment, said the results were as yet inconclusive.

Both groups made use of the recently discovered Mossbauer effect: the emission and absorption of gamma radiation of highly uniform energy, or frequency, by radioactive nuclei in crystalline solids ("Science and the Citizen," January). In the English experiment, performed by T. E. Cranshaw, J. P. Schiffer and A. B. Whitehead, the radiation was emitted from iron-57 nuclei at the top of a 40-foot evacuated tower and absorbed by other iron nuclei at the bottom of the tower. The shift in frequency was detected by the change in absorption as compared with that measured when the emitter and absorber were only a few feet apart. At Harvard R. V. Pound and Glen A. Rebka used iron-57 in a 70-foot tower. By switching the positions of emitter and absorber they studied the shift in frequency for rays traveling both upward and downward.

These experiments do not actually test the general theory of relativity itself, but the more general "principle of equivalence" that underlies it. The principle says that the effects of gravity on masses and electromagnetic radiation are indistinguishable from the effects of uniform acceleration. Both groups of experimenters expect to increase the accuracy of their results in further trials.

Special-Relativity Test

One of the most precise experiments ever performed has produced further confirmation of the basic postulate of the special theory of relativity. This states that the speed of light or other electromagnetic radiation in a vacuum is constant, regardless of the relative motion of the light source and the observer.

The first demonstration of this constancy, and the inspiration for Albert Einstein's theory, was the famous Michelson-Morley experiment. By observing interference patterns in visible light, A. A. Michelson and E. W. Morley showed in 1887 that the speed of light traveling parallel to the earth's orbit was the same as that of light moving perpendicular to this orbit. In other words, there was no relative "wind" generated by the earth moving through a motionless sea of ether. The accuracy of that experiment, however, was less than one part in 100 million, which meant that it would not have detected a difference in speed less than a sixth the speed of the earth on its orbit. Subsequent experiments improved the figure to a 20th.

Now C. H. Townes of Columbia University and J. P. Cedarholm of the I.B.M. Watson Laboratory have, according to their report in *Nature*, reduced the uncertainty to a 1,000th of the earth's orbital velocity. Instead of light waves they used radio waves generated by a pair of "masers" in which excited ammonia molecules create an extremely stable oscillation of approximately 24,000 million cycles per second. The molecules of one maser moved in the direction in which the earth travels around the sun, while the molecules in the other moved in the opposite direction. The two masers were periodically interchanged in direction by rotating the whole assembly 180 degrees in order to double any differences in the output frequency of the masers caused by the earth's motion in an ether. If the velocity of light had been affected by the motion, the orbital velocity of the earth would

have produced a difference of 20 cycles per second in the frequencies. The largest difference detected, however, was only a 1,000th of that—about a 50th of a cycle per second. Masers oscillate so precisely that the experiment is accurate to one part in a million million. Townes and Cedarholm made the maser observations during 24-hour periods at intervals of three months throughout a year in order to be sure that the orbital motion of the earth at the time of the measurement did not happen to be canceled by the movement of the solar system in space.

Older Universe

A cluster of stars that appear to be 24 billion years old has been discovered in our galaxy by astronomers of the Mount Wilson and Palomar Observatories. This figure, reported by Allan R. Sandage at the western winter meeting of the American Physical Society in Pasadena, is more than twice the age of any celestial object previously known. If it stands up under further investigation, it will either force another major revision in the astronomical distance-scale, or will clinch the argument in favor of a steady-state universe rather than one that started with a "big bang."

The estimate of age is based on the current theory of stellar evolution. It is thought that when stars are formed they consist almost entirely of hydrogen. As they start to burn, their hydrogen is converted to heavier elements through certain sequences of nuclear-fusion reactions. As long as there is hydrogen fuel at the center of the star, where most of the burning takes place, the star is a member of the "main sequence." This means that if its luminosity is plotted on a graph against its surface temperature, it falls somewhere on a diagonal line ranging from bright, hot stars at the upper end to dim, cool ones at the lower. When the hydrogen at the center of the star is used up, the star changes in appearance and moves off this line on the chart. The hotter and brighter the star, the sooner its central hydrogen is exhausted, and the sooner it leaves the main sequence. The time elapsed from birth to departure from the main sequence depends on the rate of burning, which has been calculated for stars of

various brightnesses and luminosities. Thus the brightest main-sequence member remaining in any group of stars is an index to the age of the group.

A recent survey with the 200-inch telescope of the cluster known as N.G.C. 188 shows that the brightest main-sequence star in the cluster is one magnitude fainter than any star observed before in such a group. According to the estimate of burning rates a star of this luminosity should stay on the main sequence for 24 billion years. The computation is rough, and the correct answer may be as little as 12 billion or as much as 48 billion. But even the smallest number is unexpectedly high. Sandage suggests that the burning rates should be reassessed.

If stars as old as 24 billion years really exist, and if the presently accepted distance-scale is correct, the universe cannot have started from an explosion. Measurements of the expansion rates show that such an explosion must have happened no more than nine to 13 billion years ago. Either there was no such beginning, and the universe has always been in the same, steady state of expansion, or cosmic distances must be twice as great as now believed.

The Structure of Antarctica

The controversy over whether Antarctica is a continent or an archipelago has come closer to being resolved as a result of expeditions begun during the International Geophysical Year. Several U. S. teams have traversed most of West Antarctica, an area extending from Wilkes Land (south of Australia) to the Filchner Ice Shelf south of the mid-Atlantic. Writing in *Science,* four members of the teams—C. R. Bentley, N. A. Ostenso, E. C. Thiel and A. P. Crary—state that their magnetic, geologic and seismic data indicate that West Antarctica consists of a vast extension of the Palmer Peninsula (which stretches southward from the vicinity of Cape Horn) and a mountainous island or series of islands comprising the coastal ranges of Marie Byrd Land.

The data also indicate that beneath the ice sheet covering the area lies continental (as opposed to ocean-basin) rock divided into at least three geologically distinct parts by a deep channel. The channel separates the volcanic mountains of the Executive Committee Range on the north from the metamorphic Sentinel Mountains to the east and the sedimentary Horlick Mountains to the south.

From the configuration of the ice and

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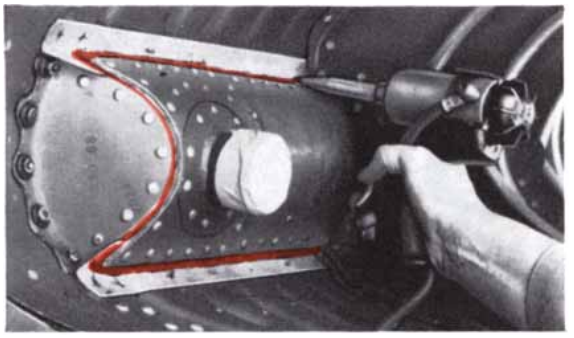

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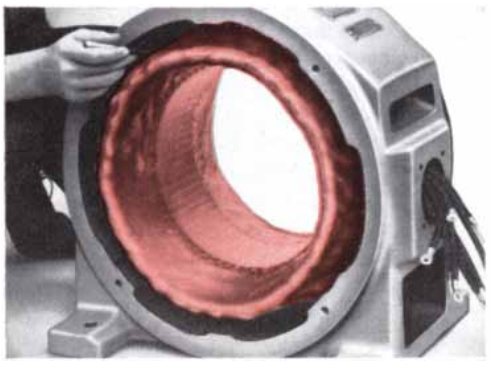

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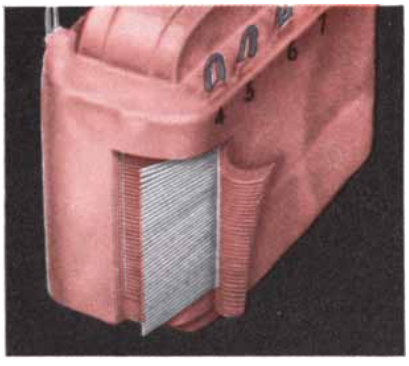


RTV COIL IMPREGNATION enables this Hughes Aircraft Co. transformer to provide top performance at 250°. Unlike other insulations tried, G-E RTV compounds proved successful both for coil impregnation and full encapsulation.

For application data and samples of General Electric RTV silicone rubber write Section U314, General Electric Company, Silicone Products Department, Waterford, New York

GENERAL ELECTRIC

rock surfaces in these regions the investigators concluded that the West Antarctica ice mass originated as two separate icecaps: one in the vicinity of the Executive Committee Range and the other between the Horlick and Sentinel mountains. The caps expanded and converged over the water between them, probably joining a floating iceshelf in the process. The shelf gradually grew thick enough to fill the sea basin and produce the present single sheet of ice.

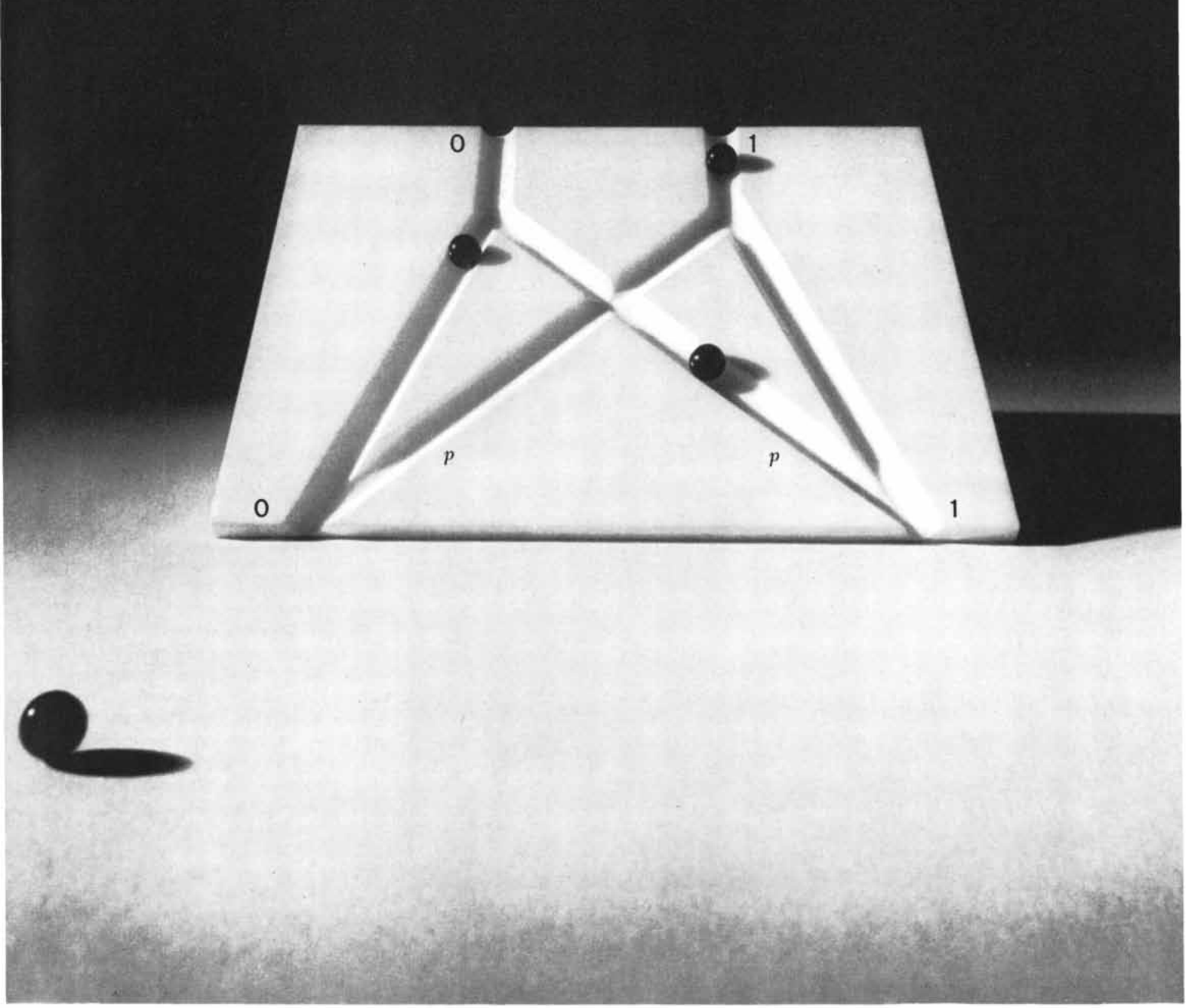
Ultraviolet Stars

The first telescope to be used in rocket astronomy has given man a brief look at the ultraviolet radiation of several hot stars and has supplied a possible explanation for the brilliant ultraviolet "clouds" that surround them. Data from a rocket-borne telescope fired to a height of over 60 miles over New Mexico last November suggest that current theories of the structure and evolution of stars may require revision.

The flight was described by Herbert Friedman of the Naval Research Laboratory at the New York meeting of the American Physical Society. It carried a four-inch reflecting telescope coupled to a photodetector, signals from which were telemetered to the ground. Though the apparatus could scan only a small part of the sky during its brief journey, its signals revealed at least seven stars that appear to be point sources of ultraviolet radiation, each star surrounded by a region of ultraviolet nebulosity.

While none of the stars has yet been positively identified, preliminary results suggest that their ultraviolet luminosity is considerably smaller than had been expected. Previous estimates of stellar ultraviolet emissions were based on rough extrapolations from the visible part of their light, which for a hot, blue star may account for only 5 per cent of the total energy-output. Rocket studies of the sun have already shown a similar but smaller gap between estimated and observed ultraviolet radiation. The discrepancy is ascribed to absorption by outer layers of the solar atmosphere. The larger discrepancy for hot stars, presumably due to similar atmospheric absorption, may force revisions in present models of stellar atmospheres.

Other results from the flight, together with data from previous flights, indicate that almost all the nebulous radiation surrounding hot stars lies in a narrow band surrounding the Lyman-alpha line. Much of this energy was originally radiated by the star itself at higher frequency, and then converted to ultra-



This model of the binary symmetric channel symbolizes the probability of error, p. How can a one received in the zero slot be caught and corrected?

Group codes for prescribed error patterns

Information signals, representing zeros and ones, are transmitted through a binary symmetric channel at such high speeds that they are subject to channel noise. Through group codes it is possible to detect and correct automatically large classes of errors that may arise from such disturbances.

Usually, in optimizing these codes all possibilities are classified and samples of each are evaluated. But this task can become enormously complex. For large information blocks, such as a 70-place code, there may be billions of possibilities to evaluate. To reduce the need for these exhaustive methods, IBM scientists have evolved a preliminary theory for constructing group codes through a correlation analysis of error patterns.

Correlated patterns of errors are organized into equivalent classes and a code is formulated to overcome the error-producing characteristics of the communications channel. A code for one pattern of errors may be transformed mathematically into codes for other patterns of the same class. By prescribing which error patterns can be corrected, codes with a minimum number of checking signals may be formulated.

This optimizing process can have practical significance since every checking signal for a given number of information signals in a group code increases the cost and delay in information processing. In addition to the work described here, other approaches to the problem of code simplification are being made at IBM through linear programming and computer simulation.

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violet by the excitation of hydrogen in the stellar atmosphere. Thus the atmosphere acts as a spectrum converter, transforming almost all the high-energy emission of a star (about half its total output) into ultraviolet radiation.

Of Porpoises and Ships

A new outer coating for ships, modeled after the skin of a porpoise, promises to reproduce that animal's remarkably effortless glide through the water, according to a recent announcement by the United States Rubber Company.

Max O. Kramer, inventor of the coating, was inspired by a school of porpoises swimming past an ocean liner carrying him to this country from his native Germany. He calculated that the drag on their bodies must be only a 10th of that which would have been expected for their shape and size. Subsequent studies showed that the animal's skin, which is elastic and ducted, damps out turbulent eddies that would otherwise form along its sides.

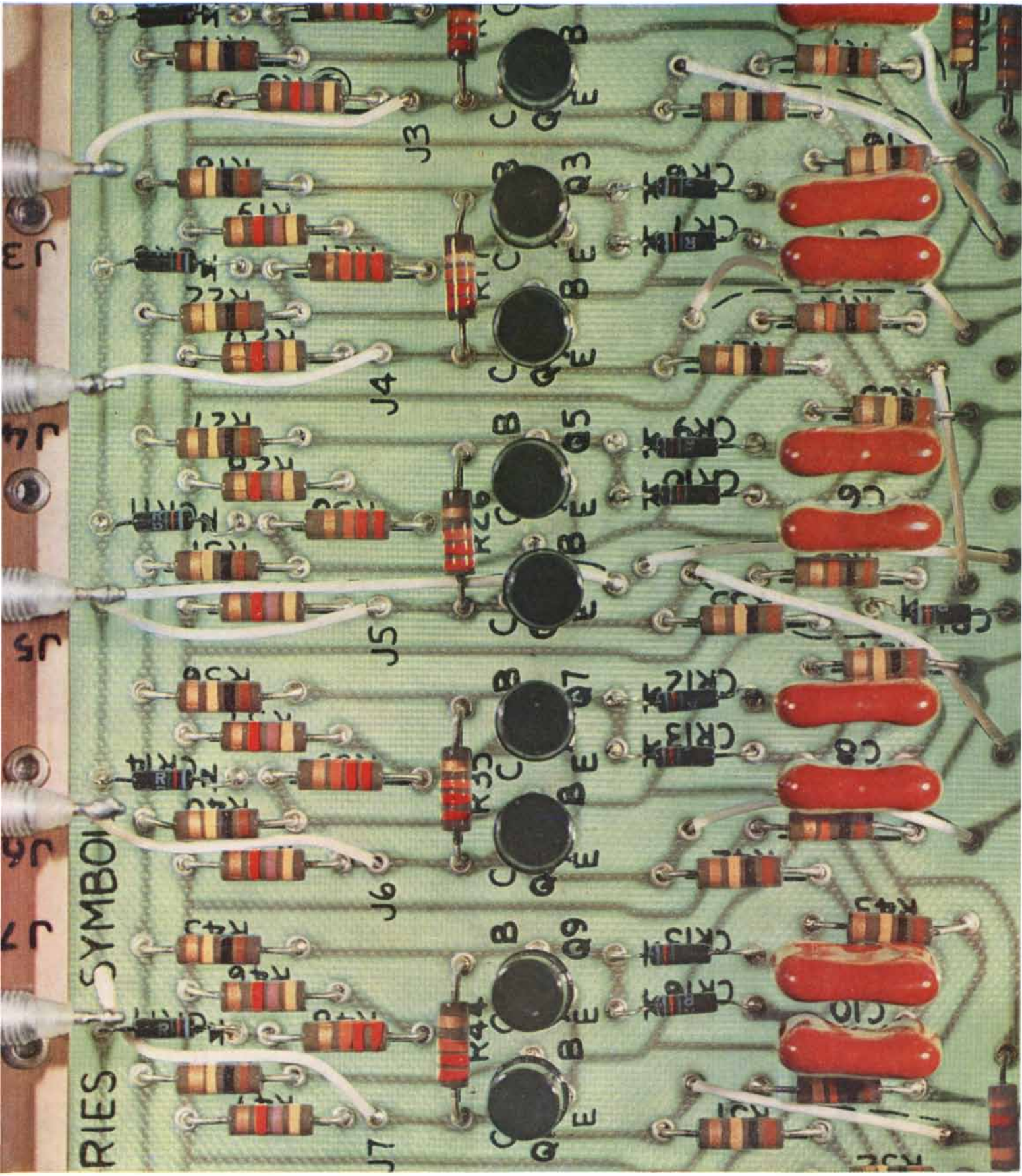
Kramer and a team from U.S. Rubber then set out to make a structurally analogous rubber "skin" to reduce the turbulent drag on the hulls of ships. The coating they have developed consists of two thin sheets of rubber separated by thousands of tiny, closely spaced rubber pillars. Between the pillars is a viscous liquid silicone. The elasticity of the rubber and the hydraulic action of the silicone combine to make the coating resilient enough to suppress turbulence. Preliminary tests indicate that the coating reduces drag on streamlined submerged objects by about 50 per cent. Kramer is now investigating methods of improving the coating and applying it to torpedoes, submarines, pleasure boats and even aircraft. It is of little value on ocean liners and other large surface ships because their motion is chiefly impeded by bow waves, which create a drag far more powerful than that caused by turbulence.

The Changing Van Allen Belt

The Van Allen radiation belts are becoming both more and less puzzling. Recent data from earth satellites and rockets have clarified the origin of the belts but have shaken previous ideas about their structure and shape.

Data from the heavily instrumented earth satellite *Explorer VII* indicate that the northern rim of the outer belt passes over the northern U. S.; previous observations had placed it over the zone of maximum auroral activity about 1,000 miles to the north. Moreover, the loca-

At 00h00m01s GMT February 1, 1960, Martin logged its 425,412,000th mile of space flight



Without electronics it is impossible to design, build, test, launch, guide, track or communicate with a missile. That is why **40% of Martin's 7,500 engineers are electronic/electrical engineers.**

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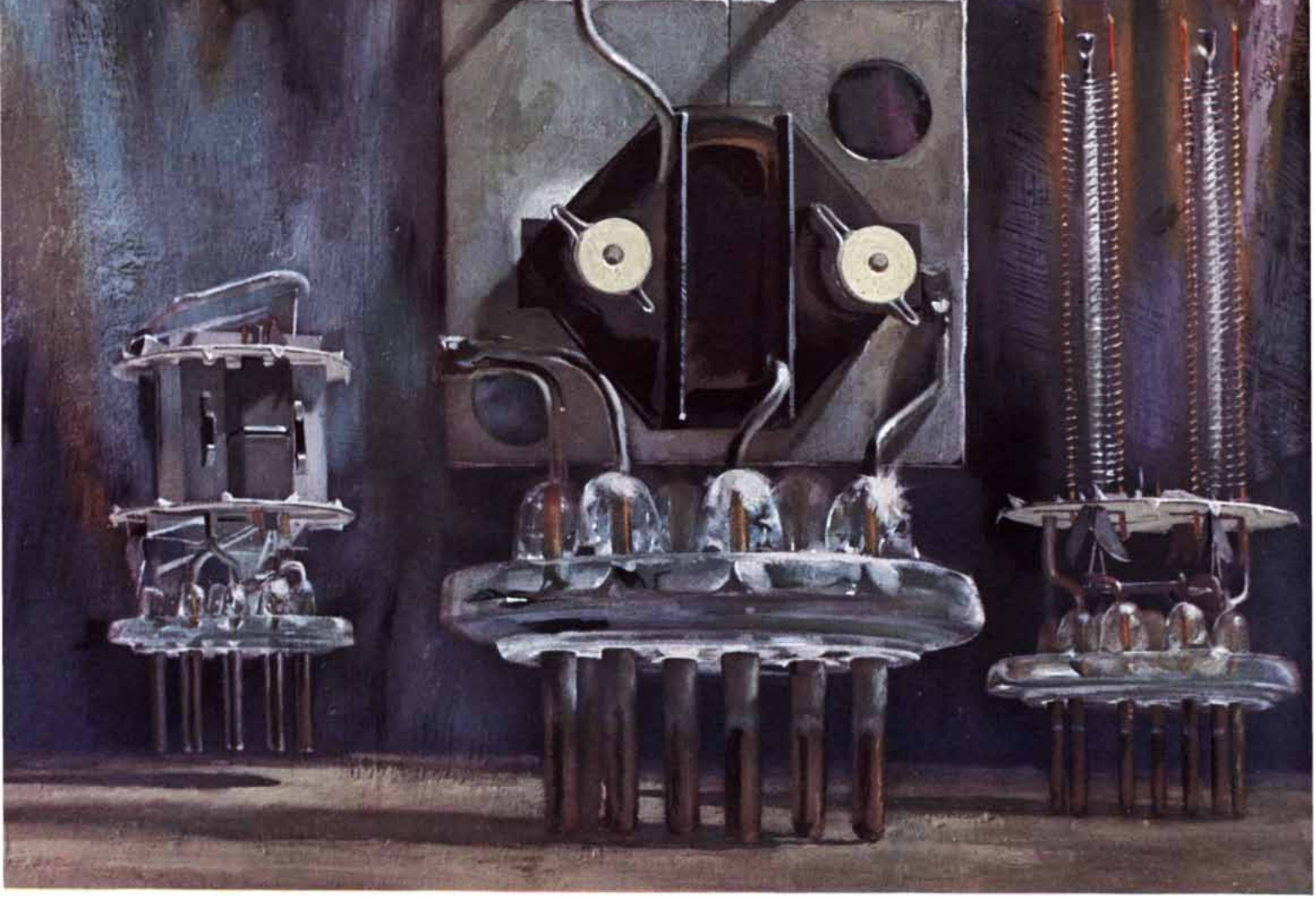

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GENERAL SYSTEM

tion of the rim is constantly shifting by as much as 500 miles from north to south. Radiation intensity at a given altitude and latitude may vary 10-fold within a few hours; sometimes sharp "spikes" of radiation, only a few miles thick, reach down toward earth. The inner belt, lying over the magnetic equator, appears by contrast to be stable in both location and structure; the same was true of the "shells" of charged particles injected between the two belts by high-altitude nuclear explosions in 1958.

The cause of the changes in the outer belt is not yet clear. Some of the spikes have been associated with disturbances on the sun and with magnetic storms on earth. One of the sharpest spikes, observed last November 27, coincided with one of the most violent magnetic disturbances on record and with an unusual red auroral display over Canada, Alaska and the central U. S.

Information from the "paddlewheel" satellite *Explorer VI* indicates that both belts are larger and probably more homogeneous in structure than was originally thought; some data suggest that the two belts may at times become one.

A rocket flown through a portion of the outer belt last summer has provided the first comprehensive data on the angular motions and energy spectrum of the electrons in it. John B. Cladis of the Lockheed Missiles and Space Division reported to the New York meeting of the American Physical Society that most of the electrons are of low energy. Half of them have energies under 100,000 electron volts; less than 1 per cent exceed 500,000 electron volts.

This energy distribution provides further confirmation for the theory that the particles in the outer belt originate in the sun, rather than from the decay of neutrons liberated by cosmic rays. However, the observed energies are not wholly consistent with the solar origin theory. Some of the particles may be accelerated by a sort of cyclotron mechanism in which they are swept in expanding spirals about the sun; others, by some still-unknown effect of terrestrial magnetism.

Cancer-Inducing DNA

A form of deoxyribonucleic acid (DNA) that produces cancer in experimental animals has been extracted from a mouse-cancer virus by workers at the National Institutes of Health and the Sloan-Kettering Institute for Cancer Research. This is the first DNA of proved infectiveness to be isolated from a virus, although infective ribonucleic acid

(RNA), has been separated from several viruses. It is also the first nucleic acid of any kind that has been shown to cause cancer. Since DNA is the material of the genes, the new finding may throw important light on the basic process that converts a normal cell to a cancerous one.

In experiments described in *Proceedings of the National Academy of Sciences,* the Sloan-Kettering and N.I.H. investigators extracted nucleic acid from virus particles grown on mouse-embryo cells and added it to fresh mouse-cell cultures. Fluids taken subsequently from these cultures produced tumors when injected into hamsters or other laboratory animals. In later experiments the nucleic acid itself was injected into test animals, without being passed through a tissue culture, and also proved to cause cancer. The material was identified as DNA by showing that it was inactivated by an enzyme that destroys DNA, but not RNA.

Roman Vital Statistics

Roman tombstone inscriptions indicate "the average lifetime of the ancients was short—as short, or shorter than, it is now, even in the parts of the world where conditions of health and mortality are at their worst." John Durand of the United Nations Bureau of Social Affairs, writing in *American Journal of Sociology,* concludes that a Roman born during the first two centuries A.D. could probably look forward to about 25 or 30 years of life. This compares to an estimated life-expectancy of 32 years in India, as of a decade ago, and some 70 years in the U.S.

The idiosyncrasies of the Romans make the estimating of life expectancy from their tombstones an adventurous enterprise. Many inscriptions do not mention age, and those that do are suspect. The tombstones of young children tend to heighten pathos by recording them as even younger. So, also, women who died in their middle years are accorded the deference of understated age. Since beyond a certain point age meant prestige, however, the ages of older men and women are often rounded off to the next higher decade.

The high mortality rate, even though offset by a high fertility rate, indicates that population replacement in ancient times must have been precarious. "The balance of births and deaths could easily have been shifted to the negative side," Durand says. This may explain the depopulation of the western Empire that is thought to have occurred during the last centuries of Roman sway.

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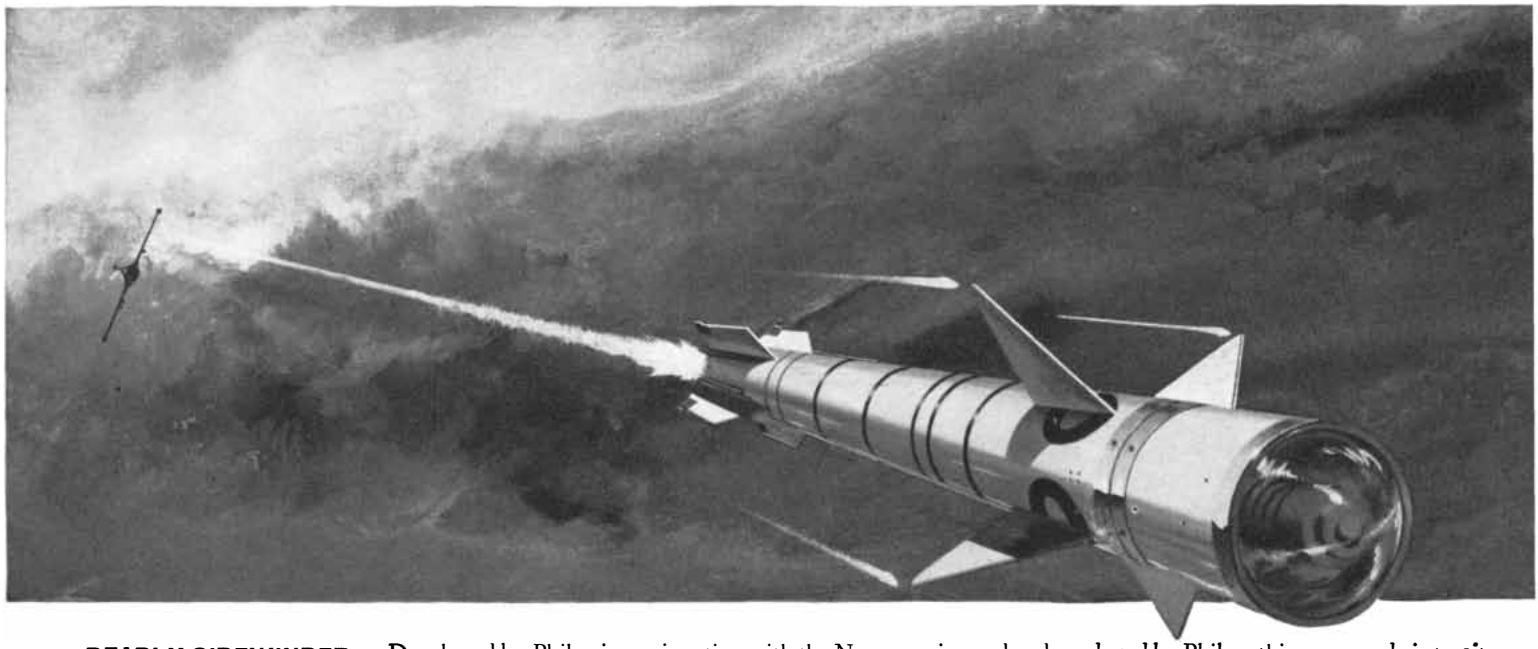

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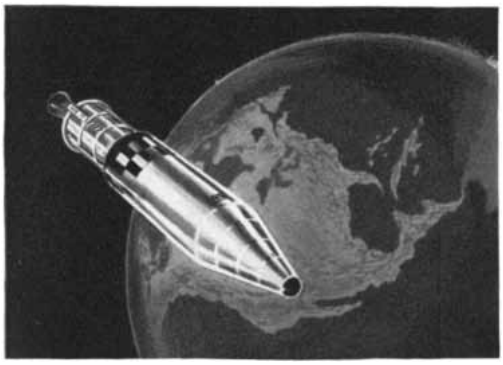

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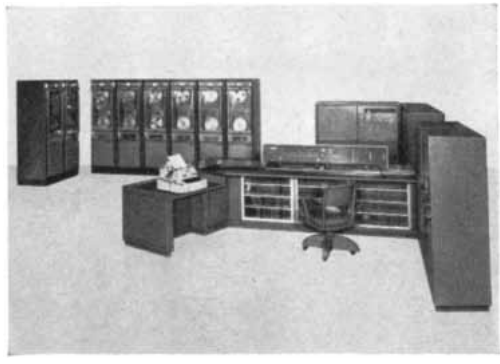

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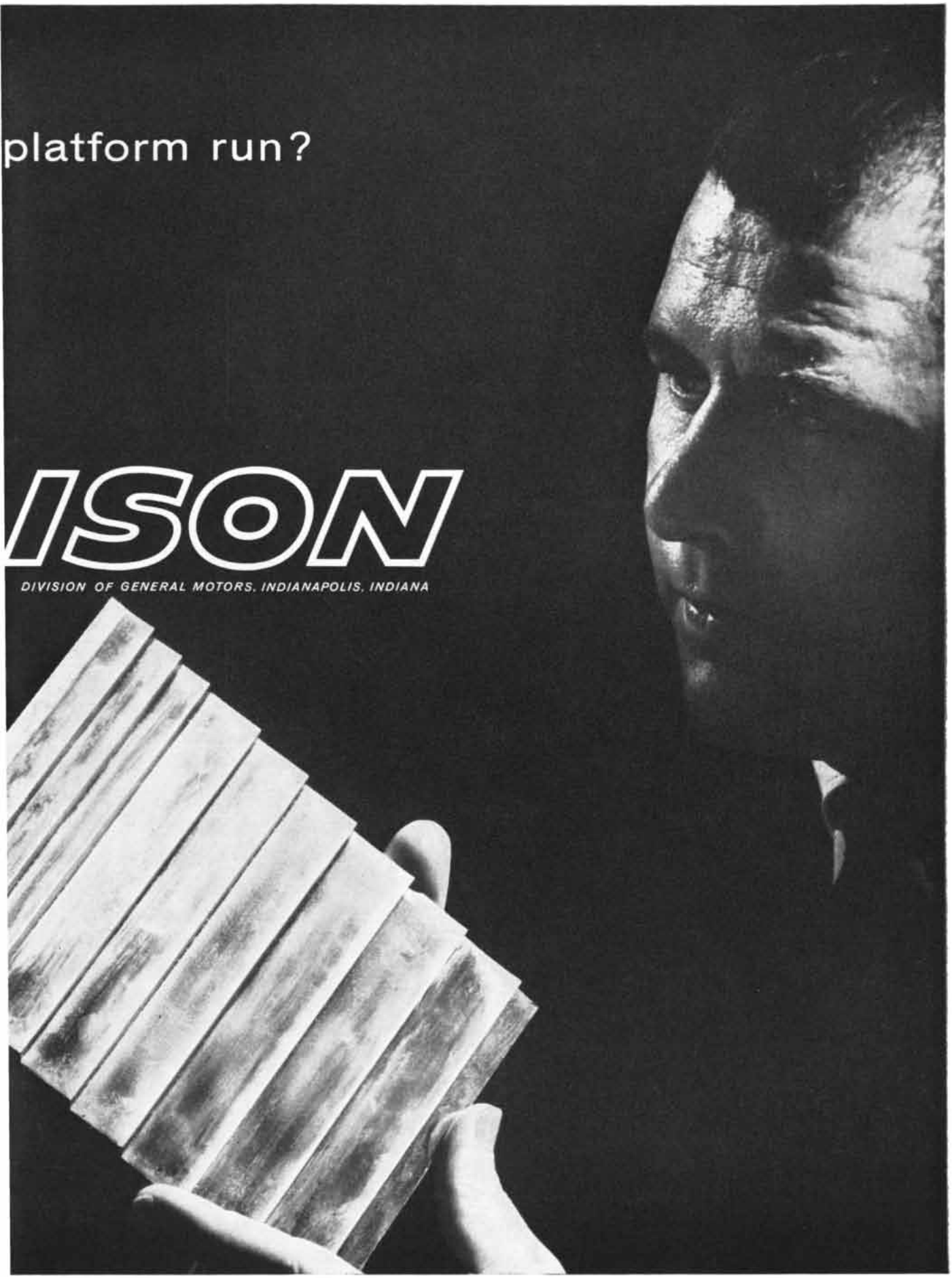
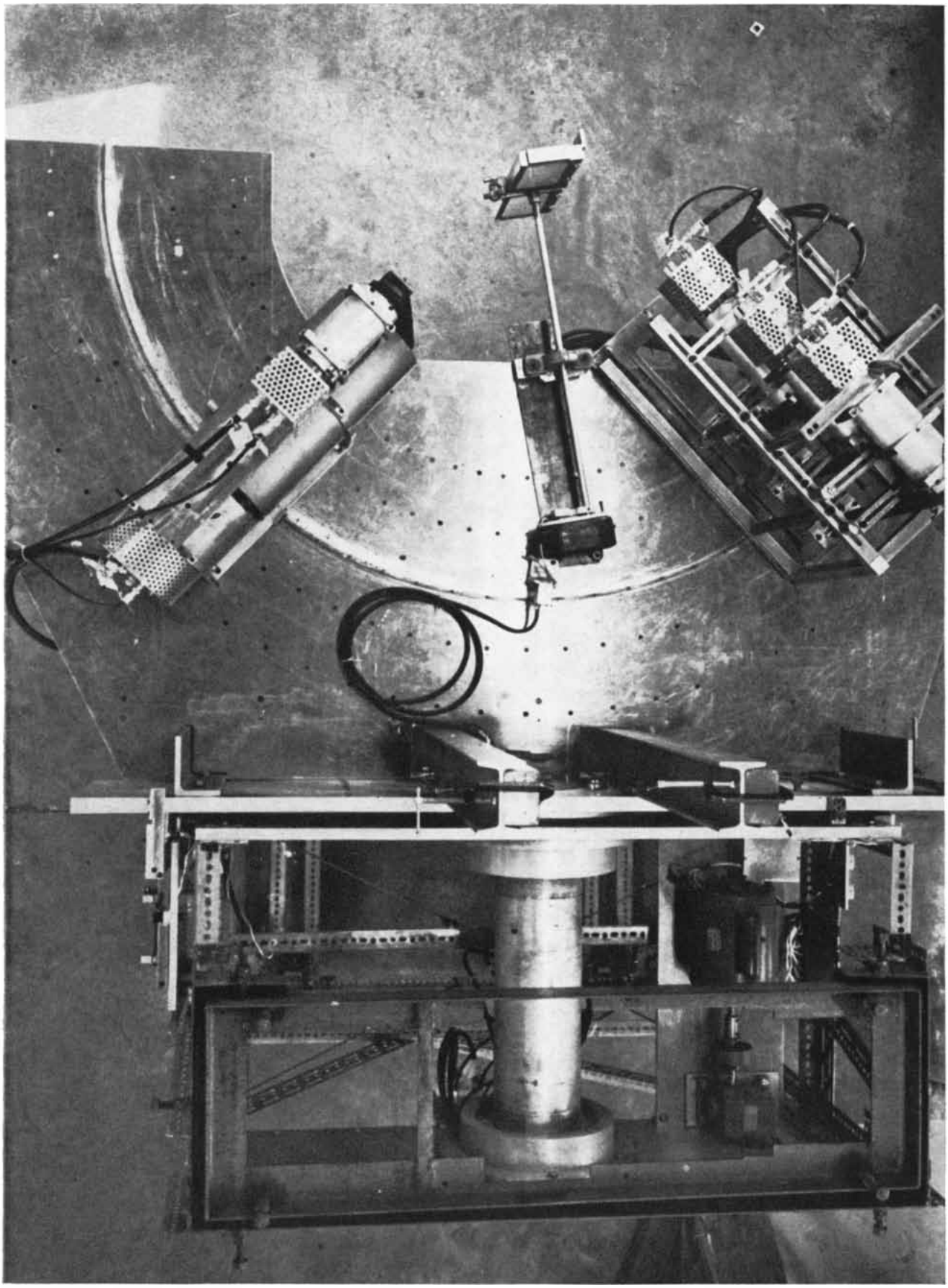




DOUBLE-SCATTERING EXPERIMENT is photographed at the University of Rochester. The first scattering target is located within the accelerator (*not shown*). Second target appears at top center. Just below it are a neutron counter (*left*) and a proton counter (*right*) which respectively record the recoiling neutrons from a deuteron target and the deflected protons of the incident beam.

THE NUCLEAR FORCE

The deflection of high-speed nuclear particles by samples of matter is yielding new information about the strong and complex force that holds the atomic nucleus together

by Robert E. Marshak

What holds the nucleus together? The problem remains one of the most challenging in physics, as it has been ever since Lord Rutherford discovered that the atom has a nucleus. Discussing the question in SCIENTIFIC AMERICAN six years ago [September, 1953], Hans A. Bethe guessed that it had consumed "more man-hours than have been given to any other scientific question in the history of mankind." Since then the man-hours have continued to pile up, and considerable progress has been made.

It would be satisfying to be able to report an advance in fundamental understanding. The fact is that we are not noticeably closer to the eventual goal: a theory that will allow us to deduce nuclear forces mathematically from a few basic assumptions and experiments. But we do know much more about what the forces are like. While still unable to predict them, we are at least learning how to measure them.

This is no trivial accomplishment. An enormous effort has gone into designing and performing experiments to illuminate different aspects of the complicated interaction of the particles that make up nuclei. And once the experiments were done, theoretical physicists had to work equally hard to interpret the results.

Simpler Forces

Before plunging into the complexities of nuclear forces, let us recall, for purposes of comparison, some of the properties of more familiar, and much simpler, forces. Consider first the force of gravity. As everyone knows, it is an "inverse-square law" force: the gravitational attraction between two masses varies inversely as the square of the distance between them. (If the distance is doubled, the force is divided by four, and so on.) Gravity is also a "central" force. It depends on the distance between the attracting masses but not on their relative direction, and always points along the line joining the two masses [*see illustration at left on next page*].

There is another way of looking at the interaction between two attracting (or repelling) bodies that the physicist often finds more convenient. Instead of talking about forces he speaks of potential energy. The potential energy stored up in a pair of attracting bodies is equal to the work that would be necessary to pull them infinitely far apart, so that they would no longer act on one another. Obviously the amount of work depends on the way in which the force of attraction decreases with distance. For gravity, where the force varies as $1/r^2$, the potential energy varies as $1/r$, r being the distance of separation [*see illustration at top of page 101*]. In general there is a simple relation between the two concepts: Force is measured by the rate of change of potential energy. In graphical terms this means that where a plot of potential energy is steep, the corresponding force-curve has a large value. Where the potential-energy curve is comparatively flat, that is, has a low rate of change, the force is small.

Suppose now that we did not know the laws of gravitational force or potential energy. How could we discover them? One possibility would be to study the motions of objects under the influence of gravity. The laws of motion tell how bodies react to any force. Thus by observing their particular paths and speeds when acted on by gravity alone, the nature of the force can be deduced. When Isaac Newton calculated the elliptical paths of the planets around the sun, he was proving his inverse-square law of gravity, as well as demonstrating the validity of his laws of motion.

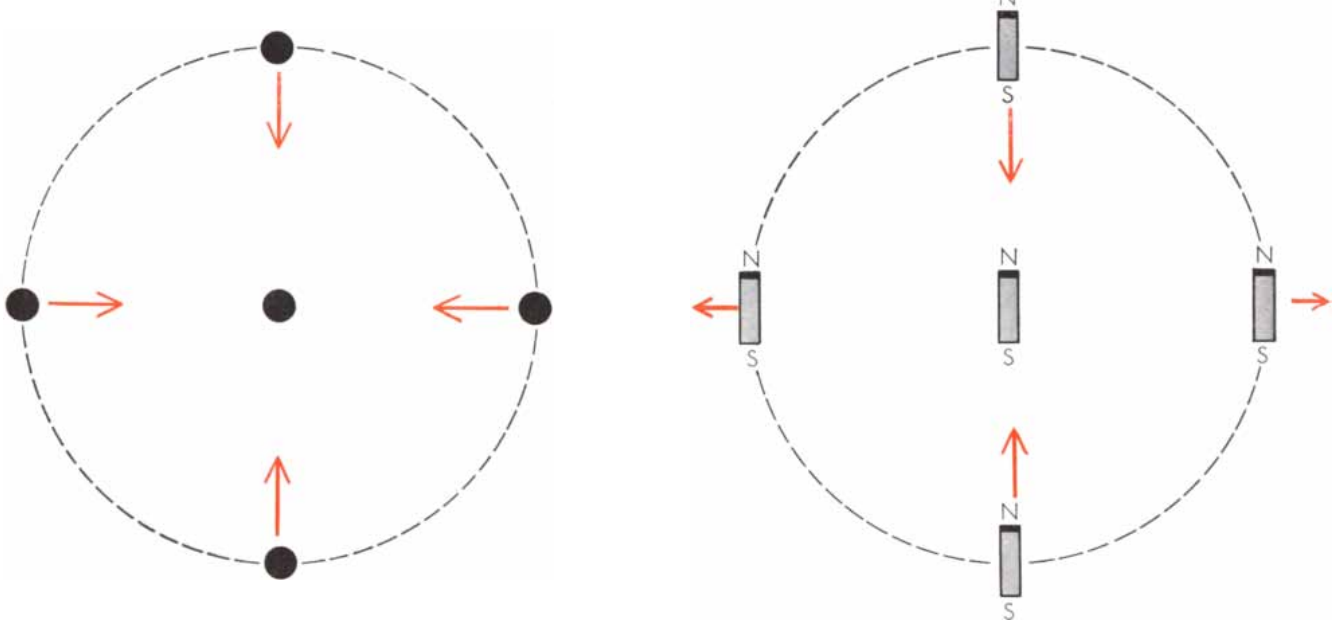
All the characteristics of gravity that have been listed apply equally well to electrostatic forces. These too are central and obey the inverse-square law. They differ only in being very much stronger than gravity, and in having two possible directions: attractive and repulsive.

When we consider magnetic forces, however, we find a different situation. If two magnets are held near each other, the force between them depends not only on their distance, but also on their relative direction with respect to their north-south axes [*see illustration at right on next page*]. Because of its mathematical properties, a force that behaves this way is known as a tensor force.

To find the force between a pair of magnets experimentally would be somewhat more difficult than to determine the nature of gravitational or electrostatic force. Many more measurements would be necessary in order to exhaust the various possible relative directions. In practice, of course, no measurements are necessary. We know enough about magnetism to compute the force between any pair of magnets in any relative position. Not only that, but magnetic, electric and gravitational forces can all be deduced from underlying theories.

The Nuclear Force

Now let us turn to the nuclear force. When the problem first presented itself, about all that could be said was that the force of attraction between particles in the nucleus must be extremely strong, but can only extend over a very short range. The fact that positively charged particles (protons) are bound together in nuclei showed that the nuclear attrac-



GRAVITY AND MAGNETISM are contrasted in these diagrams. Gravitational force (*left*) is "central"; *i.e.*, it depends only on distance between attracting masses (*dots*) and not on their relative direction. Magnetic force (*right*) is a "tensor" force, differing for different directions with respect to magnetic axes. Arrows represent forces on outer bodies due to presence of body at center.

tion was stronger than the force of electrical repulsion. We now know that at a distance of one fermi (10^{-13} centimeter) the nuclear force is 35 times as strong as the electrostatic force and 10^{38} times stronger than gravity. (The fermi is the natural unit of length in this domain of physics. A nucleus measures a few fermis across.) At somewhat shorter distances it is even stronger. And at still shorter distances it reverses its direction and becomes repulsive. On the other hand, at distances beyond a few fermis the nuclear force rapidly drops to zero. The interaction of nuclei with particles a little way outside of them is almost wholly electric and magnetic.

When the English physicist James Chadwick discovered the neutron in 1932, it became clear that there are two types of nuclear building-blocks, or nucleons: the neutron and the proton. This meant that there might well be three kinds of nuclear force: proton-proton, neutron-neutron and proton-neutron.

How could they be measured? To use nuclei containing many protons and neutrons would only be compounding the difficulties. It is very hard to calculate the behavior of an assembly of many particles even when the law of force between them is known. To try deducing a law of force, or possibly several different laws, from the properties of the assembly is hopeless. The only practical way to begin was by studying isolated pairs of nucleons.

Nature has provided just one such combination—the deuteron. This nucleus of heavy hydrogen consists of one proton and one neutron. More than 20 years ago studies of the behavior of deuterons began to reveal some of the details of the nuclear force. It at once turned out to be more complicated, as well as more powerful, than anything that had been known previously. The attraction between neutron and proton proved to be of at least *two* kinds. In part it was central: the same for all relative directions of the particles, like gravity. In part it was tensor: differing for different directions, like the force between two magnets.

Although we could not have predicted in advance that there would be a noncentral component, we did know that there might be. In order to have a force that depends on relative direction there must be some standard of reference by which one direction can be distinguished from another. In the case of electrostatic forces, for example, there is no such standard. A charged sphere looks exactly the same from any angle. Hence electrostatic forces cannot possibly be anything but central. A magnet, on the other hand, has a north-south axis. Seen from different vantage points, the axis takes on different orientations and thereby distinguishes among them. Thus magnetic force can be, and in fact is, noncentral.

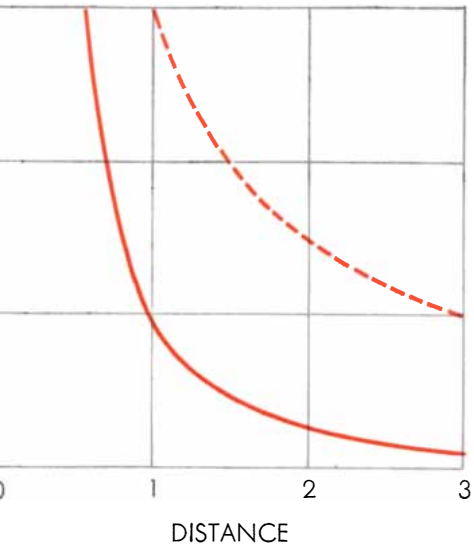
Nucleons also have a built-in direction indicator: the axis about which each one eternally spins. Hence they too can interact differently in different relative positions. (By convention the spin axes are assigned a direction depending on the sense of the rotation around them. If you curl the fingers of your right hand in the direction of the spin, your thumb gives the direction of the spin axis.) Notice that the existence of a reference direction does not guarantee that there will be a noncentral force. The sun and the planets have spin axes, but nature has not chosen to make gravity a noncentral force.

The properties of the deuteron, then, demonstrated that part of the proton-neutron force is noncentral and began to yield some specific figures for the strength of the force. But only a limited amount of information can be obtained from the deuteron. It tells only about the force between neutron and proton and only at the rather large distance of several fermis. The nucleons in the deuteron are much less tightly bound than the nucleons in heavier nuclei. Furthermore, the spin axes of the two particles always point in the same direction and can give information only about this relative orientation.

Scattering

To learn more we must make different kinds of two-nucleon systems. We do this by shooting one nucleon toward another at high speed. For a brief moment they come within range of the nuclear force, then separate again. In the process the projectile nucleon swerves from its original path and the target nucleon is pulled out of position. By studying the deflections we get an idea of the force that caused them.

Of course we do not actually deal with a single pair at a time. Instead we send



INVERSE-SQUARE FORCE, such as gravity, is represented by solid curve; corresponding potential energy, by broken curve.

a dense beam of nucleons from a cyclotron or other accelerating machine through a target material and count the numbers of particles emerging at various angles. The beam may consist of protons or neutrons. The target may be hydrogen, whose nucleus is a single proton, or deuterium, whose nucleus has a proton and a neutron, or in some cases a heavier element. Thus all the combinations can be studied: proton-proton, neutron-neutron and neutron-proton. By using beams of different energies we obtain information about the force at different distances, as we shall see.

In describing the process by which a beam is scattered it is usual to speak of "collisions" between incident and target particles. But a better picture is a near miss, with incident and target particles orbiting around each other for the brief period that they are within effective range of the nuclear force. Scattering experiments are analogous to the observations on the orbits of the planets, which led to Newton's law of gravitation. They differ, however, in that the orbits are not closed ellipses, but open curves like the path of a rocket vehicle that swings once around the moon and then heads out into space. The similarity would be greater if the vehicle were as heavy as the moon and pulled the moon off course as it went by.

Even then the analogy would be imperfect. Any picture of an atomic or nuclear process that involves distinct little balls speeding along well-defined paths is misleading. Not only are the particles far too small to see and to trace, but also the uncertainty principle of quantum physics tells us that sharp trajectories do not even exist except at energies much higher than those we shall deal with. The only rigorous way to predict, or even to describe, the interactions we are interested in is to think of the particles as waves, and of their mutual effects as a mingling of waves. In our discussions and diagrams we use both waves and particles. This is only to convey a rough, intuitive idea of what is going on. The actual computations whose results we are describing are carried out by the consistent but abstract method of wave mechanics.

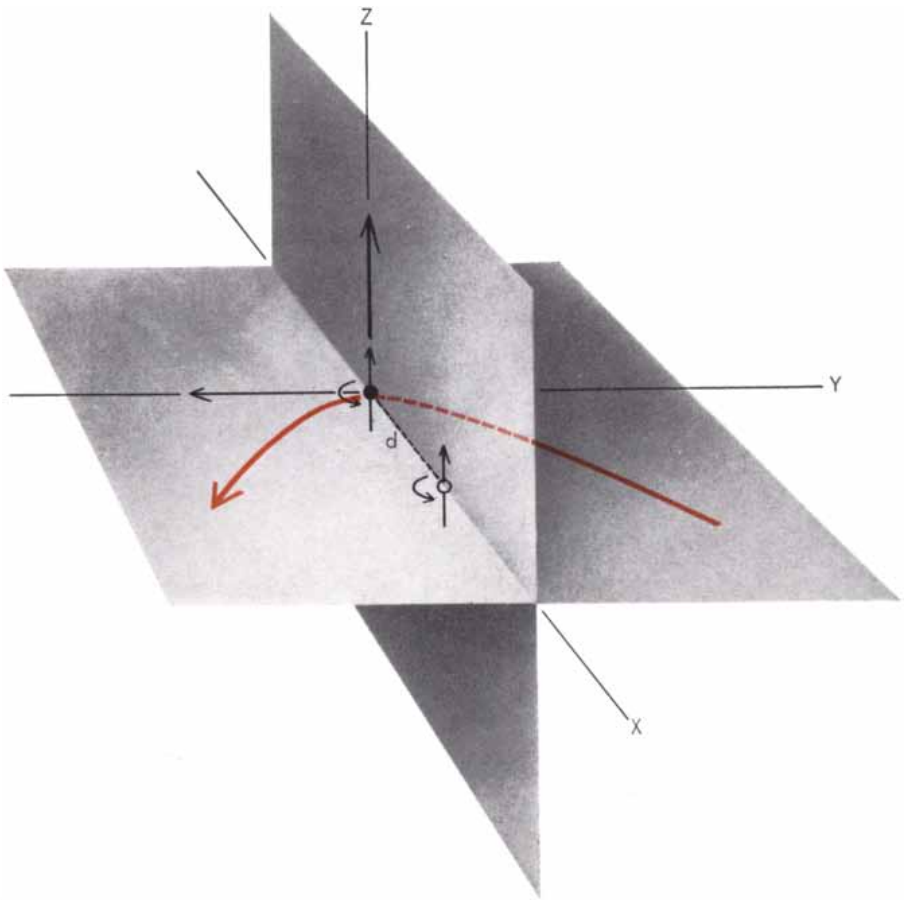
Angular Momentum

With these reservations in mind we can return to semifictional particle language to describe a scattering event. To simplify matters we may suppose for the moment that the target nucleon remains stationary while the bombarding, or incident, nucleon swings around it in a roughly hyperbolic orbit [*see illustration below*]. When the force is attractive, the orbit curves toward the target; when repulsive, the orbit curves away.

As has already been mentioned, both incident and target nucleons are spinning, and the relative direction of their spin axes may have a great effect on the force between them. If they were "classical" particles, the spins could be in any relative direction whatever. Quantum mechanics makes things much simpler; a pair of nucleons can spin only in the same direction or in opposite directions. In other words their spin axes must be either parallel or antiparallel.

This rule applies to any particle which, like a nucleon, has a spin of one-half unit. The unit is Planck's constant, h, divided by 2π, and it measures the angular momentum associated with any type of rotational motion in the quantum domain. Thus a nucleon has a spin angular-momentum of one-half unit. If the spin axis is in one direction, say up, the angular momentum is considered to be plus one-half unit. If it is in the opposite direction, or down, the angular momentum is minus one-half unit.

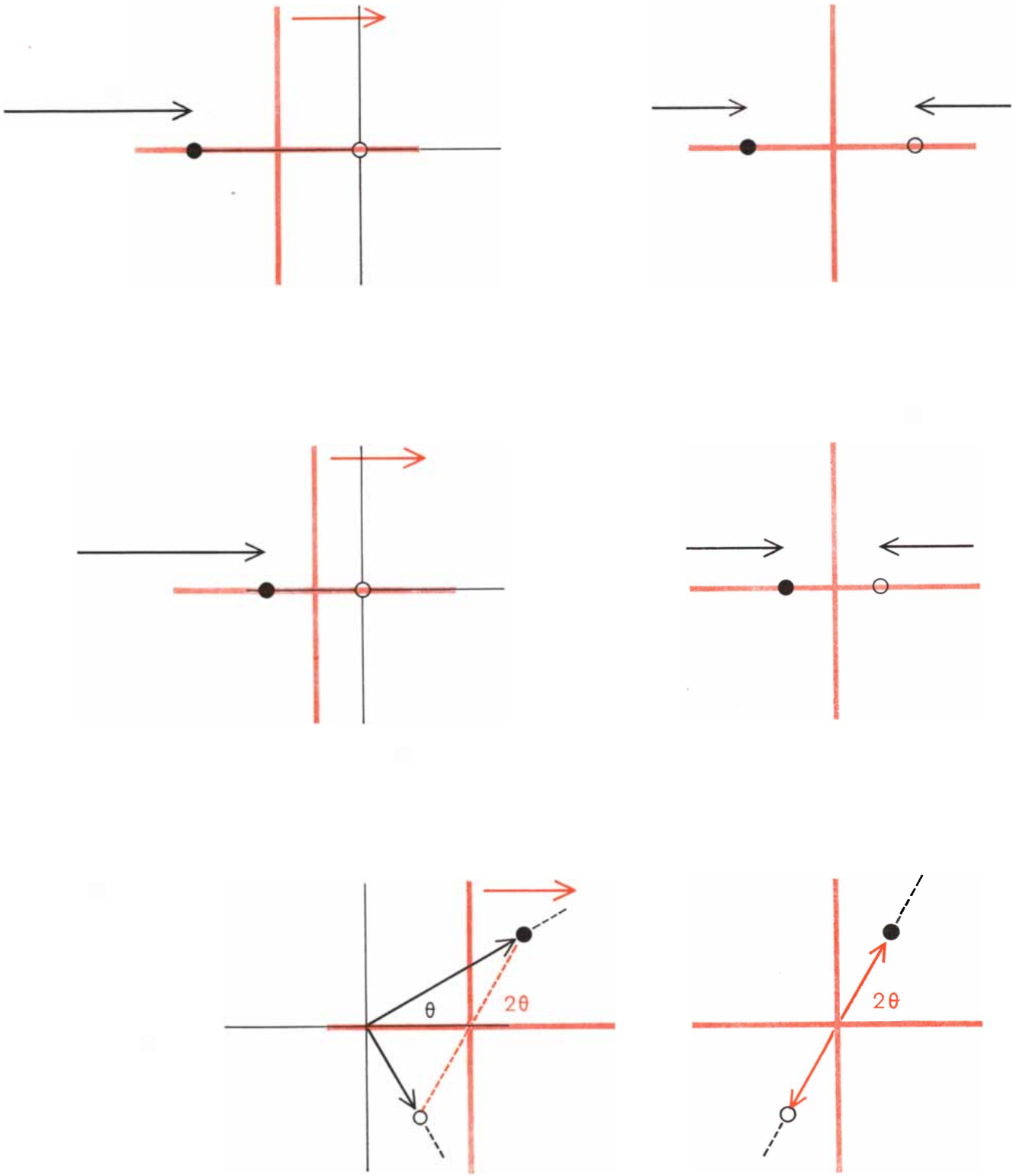
A system of two interacting nucleons



SCATTERING EVENT is illustrated in this greatly simplified drawing. Projectile nucleon (*solid dot*) follows curved trajectory (*colored line*) around target nucleon (*open dot*). (In fact both particles move.) Small curved arrows represent spins; small vertical arrows, the spin angular-momentum vector; horizontal arrow, linear-momentum vector; large vertical arrow, the orbital angular-momentum vector; *d*, the distance of closest approach.

has a total spin angular-momentum, found by adding the spins of the particles. When the individual spins of the two nucleons are parallel, the total spin is one; when they are antiparallel, the total spin is zero. Hence for the case of parallel spins there is a net total spin, providing a reference line with respect to which relative directions between the two nucleons can be differentiated. Two nucleons with parallel spins can, and in fact do, have a noncentral component in their interaction. But for antiparallel spins the total spin is truly zero. It is as if the separate particles were not spinning at all. There is no reference direction and hence no noncentral component; the force between the two nucleons is entirely central.

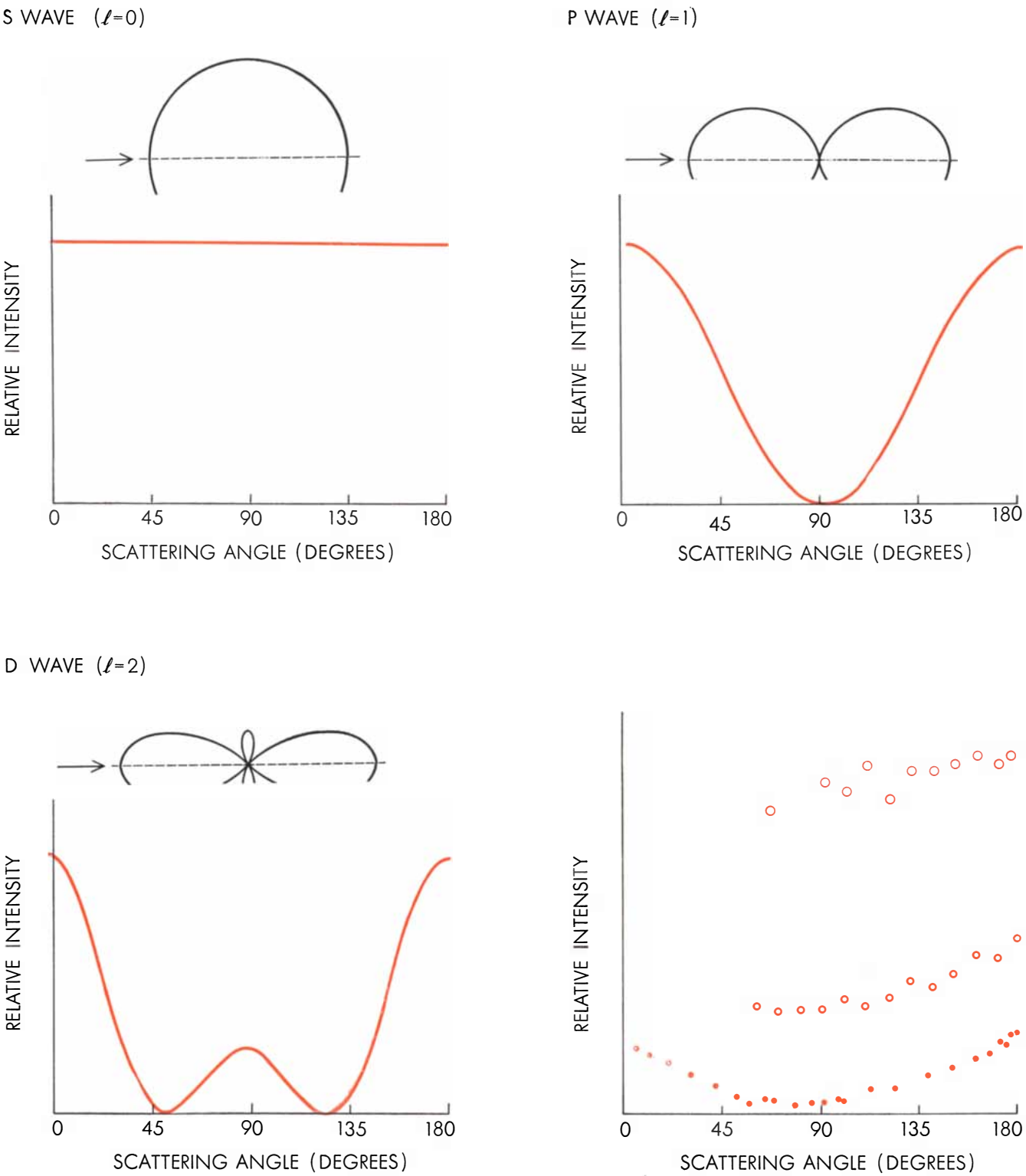
In addition to the spins of the separate particles the scattering system has



CENTER-OF-MASS coordinate system (*colored axes*) is illustrated in relation to laboratory coordinate system (*black axes*) at left, and as a stationary frame of reference at right. Incident particle is shown as solid dot; target particle, as open dot. Black arrows indicate velocities in laboratory frame; colored arrows, in center-of-mass frame. Views of approaching particles appear at top and center and a view after collision at bottom. Scattering angle, theta (θ), in the laboratory system is half that in center-of-mass system.

another rotational feature: the curved orbits of the particles. Associated with this type of motion is an orbital angular-momentum. In the simplest case, of uniform motion in a circle, the amount of orbital angular-momentum is found by multiplying the linear momentum by the radius of the circle. For the open curve of a scattering orbit we can find the orbital angular-momentum by multiplying the linear momentum of the incident particle at the moment it is nearest the target by this distance of closest approach. As with spin angular-momentum, the direction of orbital angular-momentum is represented by an arrow pointing perpendicularly to the plane of the curved path in accordance with the right-hand rule.

In the quantum world, angular momentum is a particularly important



SCATTERING PATTERNS for pure S-wave, P-wave and D-wave cases, corresponding to the orbital angular-momentum numbers (*l*) zero, one and two, are plotted at top left, top right and bottom left respectively. Points at lower right are experimental values of relative particle counts in neutron-proton scattering experiments at neutron energies of 18 million electron volts (*top*), 40 Mev (*middle*) and 150 Mev (*bottom*). The geometrical designs appearing above the S, P and D curves are polar plots from zero to 180 degrees.

quantity, and it is subject to two crucial conditions. First, when the two nucleons have a spin of one (that is, when their individual spins are parallel), the total-spin angular-momentum vector can have three, and only three, directions with respect to the orbital angular-momentum vector: the two can be parallel, perpendicular or antiparallel. This relationship provides a criterion for distinguishing a second type of noncentral force. In addition to the relative direction between the two spinning particles, which is the basis of the tensor type of noncentral force, there is now the relation between total-spin angular-momentum and orbital angular-momentum. Nature has taken advantage of this opportunity to differentiate and set up a second component of noncentral force between two nucleons which we call the spin-orbit force. (Like the tensor force it can exist only when the spins of the particles are parallel; when they are antiparallel, there is no spin angular-momentum and no spin-orbit force.)

The second quantum characteristic of orbital angular-momentum is that it can have only integral values. It can be zero, one unit, two units and so on. What does zero orbital angular-momentum mean? In classical terms it means that the distance of closest approach of the two nucleons is zero. We must think of the incident particle passing directly through the target particle. This is rather hard to imagine, so we must here have recourse to wave ideas. It is easy enough to picture one wave passing through another. For the higher values it is possible to picture curved paths, but they "really" represent wave processes too. The wavelengths of these waves depend on the orbital angular-momentum and on the distance of closest approach, as we shall see.

Beam Energy

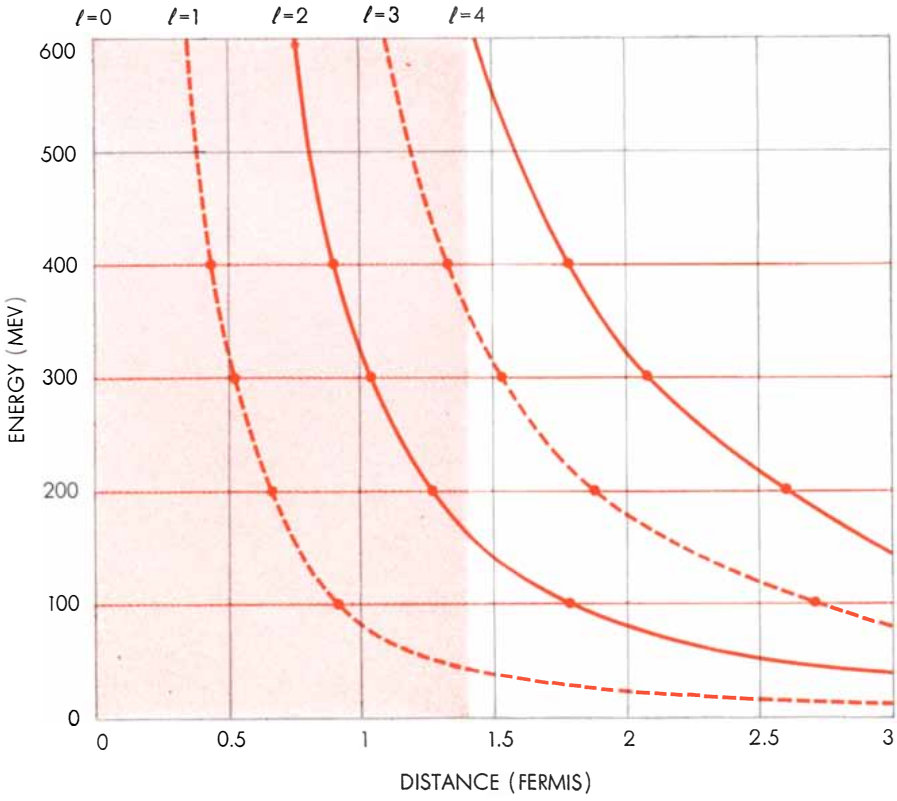
So much, then, for the complicated anatomy of a single scattering event. Imagine now a stream of billions of particles approaching a still larger number of target nuclei, as in an actual scattering experiment. First let us make the unlikely assumption that each incident particle is headed dead center at a target. In other words all the orbital angular-momenta are zero. If the particles can be thought of as passing through each other, we might suppose that the beam would simply continue straight ahead and that no sideward scattering would be observed. But not at all. If detecting counters are moved around the target, particles are found in varying amounts in all directions from zero deflection through 90 degrees (for a hydrogen target). The effect can be explained in wave terms as a diffraction process, like the angular spreading of a beam of light when it passes through a transparent diffraction grating.

Next assume that all the incident particles are aimed in such a way as to give orbits with an angular momentum of one unit. Now a quantum condition comes into play. As we have said, orbital angular-momentum is the linear momentum (mass times velocity, or mv), multiplied by the distance of closest approach, which we shall call d. The product mvd must be equal to one unit in the case we are considering. Thus the greater the value of v, the smaller d will be, which means the nearer the approach to the target. It is customary to describe particles in a beam in terms of their energy, which of course depends on velocity, rather than in terms of velocity itself. So we can equally well say that the greater the energy, the nearer the approach. Conversely, the less the speed or energy, the greater d must be, or the farther the particles are separated at their closest approach.

But nuclear forces extend over very short distances. If the speed of the incoming particle is too low, making d too large, the projectile and target will remain entirely out of range so far as the nuclear force is concerned. Then there will be no scattering at all. In order to get scattering at an orbital angular-momentum of one unit, the energy of the incident beam must exceed a certain minimum.

The same is true for the higher orbital angular-momenta, the minimum effective energy being successively greater. (If mvd equals two units, v must be still larger to make d small enough to fall within range of the nuclear force.)

If it were possible to have a pure beam of orbital angular-momentum one, then if the energy were above the necessary minimum, an angular scattering pattern would be observed that is quite different from the one for orbital angular-momentum zero. Similarly, the values two, three and so on would each give their own distinctive pattern.



ENERGIES associated with orbits of various angular momenta (l) are plotted as curved lines, with even values solid and odd values broken. Curve corresponding to zero momentum is the coordinate axes themselves. Colored horizontal lines represent energies of particle beams, and their intersections with the curves show the corresponding distances of closest approach. Shaded region within 1.4 fermis represents the range of nuclear force.

Patterns of Scattering

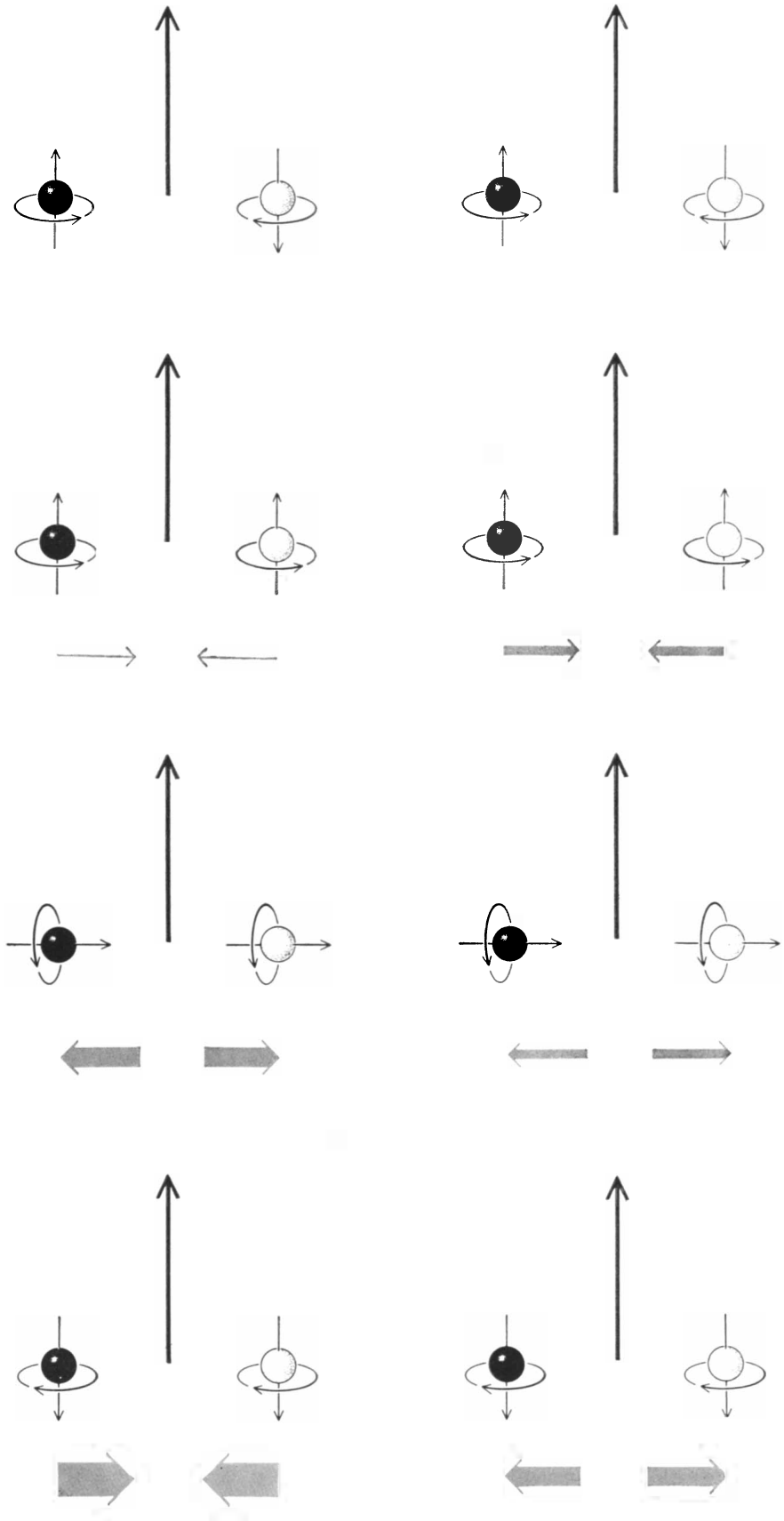
What do the scattering patterns look like? The raw angular distributions as

they are obtained in the laboratory have rather complicated shapes. But they become much simpler if translated into the so-called center-of-mass coordinate system. This reference system, universally employed in collision problems because of its mathematical convenience, has as its zero point the center of mass of the two particles. Where the two have equal masses, as they do in all the experiments we are considering, this point is midway between the two particles at every instant [*see illustration on page 102*]. If we imagine ourselves riding on the center of mass and consider ourselves at rest, then before the collision the particles would seem to be moving toward each other, each one having half the speed of the moving particle in the laboratory frame of reference. After the collision the particles will seem to be moving in exactly opposite directions, as can be seen in the illustration, and the scattering angle will be twice that measured in the laboratory frame of reference.

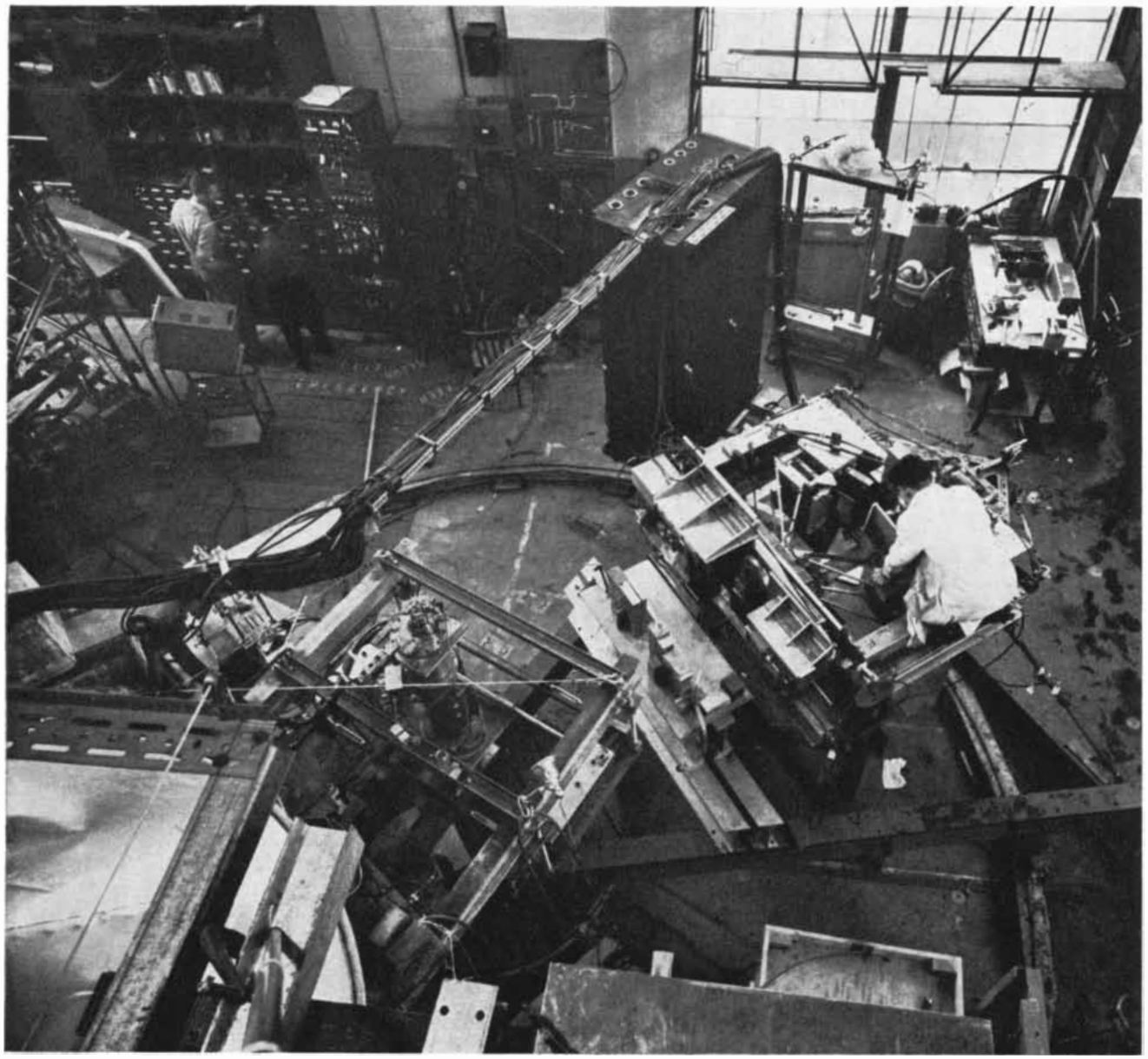
In the center-of-mass system the scattering pattern for zero orbital angular-momentum is spherical. An equal number of particles is deflected at every angle. For an orbital angular-momentum of one unit the pattern becomes a solid figure eight; the number of scattered particles is greatest in the forward direction, decreases to zero at 90 degrees, then increases again from 90 to 180 degrees and repeats on the other side of the center line, from 180 to 360 degrees [*see illustration on page 103*]. Higher orbital angular-momenta give still more complicated patterns, with several lobes. These shapes are commonly denoted by the letters S, P, D, F, G, H, etc., for patterns corresponding to the values 0, 1, 2, 3, 4, 5, etc., of orbital angular-momentum.

Although the curves are obtained by counting particles scattered at different angles with respect to the direction of the incident beam, they may be thought of in another way. They are pictures of the different waves that can make up a two-particle system. We speak of S-wave, P-wave, D-wave scattering and so on. The wavelength of all the waves grows shorter as the energy of the incident beam increases (varying inversely as the square root of the energy). It can be shown that the distance of closest approach is equal to the wavelength times number of orbital angular-momentum units.

In practice it is possible to have pure S-wave scattering when the energy of the incident beam is low. We do not see pure P, D or higher waves, however. As



NONCENTRAL FORCES between pairs of nucleons depend on the relative orientation of the particles. The tensor force is illustrated in the left-hand column; the spin-orbit force, in the right-hand column. The thickness of horizontal arrows is proportional to the size of the force in each case. The small, straight arrows passing through each particle are spin angular-momentum vectors. The large vertical arrows are orbital angular-momentum vectors.



TRIPLE-SCATTERING EXPERIMENT at the University of Rochester employs three targets. The first is within the synchrocyclotron, the edge of which appears at lower left. Polarized beam passes through cylinder of liquid hydrogen (*lower left center*) and then to third target-assembly mounted on track at right. This assembly can move around track to count particles at different angles.

the beam energy increases, the various higher modes are added to the S-wave pattern in greater and greater degree. This means that the beam contains particles of various angular momenta, with the higher values contributing increasingly to the scattering pattern as the beam energy increases.

Perhaps the easiest way to visualize the situation is to plot a series of curves, where each curve shows the energy associated with one value of the orbital angular-momentum number (usually denoted by l) at various distances of separation [*see illustration on page 104*]. On this graph a straight horizontal line represents the beam energy in a scattering experiment. Any such line will cross the successively higher orbital angular-momentum curves at greater and greater distances, which represent the increasing distances of closest approach. If we indicate the effective range of the nuclear force on the same graph, we can see at a glance which angular momenta will contribute to scattering at a given energy.

The "range" of the nuclear force is generally taken as 1.4 fermis. At this distance it does not drop to zero, but to about one third of its maximum value. In about two more removes of 1.4 fermis, the force becomes essentially zero. Any momentum curve crossing the beam-energy line beyond 1.4 fermis does not contribute very strongly to the scattering pattern.

Resolving Power

What the graph demonstrates is the increasing resolving power of higher and higher beam-energies. As energy increases, waves of higher orbital angular-momentum enter into the scattering process. As we have seen, the distance of closest approach of the two nucleons is equal to the wavelength times l, so that larger l means shorter wavelength. In addition, for any value of l, higher energy means shorter wavelength. Thus

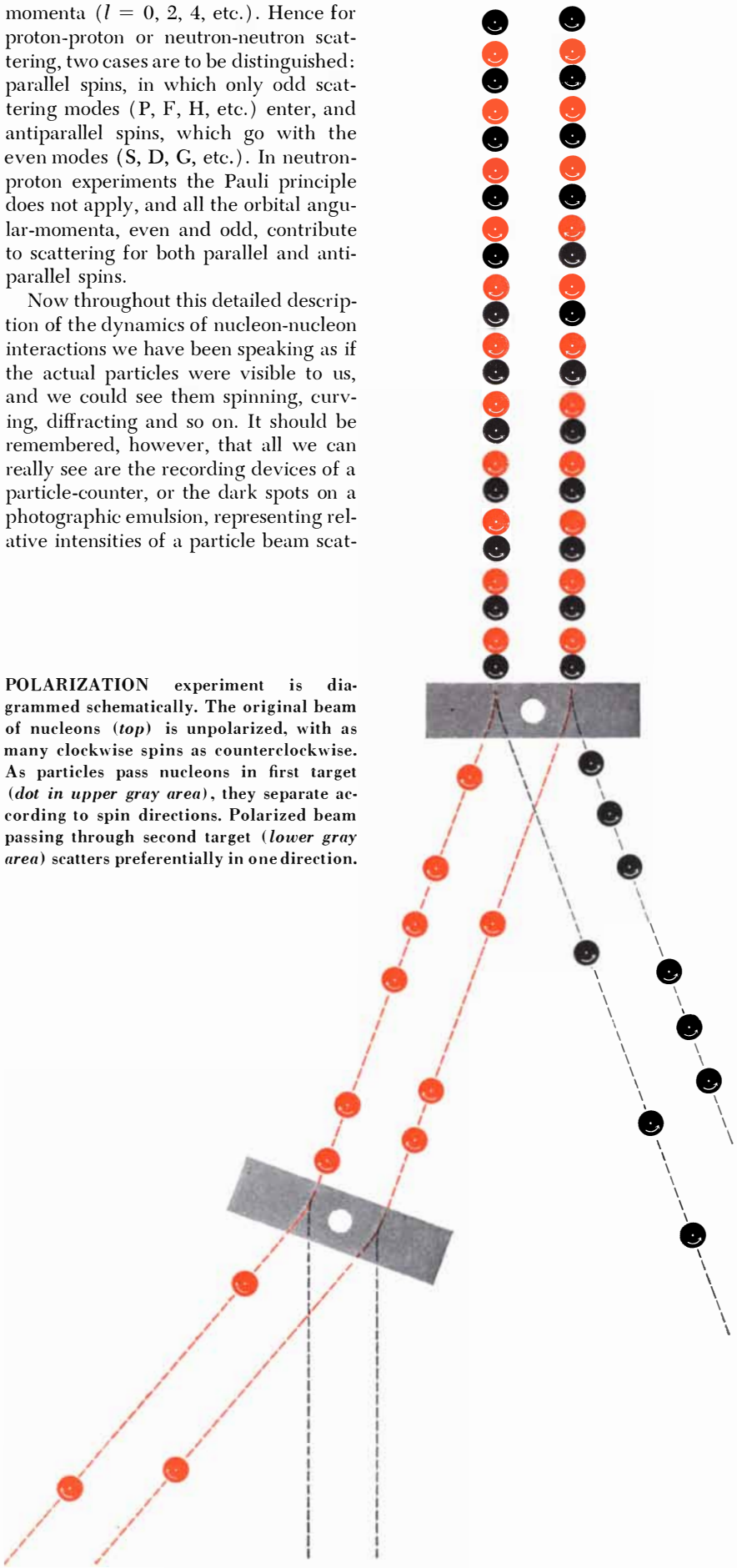
all the waves—S, P, D, etc.—have shorter wavelengths at higher energies. Just as in an optical observation, the shorter the wavelength compared to the dimensions of the object being studied, the finer the detail that can be seen. Here the "object" is a pair of particles within the range of the nuclear force: about 1.4 fermis. The more wavelengths that fit into this range, the higher the resolving power.

At first glance it might seem that resolving power could be increased indefinitely, up to the highest energies available in accelerating machines. However, above an energy of 300 million electron volts (300 Mev) a new factor complicates the scattering process. At such energies the nucleons do not simply orbit around one another and separate; instead new particles are created in the collision. These are pi mesons, or pions, which are the "field quanta" of nuclear forces [see "Pions," by Robert E. Marshak; SCIENTIFIC AMERICAN, January, 1957]. The creation of additional particles greatly complicates the analysis of scattering.

Fortunately we need not consider energies above 300 Mev if we are interested in the force holding nuclei together, as opposed to the more general nucleon-nucleon interactions of particle physics. Within the nucleus the average kinetic energy of the constituent nucleons is about 25 Mev. The maximum energy ever acquired by an individual nucleon with respect to a neighbor is approximately 100 Mev. Scattering experiments at energies much higher than this do not represent conditions that could occur with any significant probability inside a nucleus. In this article we consider only experiments up to 300 Mev, thus limiting ourselves to the range of nuclear physics rather than of all particle physics.

Our picture of scattering is now complete except for one final quantum restriction: the famous Pauli exclusion principle. The principle says that no two identical particles of spin one-half unit can be in exactly the same quantum state. In the familiar case of atomic electrons orbiting around a nucleus, this means that each orbit can contain only two electrons with spins in opposite directions. The application of the exclusion principle to the open "orbits" of the scattering process is somewhat different. Here the restriction is that pairs of (identical) nucleons with parallel spins must have odd orbital angular-momenta (l = 1, 3, 5, etc.). Nucleons with antiparallel spins can have only even orbital angular-momenta (l = 0, 2, 4, etc.). Hence for proton-proton or neutron-neutron scattering, two cases are to be distinguished: parallel spins, in which only odd scattering modes (P, F, H, etc.) enter, and antiparallel spins, which go with the even modes (S, D, G, etc.). In neutron-proton experiments the Pauli principle does not apply, and all the orbital angular-momenta, even and odd, contribute to scattering for both parallel and antiparallel spins.

Now throughout this detailed description of the dynamics of nucleon-nucleon interactions we have been speaking as if the actual particles were visible to us, and we could see them spinning, curving, diffracting and so on. It should be remembered, however, that all we can really see are the recording devices of a particle-counter, or the dark spots on a photographic emulsion, representing relative intensities of a particle beam scat-



POLARIZATION experiment is diagrammed schematically. The original beam of nucleons (*top*) is unpolarized, with as many clockwise spins as counterclockwise. As particles pass nucleons in first target (*dot in upper gray area*), they separate according to spin directions. Polarized beam passing through second target (*lower gray area*) scatters preferentially in one direction.

tered in various directions. From these data the experimenter draws a curve, which he then presents to the theoretical physicist and asks: What kind of force produced such a graph?

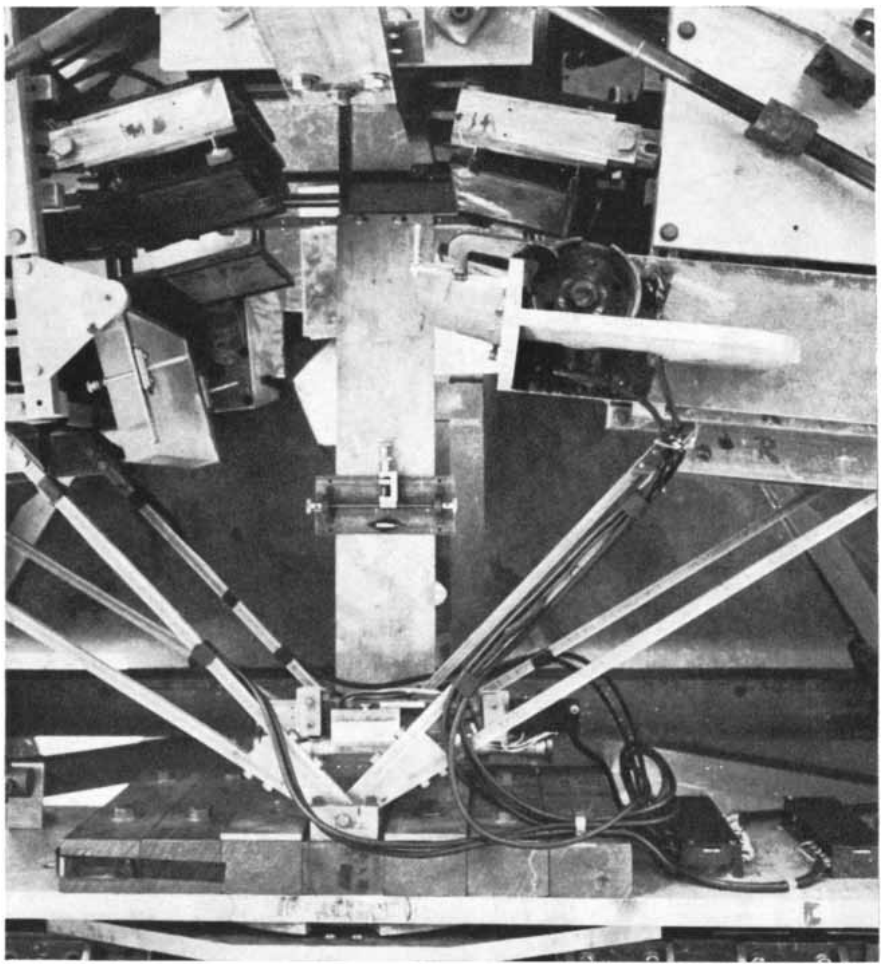
The theoretician realizes that the patterns contain unknown mixtures of S-waves, P-waves, D-waves and so on; that they may correspond to antiparallel or parallel spins; and that the parallel spins may have pointed in different directions with respect to the orbital angular-momentum. And all these variations can lead to different forces. How can they be disentangled?

Polarization

For a long time the situation seemed almost hopelessly complicated. The earlier scattering experiments had helped outline the cruder features of nuclear forces, but the fine details were beyond their power to illuminate. Then in 1953 C. L. Oxley and his colleagues at the University of Rochester, working with a 240-Mev synchrocyclotron, discovered that high-energy proton beams are strongly polarized after being scattered from a hydrogen target. The particles emerging at various angles contain a preponderance of one spin direction, up or down with respect to the plane of the incident and scattered beams. Here was a powerful new tool to help discriminate among the bewildering array of possible interactions. Soon a number of other laboratories took up polarization experiments along with Oxley's group. In particular the work was carried on at Harvard University and at the Atomic Energy Research Establishment in Harwell, England, with 150-Mev accelerators, and at the University of California and the University of Liverpool in England with 300-Mev machines. A number of theoretical physicists have applied themselves to analyzing the results with the help of large electronic computers. Out of this far-flung effort is emerging a much clearer picture of the nuclear force.

Looking back, we can see that polarization should have been expected to result from noncentral forces. To understand why, imagine a beam of unpolarized protons (with as many upward spins as downward) passing to the right and left of target nuclei [*see illustration on page 107*]. Those passing to the right have their orbital angular-momentum pointing up; those to the left, down. This means that on one side the upward spins are parallel to the angular momentum and the downward spins antiparallel; on the other side the situation is reversed. If the force is different for the parallel and antiparallel cases, the particles will be scattered differently depending on their upward or downward spin. Any difference in force is enough to upset the symmetry of scattering. Thus the spinning particles are segregated, one group going preferentially to the right and the other to the left. If the force changes from attractive to repulsive, as it can in some cases, the separation would be complete and the beams would be 100 per cent polarized.

The counters used to detect scattering, however, do not discriminate between the two types of spin. To gather the information contained in polarized beams an analyzer is needed, just as it is in polarized-light experiments. A second hydrogen target provides the necessary analyzer. If the particles approaching it are all, or almost all, spinning in the same direction, then they will be scattered most strongly in the preferred direction. The scattering pattern will now show an asymmetry as between right and left. From this asymmetry the degree of polarization can be measured [*see top illustration on page 113*]. Thus double-scattering experiments yield much more information than single-scattering ones. They were the first to demonstrate unequivocally that the proton-proton force has noncentral components.



SCINTILLATION COUNTERS (*rectangular plates to left and right of center at top*) **measure the numbers of particles scattered at a given angle to either side of the third target.**

Pictures of the Force

Recently the method has been extended another step, and the asymmetrical beam has been scattered a third time. These triple-scattering experiments reveal still further details. They were first performed by the Nobel laureates Emilio Segrè and Owen Chamberlain and their colleagues at the University of California.

What are the results? From all that has been said it is obvious that we cannot speak of *the* nuclear force. We can only study all the nucleon combinations individually and determine the force for each. The one that has been most intensively studied so far is the proton-proton interaction. Having an electric charge, protons are easier projectiles to handle than neutrons. They can be ac-

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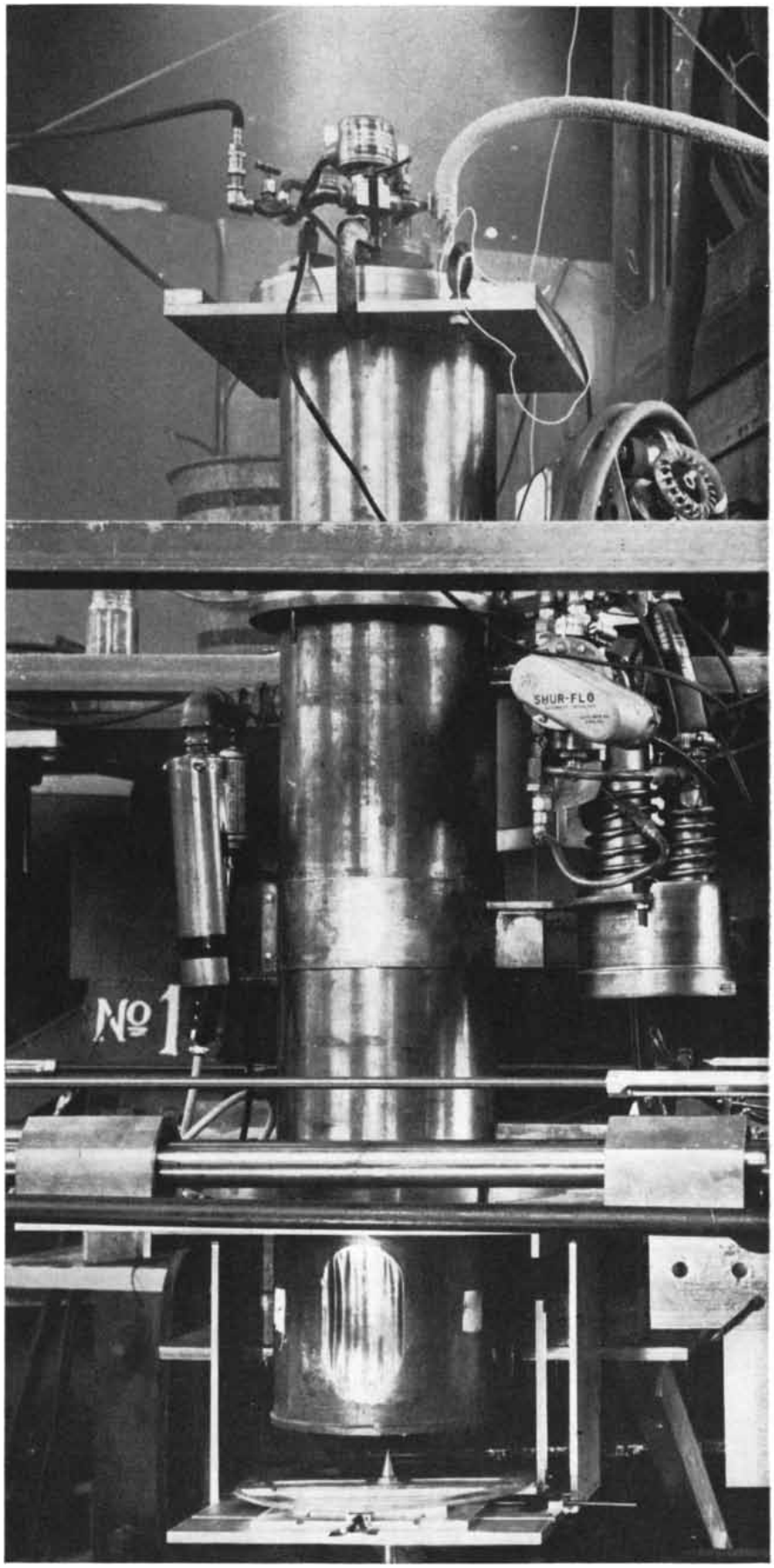
celerated, focused and aimed by electric and magnetic fields. Furthermore, there are targets of protons alone but not of neutrons alone.

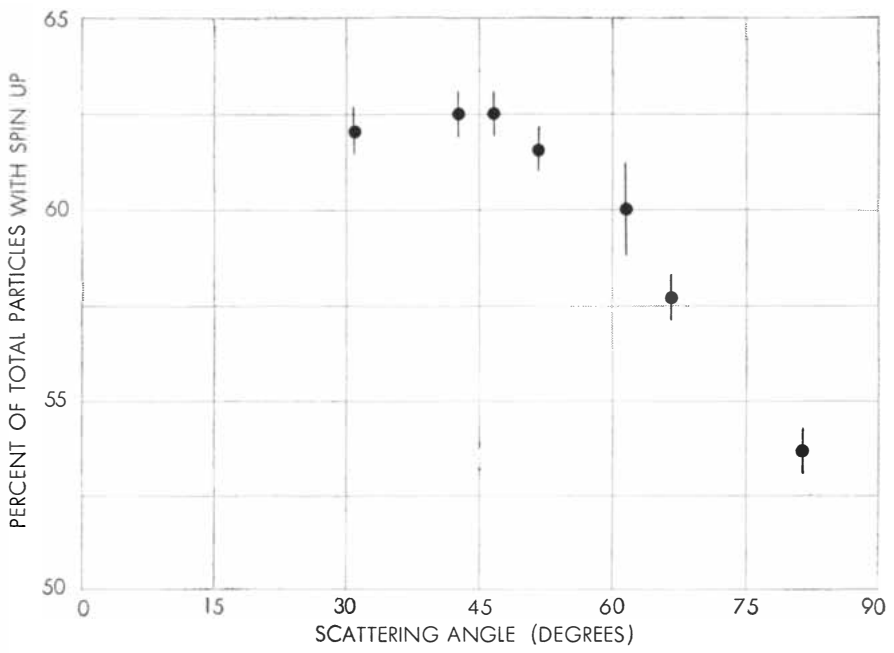
At the bottom of the next page and on page 114 are samples of the various components that combine to make up proton-proton forces. (The curves themselves show the potentials.) They represent a synthesis of calculations done by P. S. Signell and R. A. Bryan in collaboration with the author at the University of Rochester and by J. L. Gammel and R. M. Thaler at the Los Alamos Scientific Laboratory. We are fairly confident of the values of the potentials at distances greater than about one fermi, but are increasingly uncertain about the accuracy as the distance decreases. The bottom graph on page 113 shows the potential for the conditions of antiparallel spin, where the force has only a central component. The size of the force depends only on the distance between the particles. We see that at distances greater than .7 fermi the potential-energy curve slants up to the right, implying that the force is attractive. At shorter distances the curve slants up to the left, indicating a repulsive force. The force curve itself is a broken line.

The top graph on page 114 contains three curves, representing the potential energy due to the central force and one sample of the possible combinations of spin and orbital angular-momentum for the tensor and spin-orbit forces. We see that the central force differs for the antiparallel and parallel spin states. At larger distances the force for the antiparallel state is stronger (*i.e.*, the potential-energy curve slopes upward more sharply). The curve for the tensor potential represents the case where the particle-spins are at right angles to the orbital angular-momentum. The potentials are different when the spins are parallel and when they are antiparallel to the orbital angular-momentum. The same is true for the spin-orbit curve. Both types of force are strong and of short range, but the range of the spin-orbit force is about half that of the tensor force. This means that higher energy is required to bring the spin-orbit force into play than is required for the tensor force.

So we find that the nuclear force between two protons is about as complicated as it could possibly be. Two types of central force, depending on the relative orientation of the spins, and two types of noncentral force are necessary to explain all the experimental facts. And the noncentral forces even change their signs and magnitude depending on the



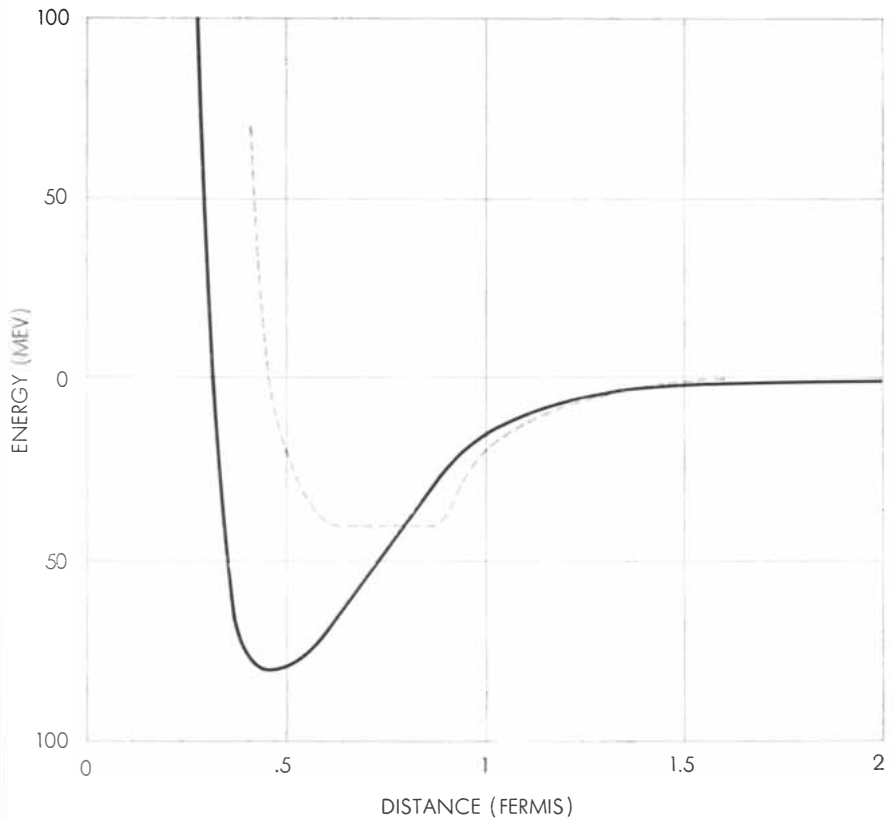
SECOND TARGET in triple-scattering experiment is liquid hydrogen contained in the brass cylinder photographed in close-up. Particles pass through the window at the bottom.



DEGREE OF POLARIZATION produced in scattering process varies with the scattering angle. Each point on this graph shows the per cent of total particles with spin vectors pointing up emerging at a specific angle from target. Lines represent limits of error.

relative orientation of the spin and orbital angular-momenta.

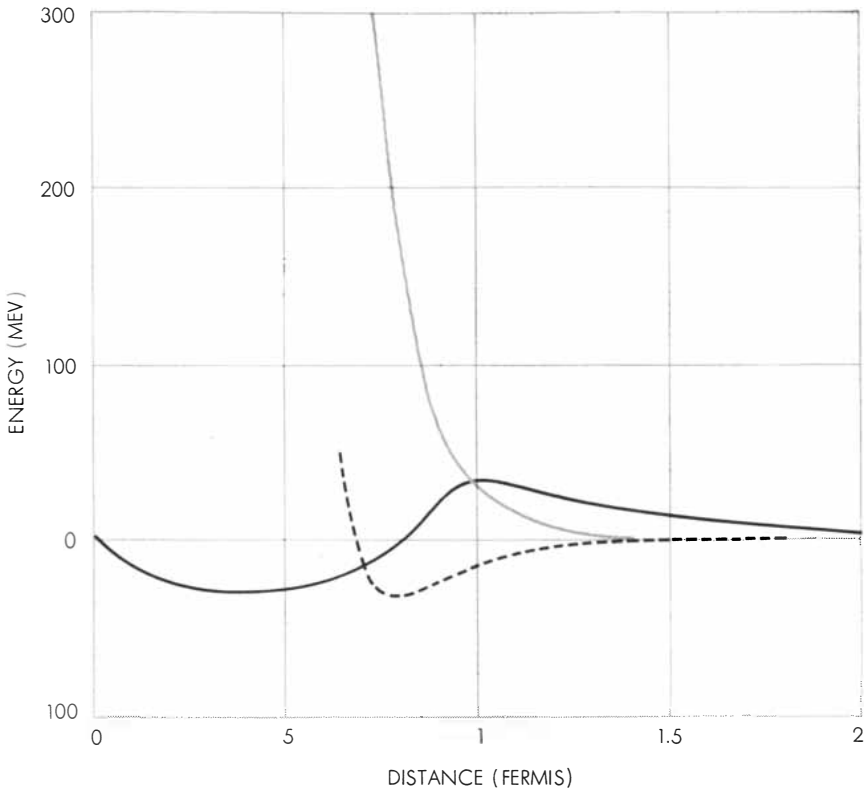
What about neutron-neutron forces? Since there are no pure neutron targets, the experiments must necessarily be less direct. Neutrons are scattered from targets such as deuterons, containing both protons and neutrons, and the effect of the pure neutron-neutron force must be calculated. So far as we can tell, these experiments confirm the long-suspected principle of charge symmetry. Nature has made an astonishing choice in favor of simplicity. With a clear opportunity



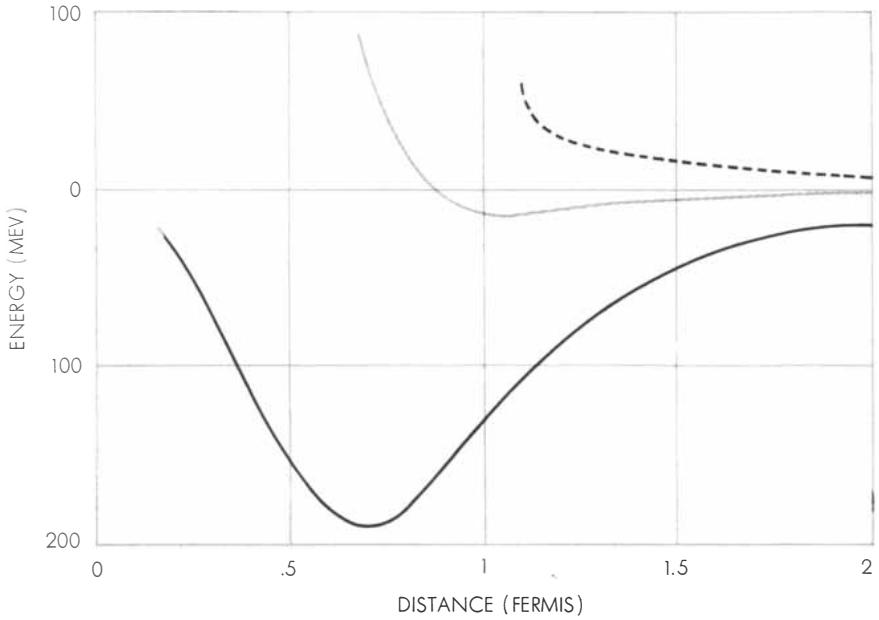
PROTONS WITH ANTIPARALLEL SPINS can have only a central force. Corresponding potential energy is shown by solid curve. Broken curve indicates shape of force itself.

to distinguish between protons and neutrons, she has chosen not to do so. The nuclear force between two neutrons appears to be exactly the same as that between two protons.

Furthermore, the independence of the nuclear force with respect to charge seems to extend to the neutron-proton system, but with a new and complicating feature added. Because the neutron and proton are different particles, the Pauli principle does not apply to them. Therefore they can go together in combinations that are excluded for two protons and two neutrons. Specifically, they can have antiparallel spins together with odd orbital angular-momentum, and parallel spins together with even orbital angular-momentum.



PROTONS WITH PARALLEL SPINS have a central force (*broken curve*), a tensor force (*black curve*) and a spin-orbit force (*gray curve*). The curves actually show potential energy rather than force itself. The tensor and spin-orbit curves that are drawn here apply to the case where the spin vector is perpendicular to the orbital angular-momentum vector.



FORCE BETWEEN PROTON AND NEUTRON can have components that are ruled out in proton-proton and neutron-neutron cases by the Pauli exclusion principle. Dashed curve gives potential energy for antiparallel spins and odd orbital angular-momentum (l). Gray curve applies to the central force for parallel spins and even l; black curve, to the tensor force for the same situation. The existence of a spin-orbit force is still uncertain.

Unfortunately no triple-scattering experiments for neutron and proton have been carried out so far; they are very difficult. But there have been single- and double-scattering experiments for quite a range of energies. The lack of triple-scattering data and the fact that there are more possible states have made it much more difficult to pin down the nuclear force between the neutron and the proton.

Analyses of the available scattering results, and of the properties of the deuteron (which is a bound neutron-proton system with parallel spins and even orbital angular-momentum) suggest that the neutron-proton force is also the same as that between two protons for the states they share in common (even orbital angular-momentum and antiparallel spins; odd orbital angular-momentum and parallel spins). The potential energies for the other two combinations of states are different. The bottom graph on this page summarizes what we know about them. Note that a tensor force is the only noncentral type represented. We do not yet have enough information to decide whether there is a spin-orbit force as well.

Working with these recently discovered potential energies between two nucleons, theorists are having increasing success in explaining the properties of nuclei larger than the deuteron. As the force picture is further sharpened, nuclear physics will continue to advance.

What of the dream of a true theoretical understanding of the nuclear force? At the moment we can hardly do more than hope we are on the right track. There seems every reason to suppose that Hideki Yukawa's famous conjecture was right, and that the pion is the "agent" that is responsible for the force between two nucleons. But although we can write equations based on this idea, we do not know how to solve them. Therefore we cannot even be sure that the equations themselves are right. Very rough approximate solutions do seem to give the correct nuclear force for large distances. For smaller distances, however, the answers do not agree with the experimental results.

We are still confident that some day we shall be able to write down the correct equations and find a way of solving them. Meantime there seems no choice but to push ahead with the empirical approach described in this article.

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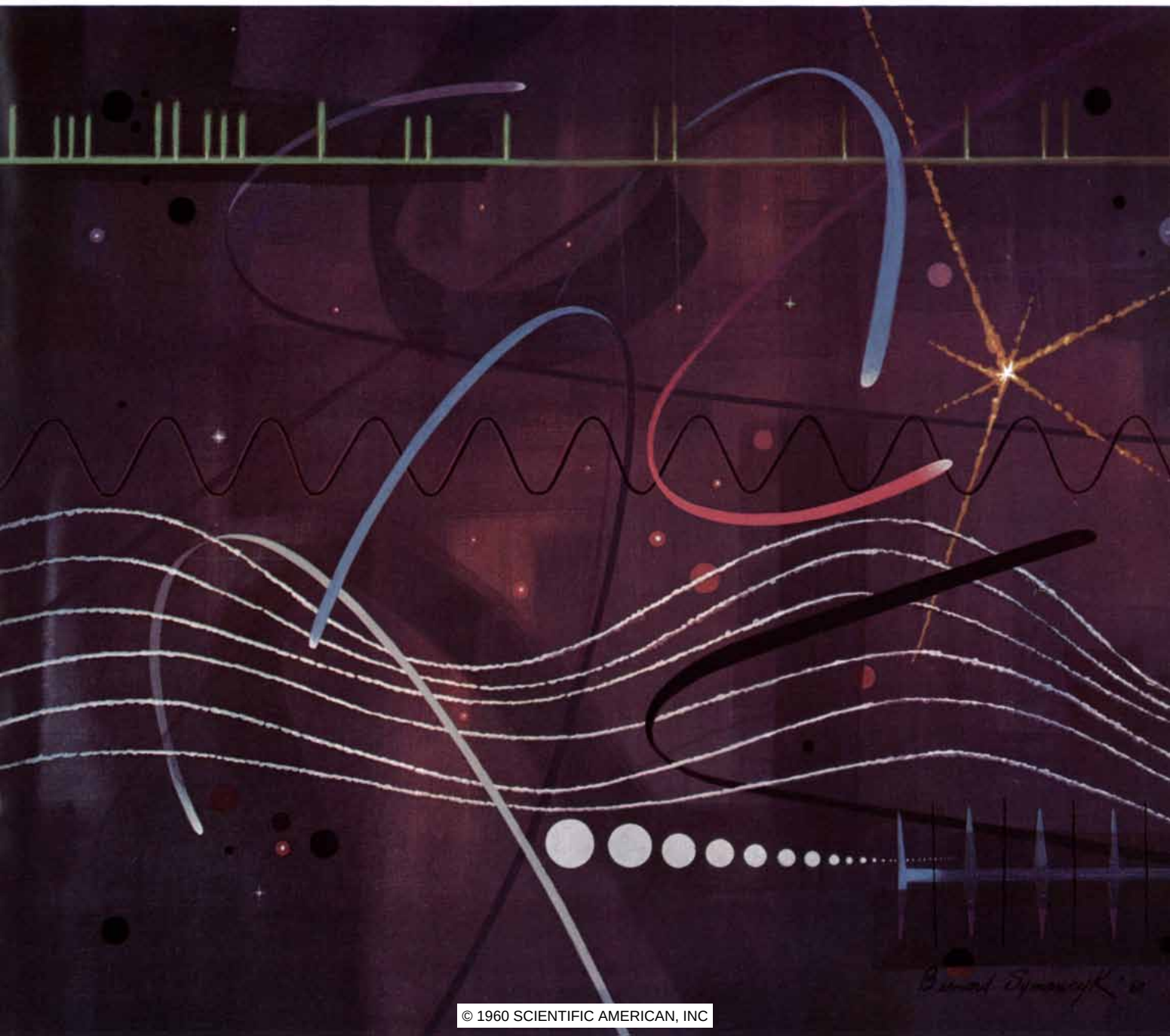

TION

AND HARVESTING

BY BORG-WARNER

A review of the roles which a versatile corporation plays in helping the farmer plant and harvest his crops

This is a Mechanized Age down on the farm—a time of automatic corn-crib loading, of tractors with tremendous lugging power, of deserts-turned-cotton fields through irrigation. And Borg-Warner has played no small part in helping the farmer achieve his present-day efficiency.

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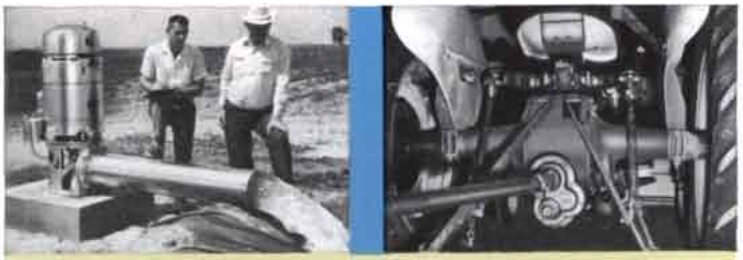

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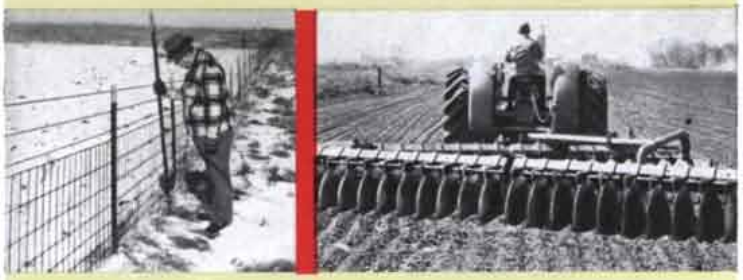

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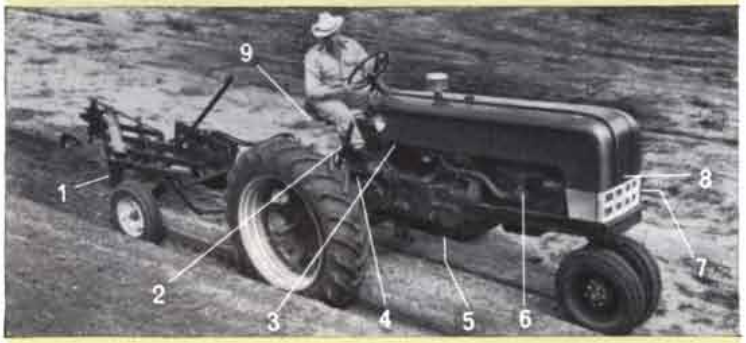

OTHER ESSENTIAL BORG-WARNER PARTS for tractors and plows are (1) Soft-center steel for moldboard plows and shares by Ingersoll Steel Division; (2) clutch by Rockford Clutch Division; (3) hydraulic pumps and valves by Wooster Division; (4) universal joint and (5) propeller shaft by Mechanics Universal Joint Division; (6) carburetor by Marvel-Schebler Products Division; (7) timing chain by Morse Chain Company; (8) radiator by Long Manufacturing Division; (9) seat, and other stampings, by Ingersoll Products Division. Also contributing to agriculture are the Borg & Beck, Marbon Chemical and Spring Divisions.

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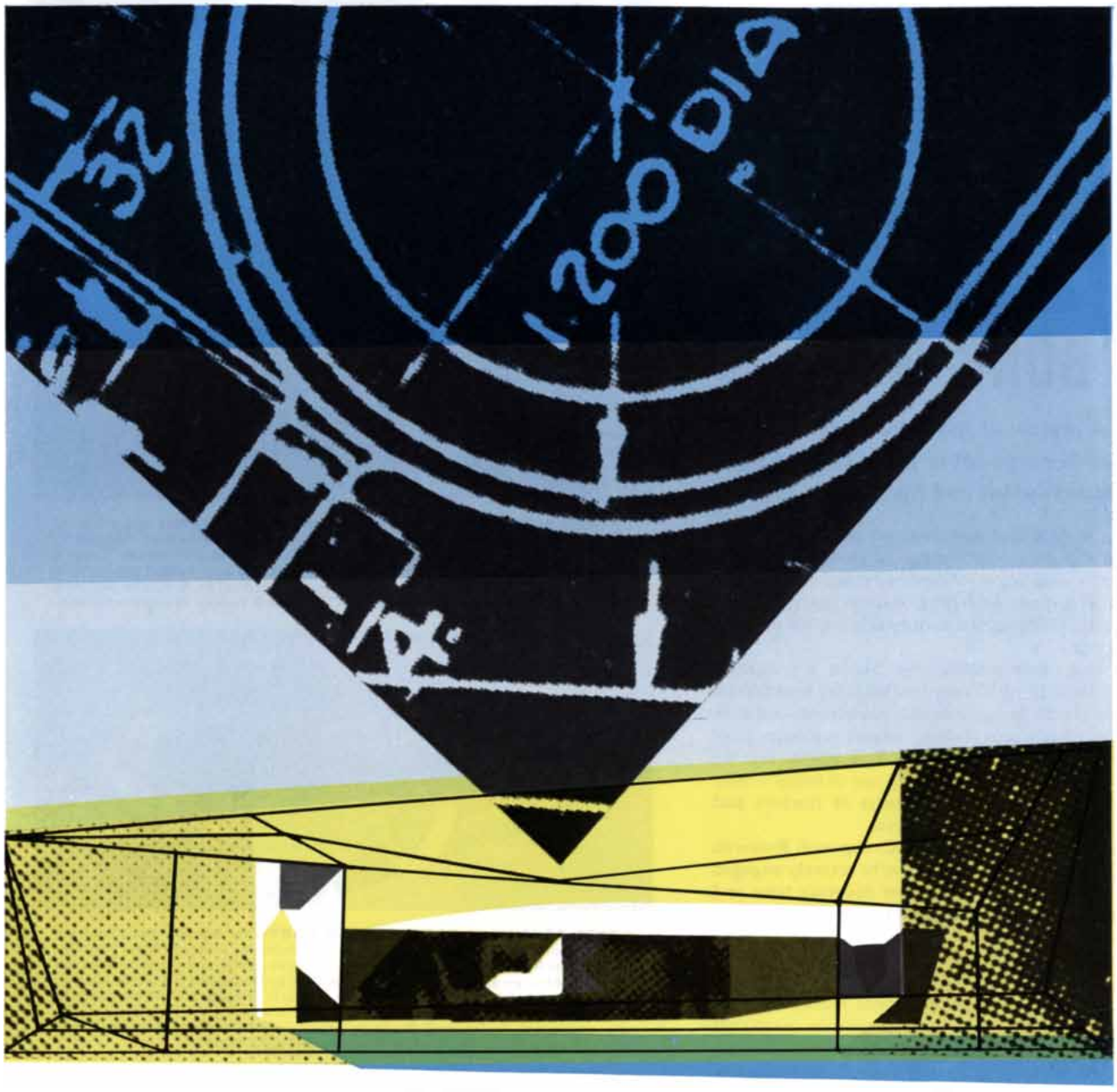

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THE THYROID GLAND

Hormones secreted by this pad of tissue in the neck control the speed of basic processes in the body. The overproduction or underproduction of the hormones can have grave consequences, particularly in childhood

by Lawson Wilkins

Our general well-being depends strongly upon the rate at which our bodies "live." The speed of virtually all the basic cellular processes of the body is regulated largely by the thyroid gland, a pad of pink tissue that weighs somewhat less than an ounce and is located at the base of the neck just below the vocal cords. The thyroid hormones, distributed by the bloodstream, stimulate the metabolism of practically all the cells of the body. Disorders of the thyroid usually manifest themselves to the body as a whole in one of two ways: the gland produces too much hormone and races the metabolism (hyperthyroidism) or the gland produces too little hormone, causing the metabolism to slow down to subnormal and even vegetative levels (hypothyroidism). Either condition, when acute, may devastate body and mind, and either may be associated with the disfiguring enlargement of the thyroid known as goiter.

Goiter has been a familiar malady since ancient times. Pliny the Elder, Vitruvius and Juvenal commented upon the prevalence of goiter among the inhabitants of the Alps. (The term derives from the Latin word *guttur,* throat.) The second-century Greek physician Galen believed that the thyroid secretes a lubricating fluid to facilitate speech. This theory had proponents as recently as 150 years ago, even though the great Renaissance anatomist Vesalius had accurately described the gland and noted that it has no duct through which a lubricating fluid could flow. In 1656 the English physician Thomas Wharton proposed the name thyroid (from the Greek word for "shield-shaped") for the gland. He thought that it served simply to round out and beautify the neck, "particularly in females to whom for this reason a larger gland has been assigned." Other writers, observing that the gland has a generous supply of blood vessels, concluded that it must be a shunt to catch excess blood that may rush from time to time toward the brain.

Toward the end of the 18th century physicians began to observe that goiter is often accompanied by severe systemic disease. Among goitrous individuals in the Alps, some appeared to be apathetic and mentally dull; they had a slow heartbeat, a cool, dry skin and the flabby, puffy condition of the tissues called myxedema—all symptoms now identified with hypothyroidism. The medical literature of the day also observed that in children goiter was often associated with cretinism, a condition in which mental deficiency and a marked stunting of growth and physical development were added to the other symptoms of hypothyroidism. But the picture was not clear-cut. Many people had goiter and were otherwise healthy. Goiters were so common in some regions that individuals without them were considered abnormal and less attractive. On the other hand, in England and elsewhere there were occasional children and adults who had all the worst symptoms of the endemic goiter of the Alps, except that they had no goiter. Autopsies showed, in fact, that they had no thyroid tissue at all.

The clinical picture of goiter became even more confused early in the 19th century, when several physicians in England, Spain and Germany independently described the first recorded cases of what is now called hyperthyroidism. The patients had goiters, but their other symptoms were the exact opposite of those associated with endemic Alpine goiter. They exhibited warm, moist, flushed skin; violent, rapid heart action; excessive nervousness and emotional instability; and loss of weight despite a large appetite. In addition, they had prominent, staring eyes. The disorder came to be called exophthalmic (bulging-eyed) or thyrotoxic goiter.

The first real understanding of the function of the thyroid dates from 1883. In order to relieve pressure on the windpipe and other organs, three Swiss surgeons completely removed over-large goiters from 46 patients. The operations brought the expected mechanical relief, but within a few months almost all of the patients had developed the worst symptoms of endemic goiter. Then experiments were performed on animals in which removal of the thyroid in early life duplicated even the symptoms of cretinism. These observations suggested that the thyroid must contain some substance essential for health and for normal growth and development. By the early 1890's physicians were successfully treating hypothyroid patients by adding sheep's thyroid to the diet and by administering extracts of thyroid gland.

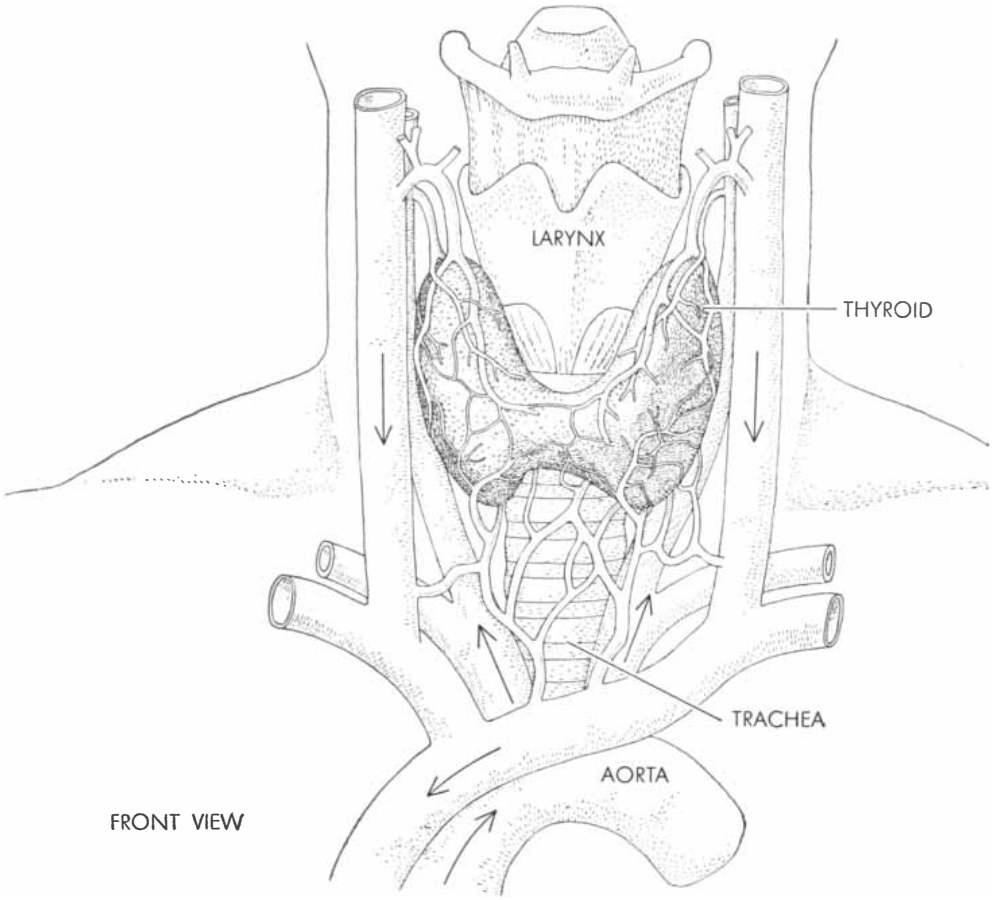
In 1896 the German chemist E. Baumann was surprised to discover that the thyroid contains iodine, an element not previously known to be present in the body. Later analysis revealed that the normal human thyroid contains about eight milligrams (.0004 ounce) of iodine, and the rest of the body some 30 milligrams. Since this was one of the first elements to be found in "trace" amounts in the body, physiologists at first paid little attention to Baumann's discovery.

It was a young American physician, David Marine, who demonstrated that iodine is essential to health. Upon graduating from the Johns Hopkins Medical School in 1905, he went to Cleveland to work in pathology. On his first day there he noticed that many people and most dogs had goiters. Even the fish in the streams of the area displayed goiters

(all vertebrates possess a thyroid gland). Marine conceived the idea that lack of iodine in the local food and water supply might be the cause. To test this idea he deprived experimental animals of dietary iodine and succeeded in giving them goiter. He then discovered that he could cure the goiters by feeding the animals minute quantities of iodine.

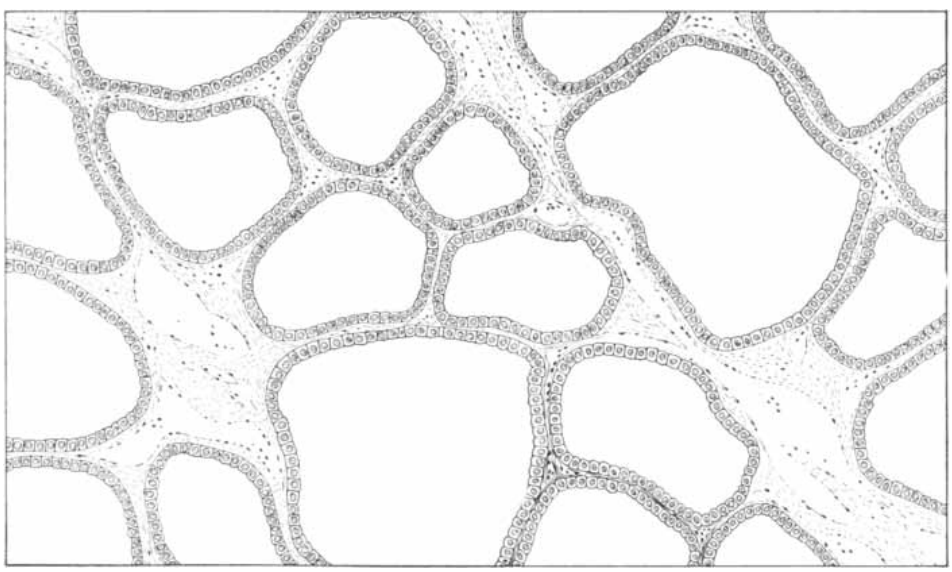
In 1916, after a decade of laboratory investigation, Marine obtained permission to give traces of iodine to some schoolgirls in Akron, Ohio. He was able to demonstrate that these children were much less prone to goiter than those who did not receive iodine, and similar tests elsewhere quickly confirmed his thesis that endemic goiter is caused by iodine deficiency in the water, soil and plants, and hence in the diet. (An adult needs only 15 billionths of an ounce of iodine a day, but even that may not be available.) Marine urged that iodides be added to drinking water and table salt in regions of endemic goiter. But his proposal drew as much opposition as the use of fluorides to prevent tooth decay does today. It was nearly 10 years before Marine and other workers convinced the world that such a simple precaution would prevent endemic goiter.

Thus by the early 1920's physicians could diagnose the principal thyroid disorders and had simple and effective remedies for most cases of them. The clinic, however, was far ahead of the laboratory. Little was known about how the gland synthesizes, stores and releases its hormone. Progress in research had to await the refinement of biochemical techniques and the availability of radioactive iodine (iodine 131), both of which developments have occurred during the past 15 years.

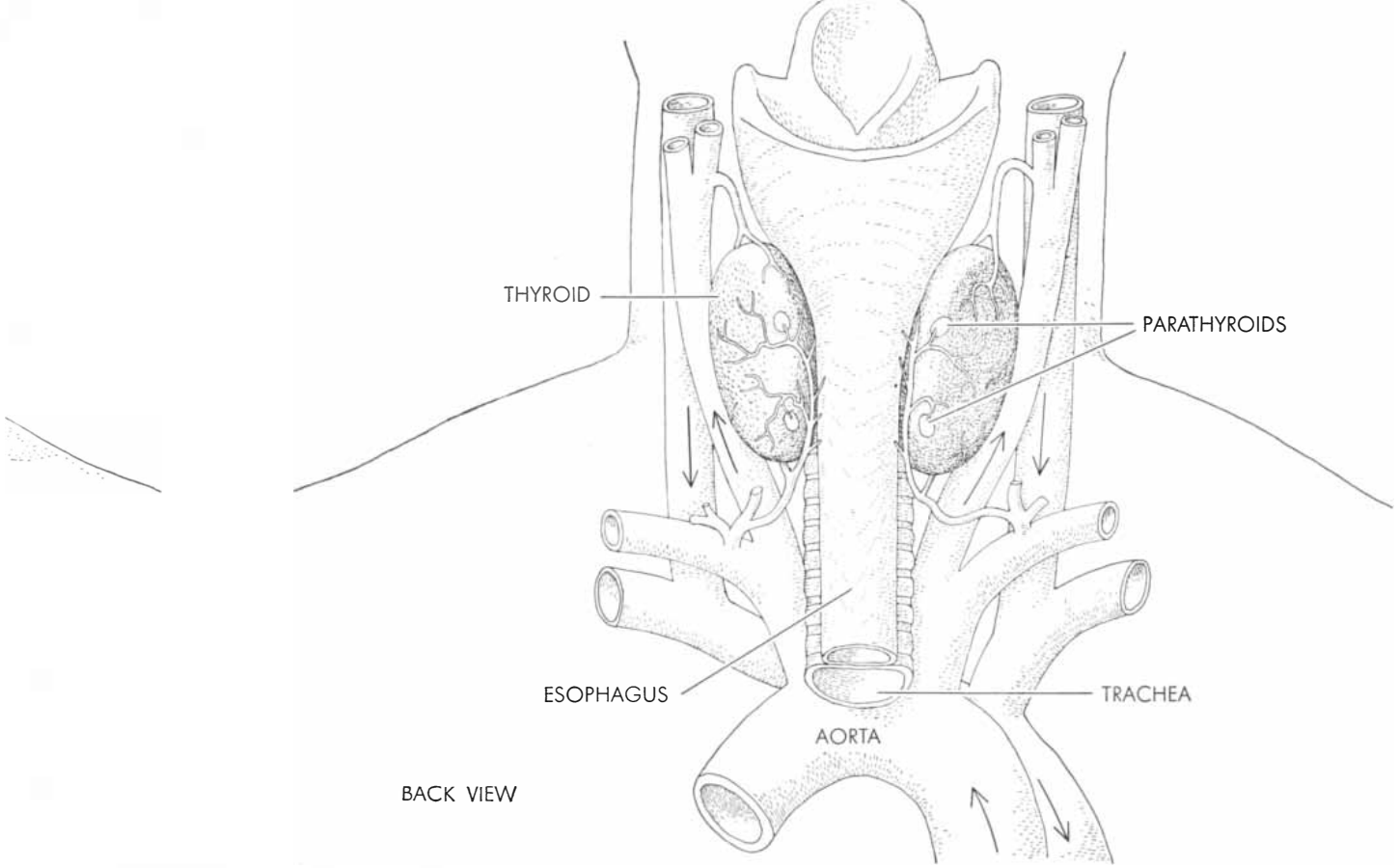


LOCATION OF THE THYROID GLAND is shown in these views of the neck. The gland is shaped roughly like an H, with lobes on either side of the trachea and larynx. Beside the

The normal thyroid is composed of millions of spheroidal sacs or follicles, each in effect a separate gland about the diameter of a pin point. Although the sacs have no external openings, they are richly supplied with minute blood and lymph vessels that bring supplies of iodide and carry away the thyroid hormones. In a healthy gland a follicle consists of a single layer of cu-

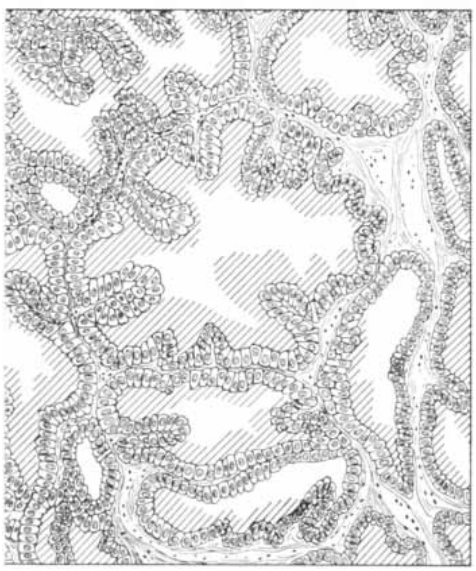


THYROID FOLLICLES in healthy gland (*left*) tend to be spherical; cells of wall are cuboidal. Open area inside the follicles is a colloid containing hormones. Blood capillaries run between the follicles. In hyperthyroidism (*center*) walls of follicles are folded inward;

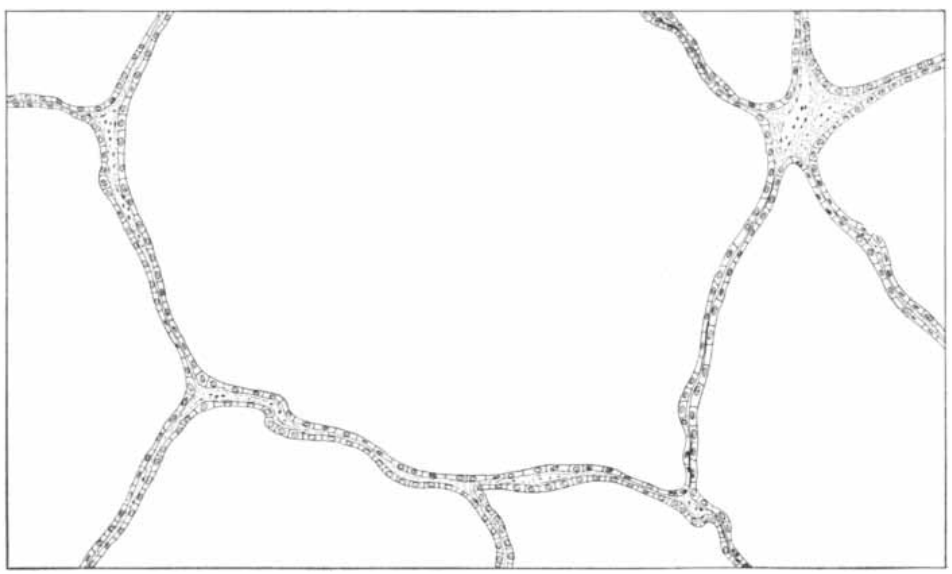


gland in front view are the internal jugular veins (*arrows pointing down in direction of blood flow*); in back view are the common carotid arteries (*arrows pointing up*). The four small parathyroid glands are located on the backs of the lobes of the thyroid gland.

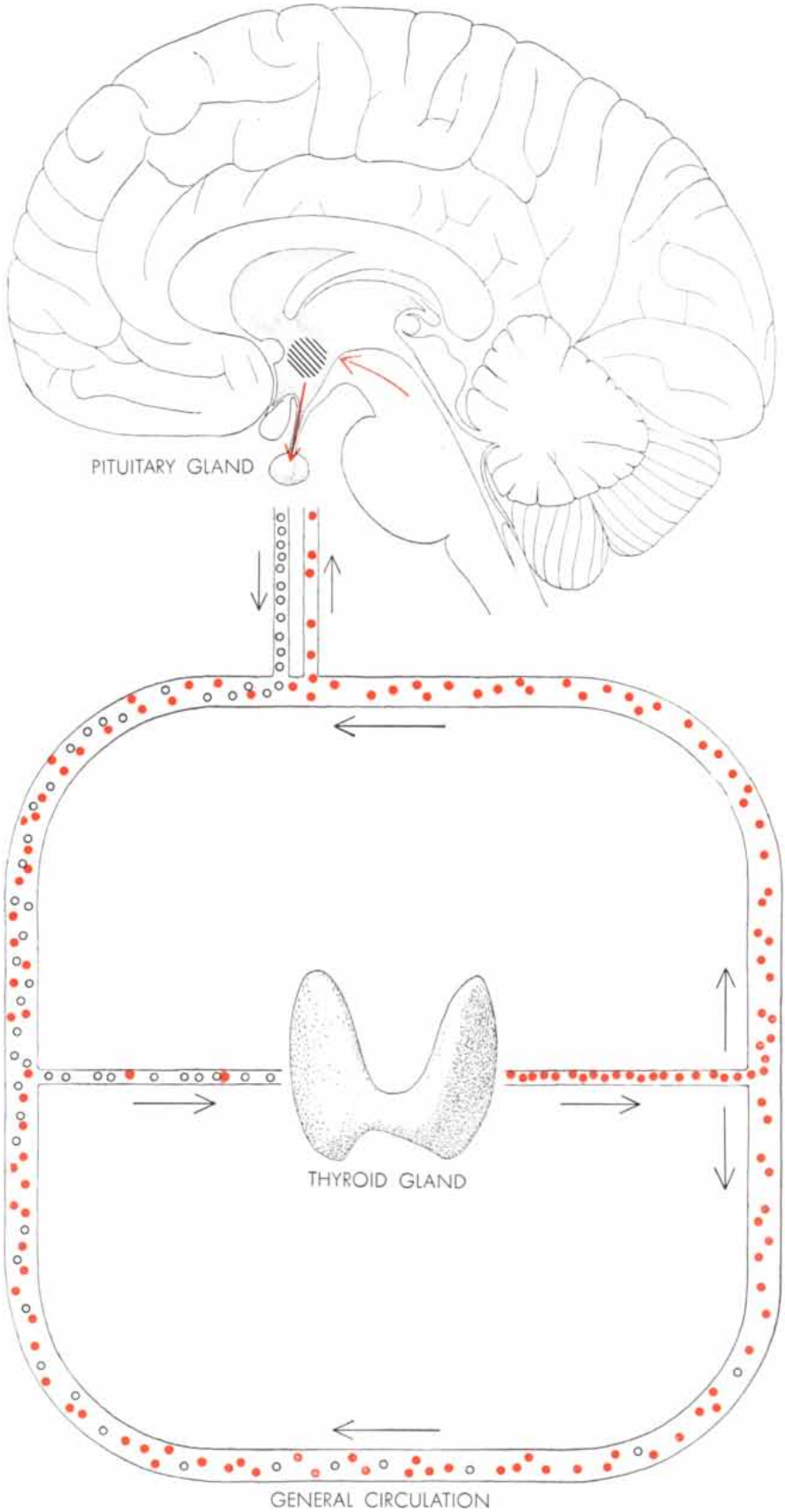
boidal cells surrounding a cavity, or lumen, filled with a homogeneous colloidal substance. In an iodine-deficient goiter, however, the cells are flattened and the follicles are greatly distended with colloid that is poor in active iodinate compounds. In the goiter of an exophthalmic, hyperthyroid individual the follicles do not get larger but their number may increase by 10 to 20 times, with corresponding enlargement of the gland. The cells become columnar in shape, and they increase in number. As a result the walls of the follicles fold into the lumens and develop a much greater surface area for producing hormone and liberating it into the bloodstream. The lumens now contain little colloid, because the active constituents of the colloid are not stored but are released as soon as they are formed.



cells increase in number and are columnar; there is little colloid substance.



Hypothyroid follicles (*right*) are distended with the colloid which is poor in thyroid hormones; the cells of the follicles are flat. Many goiters are the result of follicles swollen in this way.



CONTROL OF THYROID-HORMONE OUTPUT by the pituitary gland and hypothalamus is suggested by this diagram. Thyroid-stimulating hormone from pituitary (*open circles*) travels in bloodstream and causes thyroid to produce and excrete hormones (*red dots*). They in turn suppress pituitary production of stimulating hormone, furnishing feedback control. The hypothalamus of the brain (*hatched area*) receives nerve messages that may indicate need for rise in metabolism, and sends neurohumoral secretions to pituitary that cause it to form more thyroid-stimulating hormone. The hypothalamic secretions travel in special blood vessels within the narrow stalk that connects the pituitary to the hypothalamus.

At least six major enzyme systems are involved in the synthesis and liberation of thyroid hormone. One system obtains iodine from the blood, mostly in the form of sodium iodide. Another enzyme system changes the iodide ion (I^-) to elemental iodine (I_2), a form in which iodine combines, probably through the mediation of a third enzyme system, with tyrosine (one of the 20-odd amino acids of which the body's proteins are made). Some tyrosine molecules take up only one atom of iodine, producing mono-iodotyrosine; some take up two iodine atoms, making di-iodotyrosine. These iodinated tyrosines do not become biologically active until a "coupling" enzyme-system combines them to form iodothyronines, which can have two, three or four atoms of iodine. The best known and most abundant of these is thyroxine (tetra-iodothyronine), which has four iodine atoms and is 60 per cent iodine by weight [*see diagrams on pages 128 and 129*].

Thyroxine was isolated in 1914 and synthesized in 1927. Until the early 1950's it was thought to be the only active thyroid hormone. Then the work of Charles Leblond, J. Gross and Rosalind Pitt-Rivers resulted in the isolation of tri-iodothyronine and the demonstration that it is three to five times as potent as thyroxine, though it is active for a shorter length of time. More recently J. Roche of France has discovered in the thyroid gland small amounts of a di-iodothyronine that has biological activity.

All of these substances are stored in the colloid of the thyroid-follicle lumen. Their molecules are attached to the giant molecules of the protein thyroglobin, which are so big that they cannot normally penetrate the wall of the follicle and escape into the bloodstream. The thyroid hormones are released into the blood when they are split from thyroglobin by a fifth enzyme system. The splitting also releases the intermediate compounds mono- and di-iodotyrosine, which are not utilized by the body. A sixth enzyme system removes elemental iodine from these intermediates as the blood carries them through the gland. A defect in, or interference with, any of the six enzyme systems may lead to inadequate production of thyroid hormones.

The thyroxine and tri-iodothyronine secreted by the gland are transported to the cells in loose chemical combination with the globulin fraction of the proteins in blood serum. In this state the hormones can be precipitated from the blood for measurements of "protein-

FORECAST

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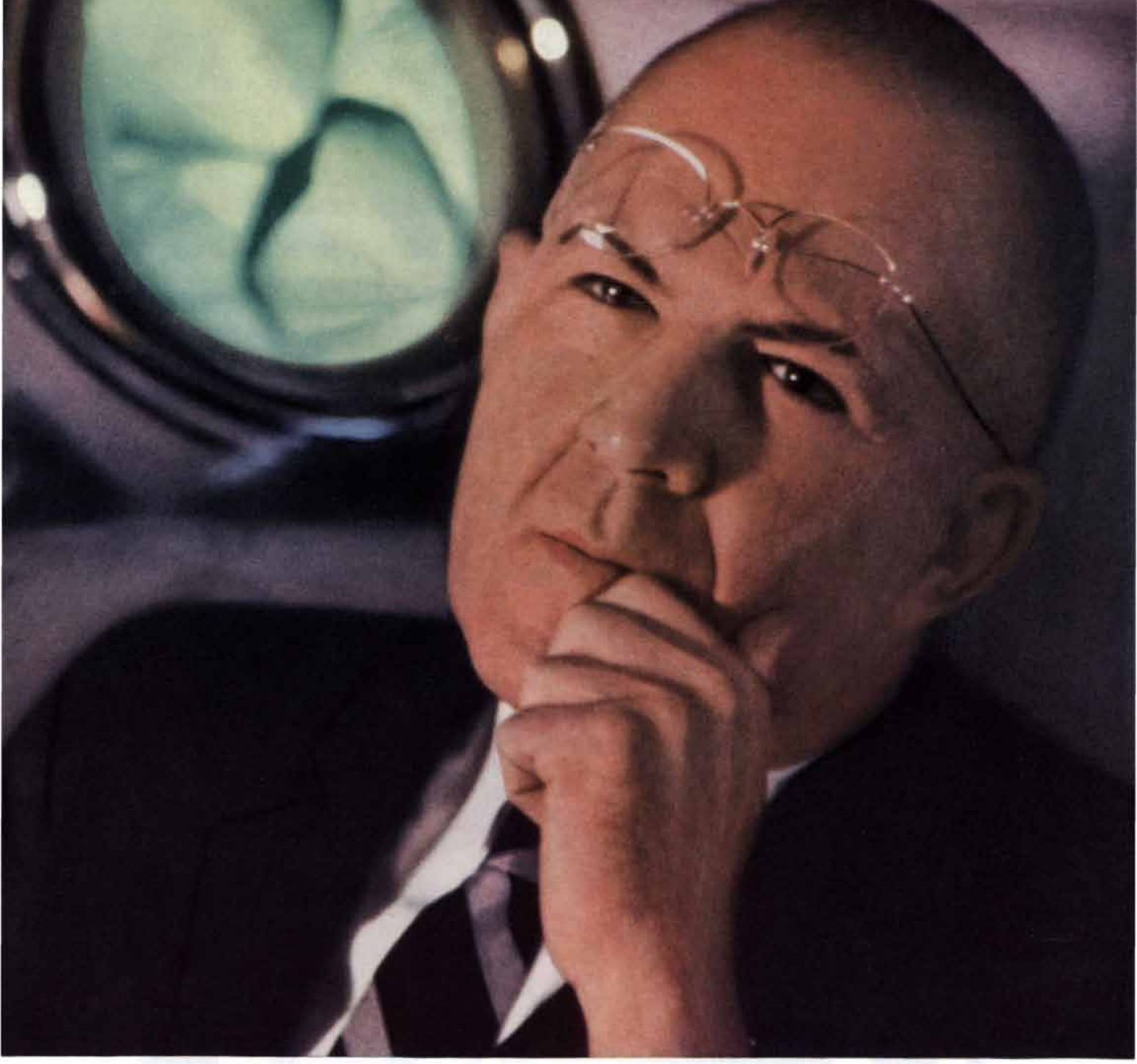

Dr. Kent Van Horn photographed with electron microscope. Photograph by Bruce Davidson

DOCTOR VAN HORN GETS THE "GREEN LIGHT"

You could staff a college of engineering from the Alcoa Research Laboratories, for 37 of 762 technical experts hold a Ph.D. degree and 275 more are Masters of Science. Alcoa built this talent pool with the same philosophy that raised research and development expenditures to $18,000,000 in a recession year when other aluminum firms chopped already slim budgets 20 to 50 per cent.

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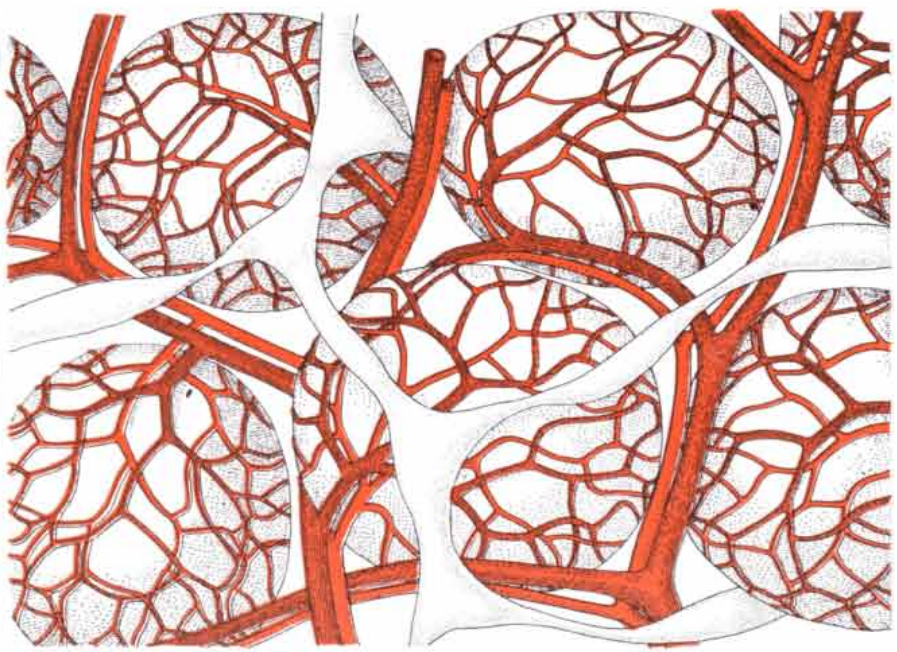
bound iodine" (PBI) that provide the most reliable index of the quantity of thyroid hormones in the circulation. Normally the concentration is four to eight micrograms of protein-bound iodine per 100 cubic centimeters of blood serum, or four to eight parts per 100 million. In hyperthyroidism the concentration may rise to 10 to 20 micrograms, and in hypothyroidism it may drop to less than one microgram.

Although it is the regulator of the body's metabolism, the thyroid is regulated in turn by the pituitary gland. Located in a bony cavity just beneath the hypothalamus of the brain, the pituitary orchestrates the work of other endocrine glands such as the thyroid, the adrenals and the ovaries or testes. In regulating the output of thyroid hormones the pituitary releases a thyrotropic, or thyroid-stimulating, hormone in greater or lesser quantity. Removal of the pituitary from experimental animals causes the thyroid gland to shrink and secrete very little hormone; as a result the animal develops hypothyroidism. Through the agency of the hypothalamus the nervous system indirectly controls the thyroid. Under nervous stimulation the hypothalamus secretes so-called neurohumors into blood vessels along the narrow stalk that connects it to the pituitary; these secretions cause the pituitary to produce the thyroid-stimulating hormone.

The final link in the chain of controls is established by feedback from the thyroid itself: the thyroid hormones suppress the production of the thyroid-stimulating hormone. In response to an excess of thyroid hormone the pituitary normally reduces its output (a fortunate protection against unwarranted thyroid medication sometimes prescribed by misguided physicians). In response to a deficiency of thyroid hormone in the bloodstream the pituitary automatically secretes more thyroid-stimulating hormone. This stimulates the thyroid to work harder and may result in its enlargement into a goiter. If the enlarged gland cannot compensate, hypothyroidism results.

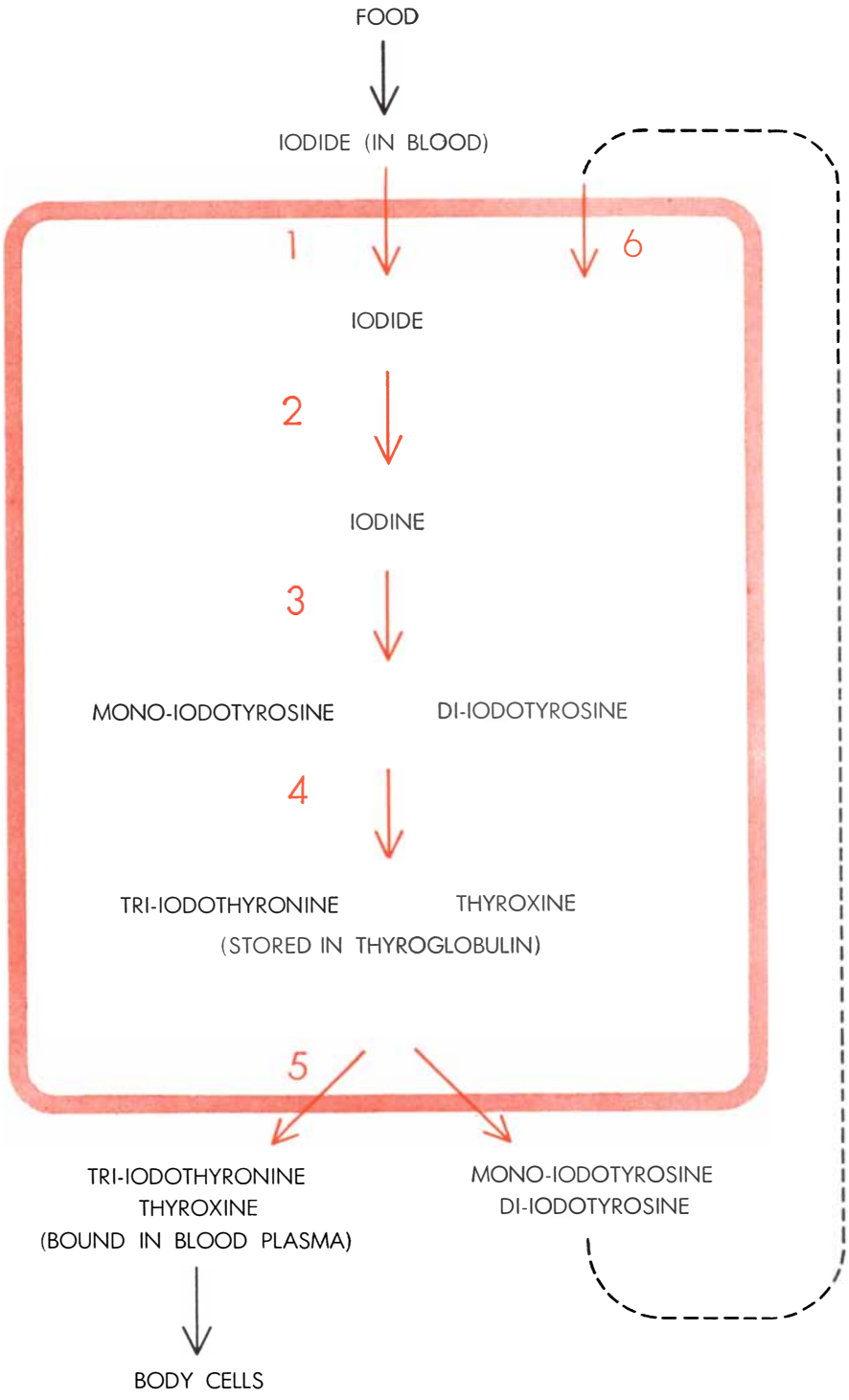
The recently acquired understanding of the synthesis of thyroid hormones and of the interrelationships of the hypothalamus, the pituitary and the thyroid gland have made it clear that there are many different causes of thyroid deficiency. In areas where iodine is adequate in the diet, by far the commonest cause of hypothyroidism is the absence of the thyroid gland. In the kind of congenital hypothyroidism known as athyrotic cretinism, the gland is either completely missing at birth or is present only as tiny and inadequate rudiments in abnormal positions in the neck and tongue. It is possible but not verified that in some cases the thyroid may have been destroyed in early embryonic life by antibodies from the mother or by some other agent. Sometimes the thyroid gland atrophies in a previously normal child or adult, resulting in hypothyroidism. The disappearance of the gland may be due to a lack of stimulation by the pituitary



RICH BLOOD-VESSEL SUPPLY of thyroid follicles is depicted. Darker tubes are tiny veins; lighter ones are arteries. Large, flat vessels belong to lymph system. Thyroid follicles are separate from one another and have no openings or ducts leading outside the gland.

or to some disease process or antibody.

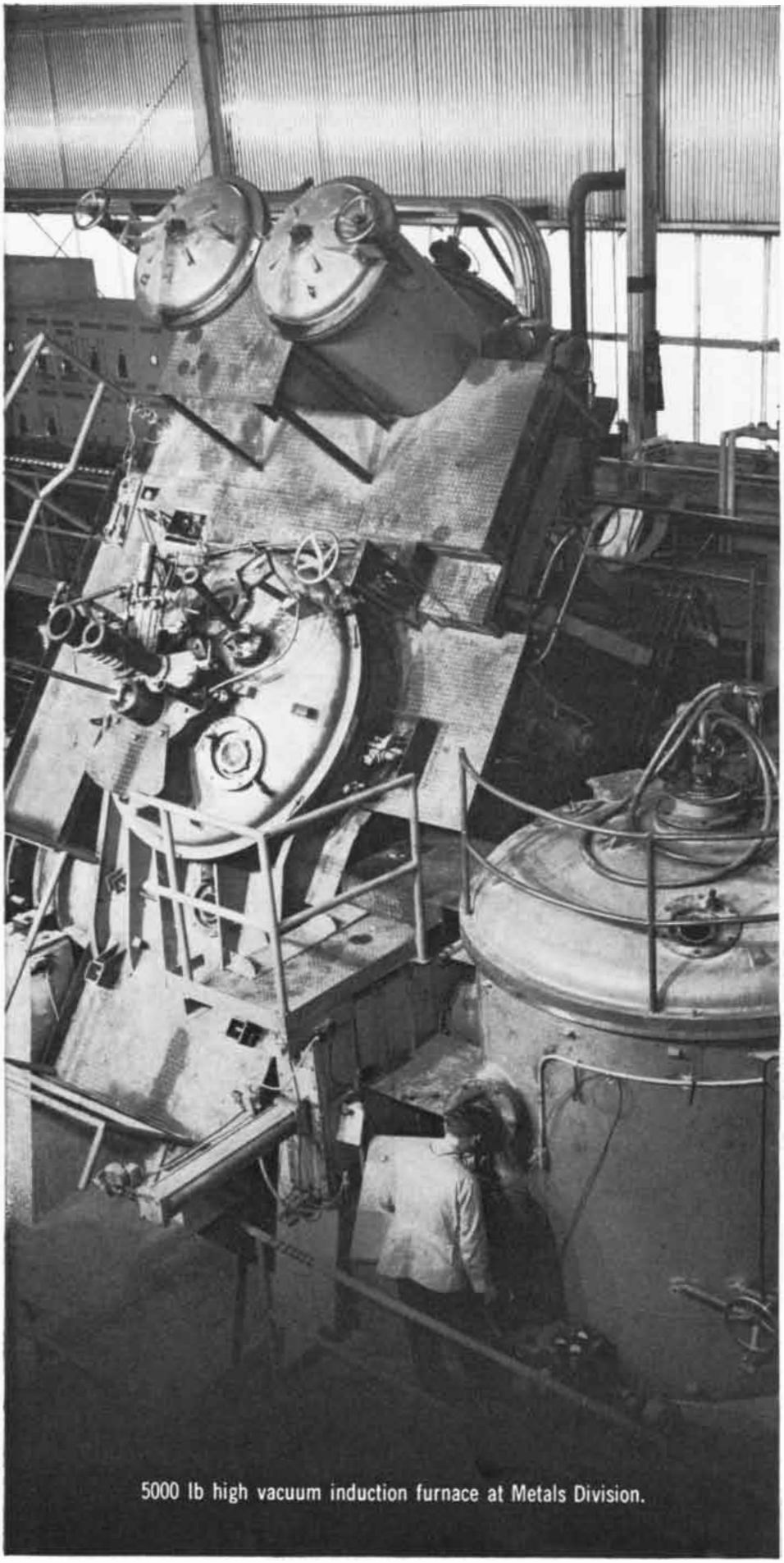
In certain individuals a thyroid gland that is normally formed and appears to be physically undamaged is still unable to manufacture adequate amounts of thyroid hormone and often becomes goitrous. Once it was thought that all these cases were due to iodine deficiency, but in 1950 it was discovered that goitrous hypothyroidism is sometimes due to congenital defects of certain enzyme systems. This disorder is one of the many inherited enzymatic defects that are proving to be the cause of widely differing congenital diseases. Cretins with enzymatic defects of the thyroid may not have a goiter in early life, and they can be distinguished from those in whom the gland is lacking only by a study of their uptake of radioactive iodine. In fact, the radioiodine studies can even indicate which enzyme system is defective. If a child with such a condition is not treated, its thyroid will eventually become goitrous. This is the only form of hypothyroidism that is inherited, and it may affect several children in the same family. It is possible that the "simple goiter" that occurs in some adolescent girls and pregnant women is due to similar but milder defects in the enzyme systems of the thyroid, causing goiter at times of life when more hormone may be needed.



HORMONE SYNTHESIS AND SECRETION is accomplished by six major enzyme systems (*colored arrows*) in thyroid gland (*represented by large rectangle*). The first takes iodides from blood. The second changes them to elemental iodine. The third attaches iodine to tyrosine. The fourth couples iodinated tyrosines to make hormones. The fifth system splits the hormones from thyroglobulin. The sixth reclaims iodine from iodotyrosines in blood.

Goitrous hypothyroidism may be induced by certain substances that block the action of normal enzyme-systems in the thyroid. These substances include perchlorates, thiocyanates, cobalt, some of the sulfonamides, iodides in large quantities and derivatives of thiourea and thiouracil. Curt P. Richter of the Johns Hopkins Medical School, who was studying the inability of rats to taste the poison phenyl thiourea, was the first to observe that thiourea caused enlargement of the thyroid. In 1943 E. B. Astwood of the Harvard Medical School, believing that this was due to an antithyroid effect, successfully employed a thiourea derivative to treat hyperthyroidism. The treatment is still standard, and when certain of these drugs are given in excessive amounts during pregnancy the newborn infant may have a goiter and sometimes mild hypothyroidism. Fortunately the infant's thyroid usually reverts to normal. Many plants—particularly cauliflowers, turnips, cabbage, kale, Brussels sprouts and other members of the *Brassicae* family—contain antithyroid substances. It is extremely rare for anyone to eat these vegetables in large enough quantities to produce goiter, but many goiters did appear among schoolchildren in Tasmania when a free-milk program was introduced and local farmers supplemented the diet of their cattle with a type of kale. In such cases the goiters disappear as soon as the antithyroid food or substance is withdrawn.

All types of hypothyroidism result in physical and mental sluggishness, slowed circulation and other symptoms of a low "rate of living." Hypothyroidism has its most devastating effects in infancy and childhood. The normal changes in body proportions and in the face fail to occur, the formation and eruption of the teeth are delayed and cartilage is not converted to bone in the normal manner. In congenital hypothyroidism, when the



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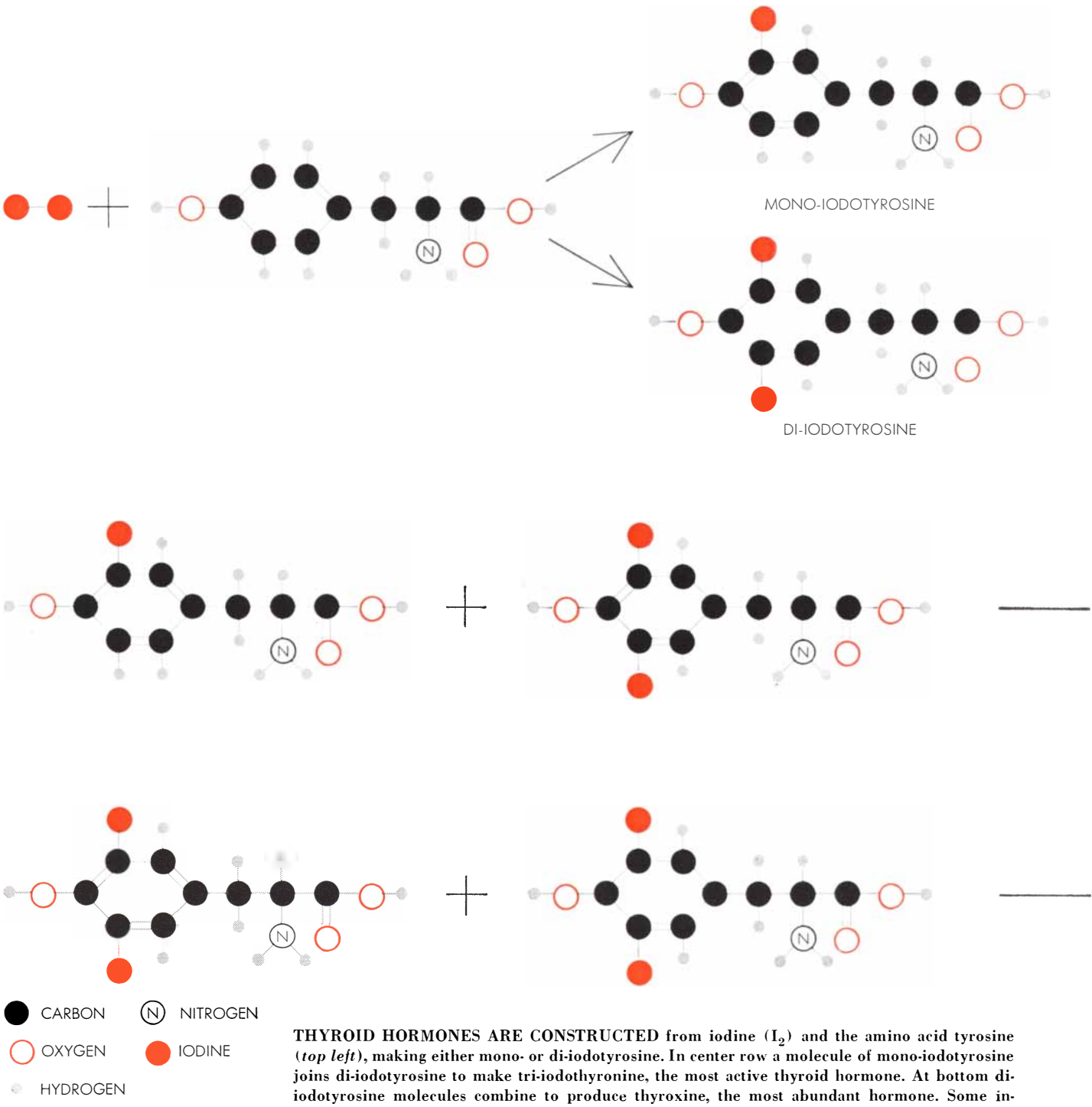
deficiency is not diagnosed and corrected in the earliest months of life, permanent damage to the brain may result, since it is during this period that brain development is normally most rapid. The treatment of hypothyroidism involves the administration of thyroid-gland extract or of thyroid hormones.

Several thyroid diseases are particularly interesting to the investigator because they seem to involve "autoimmunization," in which an individual develops specific antibodies capable of damaging the cells of one or another of his own tissues. The concept of autoimmunization is relatively new and may play an increasingly important role in medicine. It is possible that unexplained destruction of such glands as the parathyroids, the adrenals, the testes and the kidneys might sometimes be due to this process. For example, antibodies against thyroid tissue have frequently been detected in patients whose thyroid glands have atrophied. The antibodies are also found in subacute thyroiditis, which involves an inflammation of the thyroid that may be due to a virus infection. Some thyroid follicles are destroyed, liberating thyroglobulin and bits of cells into the bloodstream. Since these substances are foreign to the body as a whole, patients develop antibodies against thyroglobulin and their own thyroid-gland cells. (The thyroglobulin may also make them temporarily hyperthyroid, and if a sufficiently large number of follicles are destroyed hypothyroidism may ensue.) Most patients suffering from the disease called Hashimoto's struma (struma is another word for goiter) possess antibodies against thyroid tissue, but whether the antibodies are a cause or an effect of the disorder is not known. The patients have a hard and often nodular swelling of the gland which is infiltrated with lymphocytes (one type of white blood cell).

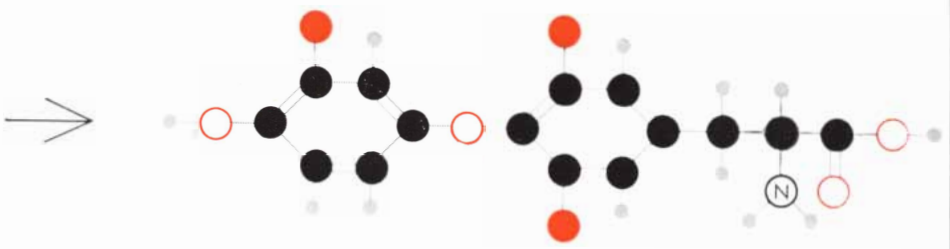


THYROID HORMONES ARE CONSTRUCTED from iodine (I_2) and the amino acid tyrosine (*top left*), making either mono- or di-iodotyrosine. In center row a molecule of mono-iodotyrosine joins di-iodotyrosine to make tri-iodothyronine, the most active thyroid hormone. At bottom di-iodotyrosine molecules combine to produce thyroxine, the most abundant hormone. Some in-

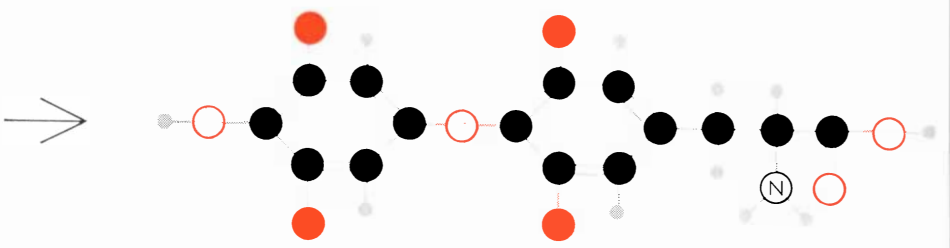
Probably the most common and most serious of all thyroid disorders is hyperthyroidism, which is usually accompanied by thyrotoxic or exophthalmic goiter. Although it was thoroughly described by the Irish physician Robert Graves in 1835 and the German Karl von Basedow in 1840 (it is sometimes called Graves's disease or Basedow's disease), its exact cause is as obscure today as it was then. The administration of large amounts of thyroid hormone to animals produces most of the symptoms of hyperthyroidism, but not the protruding eyes. The pituitary gland appears to play some role, because the bulging eyes appear in certain animals after injection of pituitary extracts containing the thyroid-stimulating hormone, even when the thyroid has been removed. The excessive secretion of thyroid hormones that occurs in hyperthyroidism does not turn off the thyroid-stimulating secretions of the pituitary. Perhaps the trouble is due to a disorder of the mysterious regulating centers in the hypothalamic region of the brain. There are many other theories of the cause of hyperthyroidism, but none has been conclusively demonstrated. Treatment, however, is well understood. The physician can choose among the alternatives of surgery to remove a large part of the thyroid, administering radioactive iodine to destroy the gland, and using antithyroid drugs to block the production of the thyroid hormones. Nonsurgical treatment with antithyroid substances such as thiouracil or perchlorate controls the disease in 50 to 60 per cent of the cases.

Like all the other organs of the body the thyroid may become cancerous. Thyroid cancer occurs in all age groups. Some observers believe that it can be caused by X-rays administered in the region of the neck to combat an enlarged thymus, to reduce infected and inflamed adenoidal tissue or to ameliorate other conditions. The only treatment for cancer is complete extirpation of the gland by surgery or, if this is impossible, destruction by large doses of X-rays. Treatment with radioactive iodine holds some hope for patients in whom the thyroid cancer has spread to other parts of the body. Thyroid-cancer cells frequently have the ability of normal thyroid cells to absorb iodine; hence radioactive iodine may selectively destroy the cancer cells. The occasional benign tumors (adenomas) found in the thyroid gland should be removed surgically, especially in childhood, as a precaution against cancer.

Though physicians are now able to manage most thyroid disorders, and laboratory investigators have learned much about the function of the gland, large areas of ignorance remain. One basic question that remains unanswered is: Exactly how do the thyroid hormones accelerate the processes of the body?



TRI-IODOTHYRONINE



THYROXINE

vestigators believe that thyroxine may be formed first and then be converted to tri-iodothyronine by the loss of one atom of iodine. All the steps shown here are mediated by enzyme systems. Only significant products are shown; the equations are incomplete. The recently discovered hormone di-iodothyronine, which has two atoms of iodine, is omitted.

IMMUNOELECTROPHORESIS

This formidable word and the technique it identifies are derived from immunochemistry and electrophoresis. These methods have been combined into a precise tool for the study of protein chemistry

by Curtis A. Williams, Jr.

Proteins, as every elementary textbook of biology states, are among the fundamental molecular constituents of living matter. Hundreds of these giant molecules have been identified; in some cases their size and shape have been determined and their structure has been roughly diagrammed. As enzymes, hormones and antibodies they are assigned numerous specific roles in the chemical reactions that constitute the normal and pathological processes of life. This knowledge, much of it gained only in the past two decades, already serves practical ends in medicine and in industrial chemistry.

Most of what is known about proteins, however, concerns proteins in general, not individual proteins. So far no investigator has been able to determine the complete structure of even the simplest protein molecule. By the same token no one has worked out in full how any one protein is synthesized or how it performs its biological function. One measure of the present humble state of knowledge is the fact that it is practically impossible to isolate a single protein in a homogeneous preparation. The task of purification is made more difficult by the insensitivity of present analytical techniques to the differences among very similar proteins.

All methods of physical and chemical analysis fail when it comes to determining what proteins are present even in such a thoroughly studied substance as blood serum. This pale yellow fluid, which comprises those fractions in a sample of blood that remain when the other fractions have clotted, contains dozens of different proteins. The classical procedure for separating the protein constituents of such a complex solution is to add protein-precipitating reagents under carefully controlled conditions of concentration and temperature. The protein fractions are thus separated according to their relative solubility in different environments. Differences in solubility are also the basis for classifying proteins as albumins or globulins and globulins in turn as euglobulins and pseudoglobulins. Each of the fractions thus obtained is made up of a greater or lesser number of different proteins so similar chemically that they cannot be distinguished from one another by solubility criteria alone. This becomes apparent when one of the fractions is itself analyzed by the far more precise and discriminating tool of electrophoresis. A technique developed for just this purpose, electrophoresis distinguishes proteins by the rate at which they migrate toward an electrode in a conducting solution. In an electrophoresis apparatus the globulin fraction of blood serum separates into at least three subfractions, called alpha, beta and gamma globulin.

But each of these subfractions still represents an assortment of individual proteins. As is well known, the gamma globulin subfraction contains most of the antibodies that the tissues of the body generate in the so-called immune response to a foreign substance such as an antigen from an infectious organism. The high specificity with which each antibody reacts with its complementary substance only serves to emphasize the lack of discrimination in the available techniques for analyzing and separating proteins from one another. Specificity is a characteristic of almost all proteins, either in their biochemical activity or in their unique structures, which are determined by the biological species from which they are derived. Among proteins, enzymes and antibodies are the most specific in their chemical activity. The enzyme urease catalyzes the breakdown of a certain chemical bond in urea, but it has no effect upon the same type of bond in hundreds of other biological molecules. The specificity of protein reactions underlies the fact that a sperm cell can fertilize only the egg cell of its own species; it also explains many other aspects of the individuality of cell, tissue and organism. Biochemical specificity thus provides a useful criterion for the identification of a protein.

Further chemical characterization requires that the protein be isolated. It is difficult, however, to secure a pure preparation of an antigen, and even more difficult to prepare a single antibody from an antiserum; consequently some analyses must be made with solutions that are mixtures of these reactants. If whole unfractionated serum is used as an antigen and an antiserum specific for serum proteins is used as the antibody, the resulting product would contain the precipitates of several antigen-antibody reactions. Thus even the immune reaction sometimes fails to provide an analytical method.

To meet this difficulty Pierre Grabar of the Pasteur Institute in Paris and I undertook to combine electrophoresis and the antigen-antibody reaction as a method of identifying a single protein in a mixture. As the result of our work and important contributions by others, biochemistry now possesses a technique, known as immunoelectrophoresis, that has demonstrated great analytical power. It employs two independent criteria to distinguish proteins from one another, first segregating the proteins according to their electrophoretic mobility and then identifying them by the highly specific immune reaction. Immunoelectrophoresis thus takes advantage of fundamental developments achieved along

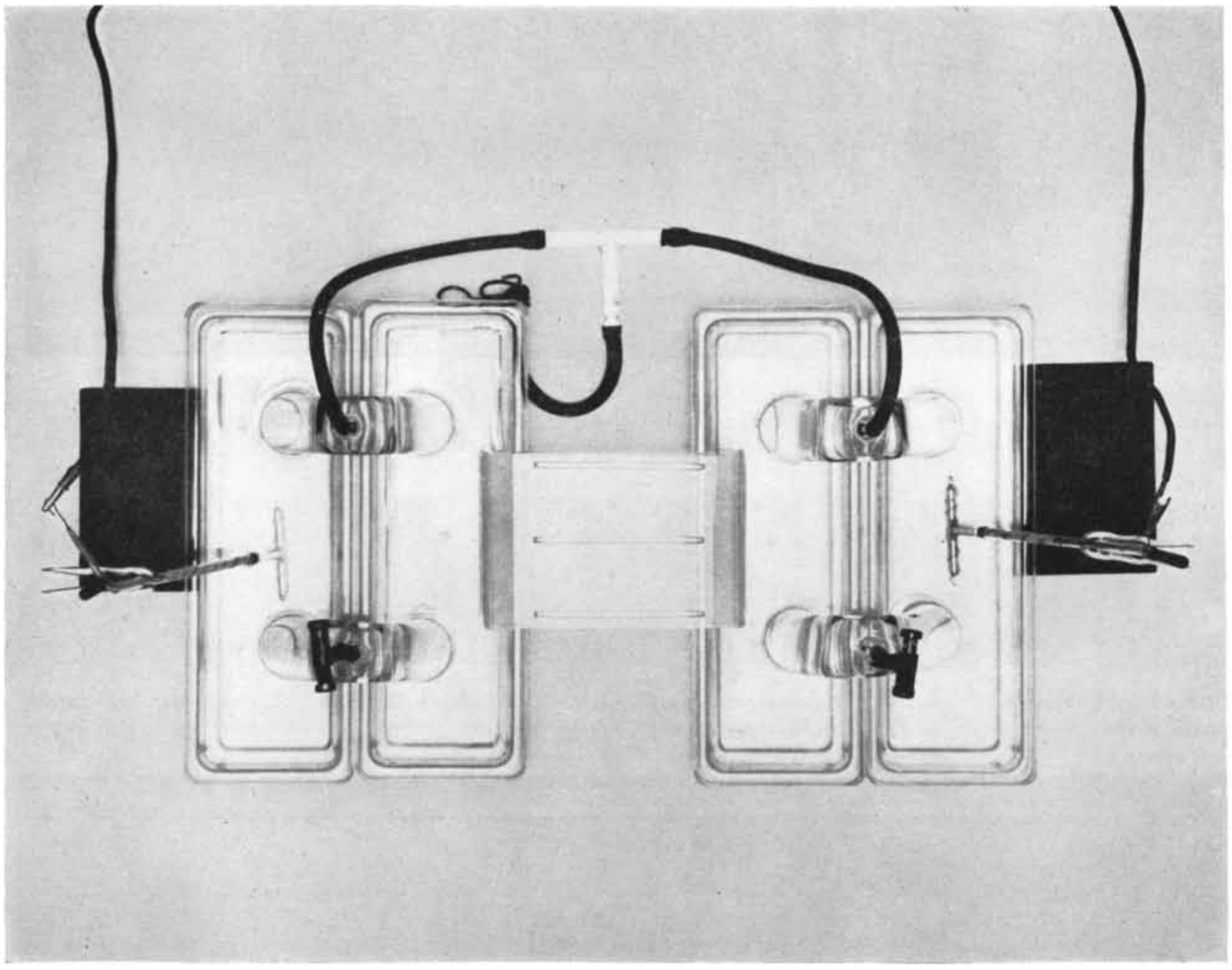
two different lines of research during the past 25 years. These were developed principally by Arne Tiselius and Orjan Ouchterlony of Sweden and Jacques Oudin of France.

It was Tiselius who established electrophoresis as a technique for analyzing and separating proteins [see "Electrophoresis," by George W. Gray; SCIENTIFIC AMERICAN, December, 1951]. The electric charges that cause proteins to migrate in an electric field are carried by acidic or basic groups of atoms in the molecules; whether the net charge is positive or negative varies with the hydrogen-ion concentration (pH) of the solution. Tiselius's apparatus consists of a U-shaped tube with an electrode in each arm. The protein sample to be analyzed is dissolved in a buffered solution of known pH. In the case of blood serum the buffer (usually Veronal, the well-known barbiturate) gives all of the important proteins a net negative charge. When the solution is poured into the tube and the current turned on, the proteins all migrate toward the anode, but each migrates at a characteristic rate determined by the amount of its charge. Thus they separate from one another in the solution, with reasonably sharp boundaries between them.

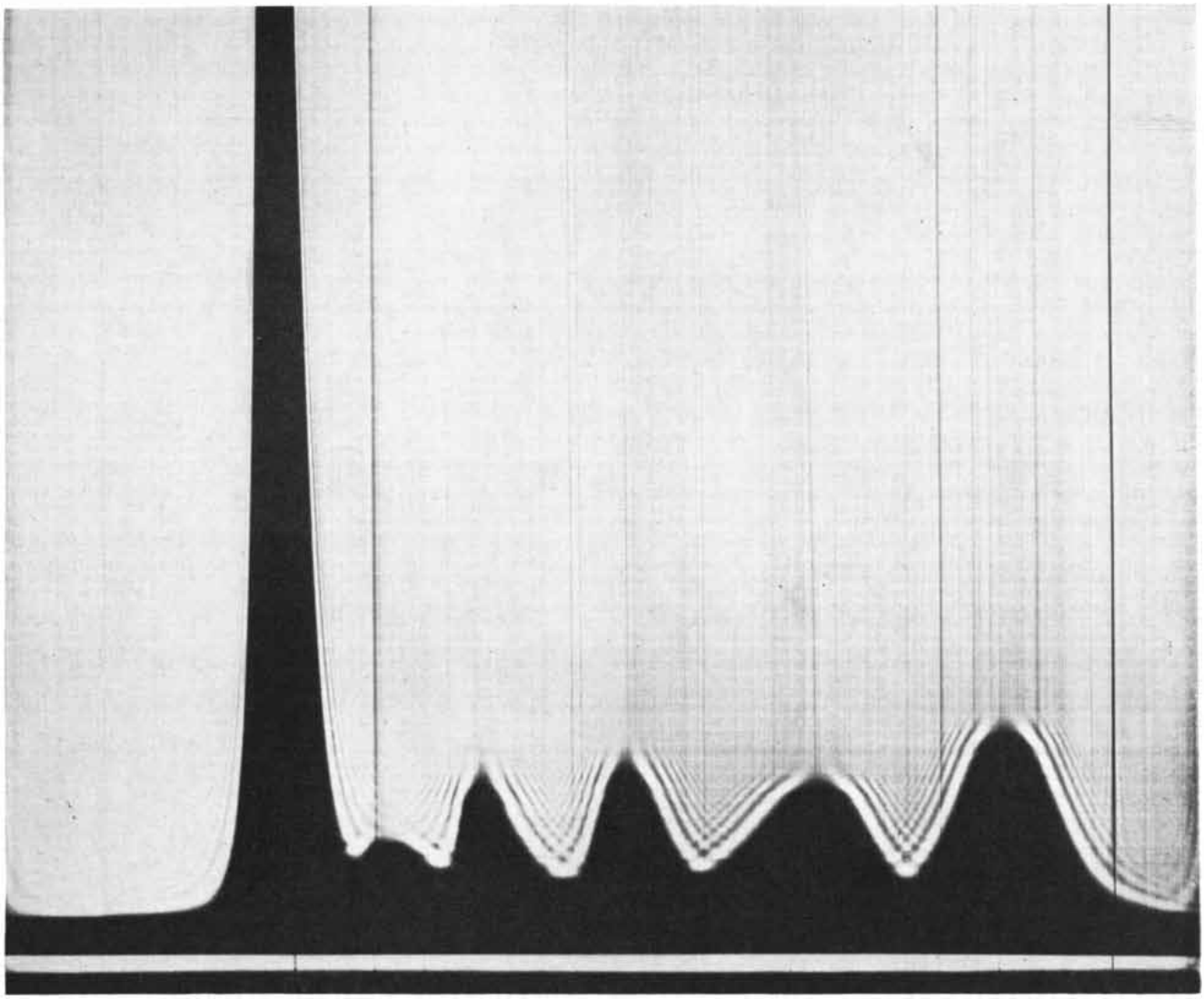
In 1937, with his first publication on this brilliant invention, Tiselius demonstrated that serum proteins could be classified according to their electrophoretic mobility. In addition to distinguishing the fast-moving albumin fraction he showed that the globulin fraction contained at least three different proteins, which he called alpha, beta and gamma globulins in the order of their decreasing mobility. Although it is now known that these components contain many more proteins, Tiselius's system of nomenclature still stands.

An ingenious refinement was added to Tiselius's "moving boundary" apparatus in 1939 by Lewis G. Longsworth of the Rockefeller Institute. Tiselius had originally equipped the device with an optical system that made the boundaries between the protein layers visible as shadows, or schlieren. Longsworth introduced a mechanical schlieren-scanning device that showed the positions of the boundaries as a pattern of peaks and valleys that can be projected onto photographic film [*see top illustration on next page*]. The area under each peak indicates the concentration of the protein fraction responsible for the boundary. (The last peak in the illustration, however, represents the buffer.) This is the form in which moving-boundary electrophoretic patterns are most often seen today.

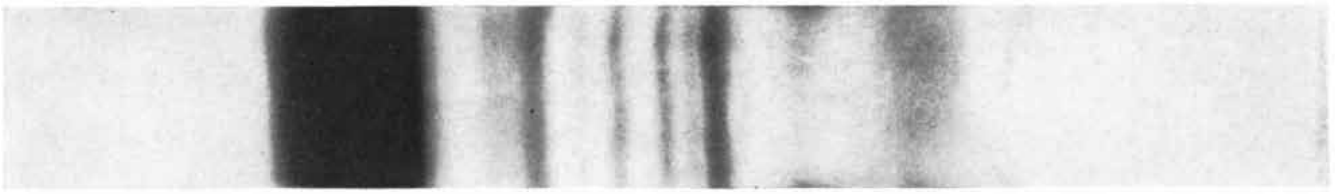
Moving-boundary electrophoresis is best suited for the analysis of the rela-



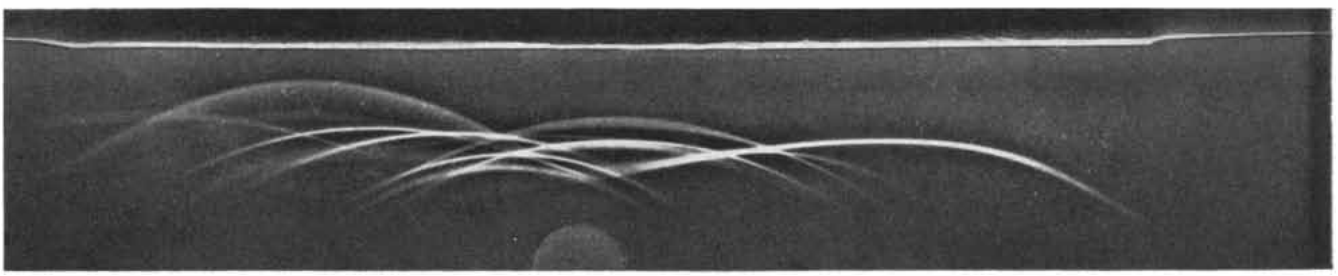
MODIFIED ELECTROPHORESIS APPARATUS is used in immunoelectrophoresis to separate proteins according to their mobility in an electric field. A drop of the protein solution is placed in either of the two small round wells on the agar-covered glass plate at center. Direct current flows through the electrically conducting buffer solution in the trays via two T-shaped electrodes (*left and right*). Two strips of wet filter paper dipping into the buffer provide the necessary electrical contact with the plate.



MOVING-BOUNDARY ELECTROPHORESIS pattern of normal human-blood serum was made by the schlieren-scanning method. Area under each peak indicates the concentration of one component of the solution. The tall peak at left represents albumin; the second, alpha-one globulin; the third, alpha-two globulin; the fourth, beta globulin; the fifth, gamma globulin; and the last, the buffer.



ZONE ELECTROPHORESIS shows the components of human serum as a series of dark bands. Band at left is both albumin and alpha-one globulin; band at right, gamma globulin. The bands between show more fractions than does the moving-boundary pattern.



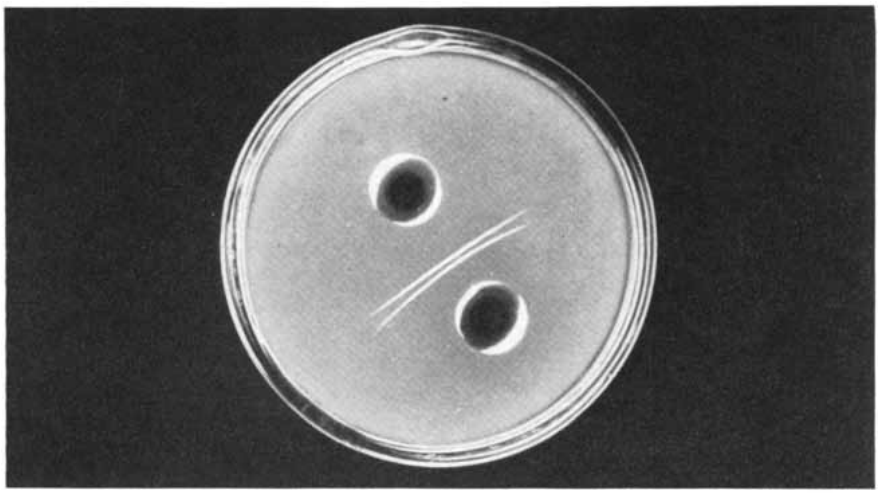
IMMUNOELECTROPHORESIS pattern is a series of arcs. Albumin is represented by the arc at far left; gamma globulin, by the flattened arc at far right. The remaining arcs represent a variety of globulins and other proteins (*see top illustration on page 138*).

tive amounts of protein in each fraction. Because the protein solutions overlap each other in the U-tube, the method is not suited to achieve actual physical separations of the proteins. For this purpose most workers use a related technique known as zone electrophoresis, first described by P. Koenig of Brazil in 1937 and later developed by the British chemists R. Consden, A. J. P. Martin and A. H. Gordon. In this method a solid or semisolid support such as filter paper, starch grains or agar gel contains the buffer solution. To prepare a starch matrix, a slurry of buffer solution and starch grains is deposited on a glass plate to build up a cake about half an inch thick. The proteins, in a slurry of buffer and starch, are deposited in a trough cut in the cake at right angles to the path of electrophoretic migration. At the end of electrophoretic migration the several proteins will be resolved into zones according to their electrical mobility [*see middle illustration on opposite page*]. The zone containing the desired protein can now be cut away and the protein extracted.

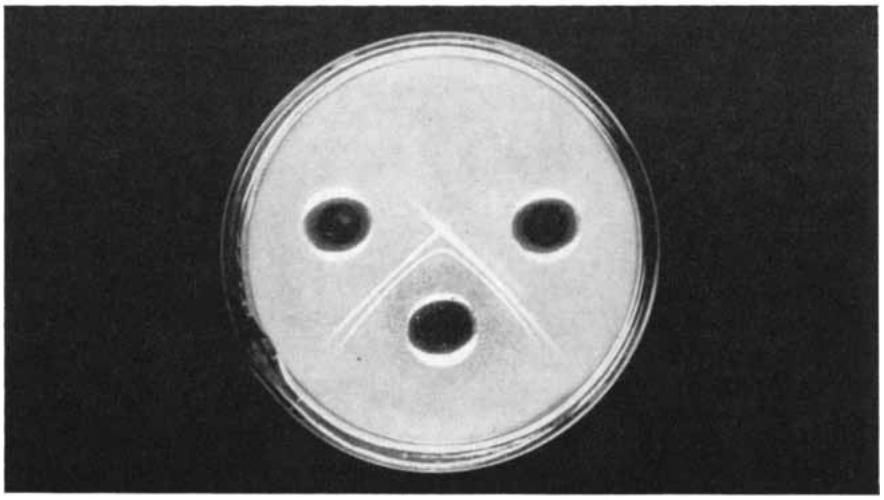
Zone electrophoresis can also be used for analysis, particularly when the high precision of the Tiselius technique is unnecessary, or when many samples must be examined, as in clinical studies. Here filter-paper strips soaked in buffer solution are the customary medium, although thin layers of starch or agar are also used.

Even serum protein fractions prepared by zone electrophoresis, however, behave immunochemically as complex mixtures when they are reacted with antiserum containing antibodies against the many protein antigens in whole serum. Working independently, Oudin at the Pasteur Institute and Ouchterlony at the Karolinska Institute found ways to circumvent this difficulty. Oudin devised a method by which complex antigen-antibody systems could be analyzed by allowing them to react in a capillary tube filled with agar. The antibody solution is mixed with warm agar, which is then allowed to harden in the tube. When the antigen solution is added, the reaction of antigen and antibody forms a layer of precipitate in the agar. With several antigen-antibody systems generally present, several layers of precipitate form at different levels in the tube, depending upon the rates at which the antigens diffuse into the gel.

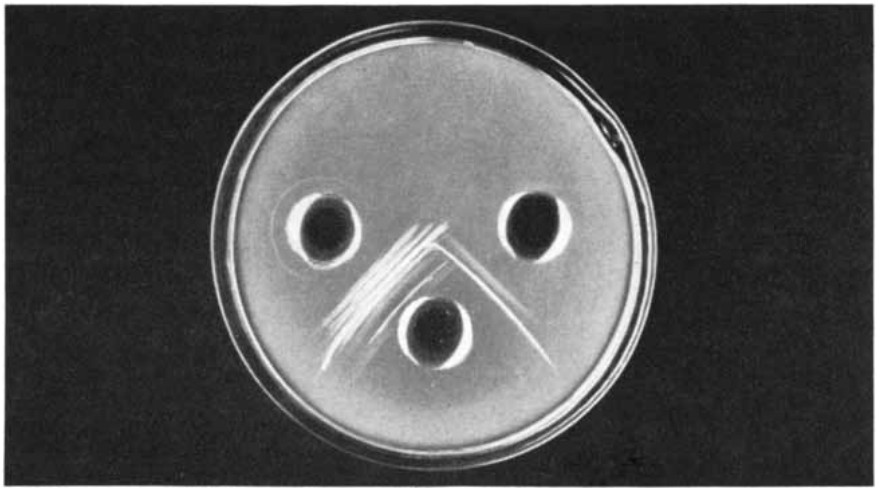
Ouchterlony's technique is similar, but differs from Oudin's in that it permits both antigen and antibody to diffuse into



DOUBLE-DIFFUSION TECHNIQUE of Orjan Ouchterlony produces a pattern of lines on an agar plate. Antigen and antibody solutions are placed in separate wells and diffuse together to form milky lines of precipitate, one for each antigen-antibody system present.



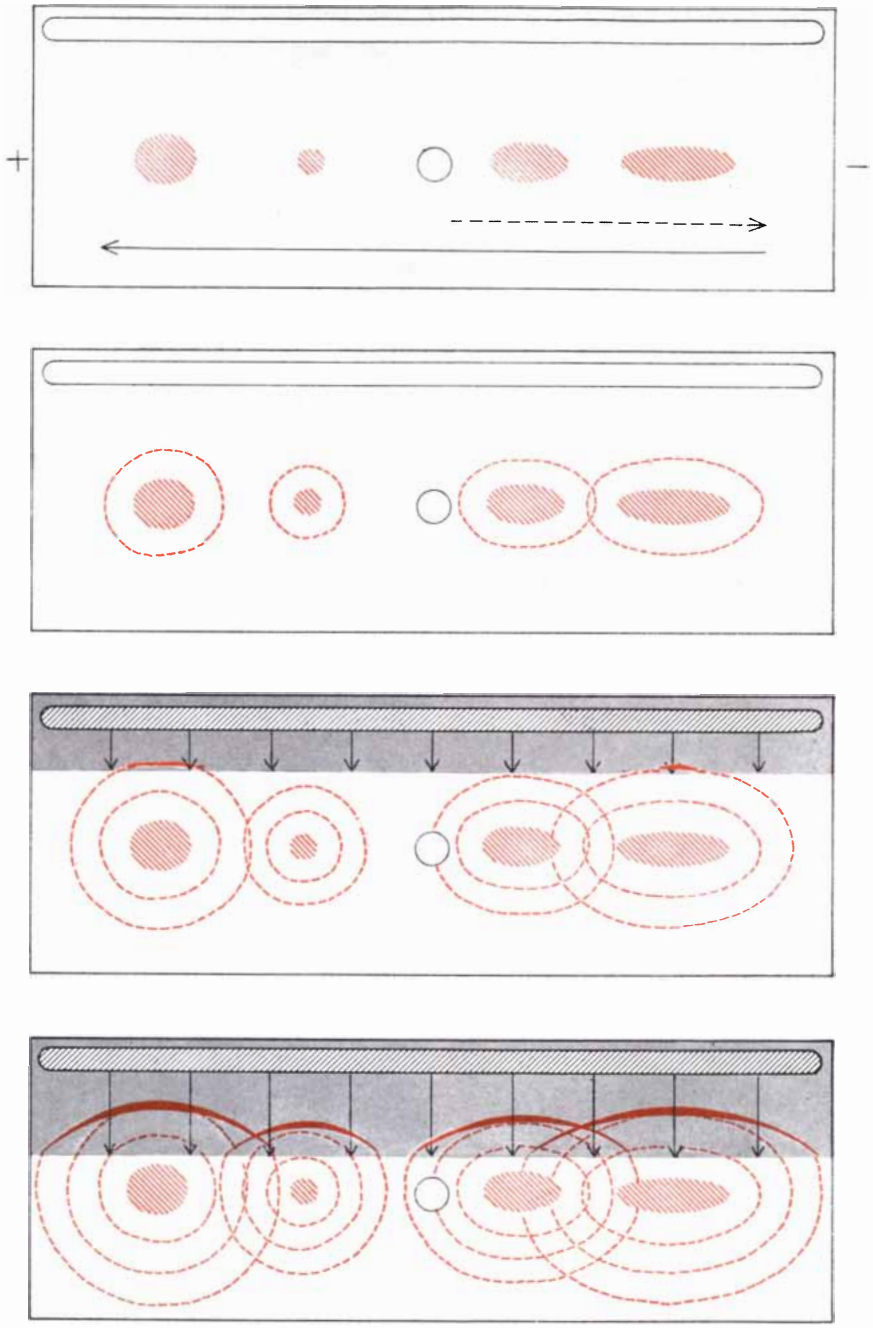
REACTION IS IDENTIFIED by cutting a third well in the agar and filling it with a purified solution of either the antigen or the antibody. The line of precipitate formed by their reaction will join that of the identical reaction to form a continuous chevron (*bottom*). Lines that intersect (*top*), or those that do not touch, indicate reactions of nonidentity.



COMPLEX PATTERN of precipitates appears when whole human serum is reacted with antiserum from horse 31. Although more than 20 different antigen-antibody systems are present, the location of the gamma globulin reaction is indicated by a chevron of precipitate.

an agar-filled glass dish that initially contains neither reactant. A few drops each of the antigen and the antibody solution are placed separately in small wells cut into the agar. Antigen and antibody diffuse outward toward each other at a rate related to their concentration and their diffusion coefficients. A line of precipitate forms where an antigen encounters its antibody. Because of differences in diffusion rate, the lines are distinctly separated [*see top illustration on page 133*]. The clean separation of lines on the Ouchterlony plates makes it possible to distinguish more reactions with them than with the Oudin tubes, and consequently the plates are more useful in studies of complex systems.

The line of precipitate formed by an individual reaction can be identified if either the antigen or the antibody is



ARC PATTERN IS DEVELOPED on immunoelectrophoresis plates by first spreading out the antigens (*colored spots*) by electrophoresis (*top plate*). Their final position on the plate is determined both by their electrophoretic migration (*solid arrow*) toward the anode and by the movement (*broken arrow*) of the buffer solution toward the cathode. When current is turned off (*second plate*), antigens diffuse outward and meet antibodies diffusing inward from a trough in agar (*third plate*). They precipitate (*bottom plate*) in a pattern of arcs.

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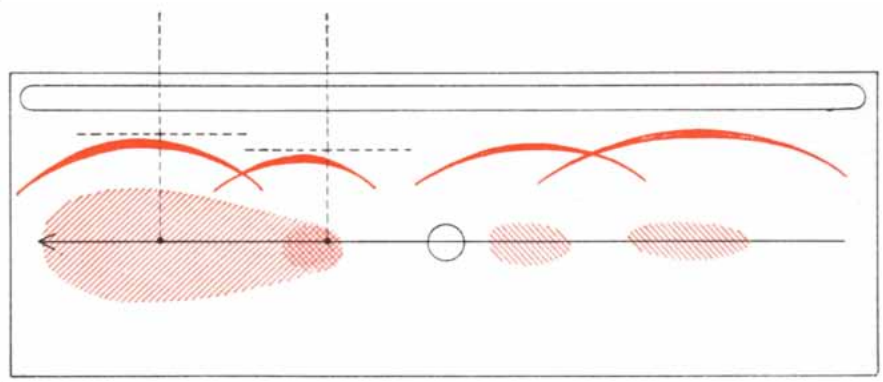
available in relatively pure form. The precipitate of diphtheria toxin and its antibody, for example, can be located on an Ouchterlony plate on which the toxin and the antibody have already formed lines of precipitate. A third hole is cut in the agar and filled with purified toxin. Just as in the previous reactions, the toxin diffuses passively through the various reactants until it encounters and reacts with its antibody. The line of precipitate formed by this reaction joins the line formed by the same reaction in the original pattern, producing a continuous "chevron" of precipitate [*see middle illustration on page 133*]. The "identity" reactions marked by these chevrons permit the investigator to label the components of a complex mixture of proteins. Conversely, lines of precipitate that intersect without joining indicate reactions of "nonidentity."

Ouchterlony's double-diffusion method found immediate success in immunochemistry and has become a standard technique in protein studies. Powerful as it is, it was not equal to the task of identifying all the antigens revealed by an antiserum against whole human serum. In 1952, when I joined Grabar and his colleagues at the Pasteur Institute, they were attempting just such a task with antiserum from a horse designated horse 31. The unusually large number of distinct antibodies induced in horse 31 by the injection of whole human serum produced an indecipherable array of lines on an Ouchterlony plate. With only two or three human-serum proteins available in even partially purified form, only two or three of the lines could be labeled by means of the identity reaction [*see bottom illustration on page 133*].

It was then that Grabar and I decided to try a new approach. We reasoned that on an agar-covered glass plate electrophoresis would string out the human antigens in a line of spots, as if the various antigens had been separated and placed in separate wells to begin with. After the electrophoresis was completed, the antigens would diffuse radially outward from each of these spots, as on a standard Ouchterlony plate. To precipitate each of the antigens the antibody solution had to be placed in a trough extending the length of the plate and allowed to diffuse laterally inward toward the line of spots [*see illustration on page 134*]. Within a week these speculations were supported by a successful experiment; using the antibody-rich serum from horse 31 we were able to detect about 25 distinct human-serum proteins distributed among the electrophoretic zones on the plate.

The geometry of the diffusion fronts in this procedure provides an added refinement: The antigen-antibody pairs precipitate not as straight lines but as elliptical arcs. Since each of the pairs reacts and precipitates independently of the others, its arc crosses those of unrelated reactions. Like the intersecting lines on Ouchterlony plates, the crossed arcs indicate that their reactants are immunochemically different proteins. Thanks to the geometry of the arcs the pattern has a high resolving power. A line drawn through an arc at the point farthest from the path of electrophoretic migration, and perpendicular to this path, will indicate the center of concentration of each antigen on the plate regardless of the antigen's relative concentration [*see illustration below*]. Presence of large amounts of two or three antigens thus cannot mask the presence of trace amounts of others, provided the others are abundant enough to cause the formation of an arc of precipitate. Usually a few millionths of a gram are sufficient, giving the method the ability to detect smaller quantities of protein than any other electrophoretic technique.

Our next step was to decipher and in-



RESOLVING POWER IS ENHANCED by the geometry of the arcs. By drawing a perpendicular (*vertical broken line*) from the widest point of the arc (*horizontal broken line*) to the path of electrophoretic migration (*arrow*) it is possible to locate the center of concentration of each antigen, thus preventing an abundant reactant from masking traces of another.

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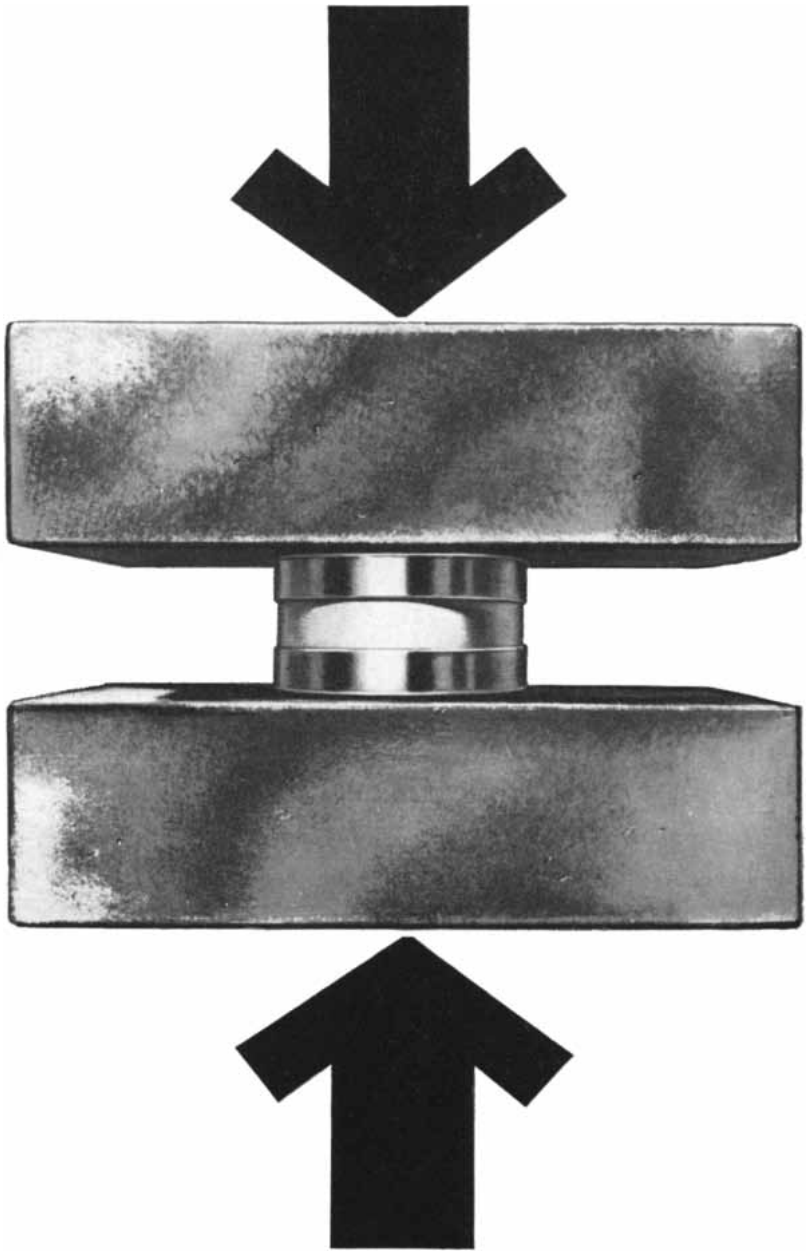

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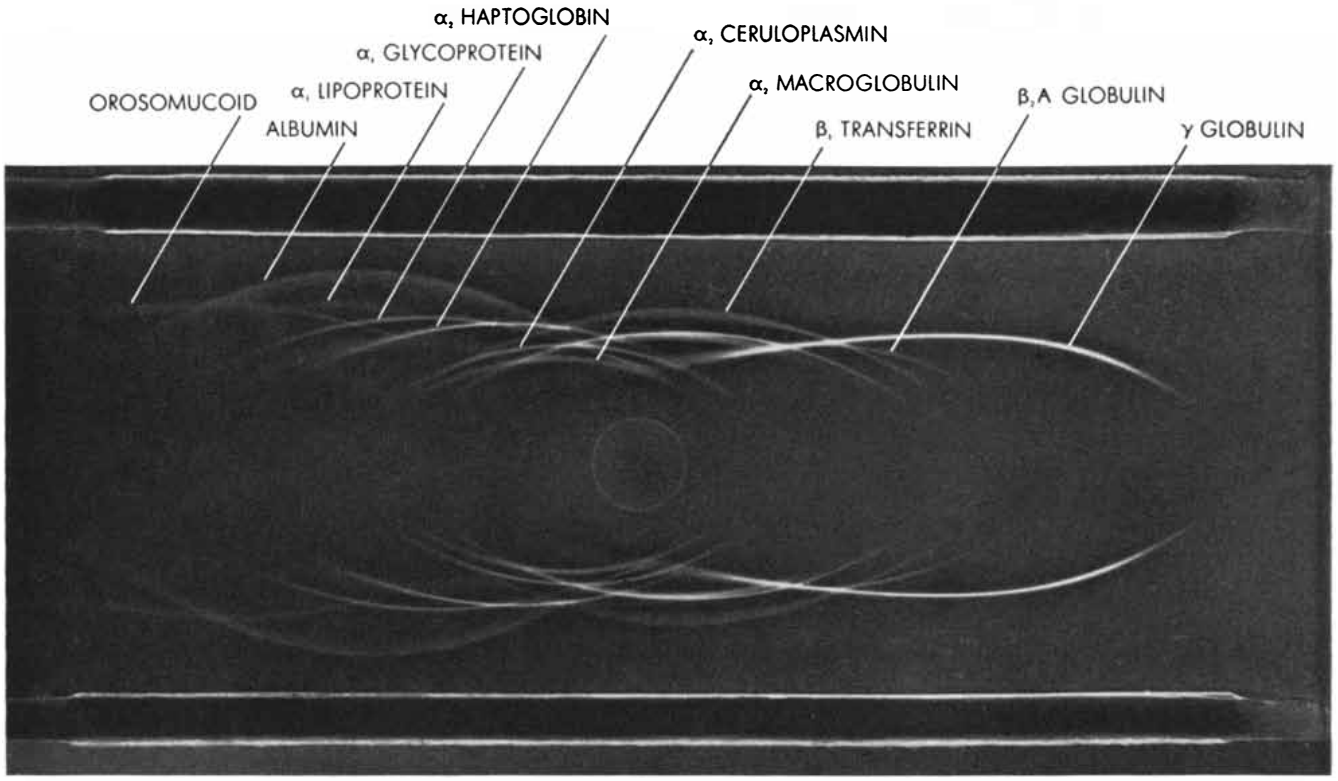
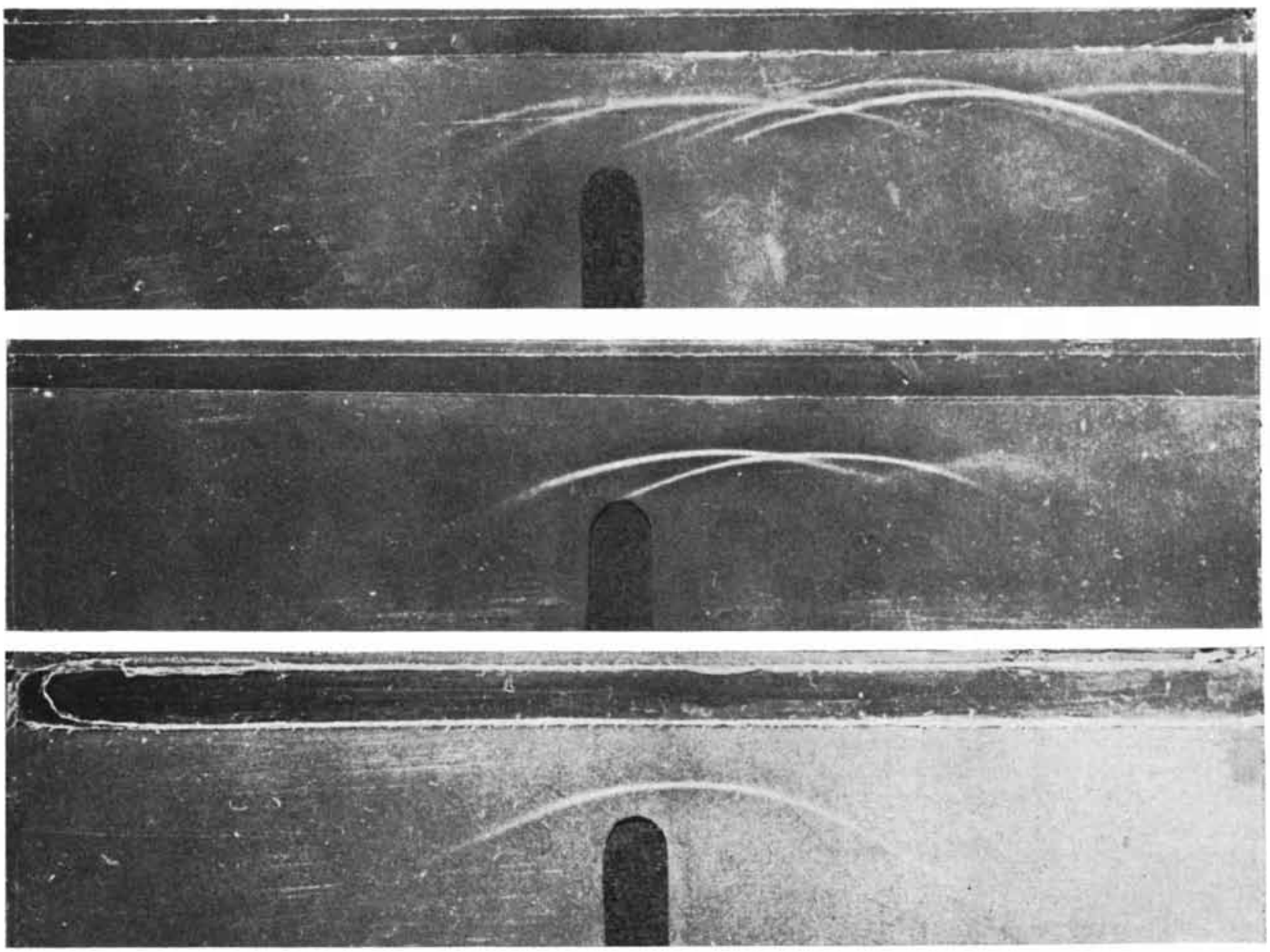


HUMAN SERUM PROTEINS produce this pattern on an immunoelectrophoresis plate when reacted with horse antiserum. Arc pattern is the same at top and bottom of plate because the antiserum was allowed to diffuse inward from two troughs instead of one.

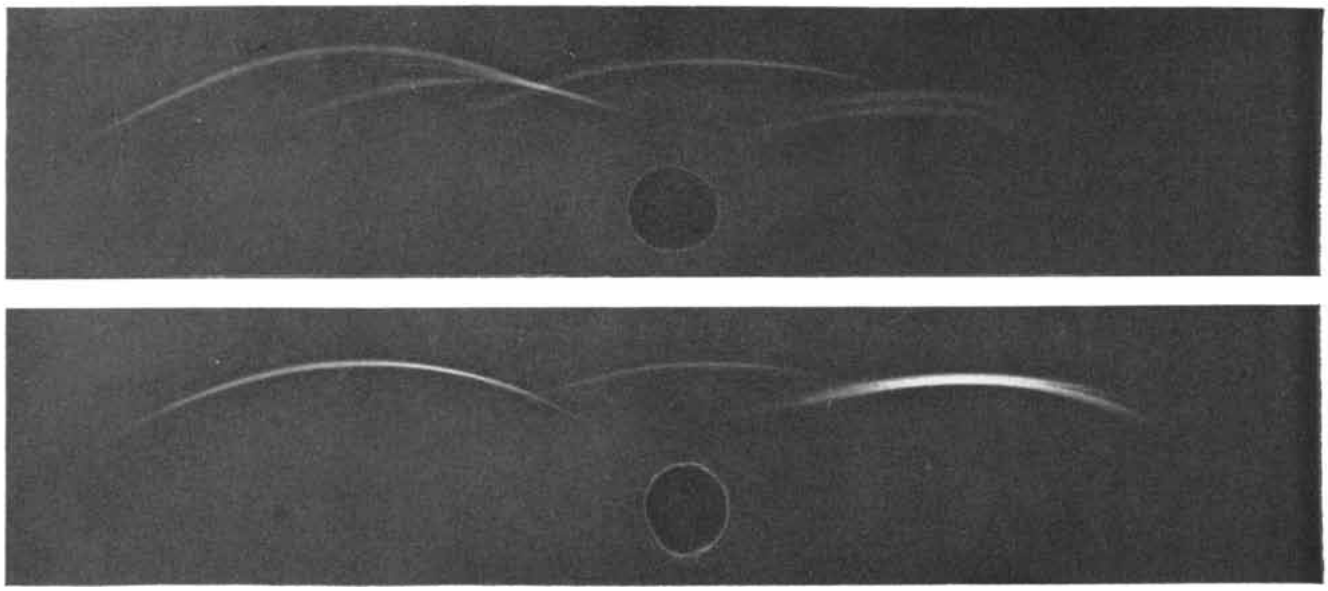


A GLOBULIN IS PURIFIED, using immunoelectrophoresis to detect impurities. First crude fraction (*top*) contains a complex mixture of antigens; after further purification (*center*) two antigens remain; finally (*bottom*) only a single beta-one globulin remains.

terpret a variety of new arc patterns that appeared on the slides. The gamma globulin arc, for example, was asymmetrical, resembling an unevenly bent bow. We now know that this peculiar pattern arises from the fact that some of the gamma globulin proteins migrate electrophoretically much faster than others, skewing their distribution on the plate. Despite their differences in mobility, however, these proteins are so closely related chemically that some antisera will not distinguish between them, which explains why the precipitate forms a smooth, continuous line rather than several intersecting arcs.

Occasionally a continuous, double-humped arc appears. The distance between the humps indicates the presence of at least two electrophoretically different substances; yet the two antigens are so similar that once again a less specific antibody fails to distinguish between them. Diphtheria toxin and toxoid are excellent examples of such substances. The toxoid is produced in the laboratory by treating the purified bacterial toxin with formaldehyde. The slight chemical change brought about by this treatment brings a radical change in biological activity: the toxoid is harmless to the body. Nonetheless it induces the formation of antibodies (in this case called antitoxin) that neutralize the toxin. Immunologically the toxin and toxoid are indistinguishable; they react identically with the antitoxin in the test tube and on the agar plate. But the slight chemical difference between the toxin and the toxoid gives them different electrophoretic mobilities. The two may therefore be distinguished from each other by immunoelectrophoresis.

During the past six years immunoelectrophoresis has been modified and adapted to research and clinical work in laboratories throughout the world. Shortly after we first published our results, Jean Jacques Scheidegger of the University Polyclinic in Geneva developed a method of performing the entire operation on a microscope slide. Since this technique requires only a few hundredths of a milliliter of antiserum and even less antigen, it is quite useful where these reactants are scarce. And because the antigens on many slides can be separated at one time in the electrophoretic apparatus, the technique is useful in clinics where many analyses must be performed or where the results are needed as quickly as possible. As might be expected, the resolving power is not so great as that obtainable with larger



MULTIPLE SCLEROSIS produces a high concentration of gamma globulins in cerebrospinal fluid. In arc pattern of normal spinal fluid (*top*) gamma globulins appear as the weak arcs at right; in multiple sclerosis (*bottom*) they become much more prominent.

plates; nevertheless information thus collected by Joseph Heremans of the University of Louvain has enabled us to label a considerable number of arcs in a full-sized immunoelectrophoretic pattern of human serum *v.* horse 31 antiserum [*see top illustration on page 138*].

The names of the proteins identified so far by immunoelectrophoresis reflect both their electrophoretic mobility and some of their physical, chemical or physiological characteristics. The globulin beta-one transferrin, for example, is a protein apparently associated with the transport of iron in the blood. The alpha-two haptoglobin is one of a class of proteins that combine with hemoglobin; their number and type have been demonstrated to be genetically determined in man, and they are currently the subject of numerous studies.

The use of immunoelectrophoresis to test the purity of a solution of one of these proteins is demonstrated in the three photographs at the bottom of page 138. The large number of lines in the top plate indicates the antigenic complexity of a first crude fraction of beta globulins. After further separation by chemical methods, only two major components remain [*middle plate*], and finally all the unwanted proteins have been removed, leaving a single antigen, a beta-one globulin [*bottom plate*].

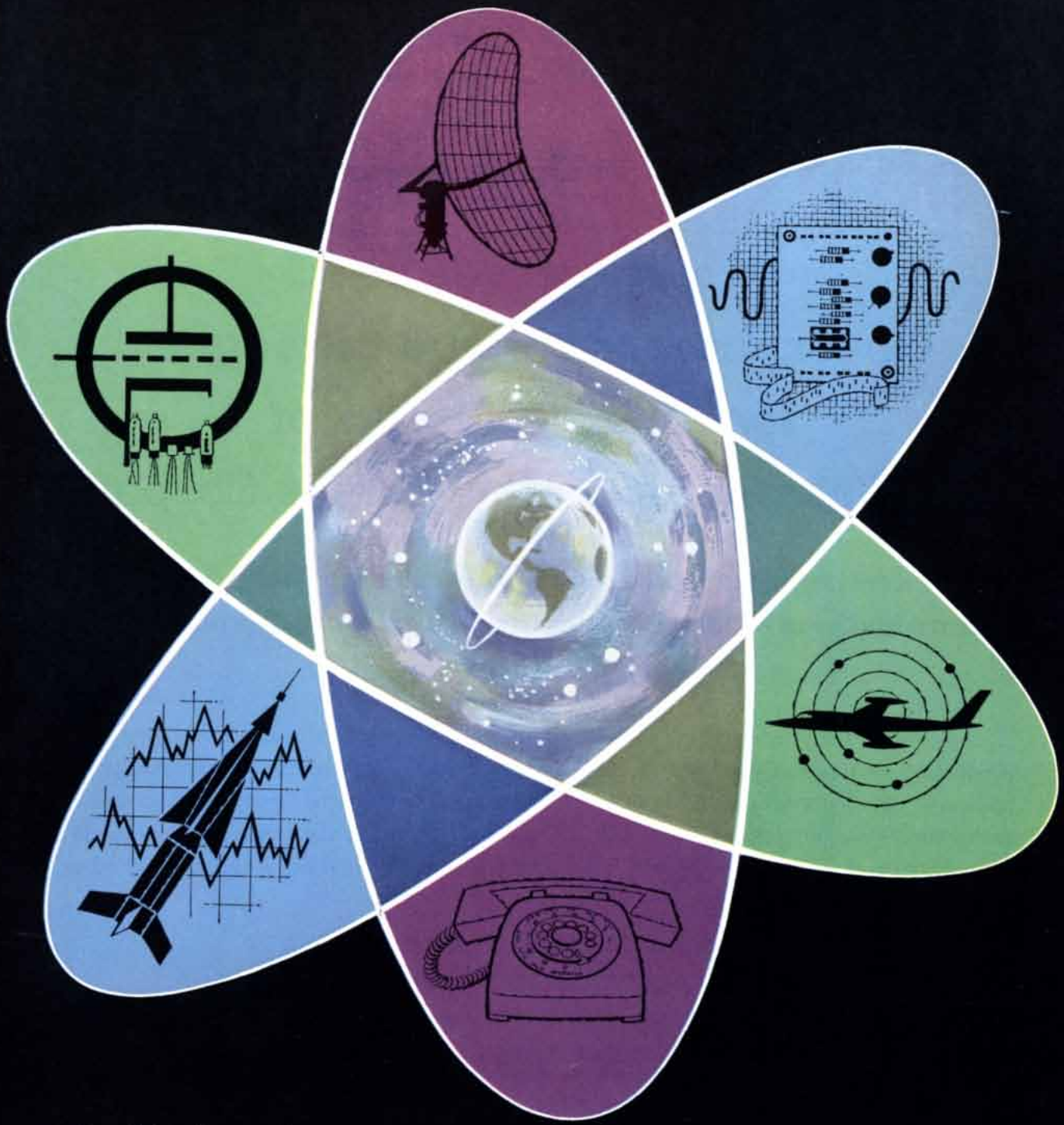
In clinical work immunoelectrophoresis has been employed as a test for the presence of serum proteins associated with disease. The bone-marrow cancer known as multiple myeloma, for example, is accompanied by the appearance in the bloodstream of considerable amounts of abnormal "paraproteins." Paraproteins are apparently modifications of normal proteins, but it is currently a matter of debate whether they are ordinarily present in undetectable amounts or whether they appear only during disease. Another controversy turns on the issue of whether paraproteins are produced by malignant cells or whether they are the product of malfunctioning normal cells. To shed light on such questions immunoelectrophoresis has been used to determine the normal protein to which a given paraprotein is most closely related. Three experiments conducted in the course of this work appear on the cover of this issue of SCIENTIFIC AMERICAN.

Multiple sclerosis, a degenerative disease of the myelin sheaths of nerve fibers in the central nervous system, is accompanied by a sharp increase in the gamma globulin content of the patient's spinal fluid. Immunochemical and electrophoretic methods have detected this symptom in up to 70 per cent of the cases examined, and in most of these the increase is quite striking. Immunoelectrophoresis has shown that this increase in the total amount of gamma globulins is due to an increase in the relative amounts of certain gamma globulin components in the pathological fluid.

Immunoelectrophoresis can also help to clarify puzzling relationships between pathogenic and nonpathogenic bacteria. For example, it has detected the protein antigens that distinguish the virulent tubercle bacillus from the harmless members of its class. Whether or not these proteins are related to the pathogenicity of the organism has yet to be determined. Immunochemical techniques have also been successfully applied to the related task of determining the biochemical kinship of animals [see "The Blood Relationships of Animals," by Alan A. Boyden; SCIENTIFIC AMERICAN, July, 1951], and some of these interesting results are being examined in depth by immunoelectrophoresis.

Immunoelectrophoresis has also opened a whole new avenue of research in embryology by making it possible to determine at what stage a developing tissue first takes on its biochemical identity. To study the development of the liver in the chick, for example, an antiserum is prepared by injecting an extract of liver tissue from an adult chicken into another animal. The immunoelectrophoretic pattern of the antigens from the presumptive liver of, say, a 72-hour-old chick embryo can be compared with the pattern of the adult-liver antigens. Corresponding arcs in the two patterns are evidence for the presence of adult-liver proteins in the newly differentiated tissue. Conversely, the absence of an arc indicates that such antigens have not yet developed. Repetition of the test until a positive result is achieved should accurately determine the stage at which the adult proteins appear.

It is safe to predict that the most rewarding applications of immunoelectrophoresis still lie ahead. At present it is a qualitative method, but if current attempts to adapt it to quantitative analysis prove successful, it will become even more valuable in the study of proteins.



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- Automatic warning and alarm systems

DATA PROCESSING AND DISPLAY

- BMEWS data take-off and data processing subsystems
- MOBIDIC general-purpose digital computers
- UDOFT digital flight trainers
- Data processing subsystems for AN/MPQ-32, AN/ASD-1 and PLATO
- Sylvatron electronically driven electroluminescent display systems

DETECTION AND TRACKING

- PLATO anti-missile system
- AN/MPQ-32 detection and tracking system
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- AN/ reconnaissance system
- AN/ASD-1 reconnaissance subsystems
- ADAGE system analysis

ELECTRONIC WARFARE

- Passive defense system for B-58
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"TRUTH" DRUGS

Certain drugs have been used to interrogate suspected criminals. Can they in fact elicit the truth? If truth means objective reality, the answer is no. The drugs have nonetheless been useful in psychiatry

by Lawrence Zelic Freedman

In his diagnosis and treatment of mental illness the psychiatrist relies heavily upon what the patient says about himself and the things that trouble him. On occasion the psychiatrist has employed drugs with sedative or hypnotic effects in order to stimulate the patient's talk. The technique, sometimes called narcoanalysis, proved useful to physicians charged with the care of large numbers of emotional casualties in the armed forces of the U. S. during World War II and the Korean War. In the semisomnolent state induced by sodium pentothal and other drugs, even the usually noncommunicative patient could talk uninhibitedly. The drugs thus helped to speed treatment, supplying the therapist in a comparatively short time with diagnostic material that might not otherwise have been forthcoming in hours of interrogation.

Even before it became established in the psychiatric interview, such use of drugs excited the interest of people involved in another arena of human difficulty—crime. Police investigators were attracted by the possibility that drugs might facilitate the interrogation of a suspect and of witnesses. Persons accused, reaching desperately for corroboration of their testimony, have been tempted to submit to being questioned under drugs. The subjection of any individual to involuntary examination under drugs is of course as repugnant as torture; evidence secured by such methods is inadmissible in the courts. But the technique has been employed in pretrial investigations of crime, and persons charged with offenses are sometimes challenged to submit voluntarily to examination in a drugged condition. Underlying the willingness of the prosecution, the accused and the public to tolerate this procedure is the idea that the drugs, by stripping away the conscious controls of behavior, will lay bare the "truth."

The technique raises serious ethical questions. This use of drugs plainly lays a threat to the individual's right of privacy and of self-determination. But perhaps the most fruitful way to consider the questions it raises is on practical grounds. Can the drugs in fact elicit the truth? If they do not, then what function may they effectively and legitimately serve in the management of antisocial behavior?

The modern "truth" drug has antecedents going back to earliest times. Indeed, some of the drugs employed in narcoanalysis come from the same plants that awed primitive man with their power to alter his perception, ideas and emotions. Mandrake root, nightshade, belladonna, henbane and Jimson weed all belong to the family *Solanaceae,* various species of which contain the narcotic alkaloids scopolamine, hyoscyamine, atropine and polandrene. These plants have been used in religious and magical rites in all parts of the world: in ancient Europe, in the Orient and in pre-Columbian America. The Pythian priestesses of Delphos made their revelations and prophecies under the influence of narcotic plant drugs. In Aztec Mexico it was believed that the peyote cactus, which contains mescaline, conferred the power of second sight, which could be relied upon to discover the identity of a thief, to recover lost or stolen property and to provide insight into other more arcane matters. Peyote is still consumed in a kind of communion service by the members of the Native American Church, which integrates ancient Indian ritual with Christianity; in the vivid hallucinations and strange psychic state induced by peyote the communicant believes he experiences union with God.

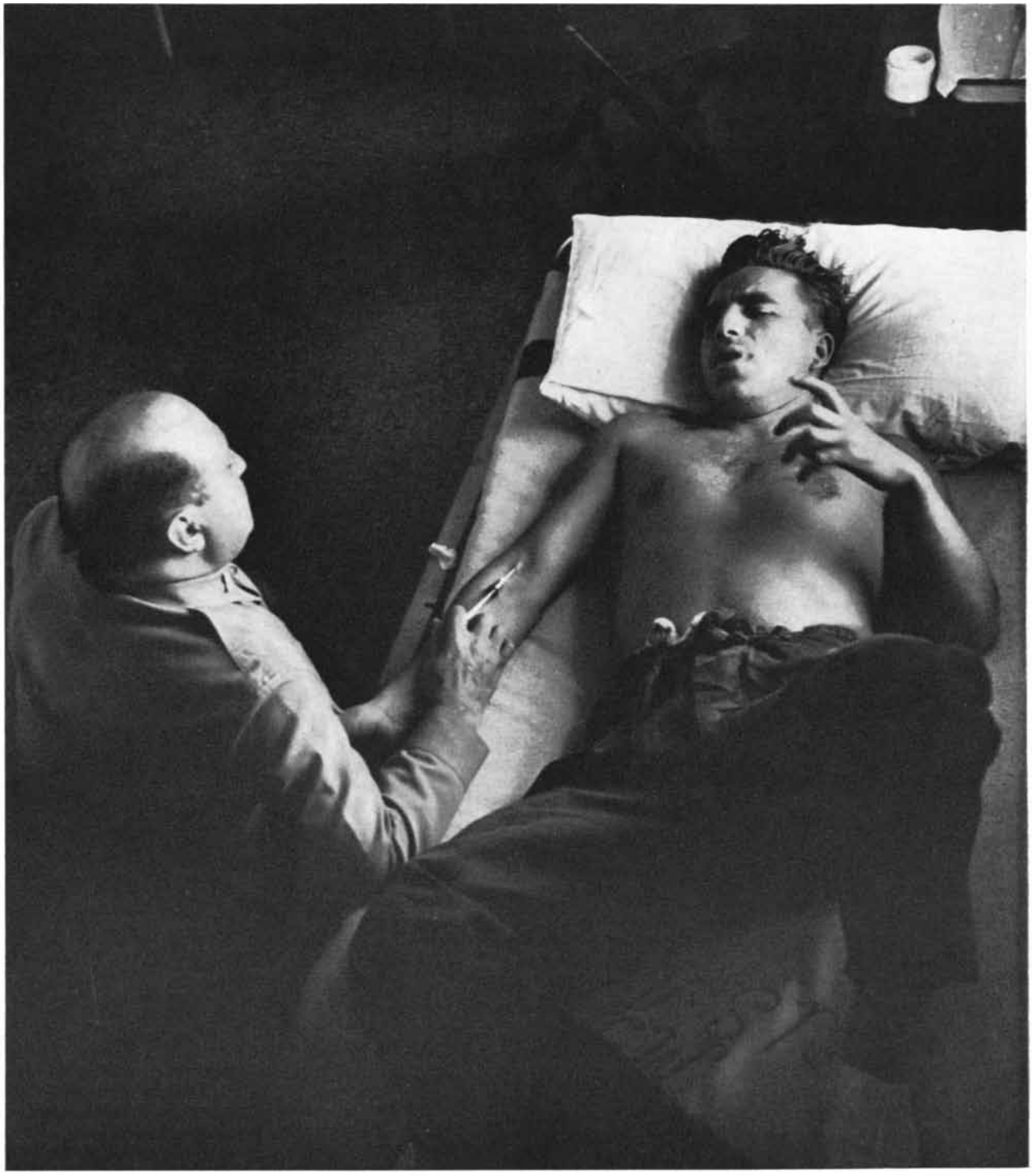
A profound change in man's thinking about himself and the universe had to occur before the revelations produced under narcotics and pharmaceutical hypnotics could appear to be psychological rather than supernatural manifestations. At the close of the 18th century the then young Humphry Davy came close to the notion of the stream of consciousness in his investigation of the effects of nitrous oxide upon himself and a number of his contemporaries. He persuaded Samuel Taylor Coleridge, Robert Southey and Peter Roget, among others, to record their sensations after breathing bags full of "laughing gas," which was a fashionable parlor pastime of that period. Davy wrote: "I gradually began to lose the perception of external things, and a vivid and intense recollection of some former experiences passed through my mind, so that I called out 'What an amazing concatenation of ideas!'" Roget, later known for his thesaurus but then a young physician, said: "My ideas succeeded one another with extreme rapidity, thoughts rushed like a torrent through my mind, as if their velocity had been suddenly accelerated by the bursting of a barrier which had before retained them in their natural and equable course."

Davy noted that the physical and mental effects of the gas varied among individuals, their temperament and mood, and found that in himself breathing nitrous oxide could alleviate anxiety. Looking back, it seems remarkable that no one picked up Davy's suggestive remarks about the anesthetic possibilities of nitrous oxide for surgery or his observations of the psychic changes it produces.

The next illumination of the subject

comes from William James, the propounder of the idea of the stream of consciousness. He was indebted to the "anesthetic revelations" of nitrous oxide recorded by Benjamin Paul Blood, a gentleman farmer of Amsterdam, N. Y. "I think," wrote Blood, "most persons who shall have tested it will accept this as the central point of illumination: that sanity is not the basic quality of intelligence, but is a mere condition which is variable, and like the humming of a wheel, goes up or down the musical gamut according to a physical activity; and that only in sanity is formal or contrasting thought, while the naked life is realized outside of sanity altogether."

This was, James said, a "stepping-stone of my thinking," though he could not share his friend's mystical views. From his own experiments with nitrous-oxide inhalation James drew the conviction that "our normal waking consciousness, rational consciousness as we call it, is but one special type of consciousness, whilst all about it, parted from it by the filmiest of screens, there



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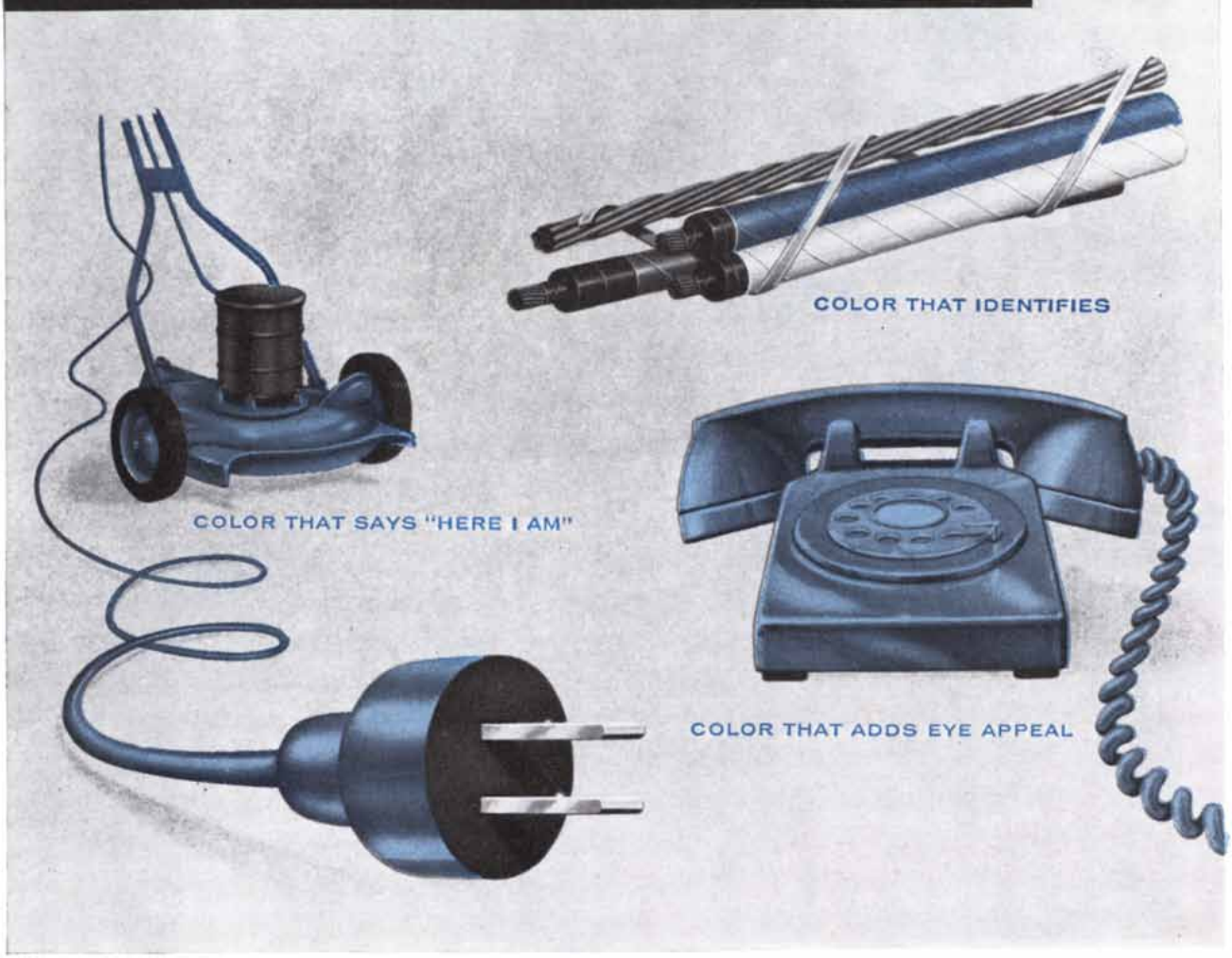

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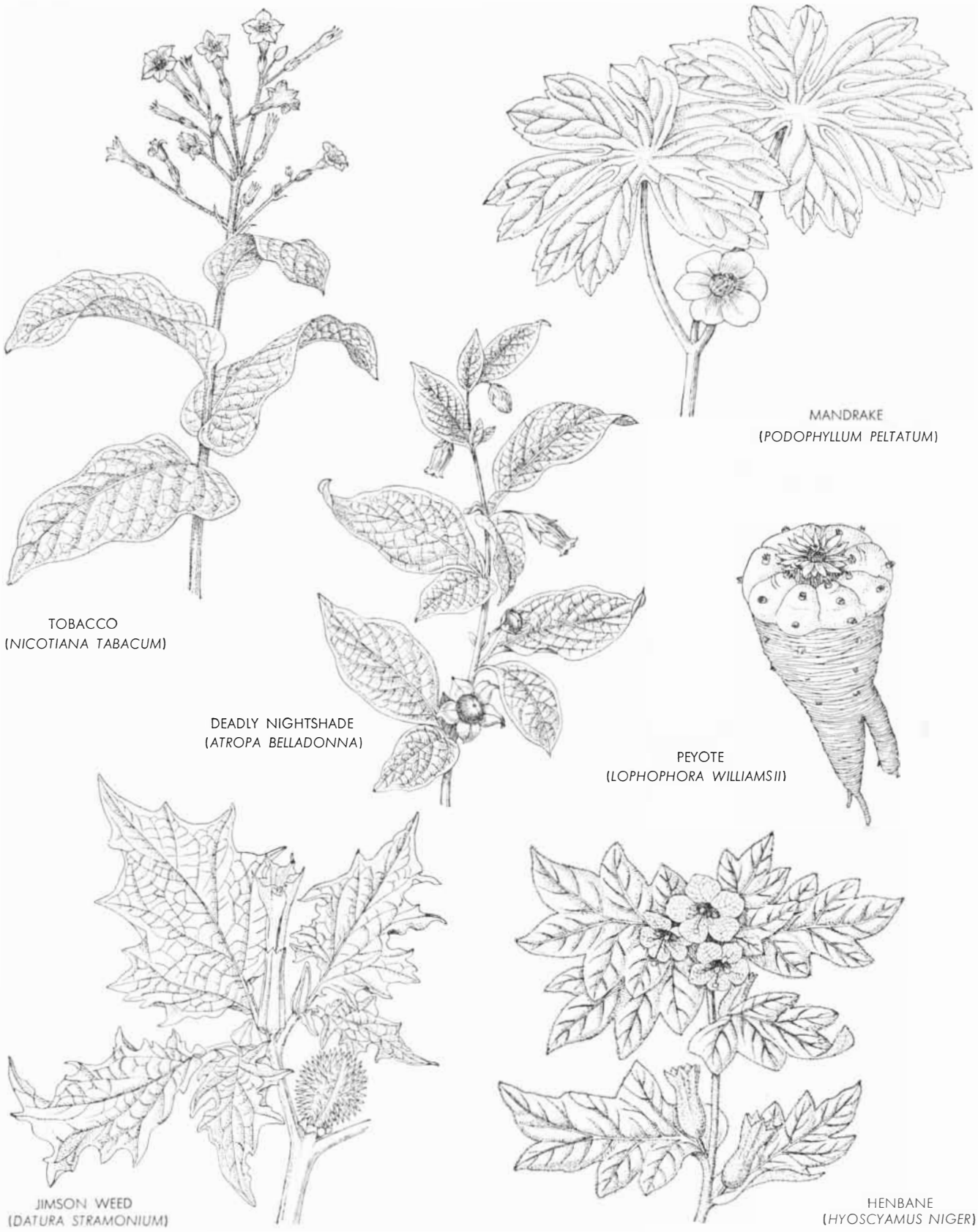


PLANT SOURCES of alkaloid "truth" drugs have been known since ancient times. Tobacco, mandrake, deadly nightshade, Jimson weed and henbane belong to the family *Solanaceae*, from various species of which can be extracted the drugs scopolamine, hyoscyamine, atropine and polandrene. From the peyote cactus (*middle right*) can be obtained mescaline, which causes hallucinations.

lie potential forms of consciousness entirely different. We may go through life without suspecting their existence; but apply the requisite stimulus, and at a touch they are there."

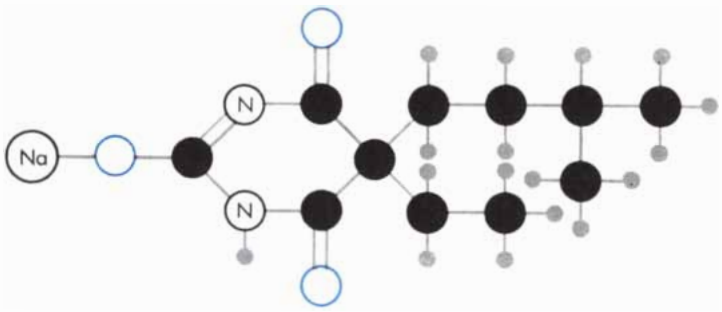
The first suggestion that drugs might be employed to facilitate communication with the emotionally disturbed patient came quite by accident in 1916. Arthur S. Loevenhart and his associates at the University of Wisconsin were experimenting with respiratory stimulants; they found that catatonic patients were good subjects because their stuporous condition made it easy to record their breathing. One such patient, who had long been mute and rigid, surprised his observers by relaxing and opening his eyes after an intravenous injection of sodium cyanide; he even answered a few questions. The experience was duplicated with other patients and by other investigators.

By the early 1930's a number of psychiatrists were experimenting with drugs as an adjunct to established methods of therapy. They were in doubt and disagreement, however, as to how the drugs brought change in the behavior of the patients. Some argued that the relaxation and sleep induced by drugs was the decisive factor. They accordingly administered sufficient doses to put the patients in deep sleep and were able to report that even severely catatonic patients seemed to resume normal behavior and experience periods of mental clarity lasting several hours upon awakening.

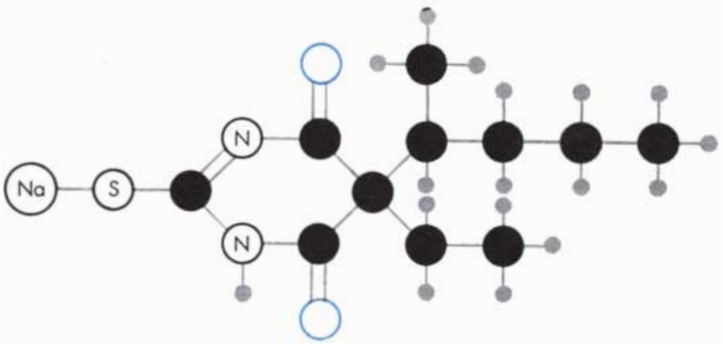
Then it was discovered that the drugs have more selective and specific effects upon mental activity. Erich Lindemann of the Massachusetts General Hospital found that doses far smaller than those necessary to produce sleep facilitated the patients' responses and their interaction with the therapist. From resistive, seclusive states they could swing into friendly, warm, communicative attitudes. When Lindemann tested the same drugs in the same doses on emotionally healthy persons, they reported a general sense of euphoria, ease and confidence, and they exhibited a marked increase in talkativeness and communicability. Their only cause for concern was a feeling that they had talked too much, though usually they had revealed less than they thought they had. None of them reported any gross distortion of perception, any hallucination or dreamlike experience. The general neurophysiological effect of the drugs was reflected in marked thickening of speech, a moderate decrease in

blood pressure, a decrease in heart rate, dilation of the pupils and double vision, some loss of muscular coordination and a marked increase in the pain threshold.

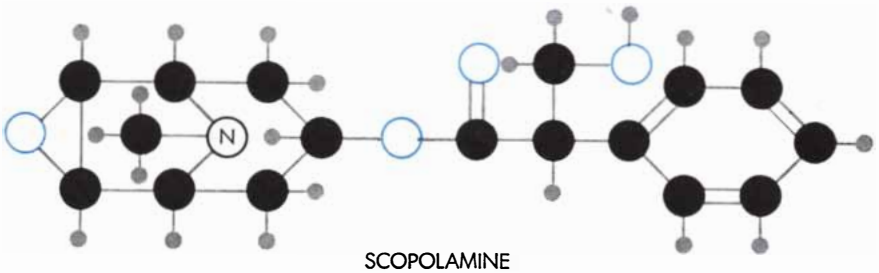
From these observations Lindemann postulated that the drugs removed certain psychic inhibitions and thus brought about verbal release. This is consistent with present views that are based upon closer study of the pharmacological action of the drugs. The drugs affect the higher brain centers generally. Those regions of the cerebral cortex that are usually thought to be of the most recent evolutionary development and that are engaged in the higher associative and behavior-organizing functions seem to be the first to yield to the diminution in brain-tissue metabolism brought about by the drugs. Larger doses in turn depress the function of the next lower centers. But the pharmacological action of the drugs does not explain or help predict the effect they will have on the behavior of a particular patient. That is the result of at least three factors: the personality structure of the subject, his physiological tolerance for the drug and equally important, the environmental stimuli acting upon him at the time.



SODIUM AMYTAL



SODIUM PENTOTHAL



SCOPOLAMINE

MOLECULES OF THREE TRUTH DRUGS are diagrammed. Sodium amytal and sodium pentothal are synthetic substances. Atoms in structures are hydrogen (*gray balls*), carbon (*black balls*), oxygen (*open colored circles*), nitrogen (N), sodium (Na) and sulfur (S).

The key role that the anticipation, or "set," of the subject may play in his responses was dramatized for me several years ago when I conducted an experiment at the Yale Medical School on sleep. I injected sodium amytal very slowly into a large number of volunteer medical students, having previously attached electrodes to their heads and chests in order to take measurements related to sleep cycles. Since I was concerned with getting them to sleep, I simply informed them of my intention, but the method and rate of injection were otherwise identical with the technique I had used for psychiatric interviews. In only one instance was there any talking, and the subject revealed no "truths" about himself spontaneously. This observation suggests that the role of sodium amytal in an interview involves far more than a "release mechanism."

Unfortunately the whole picture was still quite unclear when the idea of using drugs to "get at the truth" in criminal proceedings first captured the public imagination. Early in this century physicians had begun to employ scopolamine, along with morphine and chloroform, to induce the state of "twilight sleep" during childbirth. They were impressed to note that women in this condition were able to answer questions accurately and often volunteered exceedingly candid remarks. In 1922 it occurred to Robert House, a physician in Dallas, Tex., that scopolamine might be employed in the interrogation of suspected criminals. At the Dallas County Jail he interviewed two prisoners who had received injections of scopolamine. Both men denied the charges on which they were held; both, upon trial, were found not guilty. In his enthusiasm House concluded that the patient under the influence of scopolamine "cannot create a lie . . . and there is no power to think or reason." His experiment and conclusion attracted wide interest, and the truth drug was launched upon the popular consciousness.

Upon closer acquaintance, however, scopolamine was disqualified for service as a truth drug. It proved to have several toxic effects, among which the most

disabling is the production of hallucinations. Scopolamine therefore saw only brief service in narcoanalysis before it was abandoned.

The drugs now most frequently used in psychiatric interviews are sodium amytal and sodium pentothal. They are the most easily administered, have the least toxicity and unfavorable side effects and give the most predictable results. The behavior of the subject, especially if he is a psychiatric patient in anxious tension, is dramatic. His features slacken; his body relaxes. Some people are momentarily excited; a few become silly and giggly. This usually passes, and most subjects fall into a state that may be compared to that of a person who has just awakened from a deep sleep.

To form a judgment of what drugs may contribute to establishing the truth, it is necessary to consider what it is that drugs help to elicit from the patient in the psychiatric interview. The psychiatrist is not interested in establishing the truth in any probative sense. In the development of "psychological reality," which is the object of the interview, the patient's account of his fantasies and delusions is as significant as his reliable recollection of past events. Drugs may be helpful to the extent that they provide a "psychological analgesic," a relief from the inhibition of anxiety and guilt that blocks communication with the physician. Under narcosis the patient may achieve, in the words of the psychoanalyst Lawrence Kubie, "a more direct recovery of early traumatic experience than is possible by circuitous pathways of free association in the fully awaking state." It was the resulting acceleration of diagnosis especially that made the drugs so helpful to the military psychiatrists of the U. S. armed forces. But the two medical officers who perhaps made the most extensive use of the technique, Roy R. Grinker and John C. Spiegel, concluded that in almost all cases they could obtain essentially the same material and emotional release in the course of therapy without the use of drugs, providing they had sufficient time.

During the postwar period, with the work of psychiatry proceeding at a more normal rate, narcoanalysis is far less frequently employed. The pressures of time and the stress of reality are rarely paralleled in civilian life—except in the case of individuals who are threatened by legal action and ostracism for criminal or socially offensive acts. Here a psychiatric interview under drugs sometimes offers an avenue of communication urgently needed for proper diagnosis and treatment. But the information thus obtained should never be mistaken for evidence or presented as such in court. Except under such special conditions psychiatrists prefer to deal with a fully conscious patient.

I have employed sodium amytal in investigating the personalities of men accused of various civilian and military antisocial acts. The subjects ranged diagnostically from those with character disorders and neuroses to psychotics. The offenses charged to them included mild delinquency as well as murder. Out of all the information I obtained from them during hours of interrogation under the influence of the drug there was little that could be interpreted directly in the light of its manifest content. These interviews were helpful to me as a psychiatrist and to the subject as my patient. Rarely, however, was my view of objective reality improved as a result of these revelations. I could not, on the basis of a patient's statements, testify in a court that I knew that a given act had or had not occurred. Guilt-ridden subjects under sedation were prone to confess to offenses they had imagined in fantasy but had not in fact committed. Psychopathic individuals could, to the point of unconsciousness, deny crimes that every objective sign indicated they had committed.

At times sedation may diminish self-protective censorship of speech, and the demand of an overburdened conscience may dominate the subject's responses. But these seemingly uninhibited outpourings are vulnerable to distortion resulting from fears, needs and wishes at the deepest levels of his personality. What is more, the cognitive or reasoning functions of the subject's nervous system are to a greater or lesser degree impaired. Even with the best will he may be inaccurate in his observations and recollections. Throughout the interview the psychological processes of repression and resistance and the subtle manifestations of the patients' relationship to the physician continue to operate. Where the role of the interrogator is that of a police investigator or prosecutor, it is hardly likely that the subject would be motivated toward cooperation. "Confessions" obtained with the use of drugs cannot be relied upon, therefore, as testimony or evidence under the standards that are observed by our courts.

In an adversary proceeding, at least one experiment has shown, subjects are capable of maintaining a lie despite injections of a drug. Investigators from

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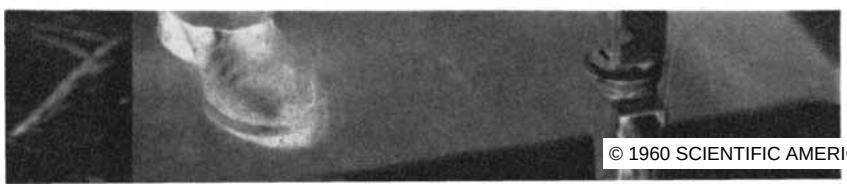
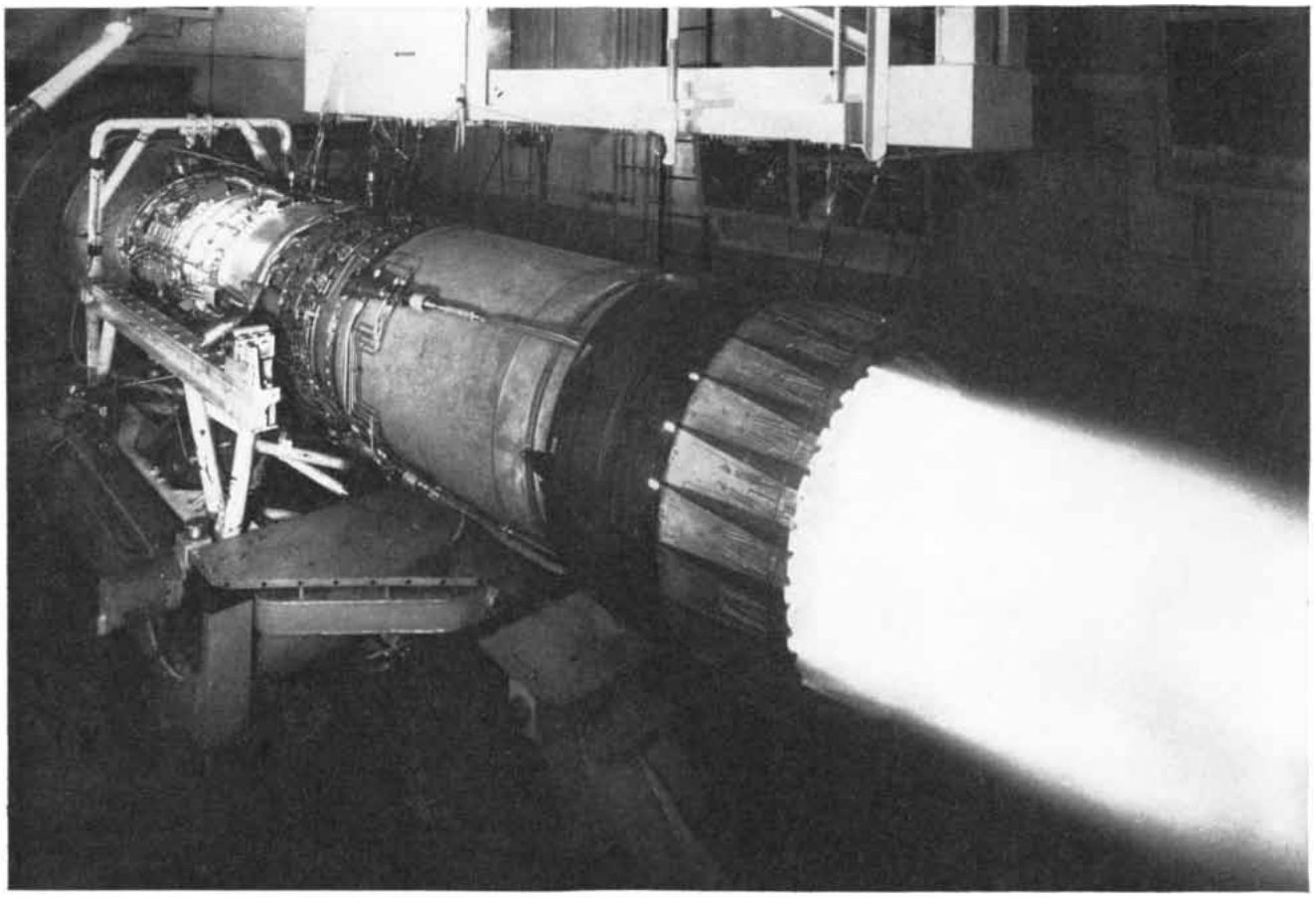


the department of psychiatry at Yale University, Frederick C. Redlich and Leonard J. Ravitz, Jr., working with the late George H. Dession of the Yale Law School, conducted the experiment with the aid of volunteers. They administered sodium amytal after the subjects had revealed shameful and guilt-producing episodes of their past and had then invented false self-protective stories about these episodes. Thereafter, under the influence of the drug, they were subjected to cross-examination on their cover story by a second investigator. The results, though not definitive, showed that normal individuals, with good defenses and no overtly pathological traits, could stick to their invented stories and not yield confessions. On the other hand, neurotic individuals, with strong unconscious self-punitive tendencies, not only tended to confess more easily but also to substitute fantasy for the truth, confessing to offenses never actually committed.

In sum, experimental and clinical findings indicate that only individuals who have conscious and unconscious reasons for doing so are inclined to confess and yield to interrogation under the influence of drugs. On the other hand, some are able to withhold information and some, especially character neurotics, are able to lie. Others are so suggestible or so impelled by unconscious guilt that they will describe, perhaps in response to suggestive questioning, behavior that never in fact occurred. The material produced is not "truth" in any sense of conforming with empirical fact.

Serious wrong can be done both to the embryonic science of criminology and to the administration of justice if this procedure is employed as a fact-finding instrument. As the psychoanalyst Theodor Reik pointed out 20 years ago, "fact-finding is still in the province of the police investigator." Moreover, in view of the emphasis upon confessions in this discussion, it should be observed that the extraction of confessions is not the only kind of fact-finding expected of the police.

It is precisely because drugs may facilitate access to psychological reality, as opposed to empirically factual data, that narcoanalysis may have importance for the psychiatrist. The procedure can be helpful in obtaining keener insights into the motivation and psychogenesis of antisocial behavior. Through such studies the psychiatrist may make the best use of drugs in the area of violent criminal behavior. Understanding of the genesis of crime is the rational precursor to the discovery and implementation of preventive measures.



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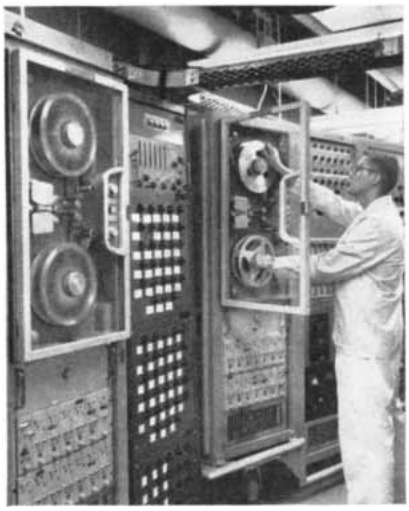

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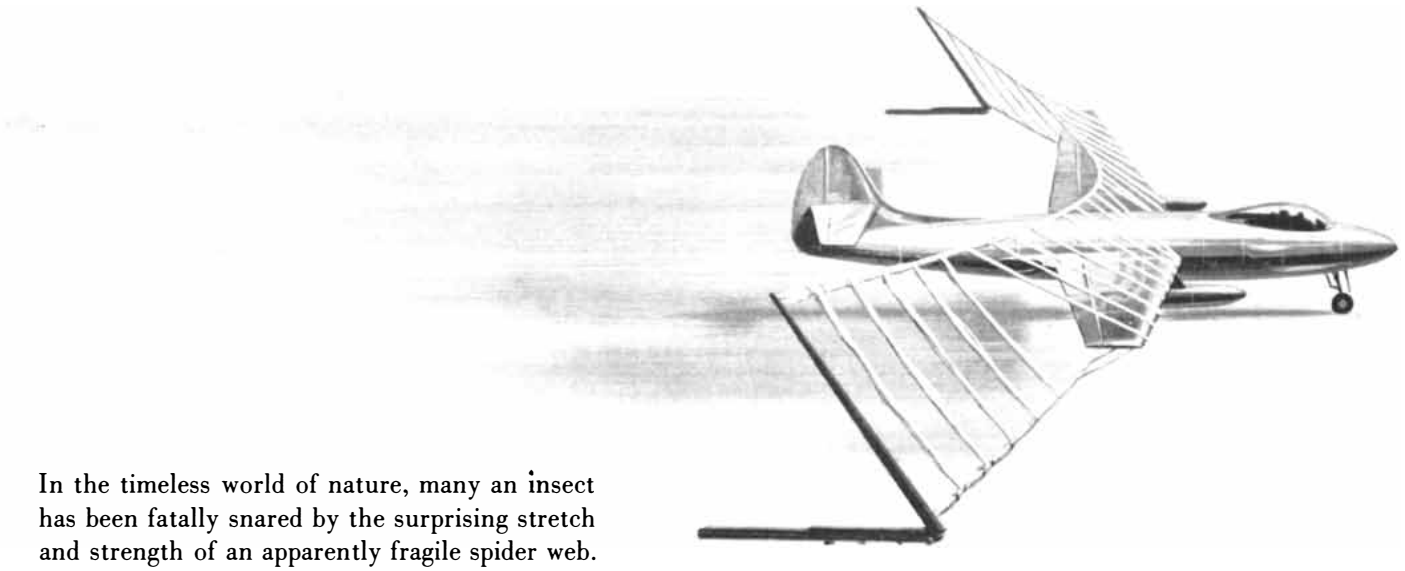

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The Portuguese Man-of-War

This colorful jellyfish is not one organism but a colony of four kinds of polyp. The stinging cells on the tentacles with which it fishes secrete a substance that is almost as toxic as cobra venom

by Charles E. Lane

During the winter the ocean beaches in southern Florida are frequently littered with colorful, roundish baubles of a curious gelatinous texture. The unwary beachcomber who picks up one of them for a closer inspection is usually rewarded with a painful sting. They are the remains of the jellyfish known as the Portuguese man-of-war, or *Physalia physalis*. The stinging elements by which it catches its prey in life retain their potency long after its delicate body has withered in the sand.

At sea in its native environment the Portuguese man-of-war resembles a gaudy Christmas tree ornament floating aimlessly on the blue water. What shows above the surface is a hollow crested bladder as large as 12 inches long, six inches wide and six inches high, varying in color from blue through azure, purple, lavender or orchid to pink or scarlet. Down in the water from the bottom of this float hang writhing polyps and long, filamentous tentacles that may trail 40 feet below a full-grown specimen.

The man-of-war appears to drift with the winds and currents as inanimate flotsam does, but closer observation reveals that it frequently makes a course at a significant angle to the surface winds. The boatlike shape and the sail-like crest of the float, which is stabilized in the water by the drag of the underbody, enable the animal to tack downwind. The speed is not great, but then the schedule is not demanding. The common name of the Portuguese man-of-war probably originated with its resemblance to the lumbering but formidable galleons of the time when Portugal was a naval power.

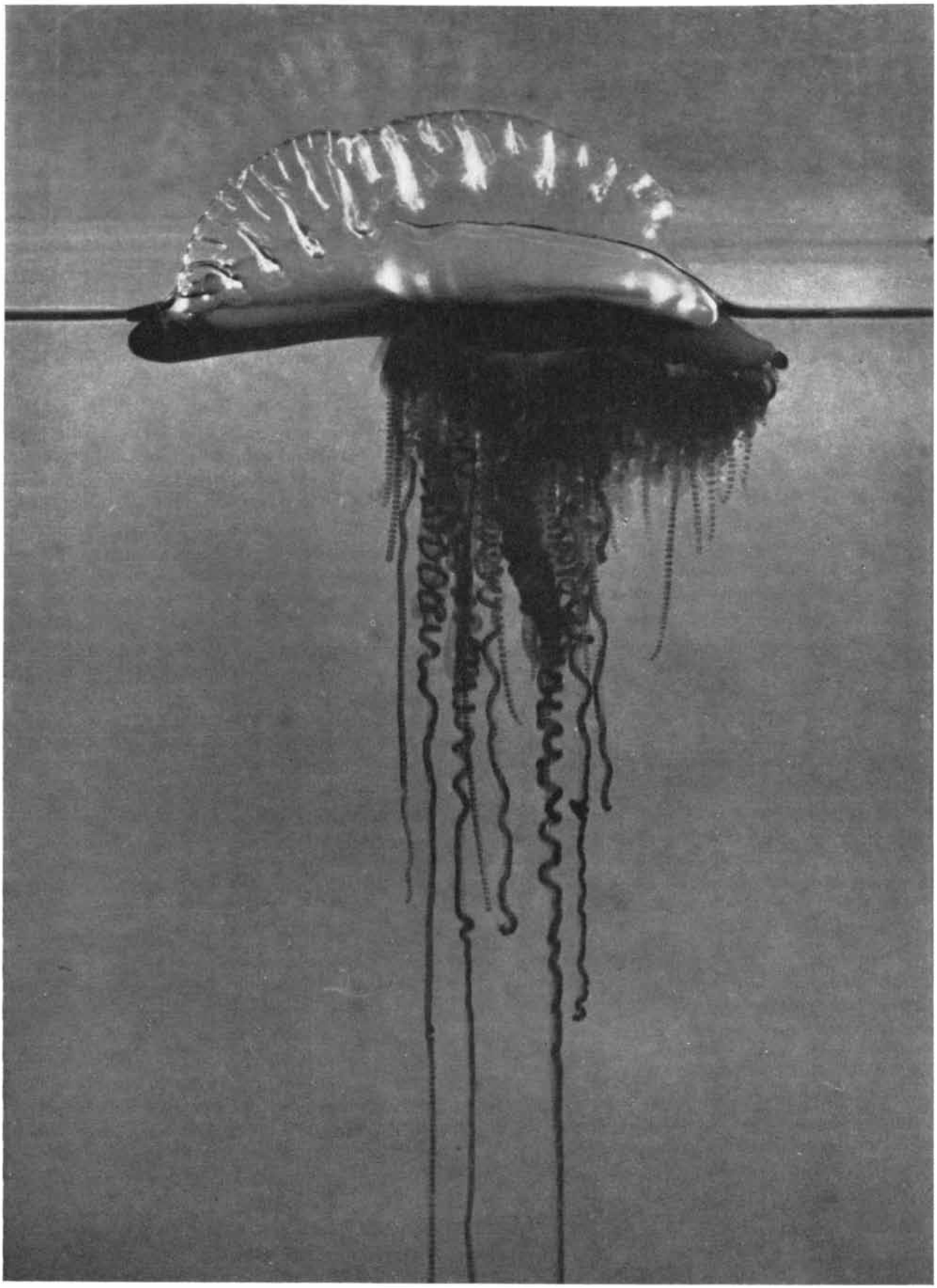
Although *Physalia* may be stranded by the vagaries of winds and currents, it normally lives on the warmer high seas. It is rarely found in the Atlantic outside the current system of the Gulf Stream. (A related form inhabits the warm latitudes of the Indian Ocean and the Pacific.) Because it does not survive in the aquarium, where its growth could be studied, little is known of its early development. Our observations in the Miami area suggest that its life cycle may be completed in a single season. Small men-of-war turn up in late October and early November. As the season advances, larger and larger specimens are stranded; the largest are found in late March or early April. Shortly thereafter *Physalia* disappears from local waters and does not return until the following fall.

A remarkable thing about the Portuguese man-of-war is that it is not a single animal but a colony of separate organisms that have banded together in the course of their evolution to share the tasks of survival. The float is one entity; another kind of organism constitutes the fishing tentacles that capture plankton and convey them to the gastrozooids, which perform the function of digestion and are a third kind of organism. A fourth kind of organism carries out the task of reproduction. Taken together the individuals in a mature *Physalia* colony may number from a few to 1,000. Each is highly specialized, and they do not live long when they are separated. How this colonial organization becomes established can only be surmised; presumably its individual members develop by budding from a central stem.

The float is essentially a gas-filled membranous bag. A carotinoid pigment that forms a complex with the structural protein of the bag accounts for its color; similar complexes are responsible for the color of the northern lobster and some other crustaceans. The thin membrane contains both isolated muscle fibers and sheets of muscle cells. Periodically this musculature so contorts and twists the bag as to submerge it; thus the membrane is kept moist and pliable. The musculature also regulates the gas pressure inside the float. Compared to the surrounding air the gas within the float contains more of carbon monoxide and of the inert gases nitrogen, argon and xenon. This gas is secreted by a gland that may be analogous to the gas gland in the swim bladder of fishes. Some sort of feedback from the gas pressure must regulate the rate of secretion; the gas gland is capable of a high rate of activity and reinflates a deflated float with apparent ease in a few minutes.

The gastrozooids, the digestive organisms on the underside of the float, respond quickly and actively to the presence of food, wriggling and twisting until they fasten their flexible mouths to it. Once attached, they become all mouth, spreading out over the surface of the morsel. The resting gastrozooid measures only one to two millimeters in diameter, but the mouth can expand to 20 millimeters or more. A few neighboring gastrozooids may thus completely enclose a small fish. They digest the food by secreting a full complement of enzymes that variously break down proteins, carbohydrates and fats.

Recent investigation has shown that the gastrozooids are remarkably sensitive to glutathione, a universal constituent of living matter that is liberated when an animal is injured or when dead tissue breaks down. In the presence of this substance gastrozooids begin to writhe restlessly and in a few minutes open their mouths. Glutathione similarly triggers the feeding response in the fresh-water polyp Hydra and in certain related organisms. Isolated gastrozooids,

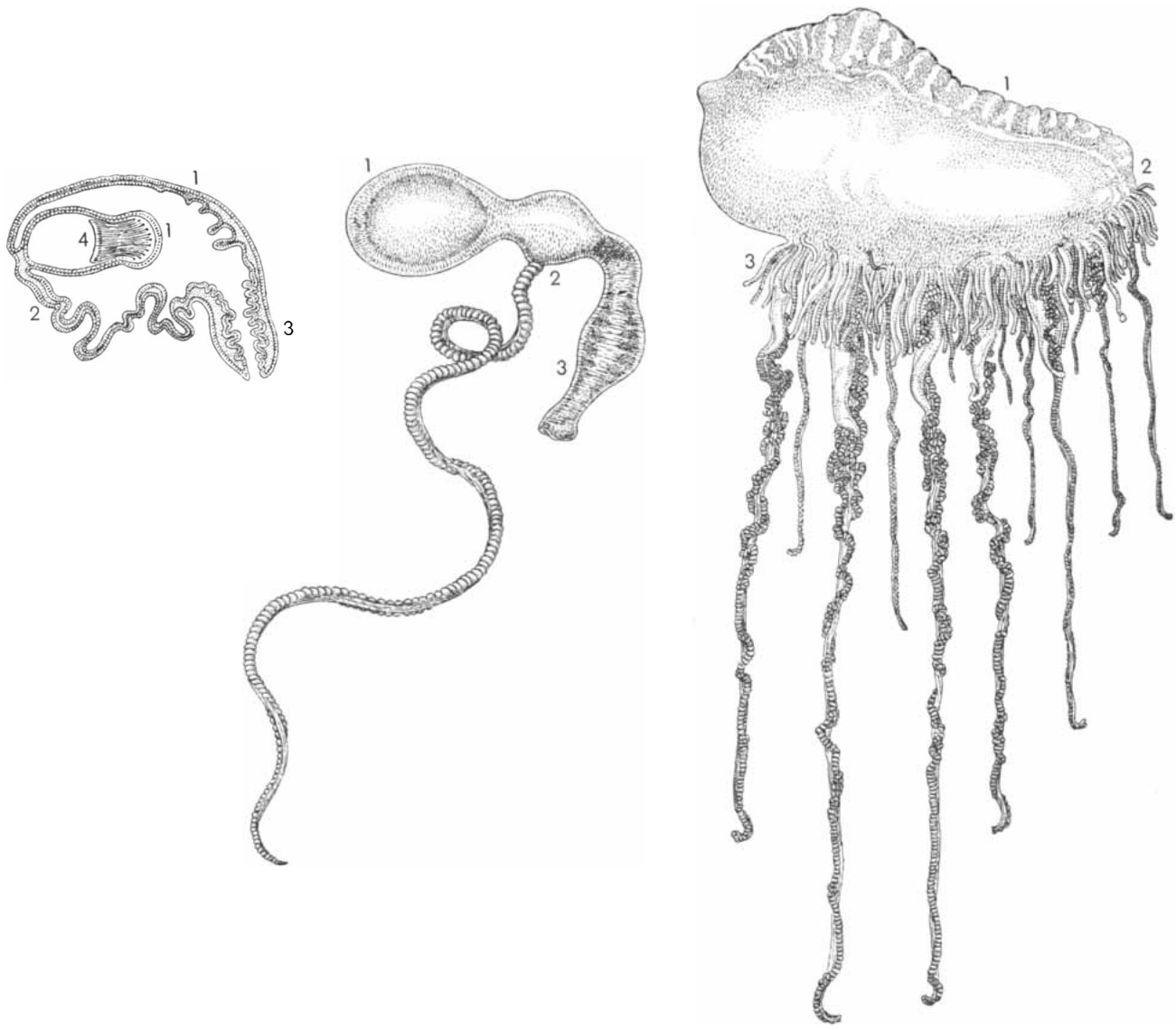


MAN-OF-WAR *Physalia physalis* is photographed through the side of an aquarium. At the top is the sail-like float, which is one kind of polyp. Immediately below the float are the gastrozooids, which perform the function of digestion. Hanging down to the bottom of the tank are the tentacles, which can reach a length of 40 feet. A fourth kind of polyp performs the function of reproduction.

cut away from the parent colony and rinsed in sea water, respond to a solution containing only .0003 per cent of glutathione. They will even ingest filter paper soaked in the solution or spread their mouths over the surface of a glass dish filled with it. Sometimes a gastrozooid stimulated in this way will so expand its mouth that it will turn itself inside out.

The remarkable length and peculiar armament of the tentacles make them the most impressive members of the *Physalia* colony. Each tentacle is a pellucid thread that bears a striking resemblance to the monofilament lines used by human fishermen. A great deal more complicated than a fishing line, it contains longitudinal muscle elements that contract to shorten the tentacle and "reel" trapped food organisms into the vicinity of the mouths of the gastrozooids. The entire length of the tentacle is beaded with localized swellings, each consisting of a battery of tiny spherical stinging cells: the nematocysts.

Stinging cells are the characteristic food-getting devices of jellyfish and their relatives. The man-of-war carries them in two sizes, the smaller a little larger than a human red-blood cell (which is .009 millimeter in diameter) and the bigger about three times as large. The individual nematocyst is a hollow sphere. Its exterior wall is pushed in at one point and stretched into a long tube that is turned outside in and tightly coiled within the sphere. The orifice left in the surface of the capsule is covered with a hatchlike membrane that is held down by a tiny hairlike trigger. When the nematocyst is stimulated, the tube shoots outward, turning itself right side out; fully extended, it may stretch 100 to 300 times the diameter of the capsule. The surface of the tube is studded with sharp projections—hooks, barbs and spikes of several different shapes and sizes—arranged in a helix along most of its length. In the sudden eversion of the tube this armament strikes into the prey. At the same time a toxic fluid inside the capsule is injected into the prey through



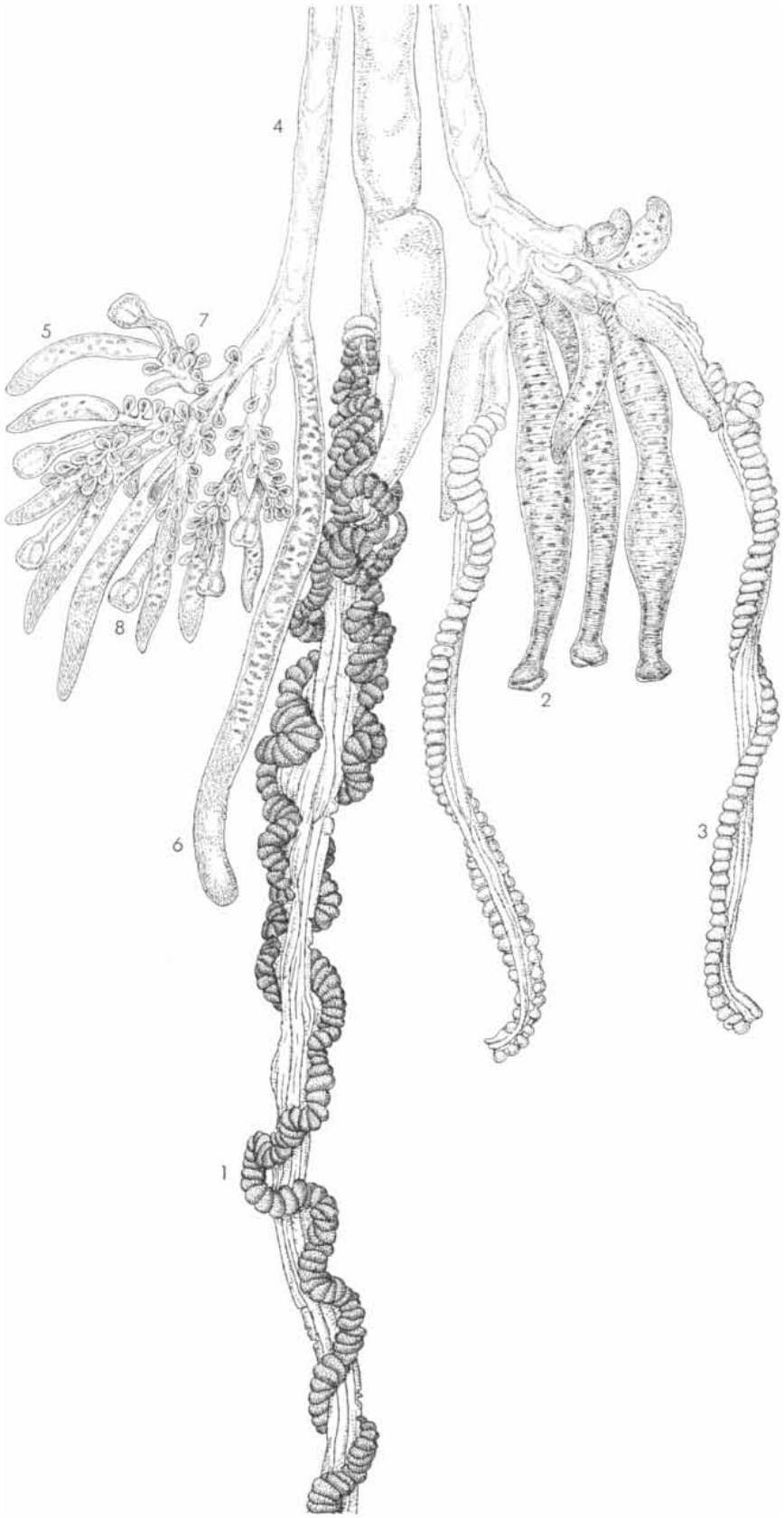
DEVELOPMENT OF THE MAN-OF-WAR can only be conjectured on the basis of small specimens observed in the laboratory. These three are not drawn to the same scale, and the first is shown in cross section. The float (1) and its gas gland (4) increase in size as the colony enlarges. A gastrozooid (3) develops at one end of the original structure; a tentacle and then additional gastrozooids and tentacles grow out of the budding zone (2) near the other end. The reproductive polyps develop much later.

a tiny aperture at the end of the tube. The mechanism operates with sufficient force to sting even through tough surgical gloves. Since the extended tube retains its connection with the capsule after it has discharged, a fish killed by a man-of-war appears under the microscope to be festooned with tiny bladders hanging by tenuous threads.

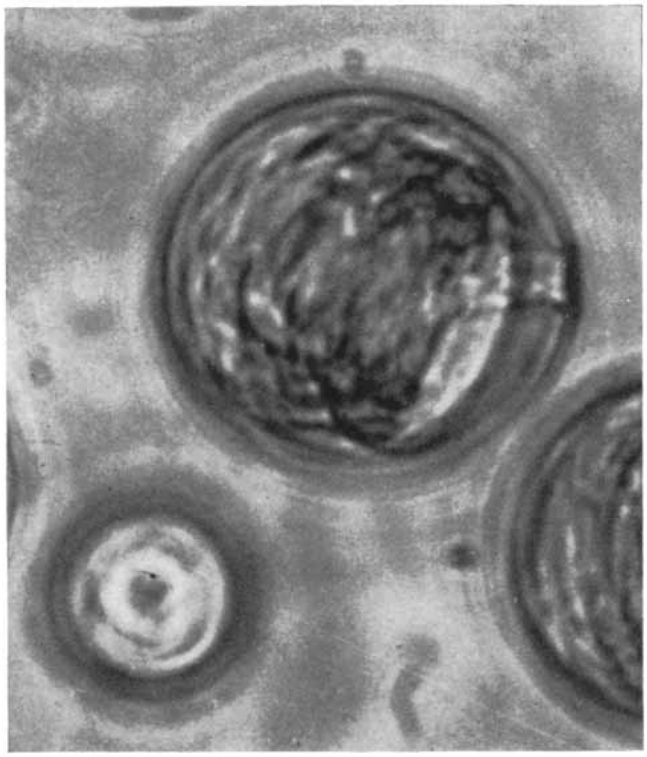
This fearsome equipment serves its food-gathering function well. As the man-of-war drifts downwind, the long tentacles move continuously, fishing the water through which they pass. The prey appears to consist mostly of tiny crustacea and other components of the surface plankton. At times the tentacles will pick up small fish and the larval forms of larger crustaceans. Although the man-of-war initially ensnares most of its prey in the tangle of nematocyst threads, or impales it on the hooks and barbs with which these threads are armed, the final subjugation is probably accomplished chemically.

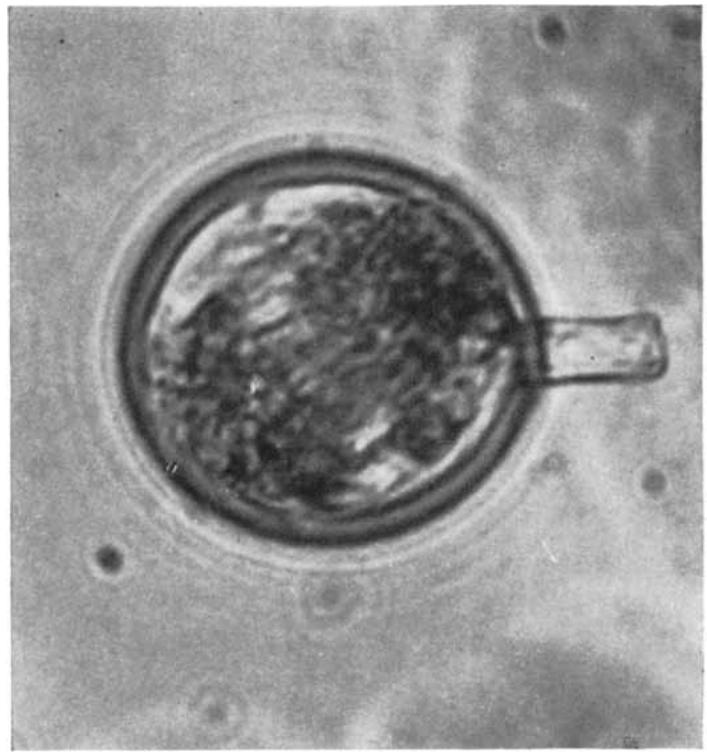
Just what mechanism everts the tube from the capsule remains unknown. It may be that a transient change in permeability of the capsular wall permits the nematocyst to absorb water until internal pressure forces the coiled tube to spring outward. The capsules discharge most readily upon contact with natural prey substances; contact with a glass rod is less effective and, according to some reports, the external surface of fish skin is more effective than the internal surface of the same skin. Nematocysts are also set off by changes in acidity and osmotic pressure and by increase in hydrostatic pressure such as may be produced when the cells are spun in a centrifuge.

For all their reactivity and apparent sensitivity in the living animal, isolated nematocysts are remarkably stable. They may be forced through graded sieves, washed in many changes of sea water, concentrated into a putty-like paste and frozen, and most of them will remain undischarged. These preparative manipulations do not diminish their ability to discharge in response to an adequate stimulus. Nematocysts may even be air-dried and still retain their ability to sting on contact with human skin. We learned this lesson rather painfully in the Marine Laboratory of the University of Miami. In connection with our study of the venom contained in the capsule we undertook to prepare a large sample of isolated nematocysts, processing many hundreds of living *Physalia*. Consequently surfaces in the laboratory became contaminated with undischarged nematocysts. For weeks thereafter we



PORTION OF A MATURE COLONY shows several types of polyp: fishing tentacles of various sizes (1 *and* 3); gastrozooids (2); male (7) and female (8) reproductive forms. The reproductive organisms are arranged on a branch called the gonadendron (4), which has associated structures (5 *and* 6) of unknown function. The tentacles are long muscular strands bordered with batteries of nematocysts, giving the tentacles a beaded appearance. The gastrozooids have expandable mouths (*all shown closed*) at the ends of their narrow necks. The spots on the gastrozooids are digestive cells visible through the stomach walls.



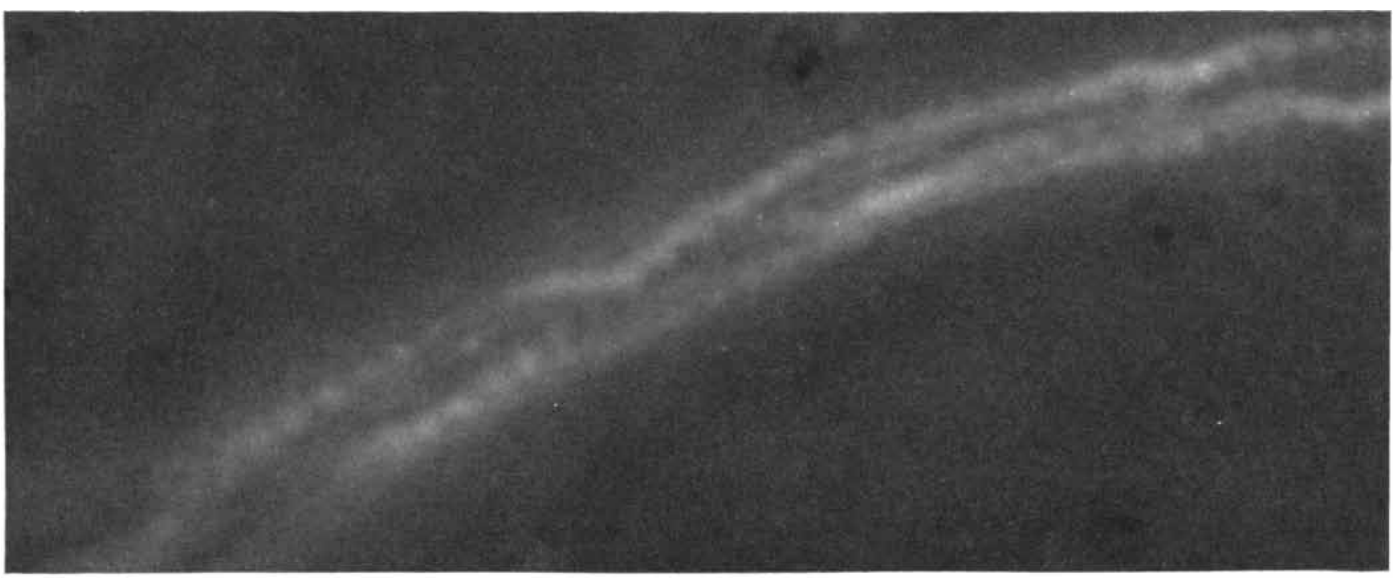


STINGING CELL, or nematocyst, is a hollow sphere with its exterior wall pushed in at one point and stretched into a long tube that is turned outside in and coiled within the sphere. The point of attachment is covered with a hatchlike membrane (*dark*

suffered reminders of our carelessness whenever we touched water faucets, bench surfaces or laboratory aprons.

Earlier investigators had not taken such pains and had simply prepared extracts of the entire tentacle or even the entire organism. As a result their preparations were often grossly contaminated with breakdown products of tentacle tissues other than the nematocysts. Our object was to isolate the toxic fluid itself.

To collect the nematocysts we first cool isolated tentacles to 39 degrees Fahrenheit. This temperature permits the tissues surrounding the nematocysts to start to break down. To hasten the breakdown and to separate the freed nematocysts from large tissue-fragments, we pass the material through finer and finer sieves. Then we wash the nematocysts thoroughly, suspending them in sea water, permitting them to settle out and discarding the sea water; we do this again and again until the water is no longer toxic to the fiddler crab, an animal that is spectacularly sensitive to a seawater extract of the tentacle. The nematocyst capsule must be nearly impervious to water, because its extremely toxic contents do not diffuse into the water in which it is washed. When the concentrated washed capsules are frozen and kept at minus 10 degrees F., they



NEMATOCYST THREAD, here enlarged 3,800 diameters, is studded with sharp projections arranged in a helix along most of its length. In the undischarged cell the projections are folded away inside the hollow thread; on discharge the hooks, barbs

area at right side of capsule at left). When cell is stimulated, the tube pushes outward by turning itself right side out, starting at its base (*center and right*). These nematocysts, enlarged some 1,800 diameters, had been isolated and kept frozen for three years.

can be stored for 18 months and longer without losing their reactivity.

We isolate the toxin by homogenizing frozen nematocysts with small amounts of distilled water or saline solution and then centrifuging out a water-clear solution of the fluid contents of the capsules. The toxic material in the solution is evidently composed of fairly large molecules: it will not diffuse through a membrane whose pores are traversed by smaller molecules. It loses its toxicity when it is heated to 140 degrees F., subjected to considerable change in acidity or treated with organic solvents such as alcohol. The toxin may be freeze-dried, however, and stored for extended periods without loss of potency. From preliminary analytical results it appears that it is largely protein, consisting of a complex of eight to 10 different amino acids arranged in eight or nine short chains of amino acid units. Glutamic acid is the most abundant of the amino acids present. We are now trying to work out the identity and order of the amino acids in each chain.

In its crude form the toxin is about 75 per cent as poisonous as the venom of the cobra and, like cobra venom, is a neurotoxin for higher animals. When it is injected into fish, it causes rapid

and spikes, now on the surface of the thread, probably keep it attached to the prey while the toxin of the cell is ejected through a hole at the end of the thread. When the thread is fully extended, its length is 100 to 300 times the diameter of the capsule.

His Problem:

To measure minute electrical thermal and magnetic effects in highly pure metals near 1°K.

Name of this scientific American:

Dr. J. E. Kunzler
Bell Telephone Laboratories

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Preliminary work showed that while instrumentation requirements for a given problem were large, they were also similar to the requirements for a great number of other problems. Accordingly, Dr. Kunzler decided to set up a generally useful facility—one which could be adapted readily for each specific study.

Suitably modified potentiometers, amplifiers, recorders and related components were integrated into a system. Over a period of several years, Dr. Kunzler's continuing refinements of both equipment and techniques led to detection of voltages as small as 10^{-9} volt, resistances in the order of 10^{-10} ohm, and thermal effects as minute as 10^{-3} erg. Direct current was kept constant to within a few parts in a million—often for weeks at a time. One phase of the program, carried on in collaboration with Dr. T. H. Geballe of Bell Laboratories, resulted in the development of a germanium resistance thermometer of high sensitivity and greatly improved stability at low temperatures.

One of the earliest uses of these facilities was for purity evaluations at low temperatures which aided in the preparation of single crystals of metals with much higher purity than were previously available. Many interesting and informative proper-

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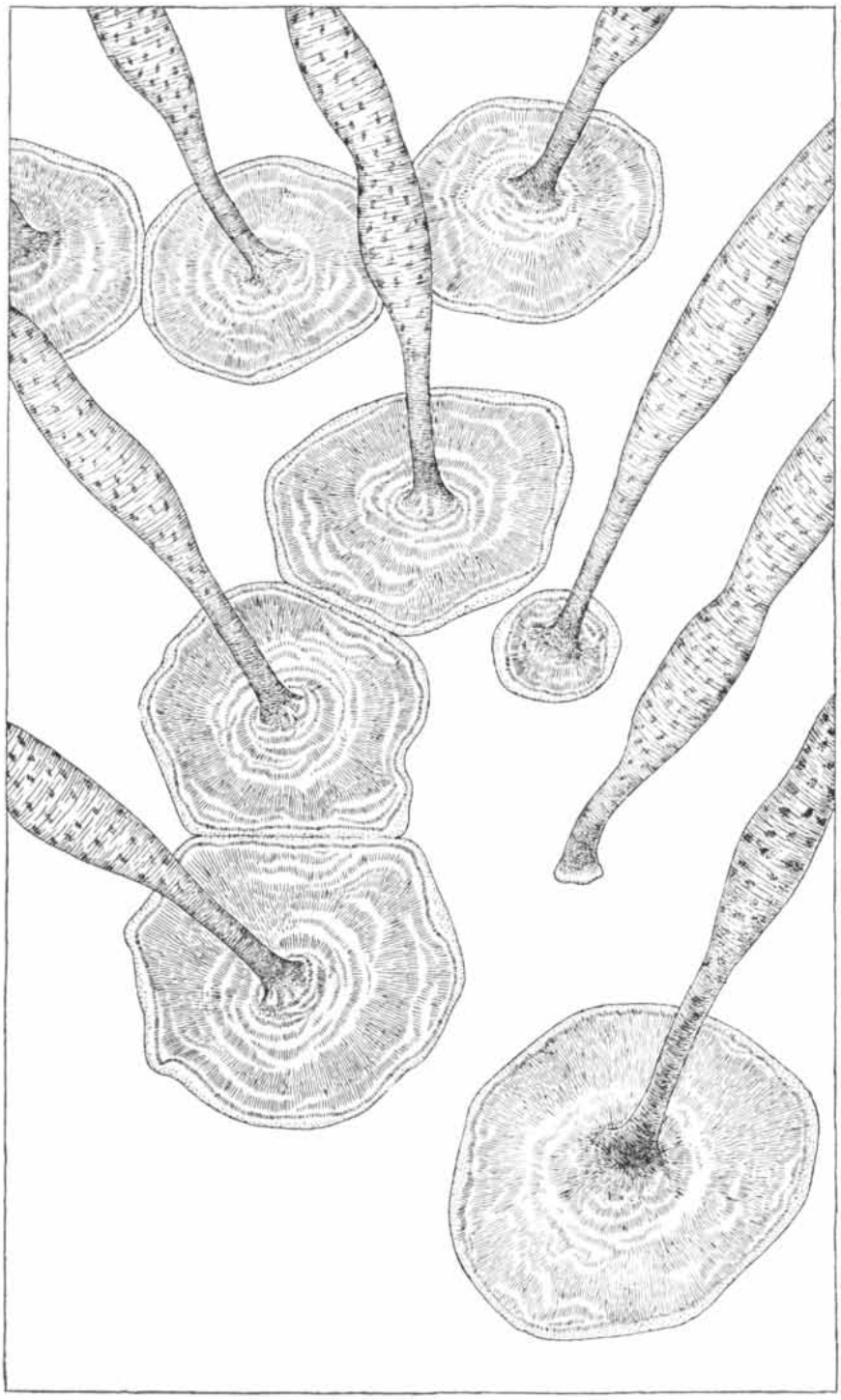
breathing, disorientation and changes in the distribution and activity of the pigment cells in the skin; paralysis and death follow within one to four hours, depending on the strength of the solution. The toxin paralyzes the fiddler crab almost instantaneously, and the animal dies within minutes of an injection. Mice also succumb to intravenous injection, suffering first motor paralysis and then respiratory failure and convulsions. Indeed, the toxin has proved lethal, in large enough doses, to every animal tested.

At least two animals, however, endure the sting of the man-of-war without apparent inconvenience. Fishermen occasionally observe the loggerhead turtle seek out and devour a patch of these jellyfish that has been gathered by the

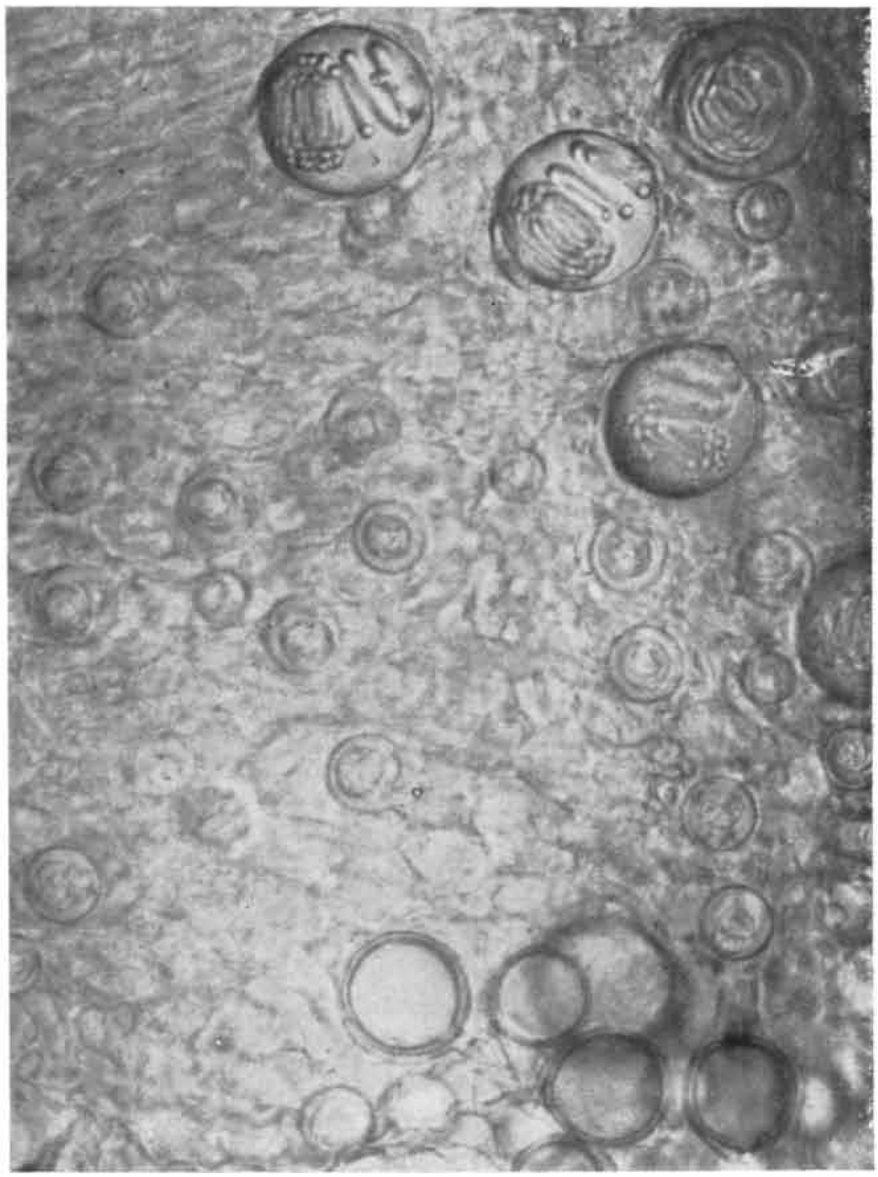


GASTROZOOIDS, cut away from the parent colony and stimulated by a glutathione solution, open their mouths widely and spread them over a glass surface. Small batteries of nematocysts edge the lips of the gastrozooids. This drawing is based on a photomicrograph.

wind; swimming at the surface, with its eyes often swollen nearly shut from the stings it has received, the turtle methodically munches its way through the patch. The turtle must receive massive doses of toxin during such a feast, but it is undaunted by, or insensitive to, its discomfort.

The small, gaily colored fish *Nomeus gronovii* is similarly unaffected. It lives in jackal-like association with the man-of-war, darting about among the tentacles and nibbling captured prey from them. We have found closely packed discharged nematocysts together with small crustaceans in the stomachs of these fish. If a *Nomeus* is forced into contact with the tentacles, as happens when the fish and a man-of-war are both caught in the same net or bucket, the fish is obviously stung. It swims erratically for a while but recovers in a comparatively short time. In the laboratory *Nomeus* shows considerable resistance to injections of the toxin. It can survive doses as much as 10 times that which would kill other fishes of the same general size and type. Whether its resistance depends upon the development of antibodies to the toxin or upon some innate neutralizing mechanism remains to be determined.

Human reactions to the man-of-war sting vary from individual to individual. Most people feel an intense burning pain, as if the skin had been seared with a hot iron. The affected skin may redden and swell with fluid to form a large wheal. This usually disappears in



BIT OF TENTACLE is greatly enlarged to show the formidable array of nematocysts of various sizes. A few of them (*bottom*) have been discharged, but most are intact. Douglas P. Wilson of the Marine Biological Laboratory in Plymouth, England, made this photograph.

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INDIUM		1*				1		1*	1					
LEAD	1*	1*	1*				1*							
SELENIUM		1*		1*						1			1*	
SILVER		1*	1*			1*					1			
SULFUR												1	1	
TELLURIUM		1*	1*											
THALLIUM	1	3	1			1			1			2	1*	
ZINC		1*	1*			1*								1*

about a week but may also ulcerate and leave an open sore that takes longer to heal. Allergically sensitive individuals run the risk of a more generalized reaction, with fever, difficulty in breathing and the other manifestations of anaphylactic shock. Application of alcohol to the skin immediately after a sting has some palliative effect, since organic solvents reduce the effectiveness of the toxin and inactivate any nematocysts that are undischarged. Obviously it is better to avoid contact with the man-of-war, alive or dead.

NOMEUS GRONOVII, a small, gaily colored fish (*bottom*) is found in association with the Portuguese man-of-war. It is apparently immune to the sting of the jellyfish and darts freely among the tentacles. In the stomachs of these fish have been found many nematocysts.

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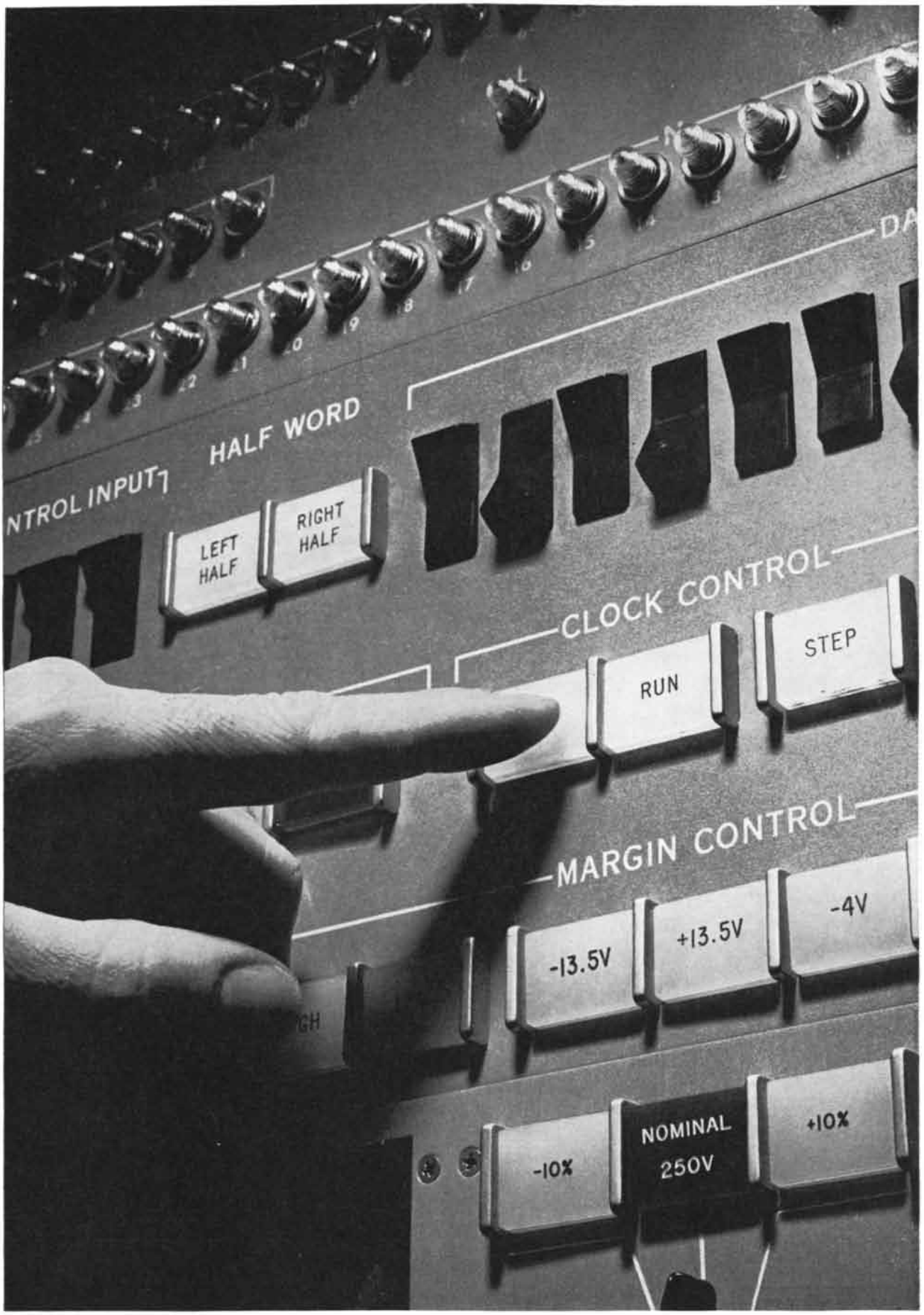

View of the RW-400 polymorphic data processing system, developed in The Intellectronics Laboratories of TRW. Close-up of operating panel is shown at left. (Photos by Don Mannix.)

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MATHEMATICAL GAMES

The games and puzzles of Lewis Carroll, and the answers to February's problems

by Martin Gardner

The Reverend Charles L. Dodgson, who wrote immortal fantasy under the pseudonym of Lewis Carroll, was an undistinguished mathematician who delivered dull lectures at Oxford and penned equally dull treatises on such topics as geometry and algebraic determinants. Only when he approached mathematics in a less serious mood did his subject and his way of writing about it take on lasting interest. Bertrand Russell has said that Carroll's only significant discoveries were two logical paradoxes that were published as jokes in the journal *Mind*. Carroll also wrote two books on logic for teenagers, each dealing with what are now old-fashioned topics, but containing exercise problems so quaint and absurd that both books, recently combined into one paperback, are now winning new readers. His serious textbooks have long been out of print, but his two volumes of original puzzles, *A Tangled Tale* and *Pillow Problems*, are also available today in a single inexpensive edition. Without touching on any topics in these four books, or overlapping any recreational material in Warren Weaver's fine article "Lewis Carroll: Mathematician" [SCIENTIFIC AMERICAN; April, 1956], let us consider some of the Reverend Dodgson's more obscure excursions into the game and puzzle field.

In *Sylvie and Bruno Concluded*, the second part of Carroll's now almost forgotten fantasy *Sylvie and Bruno*, a German professor asks a group of house guests if they are familiar with the curious paper ring that can be formed by giving a strip a half-twist, then joining the ends:

" 'I saw one made, only yesterday,' the Earl replied. 'Muriel, my child, were you not making one, to amuse those children you had to tea?'

" 'Yes, I know that Puzzle,' said Lady Muriel. 'The Ring has only *one* surface, and only *one* edge. It's very mysterious!' "

The professor proceeds to demonstrate the close connection between the Moebius strip and that other remarkable topological monstrosity, the Klein bottle: a one-sided surface with *no* edges. First he asks Lady Muriel for three of her handkerchiefs. Two are placed together and held up by their top corners. The top edges are sewn together, then one handkerchief is given a half-twist and the bottom edges are similarly joined. The result is of course a Moebius surface with a single edge consisting of four handkerchief edges.

The third handkerchief likewise has four edges that also form a closed loop. If these four edges are now sewn to the four edges of the Moebius surface, the professor explains, the result will be a closed, edgeless surface that is like that of a sphere except that it will have only one side.

" 'I see!,' Lady Muriel eagerly interrupted. 'Its *outer* surface will be continuous with its *inner* surface! But it will take time. I'll sew it up after tea.' She laid aside the bag, and resumed her cup of tea. 'But why do you call it Fortunatus's Purse, Mein Herr?'

"The dear old man beamed upon her. . . . 'Don't you see, my child. . . . Whatever is *inside* that Purse, is *outside* it; and whatever is *outside* it, is *inside* it. So you have all the wealth of the world in that leetle Purse!' "

It is just as well that Lady Muriel never gets around to sewing on the third handkerchief. It cannot be done without self-intersection of the surface, but the proposed construction does give a valuable insight into the structure of the Klein bottle.

Admirers of Count Alfred Korzybski, who founded general semantics, are fond of saying that "the map is not the thing." Carroll's German professor explains how in his country a map and thing eventually became identical. To increase accuracy, map-makers gradually expanded the scale of their maps, first to six yards to the mile, then 100 yards.

" 'And then came the grandest idea of all! We actually made a map of the country, on the scale of *a mile to the mile*!'

" 'Have you used it much?' I enquired.

" 'It has never been spread out, yet,' said Mein Herr. 'The farmers objected: they said it would cover the whole country, and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well.' "

All this is Carroll's way of poking fun at what he thought was an excessive English respect for German erudition. "Nowadays," he wrote elsewhere, "no man of Science, that setteth any store by his good name, will cough otherwise than thus, Ach! Euch! Auch!"

In *The Diaries of Lewis Carroll*, published by the Oxford University Press in 1954, are many entries that reflect his constant preoccupation with recreational mathematics. On December 19, 1898, he wrote: "Sat up last night till 4 a.m., over a tempting problem, sent me from New York, 'to find three equal [in area] rational-sided right-angled triangles.' I found *two*, whose sides are 20, 21, 29; 12, 35, 37; but could not find three." Perhaps some readers will enjoy seeing if they can succeed where Carroll failed. Actually there is no limit to the number of right triangles that can be found with integral sides and equal areas, but beyond three triangles the areas are never less than six-digit numbers. Carroll came very close to finding three such triangles, as we will explain next month. There is one answer in which the area involved, although greater than the area of each triangle cited by Carroll, is still less than 1,000.

"I have worked out in the last few days," Carroll records on May 27, 1894, "some curious problems on the plan of 'lying' dilemma. E.g., 'A says B lies; B says C lies; C says A and B lie.' " The question is: Who lies and who tells the truth? One must assume that A refers to B's statement, B to C's statement, and C to the combined statements of A and B. Carroll gives the correct answer, but again I shall withhold it until next month.

Of several unusual word games invented by Carroll, the solitaire game of Doublets became the most popular in his day, partly because of prize competitions sponsored by the English magazine *Vanity Fair*. The idea is to take two appropriate words of the same length, then change one to the other by a series of intermediate words, each differing by only one letter from the word preceding. Proper names must not be used for the linking words, and the words should be

Charles L. Dodgson sat for this studio photograph in 1885, when he was 53

common enough to be found in the average abridged dictionary. For example, PIG can be turned into STY as follows:

PIG
WIG
WAG
WAY
SAY
STY

One must strive, of course, to effect the change with the smallest possible number of links. For readers who enjoy word puzzles, here are six doublets from *Vanity Fair's* first contest. Next month I shall give Carroll's answers, and it will be interesting to see if any readers succeed in making the changes with fewer links. The doublets are:

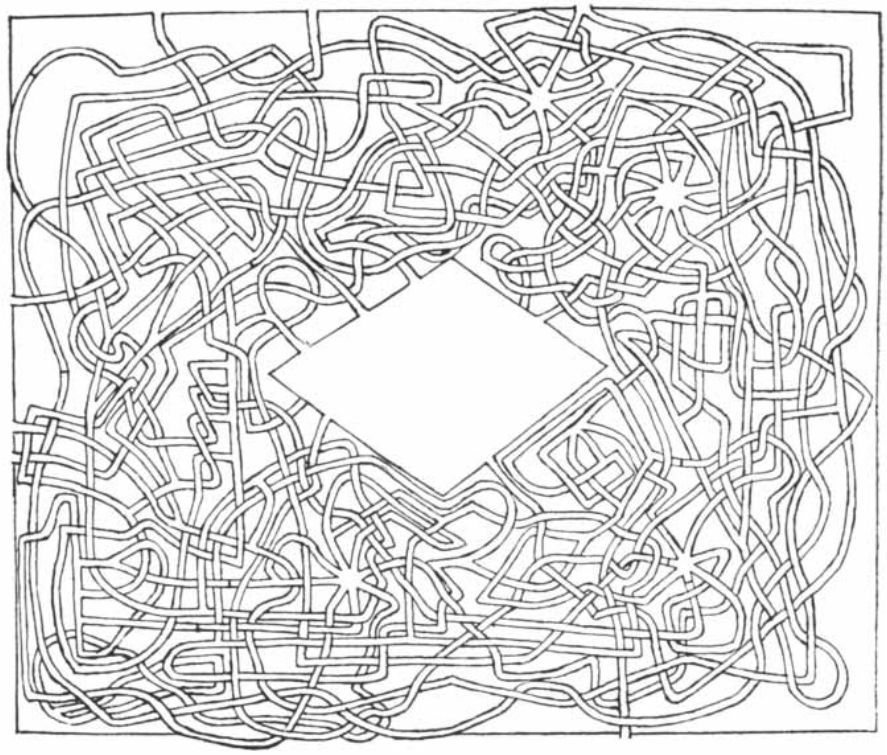
Prove GRASS to be GREEN.
Evolve MAN from APE.
Raise ONE to TWO.
Change BLUE to PINK.
Make WINTER SUMMER.
Put ROUGE on CHEEK.

Like so many mathematicians, Carroll enjoyed all sorts of wordplay: composing anagrams on the names of famous people (one of his best: William Ewart Gladstone—Wild agitator! Means well), writing acrostic verses on the names of little girls, inventing riddles and charades, making puns. His letters to his child friends were filled with this sort of thing. In one letter he mentions his discovery that the letters ABCDEFGI can be rearranged to make a hyphenated word. Can anyone discover it?

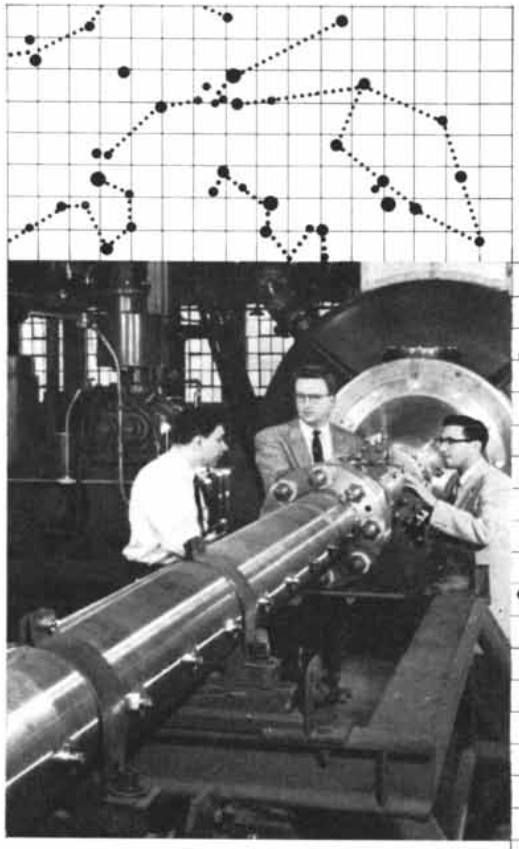
Carroll's writings abound in puns, though they incline to be clever rather than outrageous. He once defined a "sillygism" as the combining of two prim misses to yield a delusion. His virtuosity in mathematical punning reached its highest point in a pamphlet of political satire entitled *Dynamics of a Parti-cle.* It opens with the following definitions:

"Plain Superficiality is the character of a speech, in which any two points being taken, the speaker is found to lie wholly with regard to those two points. Plain Anger is the inclination of two voters to one another, who meet together, but whose views are not in the same direction. When a Proctor, meeting another Proctor, makes the votes on one side equal to those on the other, the feeling entertained by each side is called Right Anger. When two parties, coming together, feel a Right Anger, each is *said* to be Complementary to the other (though, strictly speaking, this is very seldom the case). Obtuse Anger is that which is greater than Right Anger."

Mathematical puns also provide most of the humor for another Carroll pamphlet, *The New Method of Evaluation as Applied to* π. Pi stands for the salary of Benjamin Jowett, professor of Greek and



Dodgson drew this labyrinth for Misch-Masch, *a homemade magazine of his youth*



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translator of Plato, whom many suspected of harboring unorthodox religious views. The tract satirizes the failure of Oxford officials to agree on Professor Jowett's salary. The following passage, in which J stands for Jowett, will convey the pamphlet's flavor:

"It had long been perceived that the chief obstacle to the evaluation of π was the presence of J, and in an earlier age of mathematics J would probably have been referred to rectangular axes, and divided into two unequal parts—a process of arbitrary elimination which is now considered not strictly legitimate."

One can almost hear the Queen of Hearts screaming: "Off with his head!"

Great writers who like to indulge in wordplay are almost always admirers of Carroll. There are many Carrollian references in James Joyce's *Finnegans Wake*, including one slightly blasphemous reference to Carroll himself: "Dodgfather, Dodgson & Coo." It is not surprising to learn that Vladimir Nabokov, whose novel *Lolita* is notable not only for its startling theme but also for its verbal high jinks, translated *Alice's Adventures in Wonderland* into Russian in 1923 (not the first translation, but the best, he has said), and that he owns, like Warren Weaver, a fine collection of Carrolliana. There are other interesting Carroll-Nabokov links. Like Carroll, Nabokov is fond of chess (one of his Russian novels, *The Luzhin Defense*, is about a monomaniacal chess player) and Humbert Humbert, the narrator of *Lolita*, resembles Carroll in his enthusiasm for little girls. One must hasten to add that Carroll would surely have been shocked and repelled by *Lolita*.

The Reverend Dodgson considered himself a happy man, but there is a gentle undertow of sadness that runs beneath much of his nonsense: the loneliness of a shy, inhibited bachelor who lay awake at night battling what he called "unholy thoughts" by inventing complicated "pillow problems" and solving them in his head.

Yet what are all such gaieties to me
Whose thoughts are full of indices and surds?
$x^2 + 7x + 53 = 11/3.$

The answers to last month's problems are as follows:

1.

An obtuse triangle can always be sliced into seven acute triangles in the

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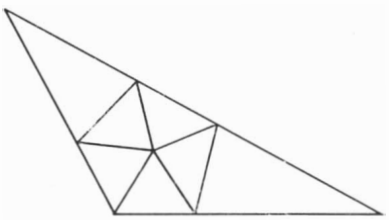
manner shown in the top illustration below. A square can be cut into eight acute triangles as shown in the bottom illustration. Points P and P′ must lie within the shaded area determined by the four semicircles. Stephen Barr of Woodstock, N. Y., was the first to send a detailed proof that eight was indeed the minimum number, but it is not yet known whether the solution shown here is unique.

2.

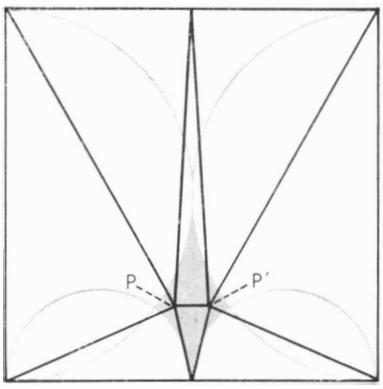
The volume of a sphere is $4\pi/3$ times the cube of the radius. Its surface is 4π times the square of the radius. If we express the moon's radius in "lunars" and assume that its surface in square lunars equals its volume in cubic lunars, we can determine the length of the radius simply by equating the two formulas and solving for the value of the radius. Pi cancels out on both sides, and we find that the radius is three lunars. The moon's radius is 1,080 miles, so a lunar must be 360 miles.

3.

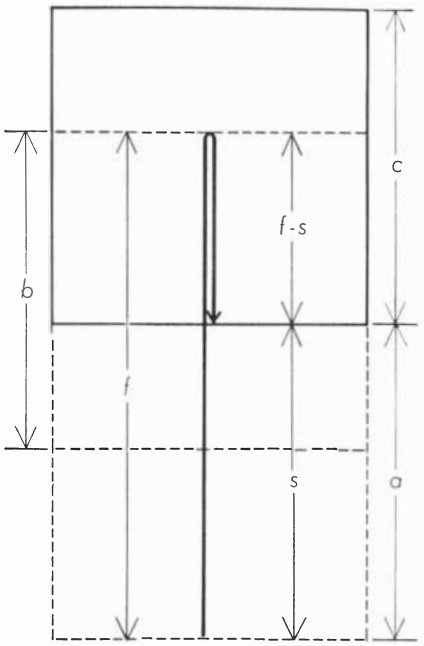
Regardless of the number of slips involved in the game of Googol, the probability of picking the slip with the largest number (assuming that the best strategy is used) never drops below .367879. This is the reciprocal of e, and the limit of the probability of winning as the number of slips approaches infinity.



Obtuse triangle cut into seven acute ones



Square cut into eight acute triangles



The problem of the trotting dog

If there are 10 slips (a convenient number to use in playing the game), the probability of picking the top number is .398. The strategy is to turn three slips, note the largest number among them, then pick the next slip that exceeds this number. In the long run you stand to win about two out of every five games.

What follows is a compressed account of a complete analysis of the game by Leo Moser and J. R. Pounder of the University of Alberta. Let n be the number of slips and p the number rejected before picking a number larger than any on the p slips. Number the slips serially from 1 to n. Let $k + 1$ be the number of the slip bearing the largest number. The top number will not be chosen unless k is greater than p (otherwise the number will be rejected among the first p slips), and then only if the highest number from 1 to k is also the highest number from 1 to p (otherwise *this* number will be chosen before the top number is reached). The probability of finding the top number in case it is on the $k + 1$ slip is p/k, and the probability that the top number actually is on the $k + 1$ slip is $1/n$. Since the largest number can be on only one slip, we can write the following formula for the probability of finding it:

$$\frac{p}{n}\left(\frac{1}{p} + \frac{1}{p+1} + \frac{1}{p+2} \cdots + \frac{1}{n-1}\right)$$

Given a value for n (the number of slips) we can determine p (the number

Mars

Because its reddish glow may have suggested blood and violence to the ancients, Mars was named for the God of War. Of all the planets it is the only one we can readily observe. Mercury is too near the sun and heavy clouds veil the surfaces of the rest.

About once every two years you may see a bright star rising in the heavens as the sun sets. The ancients named Mars for the God of War, perhaps because to them its ruddy color suggested blood.

Of all the planets, we know Mars best. We see it most clearly. We study it most closely. Yet, Mars has always been a mystery to man. And so it is today.

Of course, we know something

Changing Concepts of the Cosmos

Reproduction of one of the finest, current drawings of Mars, showing the visible markings of the planet, and a yellow dust storm sweeping across its surface. The original is by Dr. de Vaucouleurs of Harvard College Observatory.

about Mars. It rotates on its axis with a day of 24 hours, 37 minutes. It has changing seasons, and a diameter about half that of the earth.

Through a large telescope Mars looks reddish-yellow with patches of grey or grey-green. What are these patches? Oceans, said early astronomers. Vegetation, we believe today.

We can see the polar caps of Mars: most likely thin layers of frozen water, for they vanish in summer and return in winter.

On Mars, you would find the atmosphere thin and probably composed of carbon dioxide and water vapor. There would be very little water. The Martian sky would be nearly black, and dotted with high-floating blue or violet clouds of fine ice powder.

You would face storms at times. And strong winds that sweep up large clouds of yellow dust as they drift across the planet.

Some observers have said they see a complex web of fine lines on Mars. Other, equally reliable observers have seen nothing. Most astronomers now agree that these controversial "canals" may be only an optical illusion. But they are surely not artificial waterways.

Where vegetation exists—and we believe it does on Mars—animal life is possible, too, though it is not likely that human-like life will be found. But here we have no relevant observations. Only exploration of the planet—first by probes and then by manned expeditions—can answer this question in a final way.

Because we believe that cosmography—the geography of the cosmos—will play a vital role in the future, McDonnell Aircraft has instituted important basic research in astronomy, solid-state physics, chemical kinetics and mathematics.

These research programs are oriented toward a fuller understanding of the universe: That men—men of all nations—may cooperate in the exploration of space, the moon, the sun, and the planets. That, through such adventure, men may better understand themselves and one another.

McDONNELL *Aircraft* St. Louis 66, Missouri

WE INVITE INQUIRIES FROM ENGINEERS & SCIENTISTS INTERESTED IN PARTICIPATING IN CURRENT SPACE PROGRAMS AT McDONNELL AIRCRAFT

THE IRISH GEOPHYSICAL YEAR EXPEDITION HONOUR ROLL

[VOL. II Nº XIII]

We [[The Whiskey Distillers of Ireland]] feel it is not too early to commit to Irish Whiskey history the names of the 4,923 noble souls who enrolled in the Irish Geophysical Year Expedition, although we have so far heard from but a handful of those intrepid Expeditionaries who have actually set up bases at McMurdo Sound. Yes, and we suggest you go down the list and toast them one by one to spur them on in their quest after burnished, emphatic truth. And not forgetting you who are supporting the effort at home. And in the saloons and at the whiskey store; and you who demand Old Burnished Emphatic at cocktail parties. Meanwhile, any of you wishing a presentation copy of this scroll should write us at Box 186c, Dublin, Ireland. Hats off!

(We had hoped to be able to run the full Honour Roll itself in these pages but so many volunteers were there that we ran out of space and it became a matter of either abandoning the list at G or asking our friends here to move out some other advertising matter, and this for some reason they are not willing to do. We have here reduced it to illegibility to prove good faith. So what we advise is you let us send you a presentation copy of the Honour Roll. It will be a lovely sight there on the wall. Behind the bar. Flanked by burnished emphatic bottles of Irish Whiskey.)

to reject) by picking a value for p that gives the greatest value to the above expression.

4.

A general formula for this type of problem can be derived as follows. Let s be the length of the formation of cadets, and assume that they march this distance in one unit of time. The dog's trotting speed (in the same distance and time units) is d. Let t be the time it takes the dog to trot from the rear to the front of the moving formation, and f the distance of this forward trot. As the illustration below indicates, the distance of the return trip is $f - s$. This same distance can be expressed in a different way. The dog's entire trip takes one unit of time, so the time it takes the dog to trot back is clearly $1 - t$. Since the dog's speed is d, the distance of the return trip must be $d\ (1 - t)$. We can therefore write the following equation:

$$d\,(1 - t) = f - s$$

Expanding the left side and substituting dt for f on the right gives:

$$d - dt = dt - s$$

By the time the dog reaches the front, the cadets will have gone a distance of st. Therefore the dog's total distance forward must equal s plus the st feet that the cadets have moved by the time the dog reaches the front rank. This enables us to substitute $s + st$ for dt in the last equation. The resulting equation simplifies to:

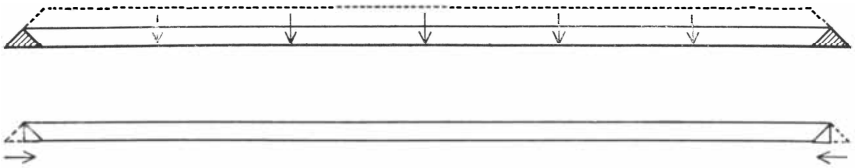
$$d = s + 2st$$

The right side of this equation is now substituted for d in the equation $dt = s + st$ to yield:

$$t(s + 2st) = s + st$$

In solving the above equation the st terms cancel out, and t is found to have a value of $1/\sqrt{2}$. The dog's total distance is now easily shown to be $s + s\sqrt{2}$; that is, the length of the marching formation plus the same length times the square root of two. In this particular case $s = 50$ feet, so the dog travels a little more than 120.7 feet.

The answer to Sam Loyd's version, in which the dog trots *around* the moving square, is 209.07+ feet. There is not sufficient space for explaining this difficult solution, which involves fifth-degree equations, but the problem will be dis-



How Barr folds his belt

cussed again if I hear from any reader who has a simple way of solving it.

5.

The simplest way to fold Barr's belt so that each end is straight across and part of a rectangle of uniform thickness is depicted above. It permits the neatest possible roll and works regardless of the angle at which the ends are cut.

6.

The assumption that the "lady" is Jean Brown, the stenographer, quickly leads to a contradiction. Her opening remark brings forth a reply from the person with black hair, therefore Brown's hair cannot be black. It also cannot be brown, for then it would match her name. Therefore it must be white. This leaves brown for the color of Professor Black's hair and black for Professor White. But a statement by the person with black hair prompts an exclamation from White, so they cannot be the same person.

It is necessary, therefore, to assume that Jean Brown is a man and that either Merle White or Leslie Black is the lady. (All three given names are used for both sexes.) Either assumption leads to the conclusion that Black's hair is white, White's hair is brown and Brown's hair is black. The lady's hair is thus either white or brown. If it isn't brown, the problem asks, what color is it? Answer: Professor Black is a platinum blonde.

7.

For exactly half of the circular path the wind boosts the airplane's ground speed and for the other half of the path the wind retards it. There is a temptation to suppose that these forces balance each other, with the result that the airplane's time for the entire circle is the same as if there were no wind. This is not the case, because the time during which the plane's speed is boosted is obviously shorter than the time during which it is retarded, with the result that the total time in the wind is greater than if there were no wind. (For a rigorous proof by way of calculus, see *The American Mathematical Monthly*, December, 1945; page 584.)

8.

Let x be the number of hamsters originally purchased and also the number of parakeets. Let y be the number of hamsters among the seven unsold pets. The number of parakeets among the seven will then be $7 - y$. The number of hamsters sold (at a price of \$2.20 each, which is a markup of 10 per cent over cost) will be $x - y$, and the number of parakeets sold (at \$1.10 each) will be $x - 7 + y$.

The cost of the pets is therefore $2x$ dollars for the hamsters and x dollars for the parakeets—a total of $3x$ dollars. The hamsters that were sold brought 2.2 $(x - y)$ dollars and the parakeets sold brought 1.1 $(x - 7 + y)$ dollars—a total of $3.3x - 1.1y - 7.7$ dollars.

We are told that these two totals are equal, so we equate them and simplify to obtain the following Diophantine equation with two integral unknowns:

$$3x = 11y + 77$$

Since x and y are positive integers and y is not more than 7, it is a simple matter to try each of the eight possible values (including zero) for y to determine which of them makes x also integral. There are only two such values: 5 and 2. Each would lead to a solution of the problem were it not for the fact that the parakeets were bought in pairs. This eliminates 2 as a value for y because it would give x (the number of parakeets purchased) the odd value of 33. We conclude therefore that y is 5.

A complete picture can now be drawn. The shop owner bought 44 hamsters and 22 pairs of parakeets, paying altogether \$132 for them. He sold 39 hamsters and 21 pairs of parakeets for a total of \$132. There remained five hamsters worth \$11 retail and two parakeets worth \$2.20 retail—a combined value of \$13.20, which is the answer to the problem.

ONE STATION TWO TALENTS

1. Stations with the *dual* capability of tracking earth satellites *and* deep space probes are being engineered and constructed by Alpha Corporation as part of Alpha ground-based surveillance systems for space research. A station tells the user the location of the vehicle . . . collects and processes telemetered data . . . transmits command communications. Alpha integrated communications systems link each tracking station to a computing facility, providing a complete surveillance complex for all locative and communications functions.

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Thermal Protection Systems: No single material possesses the range of complex properties necessary to withstand the high temperatures of missile and space requirements. To solve this problem, composite materials and structures that combine the desirable characteristics of several materials, are being developed. Some of these approaches include insulating layers and heat sinks; transpiration, film or liquid-metal cooling; ablation and sublimation coatings. Shown is an artist's rendering of an insulating, composite material made up of extremely thin layers of metal and ceramics which promises to be very efficient in protecting against high-heat environments. Development of such systems is considered at Lockheed to be an integrated relation of materials, environment and design.

METALLURGY

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Metallurgy is typical of Lockheed Missiles and Space Division's broad diversification. The Division possesses complete capability in more than 40 areas of science and technology—from concept to operation. Its programs provide a fascinating challenge to creative engineers and scientists. They include: celestial mechanics; computer research and development; electromagnetic wave propagation and radiation; electronics; the flight sciences; human engineering; magnetohydrodynamics; man in space; materials and processes; applied mathematics; oceanography; operations research and analysis; ionic, nuclear and plasma propulsion and exotic fuels; sonics; space communications; space medicine; space navigation; and space physics.

Engineers and Scientists—Such programs reach far into the future and deal with unknown and stimulating environments. It is a rewarding future with a company that has an outstanding record of progress and achievement. If you are experienced in any of the above areas, or in related work, we invite your inquiry. Please write: Research and Development Staff, Dept. C-36, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense clearance required.

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MISSILES AND SPACE DIVISION

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THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

A GOOD OLD-FASHIONED GUARANTEE AGAINST DRAINLINE CORROSION

It's the sort of thing that drives stolid corporation lawyers to scribing frantic memos, *but* we are offering a hard-rock guarantee against corrosion and leakage with our PYREX® lifetime drainline.

We use "guarantee" in the old, unweaselworded sense of the term: we replace any piping material damaged due to corrosion and/or leakage *during the life of the building*.

We insert just one escape clause: we cannot tolerate, nor can the drainline, *massive* volumes of hydrofluoric acid, *hot* alkalies or *hot* phosphoric acid. Even here, check with us just to make sure. Anything else goes—acids, alkalies, or whathaveyou.

So throw away those drip buckets, stop giving the "new man" the desk under the leaking joint . . . the next time you install or replace a drainline, make sure it bears the "PYREX" trademark.

Look at the coupon.

Longevity under adverse, even hostile, conditions is a well-known trait of Corning glasses . . . a fact to consider, even ponder, when you run up against materials with but a modicum of stamina.

WHO WANTS TO TRANSMIT 80% to 90% OF INFRARED THROUGH A WINDOW AT 900°C. OR IN THE PRESENCE OF CORROSIVES?

Ours not to reason why. Ours only to inform you that there are two VYCOR® brand glasses that service both conditions admirably.

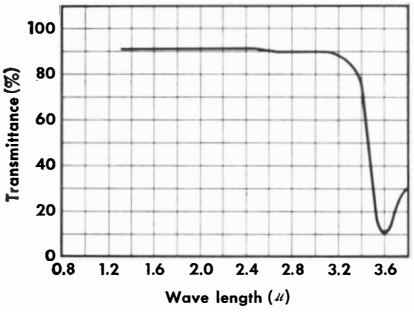
There is VYCOR No. 7905 glass. A sheet of this 2 mm. in thickness will transmit 90% of the wave lengths up to and including 3.0 microns. A 1/8 in. thickness will transmit 80% of a wave 2.75 microns across.

Then there is VYCOR No. 7950 glass. It is stained red. It does like work with infrared, but absorbs most of the visible light waves from a tungsten filament humming away at 2700°K.

Both glasses function continuously in the manners stated at 900°C. even in the presence of corrosives and will take intermittent jaunts into the 1200°C. plus region without damage.

Both will take a sudden thermal shock from these empyreal heights right down to 0°C.

INFRARED TRANSMISSION FOR GLASS NO. 7905
(2 mm. Thickness)

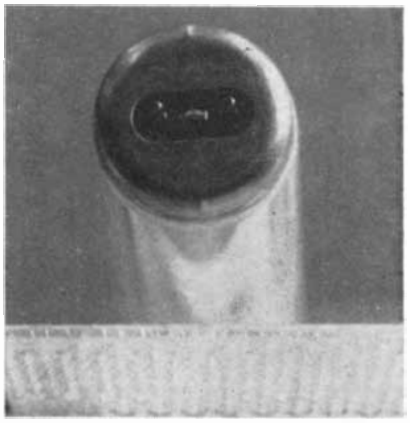


Both actually increase in mechanical strength as the temperature goes up. Odd, what?

There's much more you ought to know about these and the other VYCOR brand glasses, but we'd like to find out just how many and what kind of people are interested in such matters, so we've put the rest of the data away in a bulletin which you may have in exchange for the information asked for in the coupon.

silent light (fluorescent)

Making an electroencephalogram under fluorescent lights can be as nightmarish as listening to Leonard Bernstein conduct



in a subway. The same holds true for any sensitive electronic device that can pick up unwanted noise from a hot tube.

From now on, anyone seeing unworldly blips or blurs on his trace of a monkey's *alpha* waves might find our new PYREX brand E-C No. 70 panel helpful.

E-C No. 70 is a glass panel with an electroconductive coating fused to one side, a coating grounded with a 1/4" strip of silver running around the perimeter of the panel. The coating is "tuned" to pick up and throw to the ground all radiation from 0.018 to 25 mc.

Add a simple line filter and a GBM ballast to your fixture, and all that comes out is clear, clean, quiet light, free from both radiated and conducted radio noise.

E-C No. 70 is optically designed to give low brightness to the light it lets through, this being 70 to 78% of the light emitted by the tubes.

E-C No. 70 is made of borosilicate glass, so it takes a goodly amount of corrosive atmosphere and thermal shock in stride.

E-C No. 70 meets all the many requirements of MIL-I-1690A—ships.

E-C No. 70 may be had in panels up to 28" in width, up to 48" in length.

Still more may be learned about E-C No. 70 by posting the coupon.

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Please send me: ☐ PE-30, PYREX lifetime drainline
☐ B-91, VYCOR Industrial Glassware
☐ A2, PYREX E-C No. 70 Glass Panels.

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THE AMATEUR SCIENTIST

Concerning homemade vacuum pumps and some of the things that can be done with them

Conducted by C. L. Stong

One of the first steps in most experiments is to provide the immediate environment in which the experimental event can take place. When one must do such things as wash and sterilize laboratory glassware, this preparation can be a dull chore. But when the experiment deals with the behavior of molecules, atoms or subatomic particles, the experimental setting becomes interesting in its own right. Such experiments often require an environment of consummate orderliness: a high vacuum.

As an introduction to vacuum technology, consider the air at ordinary atmospheric pressure inside a gallon jug on an average summer day. The jug encloses about a quarter of an ounce of gas, the molecules of which, driven by thermal energy, bounce endlessly off one another and the walls of the container like a load of ping-pong balls in a truck jouncing over a corduroy road. On the average the molecules move at about twice the velocity of a bullet from a high-powered rifle, but travel only a few millionths of an inch before experiencing a collision.

To clear the myriad molecules from a vessel in preparation for an experiment, one has the choice of three basic techniques, which may be used singly or in combination. First, the gas can be displaced by another substance, which is then withdrawn to leave a vacuum. Second, gas can be mechanically pushed out of a space connected to the vessel, so that molecules in the vessel can escape by their own random motion; the gas pressure is steadily lowered as the pushing is continued. Third, a solid material, usually a thin film of metal, that removes the gas by combining with it can be introduced into the vessel.

The first of these techniques was devised by Evangelista Torricelli to demonstrate that there is such a thing as a vacuum. Torricelli's experiment is described in a letter he addressed on June 11, 1644, to Michelangelo Ricci in Rome: "I have made an instrument of glass tubing," he wrote, "sealed at one end and about two cubits [35 inches] long. It was filled with quicksilver, its mouth closed with a finger and then it was inverted in a vessel containing quicksilver. When the finger was removed the tube was seen to empty partly, without anything entering while it emptied. The lower part of the tube remained always full, however, to the height of a cubit, a quarter and a finger extra. To show that the tube was empty above, we then filled the remaining part of the bowl with colored water up to the brim and slowly raised the tube until its mouth was seen to reach the water. The quicksilver suddenly dropped down from the tube and, with a horrible impact, the water shot up to the very top! The result makes it plain that the space above the quicksilver was empty." Torricelli then surmised that air pressing down on the surface of the mercury in the bowl exerted the force that supported the mercury in the tube. In modified form Torricelli's apparatus evacuated the first electric-light bulbs, and it still renders service as the mercury barometer. Incidentally, those who repeat the experiment are cautioned to keep a finger partly over the mouth of the tube as the water displaces the mercury; otherwise the "horrible impact" may shatter the glass. It is also well to keep in mind that mercury evaporates slowly even at room temperature, and that its fumes are toxic.

It is possible to produce useful vacuums by displacing air with mercury. But pumps based on Torricelli's principle are tedious to operate. Most modern experimenters therefore employ various combinations of the second and third basic techniques. Unwanted gas is cleared from the vessel by compressors designed to operate at low pressure. Residual gas is then trapped, if desired, by a "getter" (an evaporated film of a metal such as barium) or the gas can be adsorbed on charcoal.

Compressors take a variety of forms: piston pumps, rotary pumps in which a solid cylinder fitted with sliding vanes rotates inside a sealed hollow cylinder mounted eccentrically with respect to the rotor, high-speed drums or disks that turn inside a close-fitting housing and impart a preferred direction to gas molecules impinging on them from random directions, and jet pumps of various types. In no sense do these pumps "suck" gas from the vessel being evacuated. Pumps merely gather those molecules that chance directs their way and move them to an exhaust port, from which they escape into the atmosphere. No matter how long the compressors operate, the probability is low that all the molecules will escape from the vessel.

Although a perfect vacuum cannot be achieved, one can assemble a vacuum system capable of reducing atmospheric pressure inside a gallon vessel by a factor of 100 million or more at a cost of less than $30. The uses of such a system in the home laboratory are almost endless. A partial vacuum at the end of a pipe, for example, will produce the same flow of liquid as an equivalent pressure at the other end and will greatly reduce the time required for a fluid to pass through a filter. Or, as another example, the experimenter may wish to avoid the grosser physical or chemical effects of air: its movement, heat conduction, radiation absorption or oxidation. Atmospheric pressure influences the temperature at which many chemical reactions occur. The reduction of iron oxide by carbon, for instance, is normally accomplished in a furnace. But under an adequate vacuum the reaction proceeds at low temperature to yield free iron and carbon monoxide. Another area of interest has to do with vapor pressure. The boiling point of substances is directly related to their vapor pressure and thus to the pressure of the surrounding atmosphere. In consequence the amateur equipped with a vacuum system and a few ounces of dry ice can reduce the temperature of a test chamber almost to the boiling point of liquid air. Finally, to the experimenter interested in elec-

tronic and nuclear phenomena the vacuum system is as indispensable as the lathe is to the machinist.

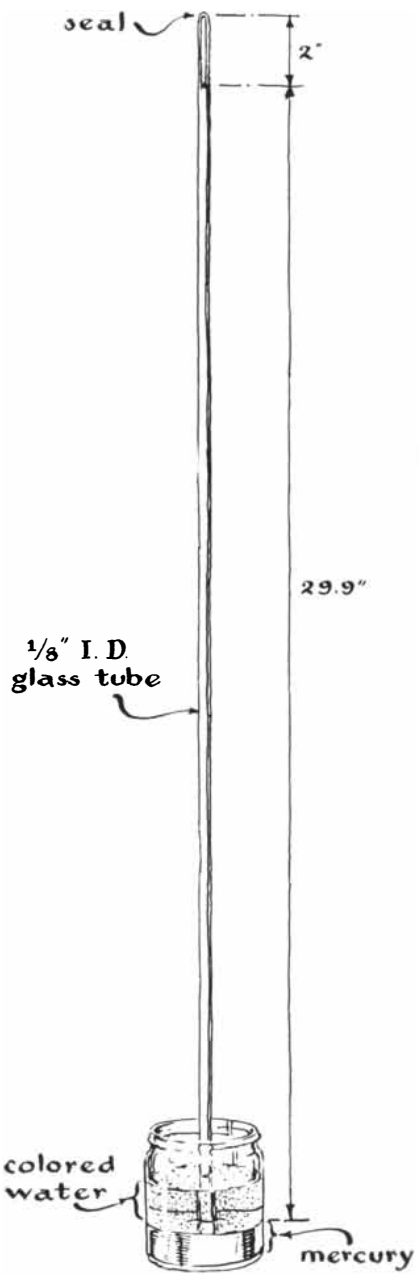
A simple but effective system can be had by modifying the compressor unit from a used refrigerator. In most communities operable units can be purchased from appliance dealers at prices ranging from $5 to $10. F. B. Lee, a member of the faculty at the Erie County Technical Institute in Buffalo, N.Y., has investigated a number of makes and reports that three lend themselves to vacuum work: Frigidaire, Norge and Coldspot.

"Of these," he writes, "the Norge Rollator belt-driven unit rates best for vacuum produced. Frigidaire rates best for availability and second best for two-stage service below .020 millimeter of mercury. (Atmospheric pressure at sea level supports a column of mercury 760 millimeters high in a tube closed at the top.) The Coldspot, though unsuitable for pressures below .5 millimeter, is superior to the Frigidaire as a single unit.

"The modifications are not difficult. Those required to convert the Frigidaire 'Meter-Miser,' the unit that has been standard on this company's domestic refrigerators since 1936, are illustrative. The smaller refrigerators contain split-phase motors rated at less than 1/7 horsepower. The Imperial or Cold Wall series and all refrigerators larger than 13½ cubic feet contain capacitor motors. The purchaser is advised to procure the capacitor as well as the compressor. The motor is not self-starting; it is therefore advisable to procure the starting relay as well. If this is not available, one may improvise a starter from a push-button switch. The motor is started by applying power to terminals 1 and 3 in the accompanying drawing [*page 190*] and short-circuiting terminals 2 and 3 (by means of the relay or push button) for a period of about four seconds.

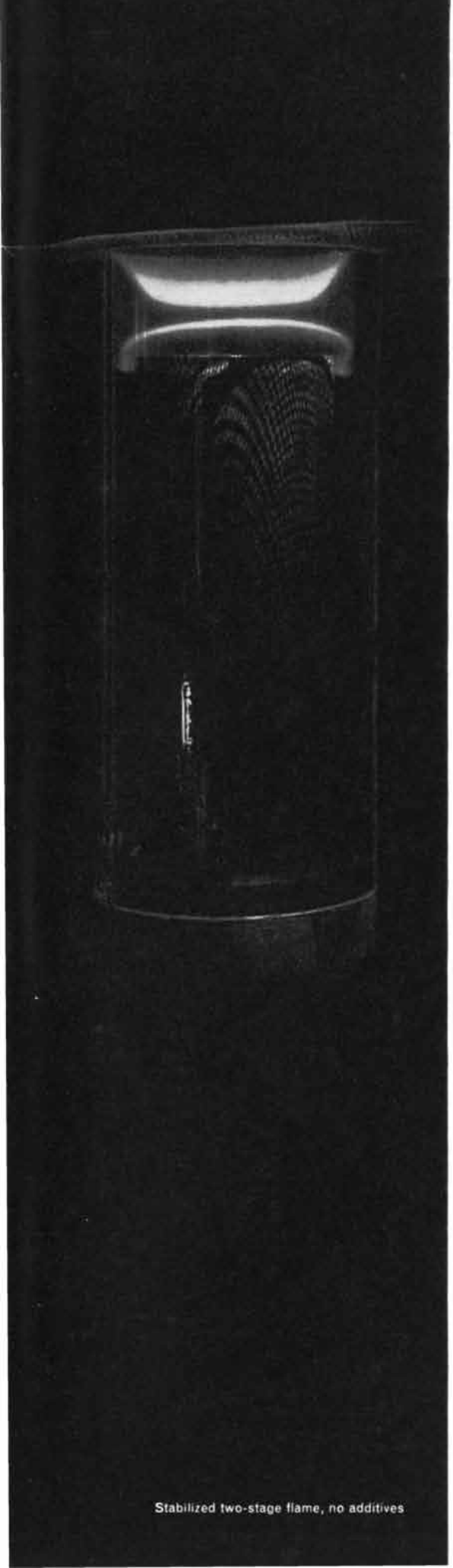
"The pump is modified in three respects. The bypass line which runs between the housing and the check valve must be cut off and the ends sealed. The pump will then produce a vacuum of one millimeter if the check valve is open and the strainer is not wet with oil. The check valve opens automatically when the pressure in the system is above three millimeters. The pressure will not drop below 10 millimeters if the strainer is wet with oil. Oil can be removed from the strainer and the check valve opened by permitting air to flow through the pump for a few minutes prior to connecting the unit to the vacuum system. The screen may be removed, but great care must be exercised thereafter to prevent dirt or foreign material from entering the pump. To make this modification, cut the intake line about an inch away from the housing. Use a tube cutter, not a hacksaw, or particles from the saw will almost certainly find their way into the pump and cause it to stall. Bend the cut tube out of the way, then dig the strainer from the opening by means of a small hook made from a nail or steel wire. Inspect the opening carefully and remove all stray wires of the screen by means of tweezers. Cap the opening with a short length of rubber tubing and close the end with a pinch clamp.

"The pump operates best when tilted at an angle of 10 or 15 degrees, as shown



The Torricelli apparatus

One of a series



Stabilized two-stage flame, no additives

The burning question of cool flames

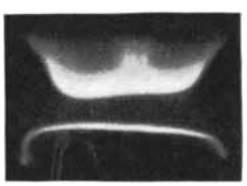
Between the brief stage of not burning and burning, many hydrocarbons react with oxygen at temperatures well below that of normal flame combustion. But the reactions are usually transient and hard to analyze. At the General Motors Research Laboratories, we have been able to investigate the *effect of chemical additives on cool preflames.*

To do this, the almost invisible cool flames are stabilized for hours in a flat-flame burner, permitting careful examination of the retardation or acceleration effects of the additives. From more than twenty additives studied, experimental results indicate that some chemicals affect combustion through the mechanism of preflame reactions. We are now accumulating new information on these additives' mode of operation. For instance: emission spectra support the conclusion that tetraethyl lead reacts with the oxygenated compounds formed in cool flames to yield lead oxide vapor. These findings of when and how lead oxide is formed are important in resolving a current controversy of science — the combustion behavior of tetraethyl lead.

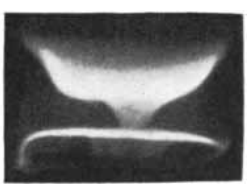
Studies such as this may lead to more economical and effective means of controlling unrestrained combustion — such as "knock" in reciprocating engines. The work is typical of GM Research's effort to provide useful information for a moving America. And in this way continue to keep our promise of "More and better things for more people."

General Motors Research Laboratories

Warren, Michigan



Iron carbonyl, an antiknock



Ethyl nitrate, a proknock

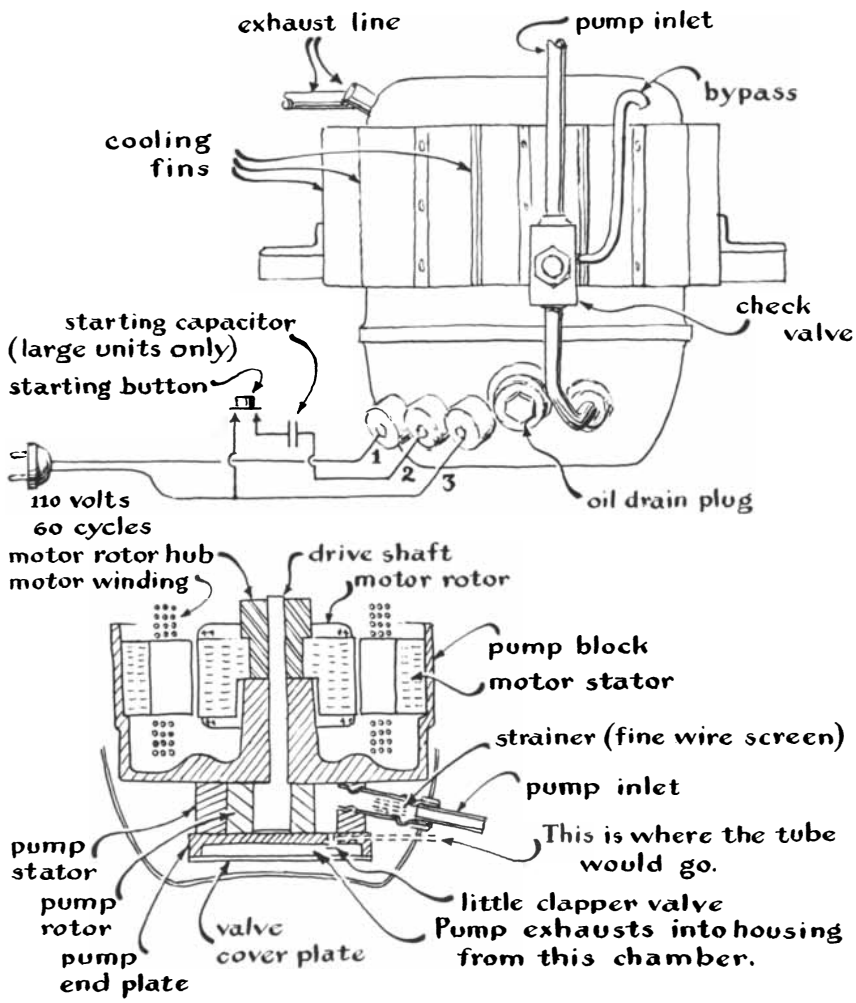
Iron carbonyl retards, ethyl nitrate accelerates central portion of cool flames.

in the drawing of the system [*page 192*]. The line to the oil trap should be pitched upward away from the pump to prevent the formation of oil pockets that would impede the free flow of air. The trap can be made from a quart milk-bottle.

"In addition to the compressor and oil trap, the system includes a dirt trap made from a half-gallon glass jug, and a pair of vacuum reservoirs, each a gallon glass jug. As a safety measure all the jugs are housed in wooden boxes to catch fragments in the event that atmospheric pressure shatters the glass. The various units of the system are interconnected by 3/8-inch copper tubing, perforated rubber stoppers and couplings of rubber hose. Five of the hose couplings are equipped with pinch clamps and act as valves as shown.

"To operate the system, first connect the vessel to be evacuated and close the clamp between the exhaust port [*knife cut in rubber tube in illustration on page 192*] and the rest of the system. Then open all the other clamps, and start the pump. This will reduce the pressure of the entire system, including that in the vacuum reservoirs, to about one millimeter. Now the clamp between the two reservoirs is closed, and operation is continued for about five minutes with the clamp between the pump exhaust and the reservoirs open. This has the effect of connecting the input of a second compressor to the exhaust port of the first, one vacuum reservoir serving as the added compressor. The clamp between this reservoir and the exhaust port of the pump, and the clamp between the reservoirs and the line leading to the oil trap, are now closed. The clamp between the reservoirs and the exhaust port of the pump is opened. This permits the system to exhaust into the second reservoir, now the one of lower pressure. With continued operation the pressure will then fall to the limit of the system's capacity. The compressor can operate for a whole day without increasing the pressure in the reservoir more than one or two millimeters."

As a rough check on the vacuum produced one can set up a glow-discharge



Details of a refrigerator compressor that can be used as a vacuum pump

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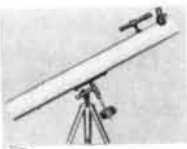

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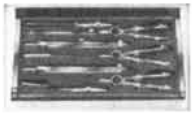

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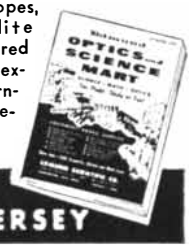

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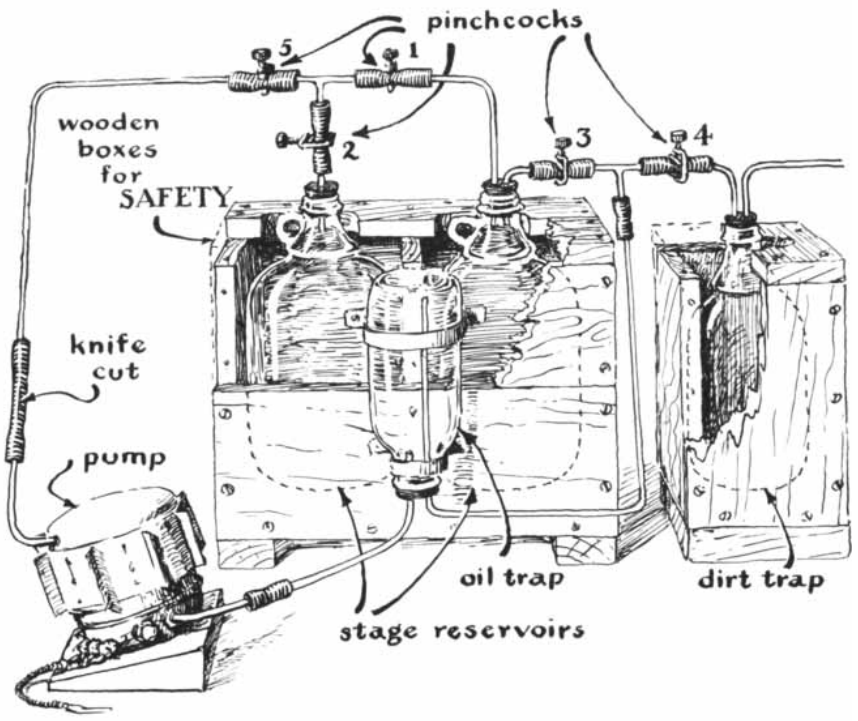


A vacuum system employing a refrigerator compressor

tube like that previously described in this department [see "The Amateur Scientist"; February, 1958]. When excited by an induction coil capable of giving a quarter-inch spark between two needle points in air, a small glow will be observed at a pressure of five centimeters of mercury. At a pressure of 10 millimeters the whole tube will fill with a pink glow, and at about 2.5 millimeters this glow will break into a series of disk-like striations. Finally, at pressures substantially below .01 millimeter, green fluorescence appears on the inner walls of the glass, and below .001 millimeter the tube goes black.

An interesting project requiring a vacuum is the construction of the radiometer depicted on page 194. The bracket for supporting the vane assembly can be made of a short metal strip as shown. The point of the needle must rest either on hard, smooth metal or on glass. It is not difficult to make the entire bracket out of two glass stirring-rods of the kind used for mixing drinks. One rod is heated by a small gas torch successively at two points, until it is soft and bent in the form of a square-cornered "C," the opening of the "C" being made just slightly wider than the length of the sewing needle previously selected to serve as the shaft. Facing indentations are next made just inside the tips of the "C," to serve as pivot bearings. Heat the tips one at a time and press the point of a nail part way into the soft glass so that the impressions face each other. (Support the hot glass on Masonite or a sheet of asbestos.) The second stirring rod is then heated in the middle and bent to a right angle. The angular member is placed on the Masonite, and the "C" is supported vertically inside the apex of the angle so that one arm of the "C" rests on the Masonite and bisects the angle formed by the second rod. Both rods are heated until they become soft and join at the point of contact. The angular member now serves as a base support for the assembly. Next the point of the needle is set in the lower bearing and supported while the upper bend of the "C" is heated until the upper arm closes down over the eye end of the needle. Two flat sheets of aluminum foil, measuring about one by two inches, are centered on and cemented to the needle. When the cement has dried, the sheets are bent to form the four vanes illustrated. One side of each vane (the same side in each case) is now heavily smoked. (A candle produces a rich flow of smoke if a few drops of machine oil are added to the pool of melted wax surrounding the wick.)

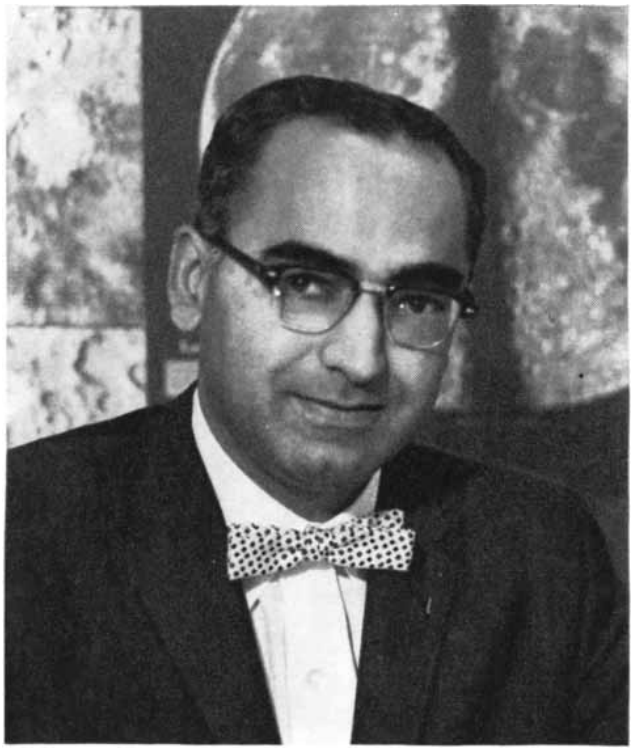
The vane assembly should be reasonably well balanced and turn freely. It is placed in a wide-mouthed jar fitted with a rubber gasket and a screw cap into which a vacuum-tight nipple has been soldered. The radiometer is connected to the vacuum system and evacuated. When exposed to an infrared lamp of

...NEWS IS HAPPENING AT NORTHROP

Solving the Problems of Space Electronics at Nortronics' New Department of Advanced Research

by Dr. K. N. Satyendra

Director of Research, Nortronics Division
Northrop Corporation



To promote the studies and technologies associated with space electronics, Nortronics has established a new Department of Advanced Research. In its work developing new products, the department utilizes scientific skills and ingenuity of the highest order. Carefully planned research — especially geared to the urgent needs of the country in the space electronics race — feature the following programs:

SPACE GUIDANCE RESEARCH includes a comprehensive analytical study of the requirements for midcourse and terminal homing systems for lunar and interplanetary probes. Such studies will also emphasize the progress required in the state of the art in order that suitable equipment can be developed in time to accomplish these missions. Also included in this phase of research are the guidance components required for satisfactory re-entry into the earth's atmosphere or for entry into planetary atmospheres.

SPACE DEFENSE RESEARCH includes hardware-oriented studies fulfilling U.S. military requirements embracing the following areas: Space vehicle detection, identification and tracking, space vehicle intercept or rendezvous, space vehicle inspection, space vehicle attitude stabilization and other classified topics.

APPLIED SCIENCES RESEARCH considers the development of new techniques for the study of various natural phenomena such as radiations in outer space, measurement of surface and environmental properties of lunar and planetary bodies through electronic means.

SPACE ELECTRONICS COMPONENTS RESEARCH activity includes selected development techniques dealing with ultraviolet and infrared sensors, solid state components, Seebeck and Peltier generators and specialized instrumentation.

NORTRONICS already has a record of achievement that includes items like the LINS—Lightweight Inertial Navigation Systems, Astronertial Systems, Hypervelocity sensors, guidance systems for the air-launched ballistic missile, and many vital classified projects now in the formative stage.

Two basic elements — a planned-research program and the top management support that it needs — are attracting new scientists with national recognition and highest qualification to the new Research Department which will be located at the Palos Verdes Research Park. The new facility will offer the scientist and engineer a rewarding opportunity to work in an atmosphere especially created for research in space electronics. The facilities of the entire Northrop Corporation are available to members of the Nortronics Division to execute planned-research activities.

Current papers by Northrop scientists and engineers include:

"Automatic Navigation for Supersonic Transports" by Ross F. Miller. "High-Speed Inertial Platform Stabilization and Control" by Martin Finkel.

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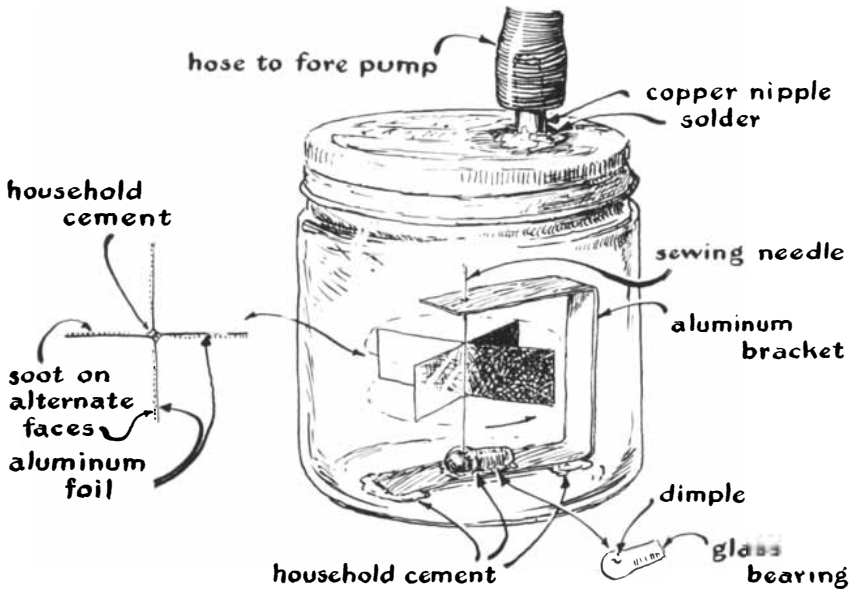

A homemade radiometer

200 watts (or an equivalent source of heat) at a distance of six inches, the vanes will spin vigorously after the pressure has been reduced to .05 millimeter.

An apparatus that opens many experimental opportunities is the dry-ice refrigerator. The ice container is made of a cardboard mailing-tube closed at the bottom by a disk of cardboard and supported on all sides by lightly crushed aluminum foil, as shown on page 196. A glass test-tube supported by a pierced rubber stopper serves as the cold chamber. The lid of the jar is fitted with an exhaust nipple and is pumped through a trap, also made of a wide-mouthed jar, charged with household lye (sodium hydroxide). The carbon dioxide combines chemically with the lye, thus reducing the load on the vacuum system. At a pressure of one atmosphere, dry ice (solid carbon dioxide) sublimes at a temperature of −78 degrees centigrade. At one millimeter the temperature drops to −135 degrees and at .001 millimeter to −166 degrees (−266 degrees Fahrenheit). Liquid oxygen boils at −183 degrees C.

To achieve pressures much below one millimeter within a reasonable interval (less than 30 minutes) one must insert a jet pump between the vessel being evacuated and the mechanical pumping system. A system of this type, constructed by Walter Semerau of Kenmore, N.Y., for evaporating films of reflecting aluminum onto telescope mirrors, is depicted on page 198. The mechanical, or "fore," pump appears at lower left; the jet, or "diffusion," pump, at lower right. The vacuum vessel, consisting of a bell jar and a base-plate assembly, appears at the top together with its accessories.

The diffusion pump consists essentially of a boiler fitted with a jet for discharging vapor (usually of mercury or oil) at high velocity into a tube of larger diameter that is maintained at a slightly lower relative temperature. Molecules of gas from the vessel being exhausted enter the cold tube at a point behind the jet and, by random motion, diffuse into the jet stream. The probability is high that collisions with the molecules in the jet will accelerate them in the direction of the exhaust port, where they will diffuse into the fore pump. The vapor condenses on the cold walls of the pump and is returned by gravity to the boiler for another cycle. Most diffusion pumps do not operate effectively above .1 millimeter, but below this pressure their speed is impressively higher than that of mechanical pumps. The diffusion pump used by Semerau employs two jets in series and pumps at the rate of 50 liters per second; his fore pump is limited to 30 liters per minute—a ratio of 100 to 1 in favor of the diffusion pump.

An aluminum film can be evaporated onto a mirror at a pressure on the order of .001 millimeter, easily attained with a modified refrigerator compressor. But such a mirror is inferior, according to Semerau, to one coated in a vacuum system that includes a diffusion pump.

"The relatively poor quality of these mirrors," he writes, "is explained by at least two causes. First, at pressures above one millimeter, a relatively large amount of gas, including water vapor, is ad-

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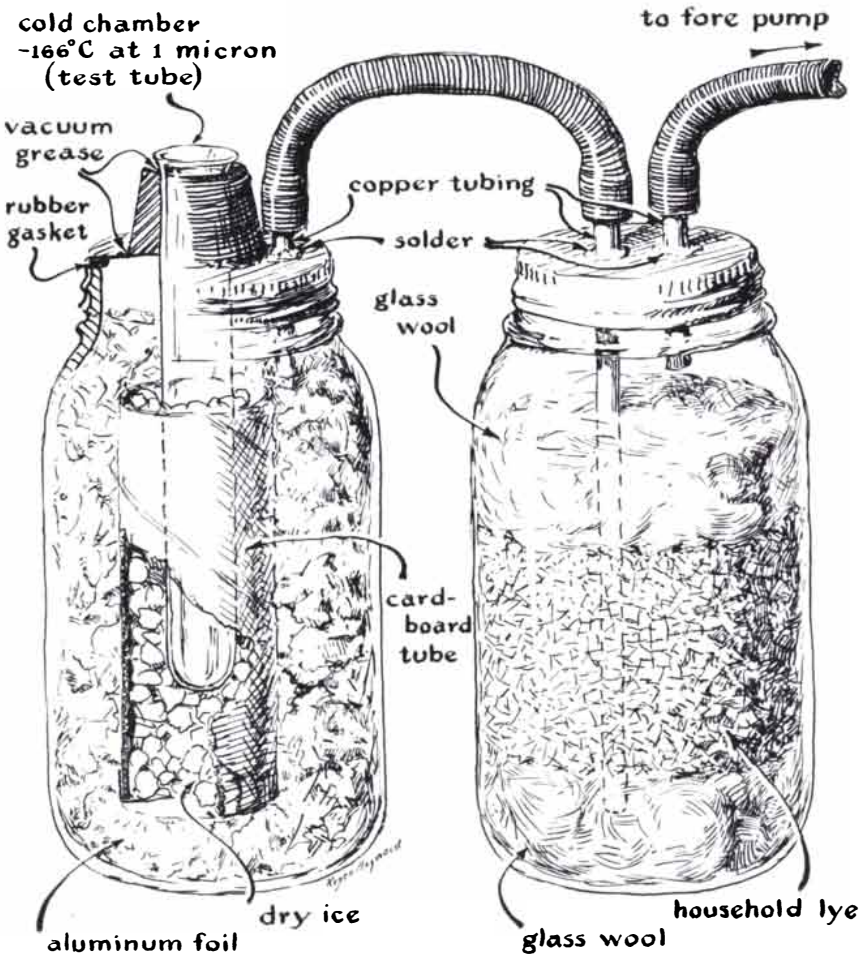
sorbed on the surface of the glass to be coated. Unless much of this is removed during pump-down, the mirror is apt to peel shortly after it is put into use. Second, mechanical pumps are inefficient at low pressures, and in the case of small vacuum-systems a pumping time of several hours would be required to reduce the pressure substantially below one millimeter. During this interval trace amounts of organic material on the glass would oxidize, or undergo other chemical change, and discolor the film. I have never succeeded in eliminating trace contamination no matter how zealously I cleaned the glass.

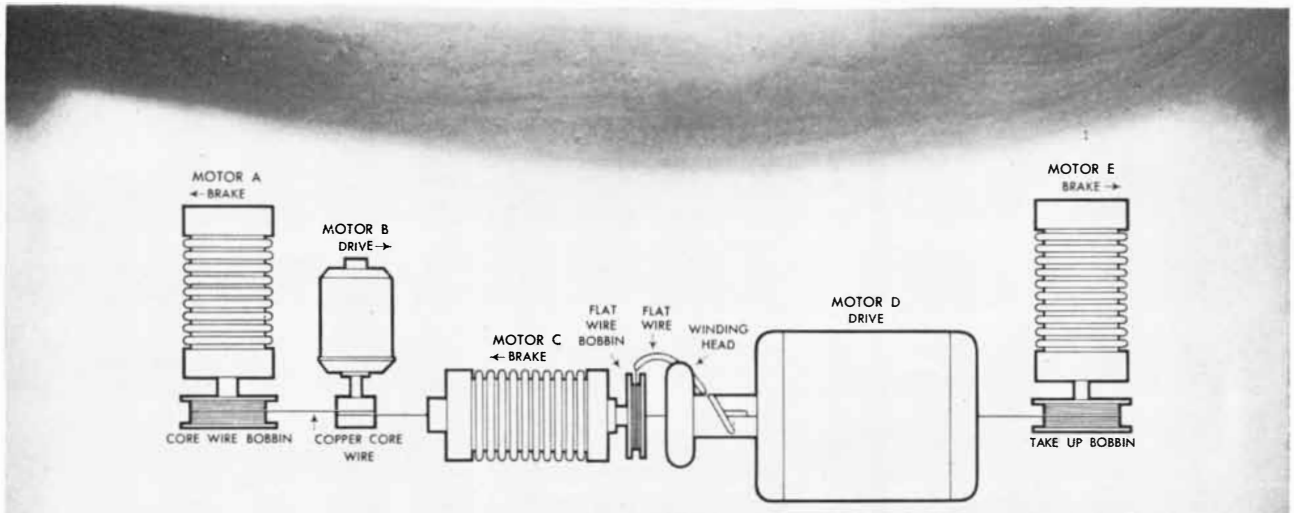
"To deposit thin films, either for mirrors, nonreflecting coatings on lenses, interference filters or for evacuating electronic devices, one requires a vacuum system that includes at the minimum a diffusion pump, a bell jar large enough to accommodate the apparatus, a tungsten heating-element, a source of high-current, low-voltage power to energize the heater, and of course a stock of the material to be evaporated.

"The bell jar may be either of glass or metal. Whatever the material, the walls of the vessel must be capable of withstanding the total pressure exerted by the atmosphere when the system is evacuated or the vessel will implode. If glass is used, the jar must, as a safety measure, be enclosed by a substantial screen. In the case of my bell jar, which has walls 3/8 inch thick and measures 12 inches wide and 18 inches high, atmospheric pressure exerts a force on the glass of some five tons. Jars can be made by cutting the bottom from a glass jug and grinding the cut edges smooth to make a tight fit with the base plate. The opening of the jug is plugged by a rubber stopper. Do not make the bell jar by cutting off the rounded top of the jug; the flat bottom will flex under pressure and shatter the glass.

"The metal base-plate on which the bell jar rests can be made of any scrap material—iron, aluminum or brass—if the upper surface is smooth and the plate is thick enough to withstand atmospheric pressure without flexing perceptibly. My plate is a slab of polished aluminum .75 inch thick. The joint between the bell jar and the base plate may be sealed with vacuum wax (a mixture of beeswax and



A vacuum low-temperature apparatus



Problem: To build a production line that will wrap delicate (breaking strength 3 oz.) "microscopic," computer "Twistor Wire"—gently, accurately, speedily.

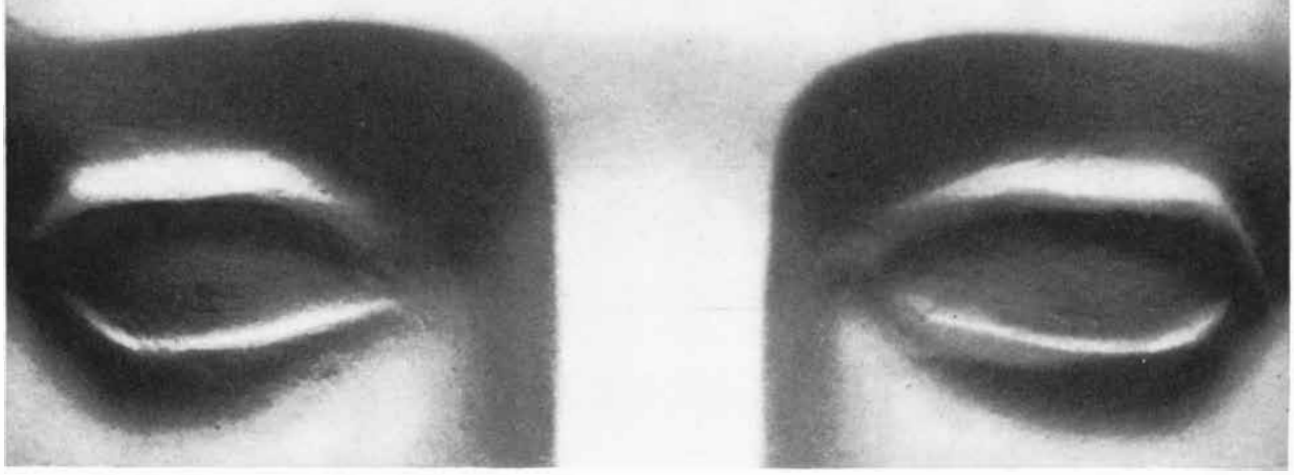
Solution: The line diagramed above. Here's how it works:

1. To start line, Brake Motors A and E pull the copper core wire taut. The flat magnetic wire is already wrapped a few times around the core wire. Brake Motor C pulls back on the flat wire bobbin holding both wires tense and motionless.

2. Wrapping begins when Drive Motor B starts core wire moving in synchronism with Drive Motor D, which revs up winding head to 6,000 rpm.

3. The Key: Brake Motor C maintains uniform, gentle tension (20 gr. ± 2 gr.) on flat wire because its response is faster than that of the Drive Motors.

Result: A "dynamic tension" production line that gently wraps Twistor Wire at 92.7± 3 turns to the inch—producing some 300 feet of magnetic memory wire per hour with an information capacity of at least 28,800 "bits."



How to build a better memory

Hair-Like Twistor Wire, magnified 33 times, forms heart of new electronic computer memory device.

Western Electric has begun production of a new memory storage unit for complex electronic computers that is less expensive than other memory components now in use. The heart of this memory is the "Twistor Wire" *(left)* which is produced by wrapping a hair-thin (.0035") copper wire with an even thinner (.0003") flat magnetic wire. Scientists at Bell Telephone Laboratories, Western's partner, discovered that separate "bits" of information could be stored as close as every ⅛th of an inch along Twistor Wire — a discovery that will have a significant impact on the entire computer industry.

To be practical Twistor Wire had to be produced in large quantities and at low cost. Working with a model 100 times larger than the finished production model, Western Electric's engineers evolved the solution — a wrapping machine *(above)* so small it can fit on a desk top. Three torque (brake) motors and two synchronous (drive) motors, held in dynamic balance by nothing more than the tiny wires they wrap, turn out the desired product to ultra-precise specifications at the rate of 300 feet per hour.

The successful production-line manufacture of Twistor Wire is one more example of Western Electric's many new developments in design and engineering techniques.

Western Electric

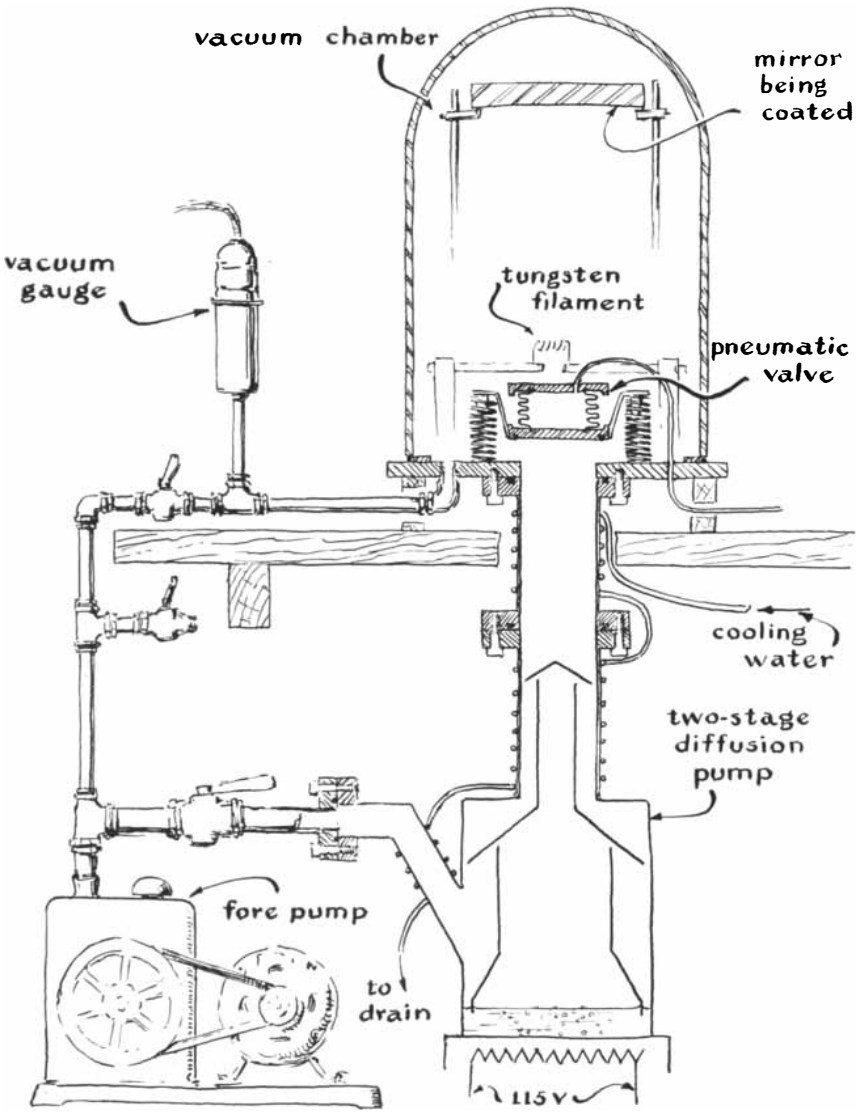
MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

rosin in equal parts by weight applied while hot) or, as a more convenient alternative, with a rubber ring.

"The base plate is drilled in the center with a hole to match the exhaust port of the diffusion pump. The pump should be coupled as closely as possible to the plate by a gastight seal. Incidentally, the speed at which gas flows under low pressure varies directly with the diameter, and inversely with the length, of the conducting channel. Avoid long runs of tubing and bends. A right-angle elbow introduces as much resistance to the flow of gas at low pressure as three feet of straight pipe of matching diameter. The interval required for exhausting the bell jar can be reduced by equipping the base plate with a valve to cut off the diffusion pump. This permits the diffusion pump to be exhausted and placed in operation while the bell jar is being loaded. The valve must of course be designed for remote operation, because it is covered by the bell jar.

"The heating element is made of .03-inch tungsten wire and is formed by winding five turns spaced 1/8 inch apart on a mandrel 1/4 inch in diameter. Because tungsten is relatively brittle at room temperature, the wire is customarily heated to a dull red by means of a torch during the forming operation. (Overheating it is likely to result in sharp bends at which the heater may break during subsequent use.)

"Molecules of metal evaporated in a high vacuum move away from the heating element along radial paths. Hence when a coating is deposited on a relatively flat disk of glass centered above the heating element, the thickness of the metal film increases from the edge to the center of the disk. In an amateur telescope-mirror the effect is not serious if the mirror is spaced at least two diame-



A vacuum apparatus for depositing metal films

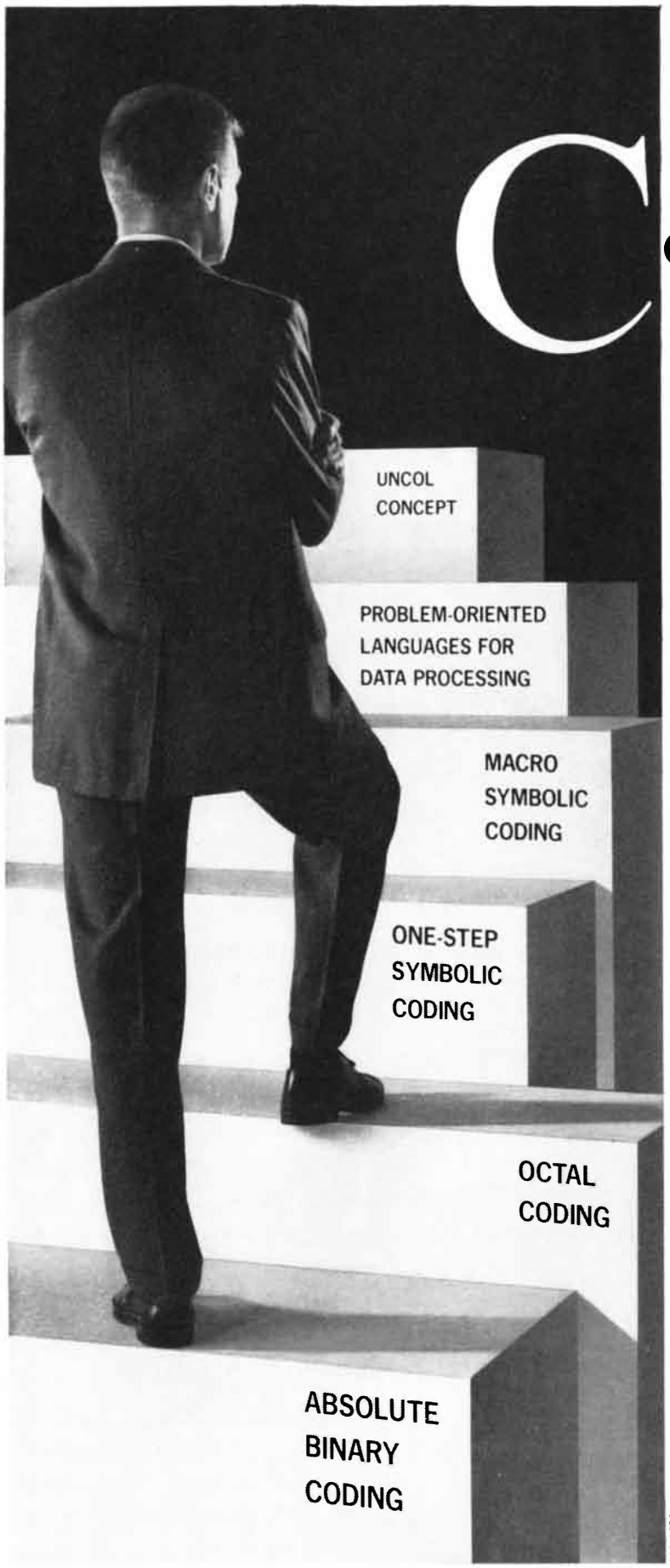
ters above the heating element. Otherwise multiple heaters must be used. The heaters are supported on studs set in gas-tight insulators that extend through the base plate. Power for the heater is taken from a step-down transformer that operates either from a rheostat or a variable transformer to control the output through the range of two to 10 volts at a maximum current of 50 amperes.

"A device for indicating pressure inside the bell jar, such as a glow tube, is useful. Aluminum films may be evaporated successfully when the tube darkens and the glass fluoresces.

"To aluminize a telescope mirror, the assembled apparatus is first pumped down until the glow tube fluoresces. The heater is then brought up to full temperature (10 volts). This reduces the film of oxide on the tungsten. The heater is cooled, air is admitted and the bell jar is removed. A hairpin loop of aluminum wire .03 inch in diameter and 3/4 inch long is suspended from each turn of the heater. Then the system is again pumped down. When the glow tube fluoresces, power is applied to the heater and gradually increased until the aluminum wire just melts and wets the tungsten. The heater is then cooled but left under vacuum.

"The glass to be coated is now thoroughly cleaned. Mere soap and water will not do; the surface must be chemically clean. I use trichloroethylene to dissolve grease, followed by acetone and a final rinse with alcohol. The glass is then dried with a well-washed cotton cloth. Permit nothing else to touch the dried surface or it will almost certainly be smudged. Next the vacuum is broken and the glass is transferred immediately to its supporting fixture. Exhaust the bell jar. When the glow tube indicates minimum pressure, apply full voltage to the heater. The aluminum will be fully vaporized within 45 seconds. Allow the system to cool at least 10 minutes before breaking the vacuum."

Amateurs who set up equipment for evaporating films will find the essential materials and apparatus (with the possible exception of the diffusion pump and tungsten wire) available in most communities. The diffusion pump used by F. B. Lee was made by a local glass-blower at about twice the cost of the used refrigerator unit. Duplicates of this pump may be procured through Lee, who, in the interest of encouraging amateurs to take up high-vacuum experiments as a hobby, has volunteered to assist in procuring tungsten wire and hard-to-get supplies. His address is: F. B. Lee, 230 Hampton Parkway, Buffalo 3, N.Y.



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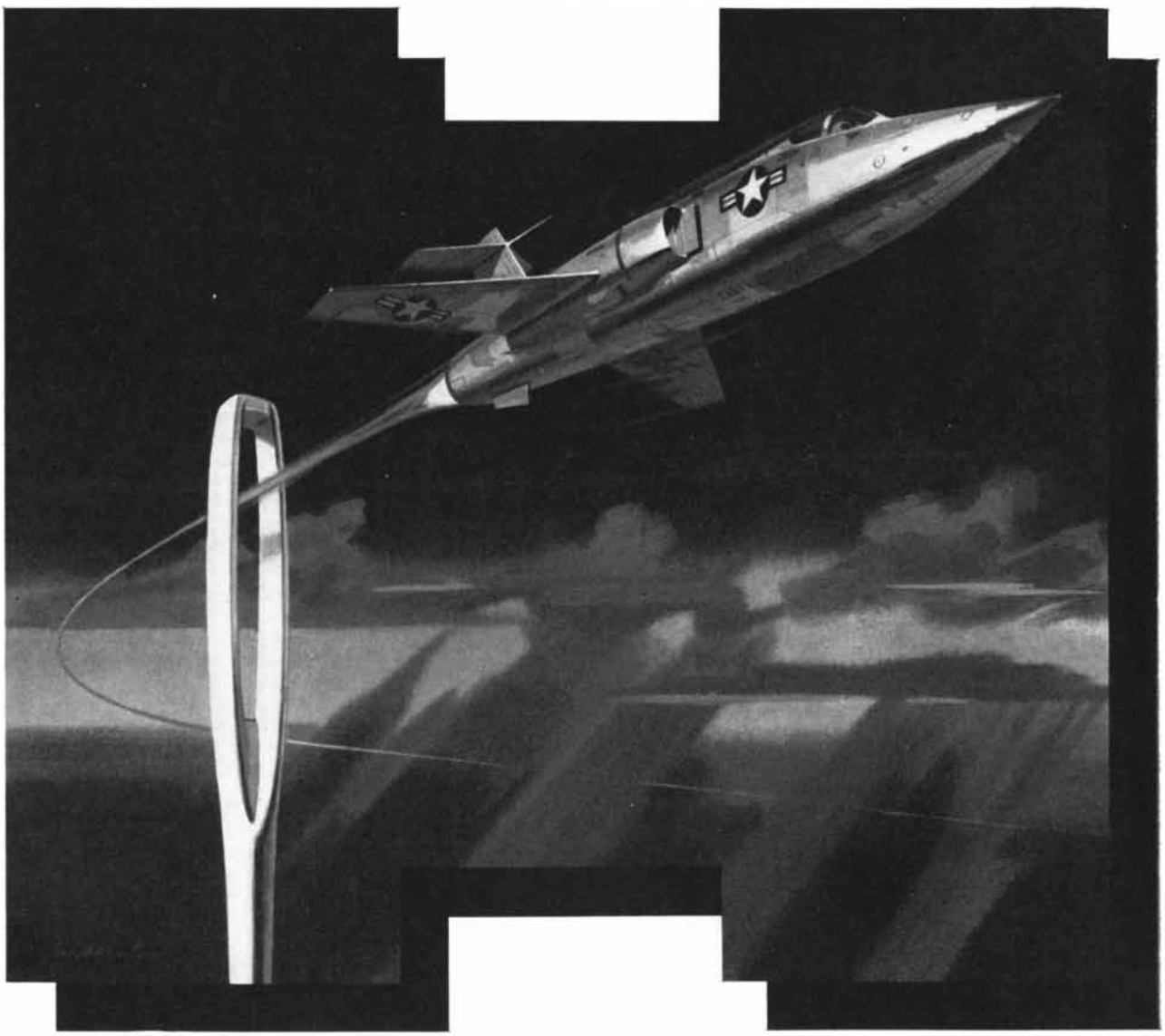

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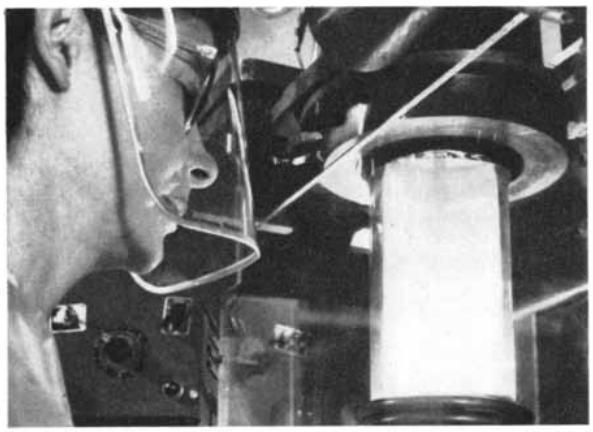

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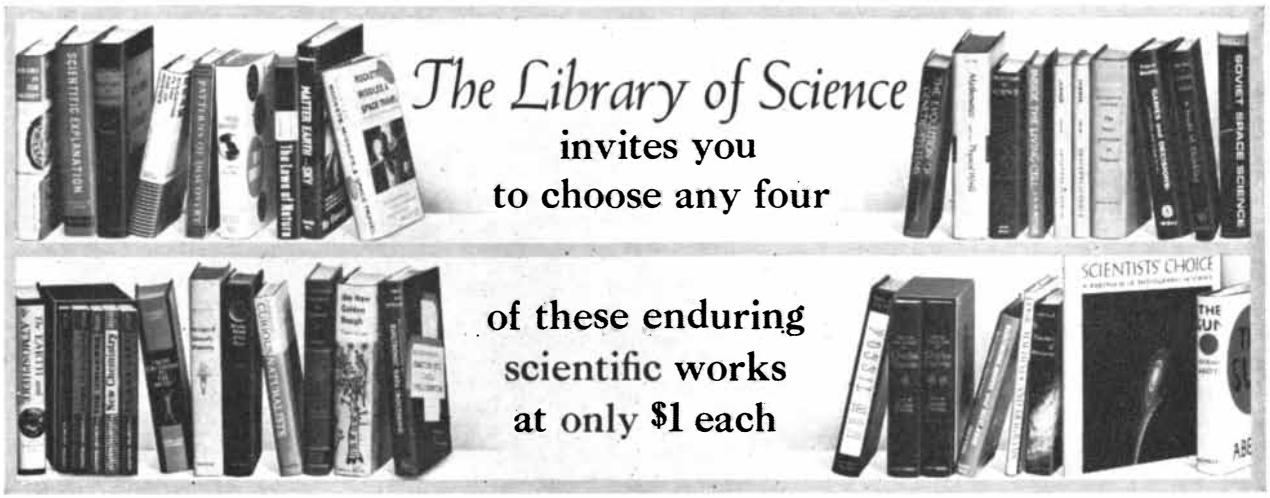

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BOOKS

A logical positivist's case against the school of linguistic philosophy

by Morton White

WORDS AND THINGS: A CRITICAL ACCOUNT OF LINGUISTIC PHILOSOPHY AND A STUDY IN IDEOLOGY, by Ernest Gellner, with an introduction by Bertrand Russell. Victor Gollancz, Ltd. (25 shillings).

One day last November the normally unphilosophical pages of *The Times* of London bore a letter from Bertrand Russell that has helped make this one of the most controversial philosophical books to have appeared recently in the English-speaking world. Its author, an Oxford-trained philosopher now teaching at the London School of Economics, became famous overnight when Russell reported that Britain's leading philosophical journal, *Mind*, had refused to review *Words and Things* on the ground that it was abusive and unfit to be the subject of printed scholarly discussion. Russell suggested that the real reason for *Mind's* action was that the book was critical of the opinions of its editor and of his philosophical friends at Oxford. This, of course, was promptly denied.

Since the end of the war Oxford, that home of lost causes, has become the seat of a triumphant movement, sometimes called linguistic philosophy, of which both Russell and Gellner vehemently disapprove. It is mainly dominated by the ideas of the late Ludwig Wittgenstein, once a pupil of Russell, but in his later years the originator of a powerful way of thinking that challenges much of what Russell stands for in philosophy. Whereas Russell's allies, the logical positivists, thought that philosophy should be exclusively concerned with the logical analysis of science and mathematics, those who have rallied to the banner of Wittgenstein have concerned themselves almost exclusively with the language of ordinary life.

One of the sources of this reaction is the linguistic philosophers' conviction that positivists were excessively restrictive when they said that only statements of mathematics and empirical science were meaningful. By contrast Wittgenstein suggested that philosophers should conceive of themselves as students of the *use* of words. In his view language is a tool that functions in many different ways, only one of which is scientific or mathematical. We can use words for commanding, promising, exhorting, telling stories and in "countless" other ways in ordinary life. Moreover, because Wittgenstein thought that metaphysical puzzlement was caused by a failure to attend to the workings of ordinary language, he believed that a painstaking description of those workings would result in the therapeutic dissolution of metaphysics. He also taught that philosophy is exclusively descriptive, that it cannot change or recommend changes in our ordinary linguistic habits. This is of course antithetical to the idea of some positivists that the task of philosophy is the "rational reconstruction" of knowledge. It also contrasts with Russell's contemptuous dismissal of ordinary language. It is more in line with the views of Russell's Cambridge contemporary G. E. Moore, who persistently asked speculative philosophers to state how their theories were related to beliefs of common sense.

Gellner's book is primarily an attack on what he calls the conceptual conservatism of the linguistic philosophers. He holds that philosophy is not a description of how language operates, but a statement of how it *should* operate. Gellner believes that philosophical indifference to revising our language is an index of social conservatism. In his final chapters he argues that contemporary Oxford philosophy is an ideological instrument of the Establishment. Gellner is fed up with Oxford's filigree work on details of ordinary language, with its ignorance of science, with what Gellner calls its esoteric discussion groups, its complacency and its indifference to the larger issues of social and political life.

Although I can sympathize with some of Gellner's irritation and find his sociological reflections interesting and to a degree plausible, I admire much of the work of several Oxford philosophers. But quite apart from the merits of their philosophy, it is exceedingly unfortunate that Gellner should accuse them of collective "evasiveness," "insinuation," "camouflage" and "dishonesty," a charge which in my opinion is neither successfully substantiated nor really mitigated by his saying that the dishonesty is not "conscious." Whatever merit this book has must be sought in its argument and not in its invective. The argument is conveniently divisible into three main parts: (1) an attempt to portray linguistic philosophy as a movement, (2) a statement of its failings and (3) an indication of the author's positive views. I shall consider them separately because I put different values on these different aspects of the book. Let us consider the first part first.

Every historian of philosophy will acknowledge the difficulty of summing up an entire movement of thought. Only catechized religious philosophies or party philosophies like dialectical materialism draw up tenets to which all adherents must subscribe. Therefore the historian must proceed with utmost care when he wishes to report the doctrines of a group of philosophers who are not formally organized and who think it important not to freeze their philosophy into a set of prescribed propositions. But because Gellner is convinced that the linguistic philosophers constitute a school with tenets that they share but do not acknowledge, he must himself formulate these allegedly unconfessed premises of their thinking. The historian who proceeded carefully in such a matter would try to show us that each and every one of them explicitly or implicitly subscribes to a list of specified doctrines. This Gellner never does. Most often he will cite a particular writer, show that he holds a given doctrine and then conclude that every one of that philosopher's supposed allies also holds the doctrine. It is almost as if Gellner were applying Wittgenstein's own concept of family resemblance to the phrase "linguistic philoso-

pher." Wittgenstein says in another connection that we cannot find one common feature which all games have in common and by virtue of which we call each game a game. Instead we have a crisscrossing of features that unites all games in the way that family resemblance unites all members of a family. Sibling *a* and sibling *b* may have the same color hair, but not sibling *c*. Yet *b* and *c* may have an eye-color not shared by *a*. Wittgenstein's other image for this sort of situation is that of the rope in which no single strand runs the length of the rope. I suggest that sometimes the members of an intellectual movement are related in this familial or ropelike way, and that it is permissible and illuminating to link them together for certain purposes. But the one purpose which is excluded is that of mass refutation. If linguistic philosopher *a* and linguistic philosopher *b* share doctrine *X* which *c* does not hold, and if *b* and *c* share doctrine *Y* which is not accepted by *a*, it is grotesque to attack the whole family of linguistic philosophers for holding, say, *X*. Yet this is very much what Gellner seems to do. Moreover, he seems to say that those who do not explicitly subscribe to *X* or to *Y* are "unconsciously" evasive or dishonest. One can imagine how maddening this must be to those philosophers who are found guilty by association.

Gellner is very much aware of the difficulties inherent in attributing views to people whose writings do not justify such attributions, for very often he will face up to the fact that a given member of "the movement" has even denied one of the doctrines Gellner has attributed to him. In such cases Gellner seems like a disappointed man whose fixed idea has suffered a blow. For example, at one point he says: "A doctrine may formally allow of facts that are adduced against it as would-be objections; and yet informally, in the whole corpus of what it intimates, indicates, in the visions and activities it encourages, the vistas it opens—in all these, it may do its utmost to obscure them. In philosophy, and perhaps in other fields, such informal aspects of a doctrine are often far more important than the formal definition." So the linguistic philosophers are damned if they do and damned if they don't subscribe to the theories ascribed to them by Gellner. I should hate to have Gellner sitting on a jury whose responsibility it was to decide whether I accepted or advocated a certain doctrine.

In the second part of Gellner's argument, even if he does not show that the philosophers he is trying to convict are all alike, he does call attention to four questionable theories or arguments that at least some of them employ. These are the four main "pillars" of linguistic philosophy which Gellner in his Samson-like way wants to send crashing to the ground. One pillar he calls the "Contrast Theory of Meaning." Its proponents say that to be meaningful a term must allow at least for the possibility of something *not* being covered by it. Gellner calls another offending doctrine "polymorphism." It says that since every term is used in a variety of ways, "no general assertion about the use of words is possible." On the whole Gellner's argument against the contrast theory is more persuasive than his discussion of polymorphism. And since I do not think that his attempted destruction of either of these two pillars is so important as his campaign against the remaining two, I shall turn to a more detailed discussion of that campaign.

Gellner is most critical of the pillar called the "Argument from the Paradigm Case," and he has little trouble in showing that, as he formulates it, it is invalid. The argument begins with the contention that the meaning of a term is its use. "We often have occasion to use the word 'table.' It means whatever it is used to refer to, and, as we often do use it, that to which it refers *is* a 'table.' Therefore, tables exist." The argument is also used in more controversial cases with the intention of establishing more serious conclusions, such as the existence of free will. "What do expressions such as 'of one's own free will' mean? Why, let us look at their paradigmatic use. Should we not use it of a smiling bridegroom marrying the girl of his choice? Well then, *that* is the kind of thing the expression means. What else could it mean? Ergo, free will is vindicated."

Gellner rightly points out that this mode of argument in its blunt form is invalid. It fails to distinguish between what are traditionally called "connotation" and "denotation," that is, between the meaning and the reference of a term. For example, the word "miracle" has a use in the sense of a meaning, but that does not guarantee its having a reference. The fact that a given group of persons uses a term with the idea that they are referring to things does not mean that they succeed in referring to things. The word "unicorn" also has a meaning, but no reference.

Having expressed sympathy with Gellner here, I must add that he underestimates the value of the Argument from the Paradigm Case because he formulates its crudest version. Although I

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do not question his accuracy in attributing this version to some linguistic philosophers, many such philosophers would not use it as a "proof" of the freedom of the will. They are more likely to point out that if a metaphysician should say that there is *no* freedom of the will, he can properly be reminded of the fact that we distinguish between grooms who marry brides of their own choice and those who are shotgunned into marriage. Therefore in one ordinary sense of the word "free" some choices are free and others not. The argument's purpose in such a case is cautionary. It forces the metaphysician to distinguish and clarify the sense in which he is denying freedom of the will. This was also the main point of Moore's asking those philosophers who said that time was unreal to tell him whether they meant to deny that he had his breakfast before his lunch. I seriously doubt that Moore ever said or implied, as Gellner says he did, that a contest between a philosophical statement and a statement of common sense must always be decided in favor of the latter. After all, Moore explicitly says that some beliefs that were once commonsensical are not true. Moreover, Gellner cannot consistently attack a philosopher who believes something firmly enough to hold on to it in the face of obscure or ambiguous philosophical theories. Gellner himself says of linguistic philosophy that "its intellectual offensiveness . . . resides in its claim that it denies legitimacy to certain questions, doubts, and a certain kind of ignorance, which in our hearts we know full well to be legitimate: we do not know whether others see the same colors as we do, whether other people have feelings, whether we are free to choose our aims, whether induction is legitimate, whether morality is binding or merely an illusion." In my opinion Moore's conviction that he had had his breakfast before his lunch is more defensible than Gellner's heart-knowledge about what "we" are ignorant of. The situation seems to be this: Some linguistic philosophers, if Gellner is right, always adopt the commonsensical half of a conflict between philosophy and common sense, whereas some of Gellner's words suggest that his own inclinations are just the opposite. In my view both Gellner and his opponents are wrong, because I believe that we must always consider such conflicts individually. To argue otherwise is to imply that one has some kind of criterion that can justify either common sense or philosophy in a wholesale way. This is absurd.

Gellner's most serious objection to the Argument from the Paradigm Case concerns the use of what are sometimes called "category terms," like the phrase "material object," which denote very general classes. Some philosophers have denied or questioned the assertion that material objects exist, and in so doing have attempted to call into question or to recommend the elimination of a whole "species of human discourse." In refuting them Gellner says that it is wrong to appeal to the fact that people *do* use the phrase "material object." I suppose he would say something similar about the attempted refutation of nominalists who, although they acknowledge the fact that people use abstract nouns like "manhood" and "justice" which allegedly refer to universals, nevertheless wish to show that assertion of the existence of universals is both obscure and unnecessary. Gellner points out that it is difficult to distinguish between category terms and those which are not category terms, and that "it is by no means obvious . . . that there is never point in recommending the abolition of a whole category. The use of teleological language has probably diminished, and it is not self-evident that it would be impossible to abolish the use of it altogether. Whether this is a good or a practicable thing or not can in no way be settled by appeal to the fact that we have used that kind of language hitherto. This constitutes some evidence, but is by no means conclusive."

This passage foreshadows Gellner's objection to the fourth type of invalid argument he attributes to linguistic philosophers. This, he says, moves fallaciously from a description of how language is used to a statement of how it should be used. After analyzing the fallacy in what is an exceedingly brief passage, considering the amount of importance he attaches to its commission, Gellner allows himself to make a positive assertion about the nature of philosophy as he conceives it. He says that "virtually [it is not clear what the use of this qualification is intended to except] *all* philosophical problems are . . . problems of value: only philologists are concerned with just how, in fact, a word is used. A question becomes philosophical when it is about the valid use of a term."

Since the matter is of great importance for assessing this book even as a critical contribution to philosophy, I shall ask the reader to recall that in the quotation preceding the last one Gellner tells us that the fact that we *have* used a certain kind of language constitutes relevant evidence when we are debating whether it is a good or practicable thing to abolish the use of it altogether. But who gathers

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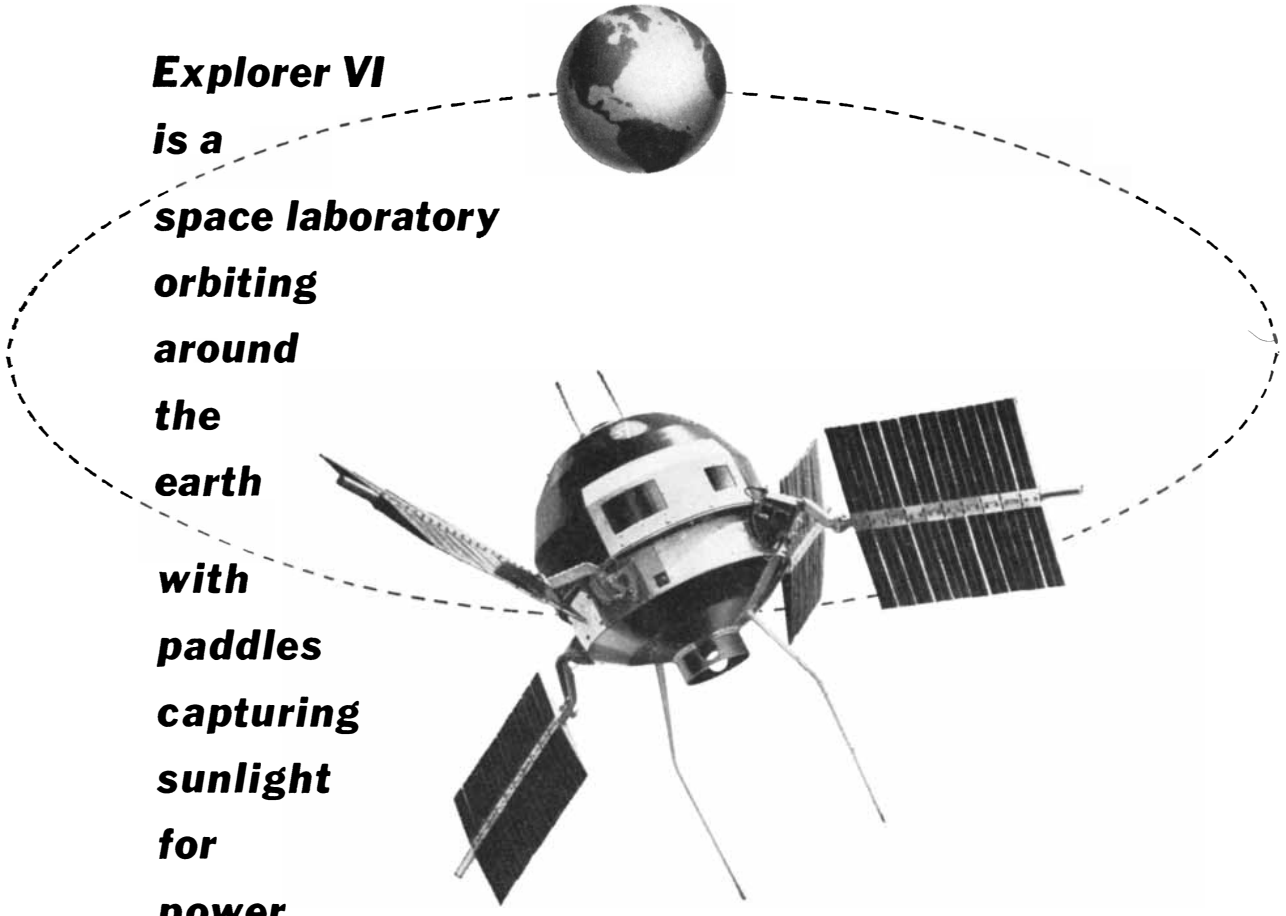

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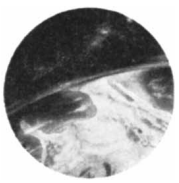

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this factual evidence? Surely not the philologist as he is normally conceived, when the question is whether or not people do use teleological language. Philologists don't discuss such questions. And who besides the philosopher is to tell us whether in ordinary language people speak realistically, that is, refer to universals? It would appear that Gellner must concede that an important part of philosophy is descriptive by comparison with that which concludes that a certain kind of language *ought to be* retained or junked. For Gellner is the last person in the world to make a sharp and artificial distinction between subjects, especially a distinction that would put evidence-gatherers in one discipline and those who do the concluding in another. Here, as in the case of his discussion of the Argument from the Paradigm Case, Gellner is driven to the absurd contrary of the equally absurd position against which he is reacting so violently. The simple truth is that philosophers of language can engage in the description of use as well as in linguistic revision. How could one know what one was trying to change without describing it?

To come to the third part of Gellner's argument, it is rather extraordinary that this book contains not a single extensive discussion of one philosophically needed linguistic change that Gellner advocates. Had he devoted himself to one such substantive problem in philosophy as he conceives it, the book would have been immeasurably more valuable. Time and time again one gropes without success for an illustration of the kind of conceptual revision that Gellner has in mind. He thinks that "philosophy is in large part a matter of explicating—and choosing—our concepts, and, incidentally, *of choosing what kinds of explication we find acceptable.*" I find this congenial, but what are some examples of philosophy done in accordance with Gellner's plan? What does he think of the explicative constructions of philosophers who use the techniques of mathematical logic? One illustration worked out in detail, or even taken from an author of whom Gellner approves, would have been worth 50 pages of accusation. I do not wish to be mean about this. Philosophers perform a great service when, like John Locke, they sweep rubbish from the paths of master-builders. But when a philosopher is so sharply critical of conceptual conservatism he should at least outline one radical linguistic alteration of which he approves. Had Gellner done this he might have shed more light on the distinction between use and valid use which is so central to his philosophy. He suggests at one point that very few ways of speaking are indispensable. What are they? Does Gellner think, for example, that human thought could get on without the languages of deduction and induction? How far does his liberalism extend? I am sympathetic with Gellner's emphasis on the expendability of some conventional ways of speaking, but without more concrete illustration from him I cannot fully understand what he is driving at.

To say this is not to deny that Gellner has written a serious, stimulating and often telling critique of certain tendencies in English philosophy today. But I deplore his method of mass refutation and his accusations of collective evasiveness, dishonesty and camouflage. I do not mind sharpness in controversy, but Gellner is too often blinded into using language that inhibits serious philosophical exchange. This is a pity, because Gellner has put his accusing finger, however shakily, on some very important issues. If philosophers who think that they have been wrongly interpreted or unfairly criticized were to meet with him in the pages of a scholarly journal, we might come closer to the truth on some of these issues at the cost of forgetting the bellicose manners of an angry young philosopher.

Short Reviews

THE BANKS LETTERS, edited by Warren R. Dawson. British Museum (12 pounds, 12 shillings). Sir Joseph Banks, naturalist and explorer, who served as president of the Royal Society for 42 years during the 18th and 19th centuries, was, as this calendar of his manuscript correspondence shows, one of the most prolific letter-writers in the English language. Banks's interests and activities were enormously varied. He went around the world with Captain Cook; he sponsored expeditions to all parts of the globe, including the journeys of Mungo Park and Matthew Flinders; he built up a great collection and a valuable library that he bequeathed to the British Museum; he was the principal scientific adviser to the King and his ministers on subjects ranging from the introduction and acclimatization of useful plants and animals to the supply and production of articles required for the Army and Navy; he was superintendent of the Royal Botanic Gardens, played a leading part in the founding of Australia, counseled the Mint on its affairs, supervised the arrangements at Westminster Abbey, served on the Committee of Trade of the Privy Council, inaugurated the subscrip-

tion for the defense of the country during the Napoleonic wars, was a prime mover in the various Acts of Parliament for Inclosures and Drainage of the Fens. He was, in short, in matters vegetable, animal and mineral the very model of the *savant officiel.* But he differed markedly from the present-day examples of the species in that he did his own work, and was a laborer rather than a conferrer and adviser. His prodigious correspondence is a case in point. When he died his files held at least 100 huge bound volumes of his letters and many separate dossiers and folders with more letters on particular subjects—perhaps 50,000 letters altogether. Banks rarely left a letter unanswered. Strangers, adventurers, nonentities got almost the same prompt attention as the great. He responded generously to appeals for help. Though he has been described as imperious and dictatorial and was known as the Bull of Revesby, his letters are usually courteous and sympathetic. He corresponded with persons all over the world on almost every conceivable subject. He wrote about breadfruit and hemp and livestock. He communicated with Matthew Boulton about machinery, wool, mining and metallurgy. He told the astronomer Jean-Baptiste Delambre about nautical almanacs and also let him know in no uncertain terms what he thought of Napoleon. He informed Arthur Lee of New York that since the Declaration of Independence "extinguished his character as a British subject," his resignation from the Royal Society would be accepted—but that he would still have to pay his back dues. He received from J. Newman, English secretary to the Russian Embassy, intelligence about Captain Cook's visit to Kamchatka. Among those who wrote to him (some wrote hundreds of letters) were Sir William Herschel, Jean d'Alembert, Joseph Louis Lagrange, Sir Humphry Davy, Erasmus Darwin, Count Sergius Ouwaroff, the mathematician José de Mendoza y Rios, the arctic navigator (and later clergyman) William Scoresby, the diplomat and antiquary Sir William Hamilton, the physician Sir Charles Blagden, the zoologist Markus Bloch. He heard much from Captain William Bligh, whom, despite the affair of the *Bounty,* he recommended as Governor of New South Wales, a testimonial he must have lived to regret in view of Bligh's arrogance and tyrannical manner which rendered him unfit for any post requiring tact and understanding. The versatility of Banks's letters is typified in a single communication to the plant physiologist Thomas Andrew Knight, which begins with Roy-

al Society business, goes on to convey his intention to supply the botanic gardens in Malta with anything that would grow there, continues with a discussion of martens, polecats and ferrets, discusses the advantages of bone manure, pronounces on the best strawberries and ends with the Lincolnshire elections. Banks never employed a secretary or amanuensis, and nearly every letter in the large mass now extant is written in his own hand. He knew no language but his own, and the many letters he got in French, German and other languages were translated for him by an assistant "viva voce"; he wrote his replies on the spot as the letters were read out to him. Of this gigantic correspondence much was lost and much else was dispersed in auction sales in the latter part of the 19th century. Still, some 7,000 letters —either originals or copies—are in the British Museum, and each of these is epitomized in the present work, a remarkable labor, invaluable as a source book and endlessly entertaining for the general reader.

THE SOVIET CITIZEN, by Alex Inkeles and Raymond A. Bauer. Harvard University Press ($10). This volume reports the results of a Harvard study of daily life in the U.S.S.R. With funds provided by the Air Force—a curious sponsor for such an undertaking—a group of scientists in 1950 and 1951 conducted 764 long interviews with Soviet émigrés and obtained answers to detailed questionnaires from 3,000 different respondents, relating to work experience and working conditions, standards of living, education, family life, keeping up with the news, attitudes toward the regime, popular values and aspirations, sources of social cleavage, popular images of the party and the secret police, nationality problems. The researchers were of course aware of the danger that émigrés might give a distorted picture of the country they had abandoned, and elaborate methods, which are fully explained, were employed to meet the problem of response bias. On the whole the book makes a good case for the relative dependability of the data. Soviet citizens, as here portrayed, are pretty much like other people. They like to eat, drink and be merry; they love their children; they grumble and compete and criticize and strive for status; they don't love policemen, don't thrive on terror, don't enjoy being spied upon; they do not admire political oafs and hacks, of which they have at least the usual share; they are more interested in social security, free education and medical care than in na-

tionalism, tradition or religion; they have suffered terribly from wars and do not want another; they have been bitterly discontented with working conditions, but these have now markedly improved. In short, the main problems touching the average Soviet citizen relate to the fact that he lives in a comparatively new industrial society, to the conditions, demands, difficulties and opportunities to which he must adapt himself, rather than to the fact that he lives in a totalitarian society. That the U.S.S.R. is not paradise seems reasonably clear from this report; that it is not on the verge of collapse, that its citizens are not waiting for us to blow a liberating trumpet or drop a small bomb on them as a signal to revolt is also clear. But the crystal ball is cloudier on the question whether the U.S.S.R. will in time become more or less totalitarian, and whether, even if the society becomes less absolutist, it may not become "more, not less, a challenge to the free world."

ARABIAN SANDS, by Wilfred Thesiger. E. P. Dutton & Company, Inc. ($5.95). The greater part of southern Arabia is a wilderness of sand, "a desert within a desert," so enormous and so desolate that even Arabs, who think a hut and a well make a village, and a few hundred hovels a metropolis, call it *Rub al Khali*, or Empty Quarter. This cruel, frightening, barren, almost waterless region of perhaps 300,000 square miles stretching from Hadhramaut on the Indian Ocean to the Trucial Coast on the Persian Gulf, was first crossed in the early 1930's by two Englishmen: Bertram Thomas from the south and Harry St. John Philby across the western sands. Wilfred Thesiger, an Englishman born in Ethiopia, made two crossings after World War II, each along a new, difficult and unmapped route, that no European before him had explored. The story of these arduous journeys is told in this engrossing volume, which deserves a place among the classics of Arab travel, and which, as Thesiger sadly observes, may well be the last of its line, for the desert is no longer empty nor undefiled. Oil prospectors have crisscrossed it in jeeps and mapped it; its sands are scarred with truck tracks and littered with "discarded junk imported from Europe and America"; the Bedouins have been demoralized, driven from the deserts into the towns, their economy destroyed, to face a life with which they cannot cope and for which their qualities do not fit them. Thesiger's account of his life with the Bedouins is superb. He saw them plain, grew to love them and

makes us see, if not quite love, them. "It is characteristic of the Bedu," he writes, "to do things by extremes." They are ignorant, mean, superstitious, cruel, filthy, primitive, murderously quarrelsome, forever chattering and gossiping; they are also brave, fatalistic, generous, loyal, self-respecting, puritanical, fiercely independent, tireless, uncomplaining, marvelously skillful and adapted to the harshness of the land and the unrelieved severities of nomadic life. Both as a traveler and a writer Thesiger is admirable. He is often bitter, but never self-pitying or complaining; he recreates adventure, the tension of monotony broken only by alarm or disaster, the joy of drinking "clean, nearly tasteless" water, the colors and shapes of the desert. A strange, memorably moving, beautiful book. Fine photographs and a splendid folding map.

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gy; it compels our attention and drains our resources, but this lunacy may end. Meanwhile workers in many different fields have gained an immense amount of knowledge—even though they have barely crossed the threshold—about the peaceful uses of atomic energy. At the second United Nations conference devoted to this subject more than 2,100 papers were submitted by 46 governments. The proceedings have now been published in 33 volumes, of which those listed above represent a substantial sample. The titles are self-explanatory, and there is no need to comment on the contents beyond saying that here is a superbly impressive and heartening record of what man can achieve in constructive research, of his ingenuity and imagination and patience. In these clearly printed, stoutly made books there is information about the future of nuclear power in the U.S.S.R. and Portugal, in Romania, Spain, Taiwan and Pakistan; about the training of nuclear specialists in Czechoslovakia, Israel, Chile and Persia; about international collaboration in atomic energy (*e.g.*, the Canadian-Indian reactor); about raw-material supplies of thorium in South Africa, beryllium in the U. S., uranium in Egypt, zirconium in Africa. Papers treat geochemical prospecting in Austria; the significance of humus in the geochemistry of uranium; the geology of deposits in Ontario, Alaska, Colorado, the Big Horn basin of Montana, southwest Greenland, northern Limousin, Sweden, Mexico; methods of aerial prospecting; radioactive prospecting for oil and gas; mining methods and costs; instrumentation in mining; algebraic theory in prospecting; ore treatment; purification of uranium concentrates; preparation of uranium hexafluoride; thorium compounds; graphite; zirconium; isotope-separation methods; separation of heavy water; boron, lithium and oxygen isotopes. Two volumes are devoted to nuclear powerplants, including ship-propulsion devices, atomic icebreakers, house heating, nuclear energy in chemical processing and the steel industry, the Yankee Atomic Electric Company, Calder Hall and the Belgian thermal reactor. Other volumes deal with reactor physics; health and safety measures; biological effects of radiation, such as symptoms of injury, carcinogenic effects, resistance to radiation, effects on specific organs and systems, genetic effects; the diagnostic uses of isotopes and other medical techniques; isotopes in metallurgy, the chemical industry, coal conveying, oil extraction, sanitary engineering, tracing beach-sand movements and water level fluctuations;

basic physics in nuclear energy; experiments in radiological protection; isotopic methods in biochemistry and physiology, in the study of organic metabolism, in endocrinology, in plant and animal physiology, in genetics and crop improvement, in insect and pest control; the chemical effects of radiation on water, organic substances, polymers and other materials; the possibility of controlled fusion; theoretical and experimental aspects of plasma physics. A monument and a promise.

WISDOM OF THE WEST, by Bertrand Russell. Doubleday & Company, Inc. ($12.50). A posh, Christmas-season-type illustrated history of philosophy from Thales to Ludwig Wittgenstein. Like everything of Russell's, it is brilliantly written, incisive and as delicious as ice cream; it is also filled with the author's own critical judgments, for he is never content to be a reporter; or, if the image may be varied, he does not merely write the play, he directs it and speaks the lines. The book is for the beginner in philosophy and is in effect a rewritten version of the *History of Western Philosophy*. How fortunate for the student to be thus initiated. Yet it is proper to caution him. Russell mainly writes about what he likes. The Greeks get very full attention, as they should; political philosophy is less well served; mathematics and logic receive their share; contemporary questions of the philosophy of science win scarcely a nod; relativity, quantum theory, indeterminacy get a better shake in a good dictionary. Much is made of the illustrations, but they don't deserve it. There are colorful portraits of philosophers, pictures of places, documents, title pages, which are agreeable and diverting; there is also a collection of diagrams that, Russell claims, convey philosophic ideas by geometric metaphor. In truth they are short on imagination and trivial. Nonetheless this is a lucid and edifying performance by an elevated citizen and thinker, a wonderfully sane and tolerant man, who by just such writings broadens respect for philosophy and inspires the best young people to profess it.

A HISTORY OF SCIENCE: HELLENISTIC SCIENCE AND CULTURE IN THE LAST THREE CENTURIES B. C., by George Sarton. Harvard University Press ($11). This is a second volume, and regrettably the last, of the late George Sarton's splendid survey, which was originally intended to run to eight volumes, and which he hoped, as I. Bernard Cohen observes in a foreword, would illuminate the

"progress of mankind" by focusing attention on the growth of "systematic positive knowledge, or what has been taken as such at different ages and in different places." The first volume, reviewed in SCIENTIFIC AMERICAN in 1953, dealt with the history of science from its Asiatic beginnings through the Golden Age of Greece; the second treats not only Greece but also Roman culture and Latin letters and the culture of Eastern Europe, Egypt and western Asia during the last three centuries B. C. For Sarton, who loved the humanities as science, it would have been impossible to write a history of knowledge confined to science alone, and here he touches upon every major intellectual achievement of these centuries. There are chapters on Euclid, Aristarchos, Archimedes and Apollonius; on the Alexandrian renaissance, harbors and lighthouses, the seven wonders of the world, the museum, the library; on mathematics, natural history, astronomy, geography, physics, engineering, technology, navigation, anatomy and medicine; on philosophy, religion, philology, historiography, language, arts and letters; on the social background, poetry, theology and orientalism. Sarton's erudition was legendary, and he handled it, on the whole, with restraint. It may be that he sometimes paraded it, but he was neither pretentious nor pompous nor a bore, and the unfeigned delight he took in knowing an incredibly varied assortment of out-of-the-way facts—about minor figures, obscure books, arcane theories, strange words, the black arts, philological curiosities, alchemical and astrological oddities, popular and scholarly errors and the like—is so infectious that his innumerable footnotes, so far from weighing down the book, make it more palatable and engross the reader's interest. There are gaps and weaknesses in this history. Sarton was apt to hit and run, to open the door to a subject without even crossing the threshold, to point and give clues without following up; but no historian of science equaled him in knowledge, breadth and enthusiasm, none saw the subject whole as he did, and none did so much to promote the study. A wonderful book.

THE ANATOMY OF AMERICAN POPULAR CULTURE 1840-1861, by Carl Bode. University of California Press ($6). An esthetic, social and historical survey. It covers the popular taste of Americans in the two decades immediately preceding the Civil War: the plays people saw, the music they sang or listened to, the books and newspapers they read, the sculpture

they admired. The all-time great "American" painting (made by the German artist Emanuel Leutze), "Washington Crossing the Delaware," caused every bosom to swell; the death of little Eva bathed everyone in grief; the dashing, sexy traveler Bayard Taylor, in Turkish costume, made ladies swoon. Hiawatha unhinged them; Hiram Powers's nude statue "Greek Slave" ennobled and transfixed every man, woman and child who saw it; Jenny Lind produced mass hysteria. But Thoreau's *Walden* had no popular importance at all. Nothing could make clearer than this book what a simple people we were; it lays bare our sentimentality, our passion for crude melodrama, our feelings about love and death, our ideal of success, our open, optimistic attitude toward life. A readable and enlightening study.

RADAR METEOROLOGY, by Louis J. Battan. University of Chicago Press ($6). A brief technical description of the fundamentals of radar meteorology, and progress in the method since its invention: the detection of spherical particles, scattering, attenuation of electromagnetic waves by gases, clouds, rain and snow, uses of radar for quantitative precipitation measurements, application of radar to hydrologic problems, radar in cloud-physics research, the study of thunderstorms, squall lines and tornadoes, radar in the study of large-scale weather systems, angel-echoes (*i.e.*, radar echoes in the absence of water or ice particles), special instrumental techniques. For practicing meteorologists, teachers and engineers. Illustrated.

NATIVE PEOPLES OF SOUTH AMERICA, by Julian H. Steward and Louis C. Faron. McGraw-Hill Book Company, Inc. ($11.50). Between 1946 and 1950 the Bureau of American Ethnology of the Smithsonian Institution issued a six-volume *Handbook of South American Indians*, a work carried out under the direction and editorship of the senior author of the book here noted. The *Handbook* assembled a vast array of information on South American physical anthropology, linguistics, archaeology and ethnology. By its very size and comprehensiveness, however, the *Handbook* was suitable neither for students nor the general reader; moreover, as a cooperative product it lacked an "integrating point of view." This book is an effort to meet the need left by the larger survey, and to take into account, though no claim is made that this can be done exhaustively, some of the major findings made in this burgeoning field of research

since the *Handbook* was prepared. In clear and concise fashion the authors present a general description of South American Indian cultures and an interpretation of how these cultures developed, beginning with very primitive man, passing through various types of communities and states based upon agriculture and culminating in the Central Andes in "fairly sophisticated militaristic empires supported by irrigation farming." Many illustrations.

THE DE MAGNETE OF WILLIAM GILBERT, by Duane H. D. Roller. Menno Hertzberger ($19). This 196-page book, issued in a limited edition by a Dutch publisher, is described as a "bio-bibliography" based on a Harvard doctoral dissertation. The author, a historian of science at the University of Oklahoma, sketches the history of electricity and magnetism before Gilbert, presents what is known about his life (which is not much) and what may "reasonably be inferred" about him (which is not especially interesting), and analyzes his views on electricity and magnetism as set forth in *De Magnete*. A concluding chapter is a register of the various editions of this epochal work. There is a bibliography of primary and secondary sources, which would have been more useful had it been annotated, and the book contains 28 illustrations and facsimiles of title pages. Even though this is a pretty job of bookmaking, the price is ridiculous.

CARCINOGENESIS BY ULTRAVIOLET LIGHT, by Harold F. Blum. Princeton University Press ($6.50). That ultraviolet light may induce cancer of the skin has been known for many years. But why it happens is far from being understood. The author of this book, a biologist and physiologist who has broad-ranging skills and interests, and who will be remembered for his *Time's Arrow and Evolution* (reviewed in these pages some years ago), has spent 15 years in experimental and theoretical research exploring the processes by which the ultraviolet portion of sunlight causes human skin-cancer. He has concerned himself in particular with the physical and photochemical principles as they apply to complex living systems, and with the biological relationships such as self-duplication, coordination of growth kinetics and the like, which find no direct counterpart in nonliving systems. He calls his book a study in quantitative biology—though the paucity of exact measurements that it contains is, in his words, all too evident—because it represents an attempt "to view certain bio-

logical problems with a quantitative perspective." But he goes further than this in proffering an intriguing speculation, based on his studies, as to the mechanism of carcinogenesis. He summarizes his view as follows: Cancer is the expression of a tendency for certain clones of tissue cells to proliferate faster than their fellows. This tendency is inherited within the clone. The inherited increase in rate may be explained on the basis of quantitative increase in some replicated pattern within the cells. The replicated pattern can in turn be explained as being carried by templates, most likely composed of nucleic acid. Thus cancer cells may be thought of as differing from normal cells in that they contain a greater number of nucleic acid templates. The templates, it is suggested, may accumulate within the cell in a variety of ways. Blum offers the hypothesis that ultraviolet light is such a causative agent, that its action produces what he calls "tems" (a concept he introduces to fit quantitative aspects of the data on ultraviolet-induced cancers), which are probably none other than nucleic acid templates or shorter nucleotide polymers. Blum invites criticism of his scheme, feeling certain that, while it will meet serious objections and may have to be modified, a firm part of the structure will be left standing. An ably written, provocative essay.

VICTORIA R., by Helmut and Alison Gernsheim. G. P. Putnam's Sons ($12.50). A thoroughly entertaining text-and-picture biography of Queen Victoria, drawing in part upon her own journals and writings. From a huge collection of pictures the Gernsheims have selected 400 illustrations, which hold one's interest throughout despite the fact that Victoria, Albert, their mob of glum and uninspiring German relatives in all sizes, shapes, ages and circumstances, and their residences, horses, carriages and servitors, are the sole subjects of the painter's and photographer's attention.

THE FOUNDATIONS OF MATHEMATICS, by Evert W. Beth. North-Holland Publishing Company ($13.25). This treatise examines the foundations of mathematics in their logical and philosophical aspects. Beginning with an examination of the influence of Aristotle's methodology of science, which, the author argues, "can no longer account for the procedures actually applied in scientific research," the book develops an outline of the foundations underlying a deductive treatment of various mathematical disciplines and explains the

formal methods, applied from both the finitistic and infinitistic point of view, in contemporary foundational research. Among other topics to which he gives full attention are the different interpretations of mathematical existence, the paradoxes of logic and mathematics, the uses of set theory and topology in metamathematics, the theory of recursive functions. An excellent bibliography adds to the worth of this richly stocked, thought-provoking work, a contribution alike to the history of the subject and to its future development.

SCIENCE AND RESOURCES, edited by Henry Jarret. Johns Hopkins Press ($5). Lectures on various aspects of the relation between scientific and technological discoveries and the conservation and use of natural resources. Some of the lectures have substance, but the book as a whole is so diffuse—space programs, weather control, economic development in the Near East, mineral exploration, viruses, heredity, government pricing policies in atomic energy—that it almost caricatures the weaknesses of symposia.

ENCYCLOPEDIC DICTIONARY OF ELECTRONICS AND NUCLEAR ENGINEERING, by Robert I. Sarbacher. Prentice-Hall, Inc. ($35). This 1,400-page reference book, containing some 14,000 entries and 1,400 illustrations, the work of a single compiler—a rare bird in an age when the average specialist is too shy to write even a chapter in a scientific handbook all by himself—is an impressive accomplishment. In addition to covering terms and definitions, instruments, tools, methods, machines, laws, effects, processes in electronics, nucleonics and nuclear engineering, the encyclopedia includes general terms of electric and magnetic theory and atomic physics and a number of definitions from the broader principles of physics. Whenever possible the compiler has used definitions "prepared and approved by the various professional societies." The cross-referencing is sound; the volume is clearly printed and well made; the diagrammatic illustrations are cleanly drawn and to the point. This is very much a technician's manual, and little attempt is made to simplify topics for the beginning student; moreover, there are occasional entries that exemplify the absurd solemnity of a jargon-ridden field (*e.g., electronic intelligence*, which turns out to be "intelligence regarding the location, volume, direction, and type of enemy electronic devices"). But in the main this is a valuable compilation that practitioners in a

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THE THIRTEEN STEPS TO THE ATOM, by Charles-Noël Martin. Franklin Watts, Inc. ($4.95). In this book are displayed 118 superb photographs of objects in a descending scale of size, from snowflakes (magnification 20) to electrons (magnification 30 million). En route to the fantastic world of minuteness the points of interest include the silk threads on a cocoon, diatoms, cancer cells, unbelievably beautiful crystals, sections of mahogany, particles of latex, fine ceramic surfaces, spirochaetae of recurrent fever, bacterial viruses, cleavage planes of mica, particles and chains of deoxyribonucleic acid, polypeptide fibers, magnesium oxide smoke, chromosomes, electron-wave fringes, atoms of iron, sulfur and rhenium, radioactive particles from radium, the high-speed creation and disintegration of a meson, nuclear collisions, an electron caught and spiraling in a magnetic field. The accompanying text is just right. A unique and fascinating book.

THE GREAT WAR, 1914-1918, by Cyril Falls. G. P. Putnam's Sons ($5.95). If histories of wars are to be written, they should be as good as this one. Falls, who was for many years military correspondent of *The Times* of London, and was professor of the history of war at Oxford, has written the clearest concise account of the great war to end wars. He is at his best in extracting the essentials of vast, confused campaigns and battles, in making sense of congeries of tactics, strategies and logistics, in giving movement and meaning to what so often seem like nothing more than imbecile orgies of slaughter. He is less impressive in diagnosing political factors and in attempting to justify the actions of military leaders responsible for the murderous stalemate on the Western Front. It is perhaps extreme to label some of the generals as mere butchers, but nothing in these pages rebuts the evidence that stupidity, vanity and irresponsibility presided over high councils and shaped momentous decisions.

Notes

DEMON OF THE NORTH, by Peter Krott. Alfred A. Knopf ($5). The story of an Austrian naturalist and animal dealer who caught and tamed wolverines. Moderately entertaining.

GUIDE TO THE SPACE AGE, compiled and edited by C. W. Besserer and

Hazel C. Besserer. Prentice-Hall, Inc. ($7.95). Defines, with no special virtuosity, some 5,000 words and phrases used in space technology and the rocket and missile business. A scope dope, you may be glad to learn, is a radar watcher.

A History of Dutch Life and Art, by J. J. M. Timmers. Thomas Nelson & Sons, Inc. ($15). This informative, ably written, admirably illustrated volume is an excellent introduction, perhaps the best of its kind, to the creative achievements of this tiny country in painting, sculpture and architecture.

Philosophy and the Modern World, by Albert William Levi. Indiana University Press ($7.50). A knowledgeable and fluent guide escorts the reader through the chief philosophical ideas of Bergson, Spengler, Toynbee, Freud, Veblen, Lenin, Einstein, Planck, Dewey, Russell, Carnap, Sartre, G. E. Moore, Wittgenstein and Whitehead. Digestible and nutritious.

Frontier America, by Thomas D. Clark. Charles Scribner's Sons ($10). A panoramic survey of the westward movement, treating its political, social and economic aspects. Illustrated.

Semiconductors, by R. A. Smith. Cambridge University Press ($12.50). This book, intended primarily for physicists, gives an account of the main physical attributes of semiconductors, substances which have yielded important knowledge of the electrical, optical and mechanical properties of solids, and which have found wide use in modern electronics.

IGY: Year of Discovery, by Sydney Chapman. University of Michigan Press ($4.95). A brief, well written, illustrated summary of the activities of the International Geophysical Year by a noted physicist who was president of the central international committee of scientists that directed the program.

The Great American West, by James D. Horan. Crown Publishers, Inc. ($10). A lively and entertaining pictorial history from Coronado to the last frontier, touching on the great expeditions, the celebrated trails, the pony express, the gold strikes and gold mining, the penetration of the railroads, the Indian Wars, the famous photographers, the cattle and cowboy business, homesteading, buffalo hunting, timbering, the bad men and the wild ways.

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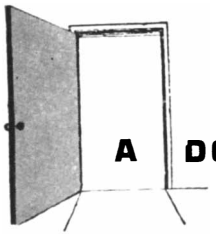


A DOOR IS OPENED... TO NEW DEVELOPMENTS IN DIISOCYANATES

"Modern chemistry has made few discoveries of greater significance than polymerization. Few polymer formers have greater versatility, actual or potential, than diisocyanates."

This quotation is from a new free booklet prepared by our National Aniline Division. Entitled "Diisocyanates," it describes the origins and development of these polymer formers which are being used to achieve that revolutionary new plastics family, polyurethanes.

Polymeric building blocks

The booklet begins with a discussion of polymers in nature, from which chemists took their cue to devise their own building blocks. One of the most intriguing building blocks for forming large polymer molecules is the class of organic chemicals called diisocyanates. With them it is possible to duplicate the properties of almost all known types of plastics.

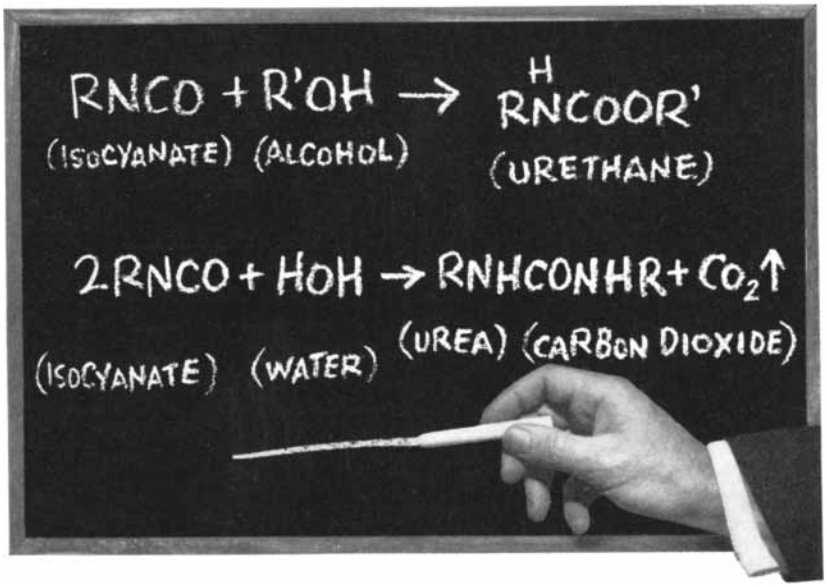
In order to help the reader appreciate the diverse materials that can be formed with diisocyanates, the booklet includes a brief history of their origins, followed by an outline of present day chemistry in the field.

Polyurethane foams

From there, the booklet takes us into a discussion of the most interesting and important polyurethanes (polymers based on diisocyanates)—the foams. It tells why and how these materials foam and describes the tremendous variations that are possible. Polyurethane foams range from one to 60 pounds per cubic foot in weight. They can be made rigid enough to support heavy loads or flexible enough to serve as mattresses and coat linings.

Flexible foams

Flexible foams may be produced which have little "bounce-back" and high shock absorbency. These are well adapted to such uses as automobile crash pads, where they minimize the danger of "snapback" injuries, inherent in pads with little absorbency, more bounce. Other flexible foam applications include pillows, furniture cushioning, vermin- and rot-proof carpet underlays, floor mops, clothes brushes, and warm yet lightweight linings for winter clothing.



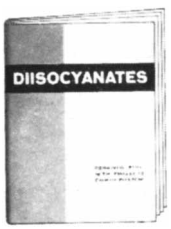
Key equations of urethane chemistry show the simultaneous reactions of isocyanates with alcohol and with water. The reaction produces a solid product and carbon dioxide, which "blows" the foam material. From "Diisocyanates," a free booklet just off the press.

Rigid foams

You'll read how polyurethanes can be cross-linked to form semi-rigid and rigid foams as well. The former of these can be sprayed onto walls as acoustical insulation or foamed in place in wall cavities where insulation is wanted. Rigid foams find application as harbor buoys, buoyancy chambers for boats, and as filling for aircraft wing tips. You may be surprised to learn that prefabricated sandwich wall panels for homes are now under test and that foamed-in-place polyurethane resins have been used for the setting of bones.

Other polyurethane products

The booklet describes the other forms of polyurethanes as well; for with more cross-links, polyurethanes become plastics that do not warp or swell and have high impact strength. Polyurethane rubbers for example: soles and heels that outlast conventional shoe materials 10 to 1... hundred-thousand-mile tire treads that promise to be a commercial reality soon.



Anyone interested in the general subject of diisocyanate chemistry, or who is working with polyurethane materials, will find the booklet, "Diisocyanates," valuable. *For a free copy,* just write, on company letterhead, to Allied Chemical Corporation, Dept. 36-S, 61 Broadway, New York 6, New York, or phone HAnover 2-7300.

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BASIC TO AMERICA'S PROGRESS

communications for roving missile bases

COLLINS ELECTRONICS

Operating under a polar ice cap or roaming the open seas under nuclear power, Polaris-launching submarines this year add a new, powerful, unique weapon to the Free World's war deterrent arsenal. Concealed by ocean depths, these ever moving missile bases cannot be accounted for by an enemy planning a surprise attack. The U. S. Navy's Fleet Ballistic Missile submarine is the product of the highest achievements in nuclear propulsion, missiles, navigation and communication. Collins long range, single sideband radio systems will provide the dispersed submarine fleet with a reliable link in communications.

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vision/avenir

"If men are ever to journey
"Pour que l'homme puisse un jour atteindre
to the planets and the stars, we shall
les planètes et les étoiles, il devra connaître, des
need to know years in advance
années au préalable, les effets biologiques et
the biological and psychological
psychologiques que produisent le rayonnement
effects of cosmic radiation, extreme
cosmique, les variations extrêmes de
temperature variation, weightlessness,
température, l'absence de pesanteur,
meteoric collision, synthetic air,
les collisions météoriques, l'air synthétique,
disorientation and illusions of space
la désorientation et la transposition de l'espace
and time. New aerodynamic forms
et du temps. D'ici quelques années, des
and new applications of atomic
conceptions nouvelles d'aérodynamique et des
power may within the next few years
applications nouvelles de l'énergie atomique
make possible the sustained
permettront peut-être une exploration
exploration of earth's upper
méthodique des couches supérieures de
atmosphere that will tell us what we
l'atmosphère terrestre, qui apprendra à l'homme
need to know before our first
ce qu'il doit savoir avant de se hasarder pour
human step into space."
la première fois dans l'espace."

reality/réalité

The USAF Atlas, designed and built
L'Atlas de l'Armée de l'air des Etats-Unis,
by General Dynamics Corporation's
conçu et réalisé par la Division Convair de
Convair Division, will put into orbit
la General Dynamics Corporation, placera en
the first of this country's manned
orbite le premier astronaute américain
capsules (Project Mercury); will help
(Opération "Mercure"), aidera à lancer des
send instrumented probes deep into
sondes munies d'instruments au plus profond
space (Atlas-Able); boost heavy
de l'espace interplanétaire ("Atlas-Able"),
satellites into polar orbit (Projects
ainsi qu'à mettre des satellites lourds en orbite
Midas and Samos); and launch space
méridienne (Opérations "Midas" et "Samos"),
vehicles for moon and planetary
et propulsera des engins spatiaux d'exploration
probes (Project Centaur).
lunaire et planétaire (Opération "Centaure").
In addition, scientists of General
En outre, l'équipe scientifique
Atomic Division are studying
de la General Atomic Division étudie
(Project Orion) the feasibility
la possibilité d'utiliser des impulsions
of using controlled nuclear pulses
nucléaires ménagées pour envoyer dans
to propel into space a ship weighing
l'espace un astronef de 1.000 tonnes
1,000 tons. Meanwhile, Atlas,
(Opération "Orion"). En attendant, l'Atlas,
America's first operational Inter-
premier engin balistique intercontinental mis
continental Ballistic Missile, with
en service aux Etats-Unis, capable de
a capability of delivering an atomic
transporter une tête atomique sur plus de
warhead at 16,000 mph over a range
10.000 km à une vitesse de 25.600 km à l'heure,
exceeding 6,000 miles, remains
demeure un des principaux moyens de
a major deterrent to nuclear war.
prévenir une guerre nucléaire.

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Photograph of ring nebula in Lyra
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