SCIENTIFIC AMERICAN

"LONG CALL" OF GULLS

FIFTY CENTS

December 1960

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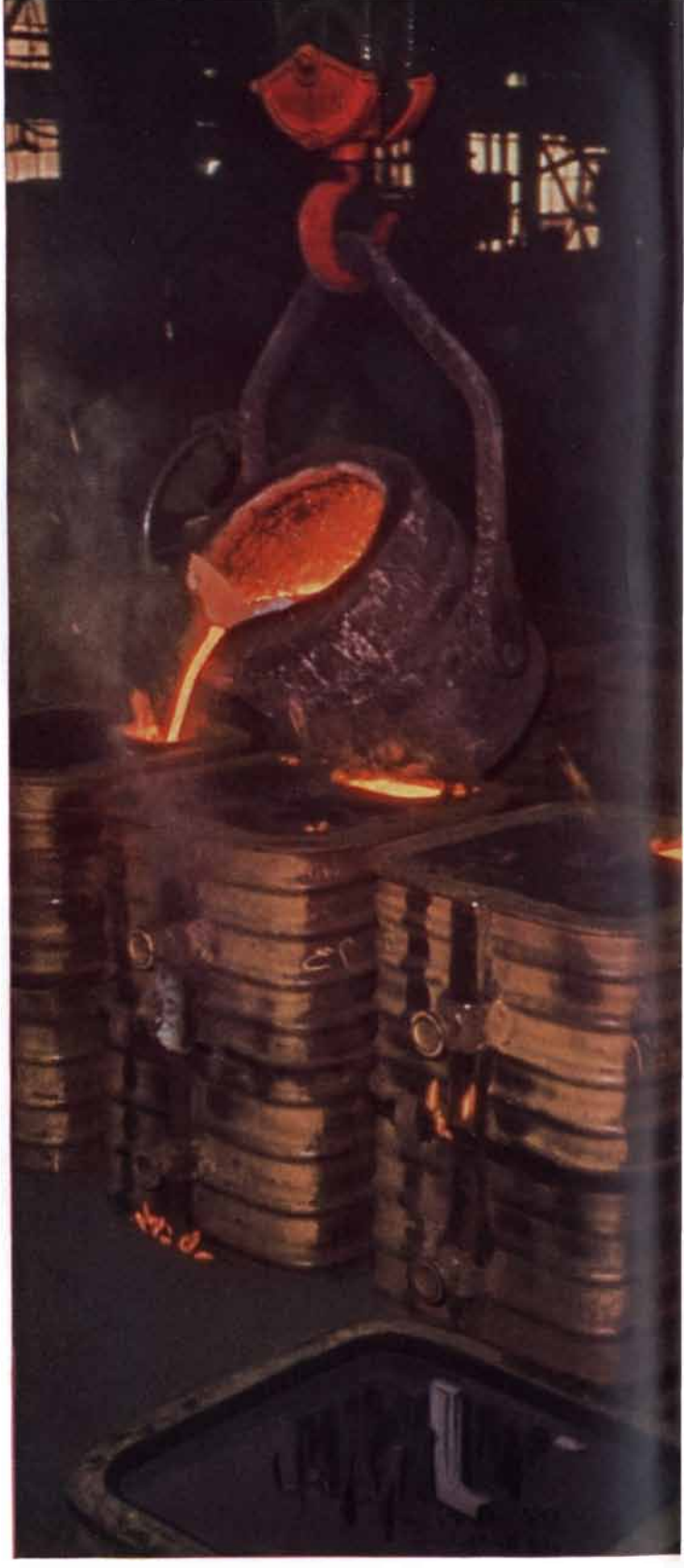
ZIRCON—A JEWEL OF PHYSICAL ADVANTAGES

Zirconium appears most abundantly as zirconium silicate, or "zircon"—a valuable industrial mineral. Granulated, it affords foundries a core sand chemically inert at molten metal temperatures. As "flour," zircon imparts a very smooth refractory coating, improves heat dissipation to avoid distortion. Milled exceedingly fine, zircon provides ideal chemical and physical characteristics, as well as opacity, in ceramic glazes. M&T mines this versatile metallic mineral; has a high temperature research center for end-use studies.

FOAM BY THE MILE IN MINUTES

Urethane foam manufacture was changed almost overnight to a simple "one-shot" system for cured foam in minutes. The stannous and organotin catalysts responsible for this breakthrough were pioneered by M&T. By greatly accelerating the typical foaming-curing reactions, M&T catalysts allow far more efficient production of foams for cushioning, packaging, insulation and moldings.



Metals meet Chemistry at M&T

Diverse as M&T's activities are, they have a common denominator...a union of metals with chemistry. You may see the result in a better ceramic opacifier; or a more powerful fungicide; or a superior catalyst that really says "go" to a chemical reaction. In each case, M&T contributes importantly to scientific or industrial progress.

FOILING THE SPOILING OF WOOD

Wood is delectable food to a great variety of insects, bacteria and fungi. Unless destructive appetites are curbed, wood rots. M&T's TBTO®—an organotin chemical—is so potent that wood brushed with a very dilute solution repels or kills the hungry microorganisms that contact it. So important is the budding area of organometallics, M&T operates one of the largest plants devoted to combining metals into the molecules of various organic chemicals.

Metal & Thermit Corporation

General Offices: Rahway, N. J.

chemicals / coatings / metals / minerals

welding products / plating products / detinning

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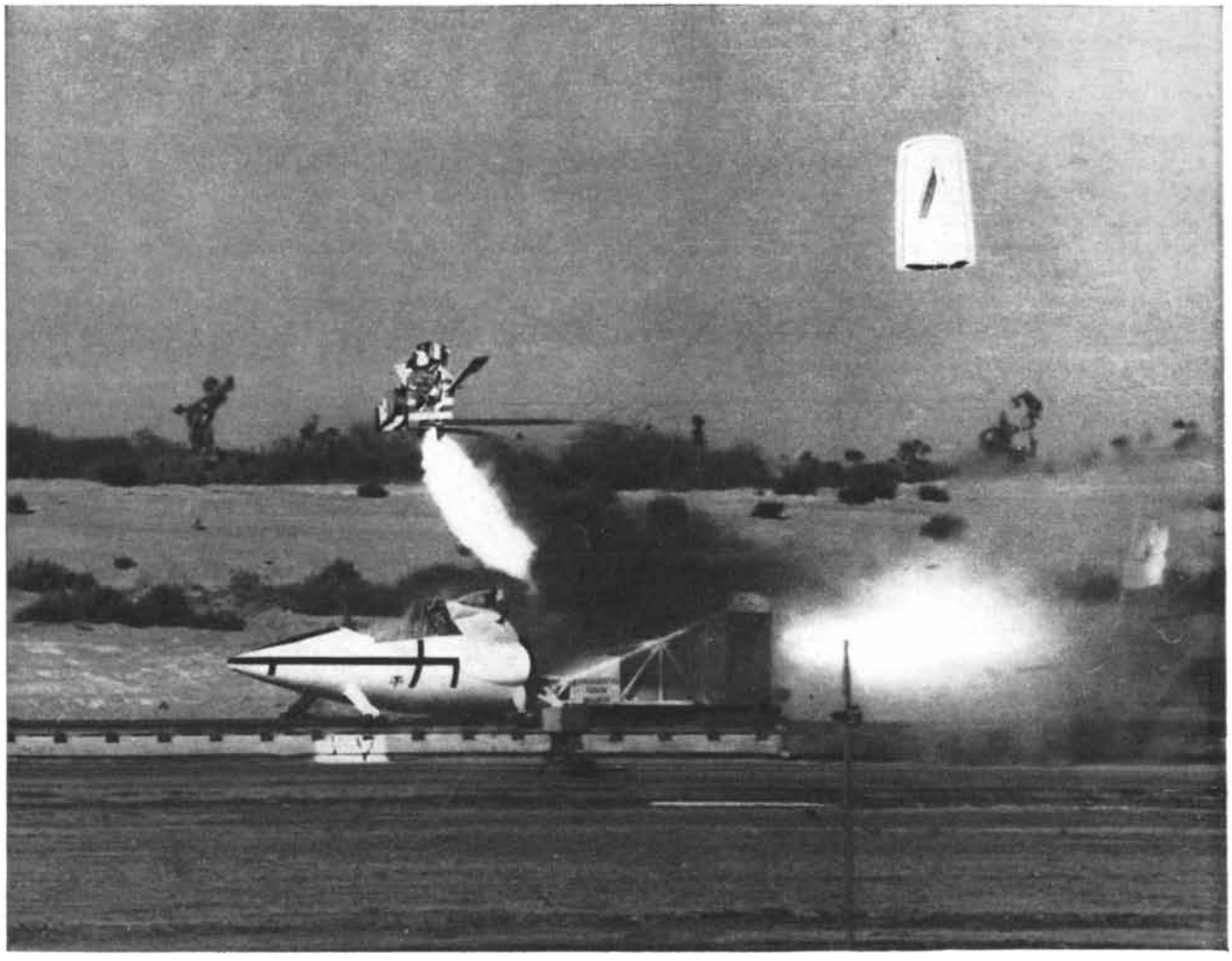
WHEN YOU WANT TO SPLIT SECONDS

You may be designing a new aircraft ejection seat . . . or a better high speed camera . . . or a more accurate precision timing device. *Whatever* you design, if it calls for precision ball bearings, Fafnir has what you need. For example, if your product needs miniature bearings, the Fafnir line includes all popular types and sizes . . . flanged and unflanged bearings, shielded types (with one or two shields), as well as unshielded bearings — all available in bore sizes from $\frac{3}{32}$″ (.0937) to $\frac{1}{4}$″ (.2500). For miniature ball bearings — for *any* precision ball bearings you need — look to Fafnir. Write The Fafnir Bearing Company, New Britain, Connecticut.

Fafnir Precision Miniature Ball Bearings were among the first to be manufactured of extra-clean, vacuum-melt 440C stainless steel to insure a minimum of impurities, and to eliminate chances of pits or imperfections in balls and races. The ultimate results are super-sensitive bearings offering low torque values.



SUPERSONIC TESTING OF AUTOMATIC EJECTION SEAT FOR NORTH AMERICAN'S X-15

FAFNIR
BALL BEARINGS

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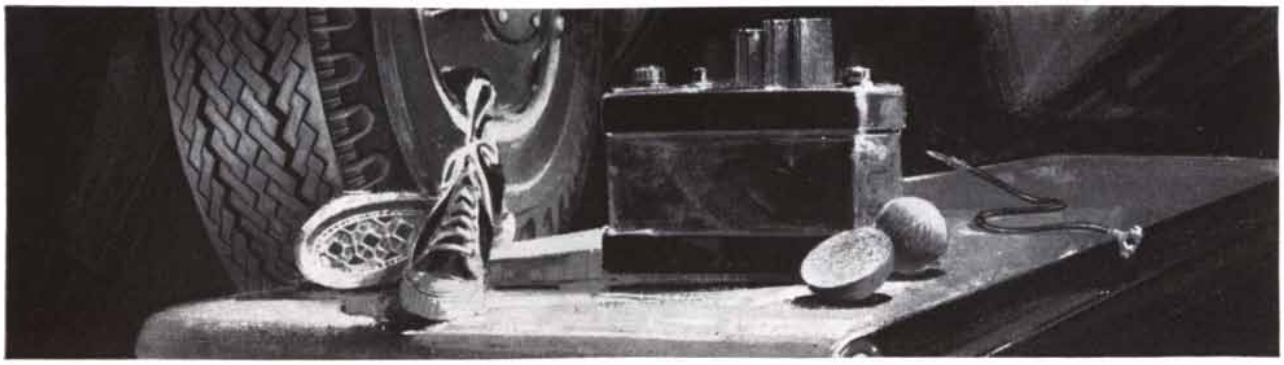

FIRESTONE'S DYNAMIC Diene

PROVIDES DRAMATIC NEW QUALITIES FOR RUBBER PRODUCTS

Diene is a rare research achievement that will allow dynamic product development to surge into hundreds of new channels. The remarkable characteristics of this new Firestone polymer may provide an exciting new potential for *your* product.

Firestone's Diene is strikingly superior to natural rubber in four important respects: resilience, abrasion resistance, high dynamic modulus and low temperature properties. In processing, it possesses a complete lack of "nerve." In content, it is extremely pure with no gel, no moisture and extremely low ash. The water soluble ash is nil, providing excellent electrical properties. Its aging and cracking resistance: better than natural rubber.

Diene is perfectly compatible with Styrene-Butadiene and natural rubber. When combined with them in major proportions, it lends startling new properties to the resultant compound—properties that expand and excel the best features of each polymer.

Truck tires combining major proportions of Diene with natural rubber were road-tested for more than three million miles with amazing results. The Diene tire's wear resistance proved stubborn and startling. Its traction is quick and eager, gripping slick surfaces when other tires spin. It runs cooler at all speeds and gives a measurable boost to gasoline mileage. Moreover, Diene promises to make equally dramatic improvements in other rubber products.

Firestone's new Diene plant—beginning operations January, 1961, in Orange, Texas—is the first to be built by any rubber company. It is another symbol of Firestone's continuing determination to have complete production facilities to make a quality rubber for *every* purpose.

Firestone Diene will be available to all rubber product manufacturers. You are invited to write Department 69-1 now for development quantities and technical information.

Diene is a Firestone trademark
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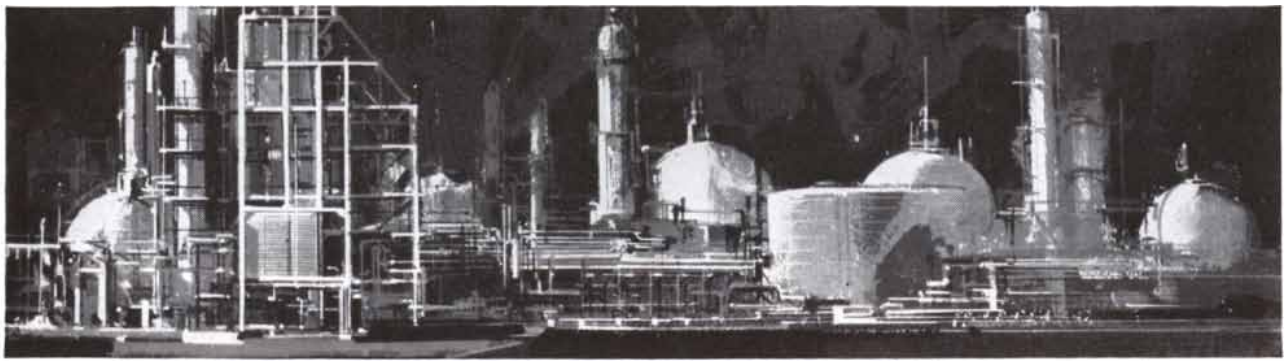
Firestone

SYNTHETIC RUBBER AND LATEX CO., AKRON 1, OHIO

Tune in Eyewitness to History every Friday evening, CBS Television Network



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Established 1845 **SCIENTIFIC AMERICAN** December, 1960 Volume 203 Number 6

ARTICLES

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Lamination gives control tapes valuable strength and stability!

Unusual resistance to chafing or stretching of Dobeckmun's laminated foil, Mylar* and paper control tapes has proved invaluable in maintaining the accuracy and fidelity vital to complex control and programming systems, and computer input-output systems.

Punched holes stay true for the life of the tape, are dimensionally stable and unaffected by atmospheric conditions or ageing. Adaptable to either photoelectric or mechanical operations. Virtually indestructible, the extra strength of Dobeckmun tapes not only offers longer service but reduces the effect of constant wear.

If you have a special problem, the flexibility of laminated tapes may well offer the most satisfying answer. Write for free test samples and complete information.

DOBECKMUN

The Dobeckmun Company, A Division of The Dow Chemical Company, Cleveland 1, Ohio
Berkeley 10, California · Offices in most principal cities. *Mylar is a registered DuPont trademark.

THE COVER

The painting on the cover depicts the "long call" of the herring gull. The long call, uttered when the gull adopts a posture called the "oblique," is part of the signaling behavior with which gulls communicate with one another (*see page 118*). The long call of the male attracts unmated females and repels other males. Signaling behavior is instinctive, not learned, and so is as characteristic of a species as the structure of its limbs and organs.

THE ILLUSTRATIONS

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PFAUDLER NUCERITE*

Here's a material of construction that copes with high temperature, impact, and corrosion.

What processes, heretofore held back for lack of a proper material, will you explore first with Nucerite?

For example, if corrosion at high temperatures is a problem, Pfaudler® Nucerite could be the answer, since it resists corrosive vapors at temperatures that would destroy most metals in minutes.

If high-temperature stability is what you're looking for, consider that Nucerite can protect a base metal from oxidation at 2000° F.

Impact strength? Only a minor surface crush is what you get on Nucerite with a point-of-impact force eighteen times greater than what's needed to shatter safety glass. Thermal shock? Nucerite can take an instantaneous temperature differential of 1200° F.

WHAT IT IS. Nucerite is properly classified as a family of ceramic-metal composites in which a ceramic formulation is physically and chemically bonded to a structural base metal.

NOT A GLASSED STEEL. After the ceramic component is applied and fired on, controlled nucleation and crystallization take place during heat-treatment as a result of agents which act as centers of nucleation.

This leads to a ceramic structure with a large number of very small crystals and results in a tough ceramic-metal composite with a unique combination of properties.

Today, Nucerite is a laboratory achievement.

You are invited to make inquiries on possible applications for it and investigate field testing programs. The above lab test data are detailed in Bulletin 999. Please direct your inquiries to our Pfaudler Division, Dept. SA-120, Rochester 3, N. Y.

FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

*Patent applied for

PFAUDLER PERMUTIT INC.

A world-wide company with plants in Germany, Great Britain, Canada, Mexico, Japan, as well as the U.S.A.

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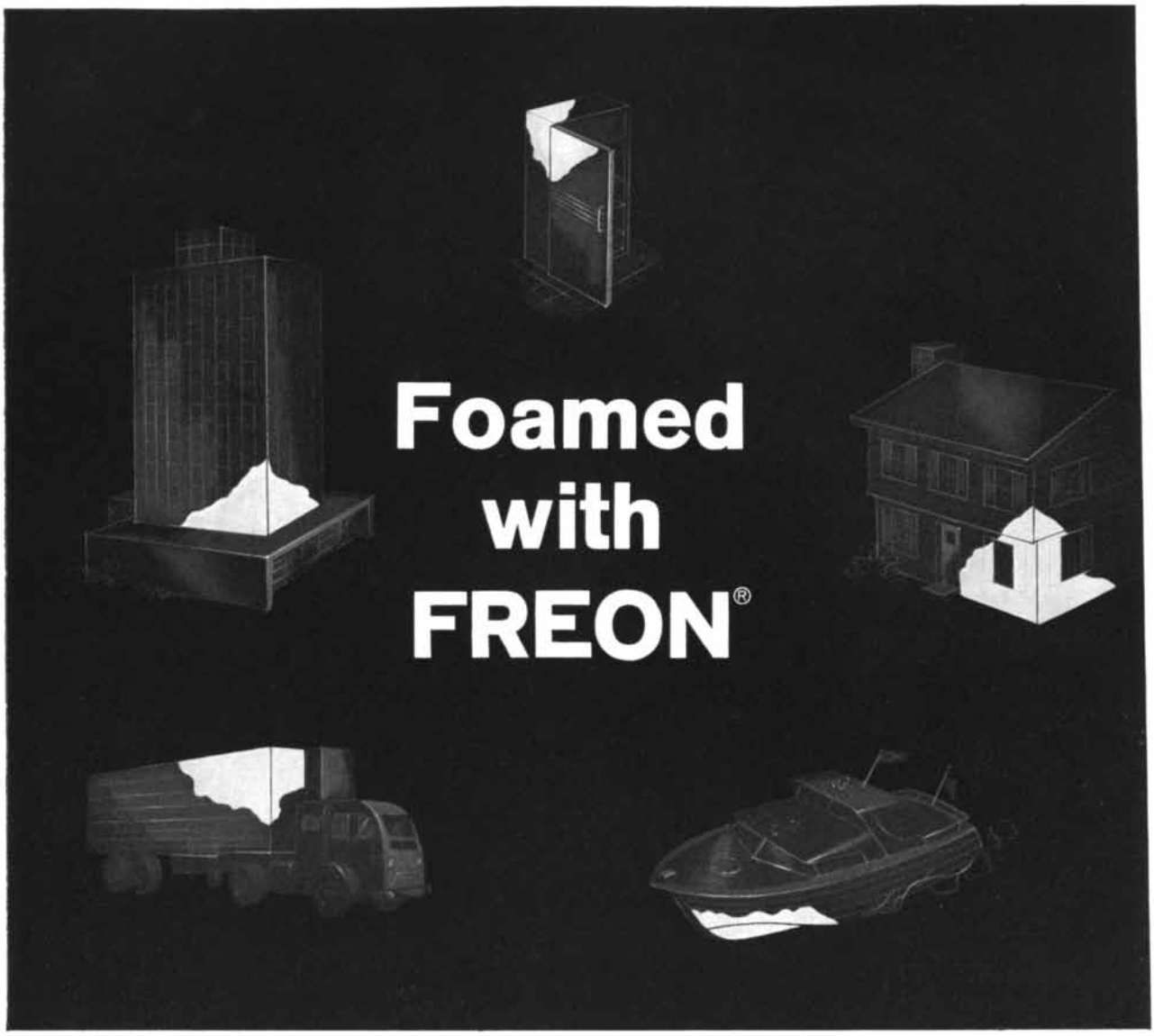

New, rigid urethane foams are filling a void in many industries

New answers to problems of insulation, structural design and costs are being provided daily by the versatile qualities of improved urethane foams—especially foams blown with Du Pont "Freon" blowing agents.

Twice the insulation possible with conventional materials of the same thickness is now obtainable from urethane foams blown with "Freon". And for the same degree of insulation, you need but half the thickness.

Surprising strength makes improved urethane foams an excellent, lightweight structural material. Adhesive tenacity bolsters this strength even more, permits use of foam for bonding purposes.

Lowered costs result from the ability of "Freon" blowing agents to produce more foam from the same base materials. The foams themselves often require just half the volume to equal other materials in performance. And you can get the installation versatility and convenience of foaming in place.

Other features—exceptional buoyancy and water resistance for marine use, freedom from rot, controllable density, vibration dampening, resistance to aging and chemical action.

Technical assistance is available from Du Pont to help you test the physical capabilities of your foams blown with "Freon", and to help you produce foams to meet your specific needs.

For more information, write: E. I. du Pont de Nemours & Co. (Inc.), "Freon" Products Div., N-2420, Wilmington 98, Delaware

FREON®
BLOWING AGENTS

DU PONT
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Better Things for Better Living... *through Chemistry*

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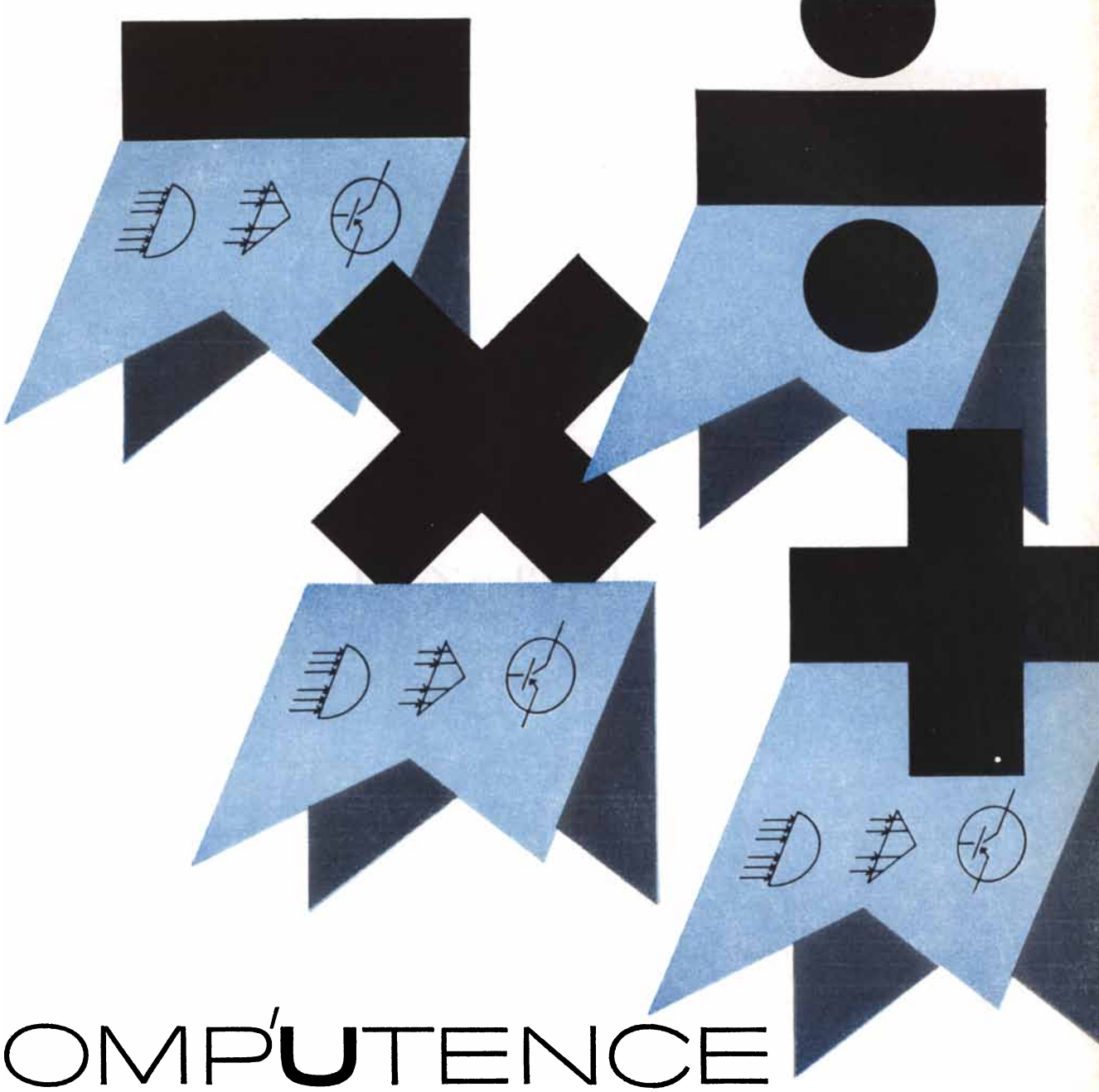

COMP'UTENCE

total competence in computation and data processing—the breadth, the brains and the background

The term: created by necessity to distinguish the new concept in computation—the computation of Burroughs Corporation. **Domain:** weapons systems, support systems for space, air, land and sea. **Qualifications:** 75 years devoted to computation and data processing; membership on Polaris and Atlas teams; system management of the ALRI team; facilities that range from basic research through production to field service. **Credentials:** high-speed computation for Polaris, miniaturized airborne data processors for ALRI, the Atlas computers that guided Explorer I, Transit and Midas satellites into orbit. **Destination:** the unknown, where total competence in computation and data processing crystallizes into Comp**u**tence to point the way.

Burroughs Corporation Burroughs *"NEW DIMENSIONS / in computation for military systems"*

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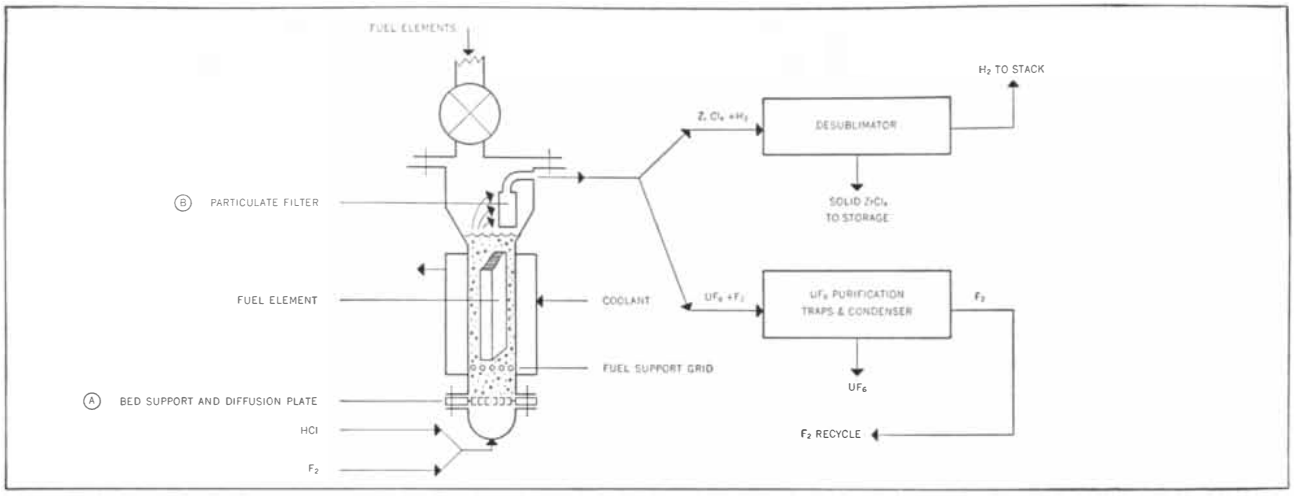

$Zr + 4HCl \rightarrow ZrCl_4 + 2H_2$
$U + 3F_2 \rightarrow UF_6$

. . . and it wouldn't be possible without the Purolator filter that helps cut nuclear fuel reprocessing time from 24 hours to 1½

The latest achievement in reducing the prohibitive fuel-cycle costs of nuclear energy is a fluidized bed halogenation process that provides clean separation of uranium from a zirconium-uranium fuel element. This new process, a big improvement on conventional gas phase volatility processes, was developed at Brookhaven National Laboratory. It would not be operable without two Purolator developments: an Inconel metal-edge distributor plate, A, which is faced on both sides with porous metal; and an Inconel frameless metal edge filter, B, which is faced on the outside with porous metal.

The principal advantage of the fluidized bed technique is its speed in recovering uranium from spent fuel elements. The standard gas phase process takes 24 hours; with a fluidized bed, recovery time is cut to 1½ hours, and the reaction is more uniform and more easily controlled, too.

To operate the Brookhaven pilot plant, a 10″ section of spent fuel element is submerged in a mass of inert granular material that is suspended in a mobile, or fluidized, state, by introducing hydrogen chloride gas at suitable velocity at the bottom of the reactor vessel. The Purolator-designed diffuser plate assures complete dispersion of the HCl through the granular bed. Inconel, a porous metal, is used to face the top and bottom surfaces of the plate, to resist the corrosion and the reaction temperature of the fluidized bed, which ranges from 400-450°C.

By creating a reaction in a fluidized bed, coefficients of heat transfer as high as 400 Btu/Hr x Ft² x °F have been observed, with corresponding reaction rates up to 6000 mg per cm²/hr, much higher than could be achieved if gas were the sole coolant. The upward velocity of the gas required to sustain the bed in a fluidized state tends to raise minute particles of uranium above the bed. The metal-edge Purolator filter effectively screens these particles to prevent their loss. The filter that Purolator designed for the Brookhaven installation is composed of a continuous Inconel spiral with integral risers, coated with a thin facing of Inconel which ensures an average filtration of 1 micron.

Performance to date has been so successful that the Brookhaven team plans to build a pilot plant halogenator to conduct complete hydrochlorination and fluorination reactions on full-scale fuel elements. The full-scale production unit will incorporate six Purolator Inconel filters. In addition, because of its corrosion resistance, Inconel will be used as construction material for the halogenator vessel, instead of the present stainless steel.

Presumably you don't have the problem we've just described, but it is a good case in point that Purolator can filter anything that flows. And if your problem (whatever it is) could conceivably involve a filter or a separator, Purolator can help you. Our address: Purolator Products, Inc., Dept. 2683, Rahway, New Jersey.

Filtration for Every Known Fluid **PUROLATOR**

PRODUCTS, INC.

RAHWAY, NEW JERSEY, AND TORONTO, ONTARIO, CANADA

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The adhesive you "fit" into place

Many bonding jobs can now be speeded up with dry film adhesives that can be cut to shape for easier, no-waste application.

These unusual Armstrong adhesives are especially useful where irregular bonding surfaces are a problem. But they are equally convenient and clean to use for many other adhesive operations.

For example, these adhesives require no mechanical application systems. And, because they are 100% solids, no volatile solvents are present to contaminate the air or create a fire hazard.

The controlled coverage possible with dry adhesives eliminates waste. You buy film in the thickness required and put it only where needed. There are no "missed" or thin spots to weaken the finished product.

To get the exacting combination of sealing qualities needed for the endcap-to-filter bonding job shown above, Armstrong developed new N-183 film. Where greater strength is required—bonding automotive brake linings to brake drums for example—Armstrong N-199 tape provides it.

Film adhesives offer speed and convenience unmatched by other thermosetting adhesives. Curing cycles can be as low as one minute at 300° F. Tensile strengths of 5,000 to 7,000 psi are possible with a 20-minute cycle at 400° F.

A cured film bond is rigid yet resilient and highly resistant to water, oil, brake fluids, and most solvents. Intermittent exposure to temperatures up to 450° F. has little effect on the bond.

A wide variety of materials—including metal to metal, and synthetic rubber or phenolic laminates to metal—can be joined with tape adhesives. Both N-183 and N-199 adhesives come in tape widths up to 15″ as well as die-cut films and thicknesses from .010″ to .030″ are available.

Samples for test purposes are now available. Please give tape width and thickness desired when ordering. Or submit parts—along with information on service requirements—to Armstrong for laboratory bonding. Write on your company letterhead to Armstrong, 8012 Inland Road, Lancaster, Pa.

Armstrong ADHESIVES

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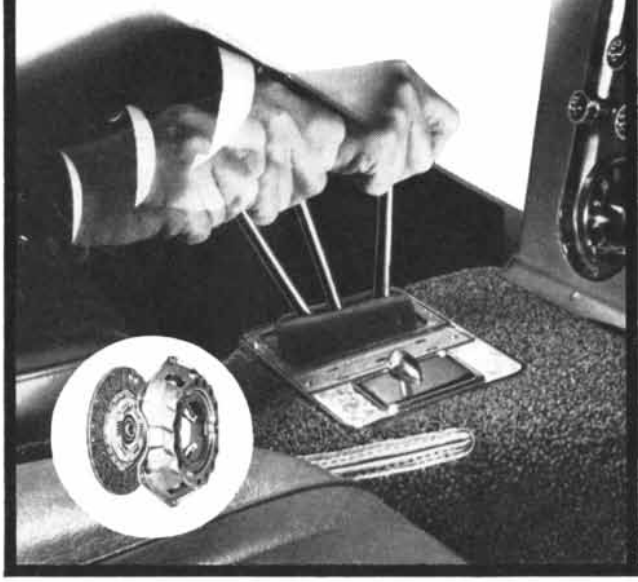
Craftsmanship in a clutch for smooth "stick shift" driving...

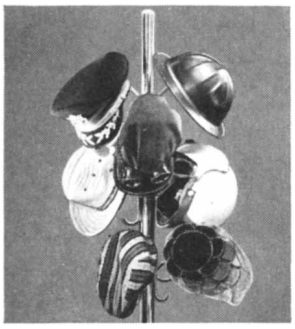


...also shows up in "erector set" simplicity of electronic cabinetry!

"Welcome back, standard transmission," says a fast-growing number of car-owners! A great majority of those who buy sports cars specify the "stick shift" for the fun of it . . . while 49% of all "compact" cars are so equipped for economy's sake. B-W's Borg & Beck Division makes these clutches—whose fast, smooth, dependable operation has been legend since 1913—for most major auto-makers.

Height? Depth? Style? Opening? Name your needs in metal cabinets, and Ingersoll Products Division can fill them immediately from over 600 basic frames in the Emcor enclosure system. By combining Emcor units (even the screwdriver is provided!), you can "custom create" an equipment bank—without costly production of custom cabinets. Above: Emcor houses "nerve center" of a new high speed wind tunnel.

back of both... **BORG-WARNER®**



The 7 Hats of Borg-Warner . . . *(top)* national defense; oil, steel and chemicals; *(middle)* agriculture; industrial machinery; aviation; *(bottom)* automotive industry; home equipment.

What does Borg-Warner mean, in the slogan below, by "better products through creative research . . ."? Just this: an automatic control rod drive mechanism, designed by the researchers of B-W's Marvel-Schebler Products Division, for safe remote control of nuclear power in atomic-generated electricity plants. And this: longer-lasting, more accurate engine timing with an automotive timing chain developed by the Morse Chain Company (a B-W subsidiary). And also this: a uniform-flow pump, researched into reality by the Wooster Division, to power the hydraulic system that gives farmers fingertip control of tillage tools. The pursuit continues. At the modern Roy C. Ingersoll Research Center and throughout the extensive facilities of Borg-Warner's divisions, a multitude of talents are dedicated to exploratory and applied research—translating ideas into better products.

B-W

BORG-WARNER

BETTER PRODUCTS THROUGH CREATIVE RESEARCH AND ENGINEERING

Borg-Warner Corporation • 200 South Michigan Avenue • Chicago 4, Illinois

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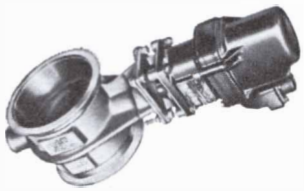
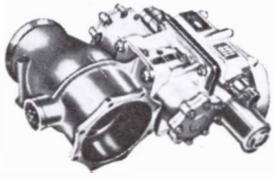


High pressure, high temperature butterfly valve.

Hot gas control valve.

Ice pre-sensing and control devices.



High temperature pressure regulator.

PRECISION PRODUCTS DIVISION

WESTERN GEAR CORPORATION

WESTERN GEAR ENTERS VALVES, CONTROLS FIELD

by R. B. WORL
Sales Manager
Precision Products Division

Precision Products Division of Western Gear has aggressively entered the controls field and now makes available a complete line of electro-magnetic valves, hot air and gas valves, time and pressure switches, pressure regulators and related control equipment and specialized test equipment for application in missile, rocket and aircraft systems.

Precision Products Division will utilize designs and products of Teddington Aircraft Controls Ltd., recognized leader in the controls field throughout the world, under terms of a cooperative sales, service, engineering and manufacturing agreement.

Present applications include Rolls-Royce powered DC-8s, Boeing 707s, Fairchild F-27s, Caravelles, and numerous missiles.

Western Gear's Precision Products Division has long specialized in aircraft, rocket and missile components and systems as well as ground handling and test equipment.

For full information on Western Gear valves and controls, call or wire collect: Precision Products Division, P.O. Box 192, Lynwood, California; NEvada 6-0911.

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A MAJOR CAUSE OF FAILURE ELIMINATED BY BUILDING A TRANSISTOR INSIDE ITS OWN SHELL

Most transistor failure is not abrupt. It consists of surface changes causing a gradual shift in parameters. While the whole industry has sought answers, Fairchild has followed a research and development course of its own. We can now reveal a unique solution.

Called "PLANAR STRUCTURE," this Fairchild answer uses a passivated surface — a hard, passive coating of silicon oxide — not new in theory, but new in the way it is done. Fairchild oxidizes the surface first. Then the transistor's junctions are diffused **under the oxide.** Contaminants cannot reach them during process or after. Result: performance is unchanged by time, use, environment or even exposure to foreign matter.

Planar is the answer: for system reliability where thousands of transistors must all be operative at an instant — for fast, simple circuits tightly packed in minimum space — for carefully matched pairs, triplets or quads that must stay exactly in balance — and for leakage reduction by a factor of one hundred. And planar is the answer even for simpler circuit requirements where high assurance has a value.

These advantages apply to planar diodes,too. Of course, Fairchild planar silicon transistors and diodes are available in production quantities. A new 12-page brochure explains the process and results more fully. May we send you a copy?

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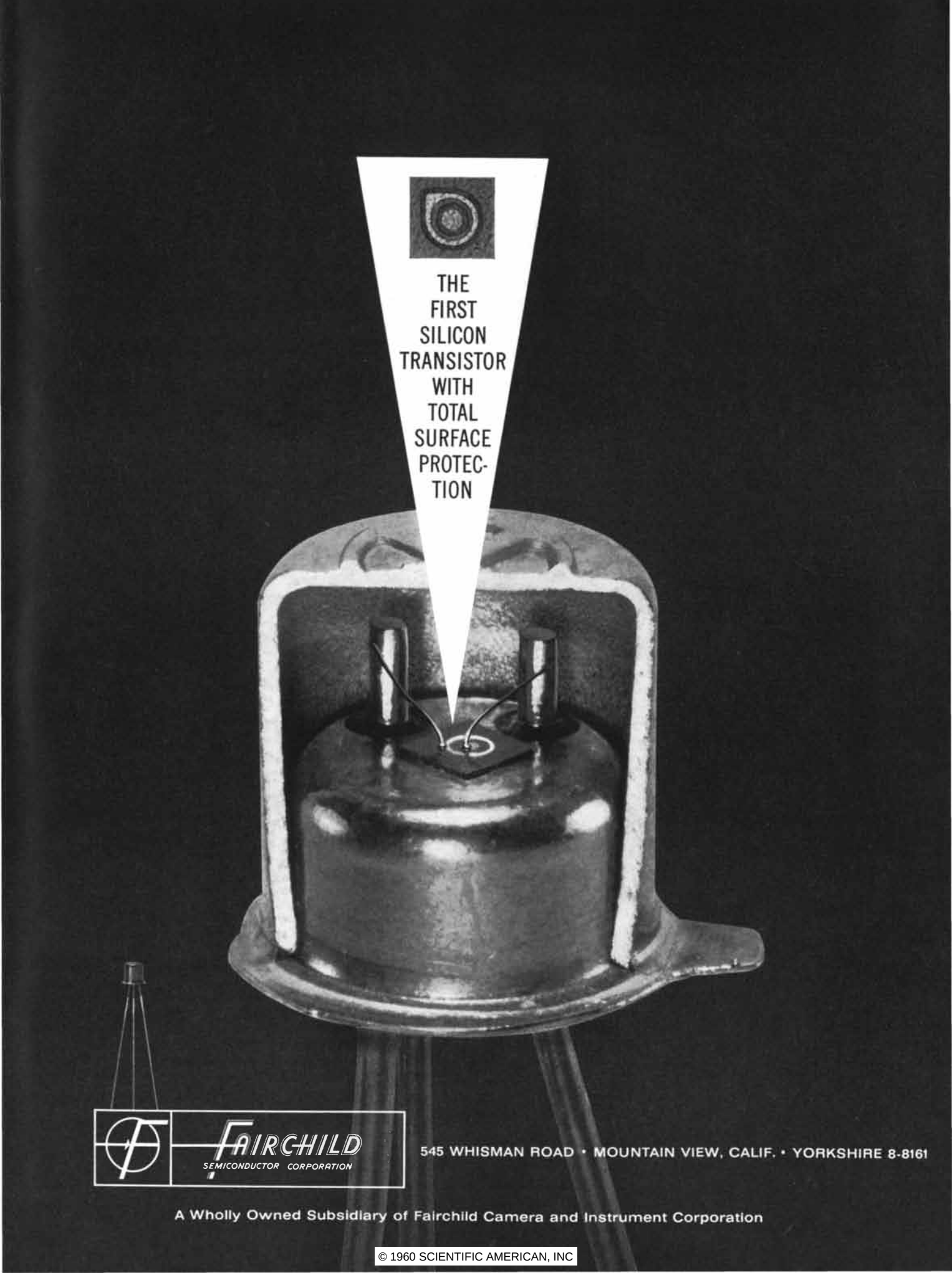

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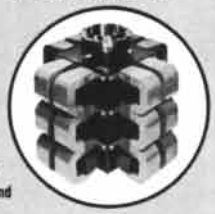
Think Clean

When you think of high vacuums, you have to think clean... and if you think of exceptionally clean vacuums, without fluids or other contaminants, you have to think of UlteVac electronic vacuum pumps —made by Ultek, the only manufacturer devoted exclusively to the technology of fluidless vacuum pumping. UlteVac pumps, using no moving parts, hot filaments, or refrigeration, produce vacuums to 10^{-9} mm Hg and below; operate unattended for months, invulnerable to power failure. System vacuum automatically measured.

ULTEVAC®

ELECTRONIC HIGH-VACUUM PUMPS

1 to 1000 Liters/Second



Series 327 Pump
270 Liters/Second

Also from Ultek, an exclusive line of high vacuum accessories, including:

- SORPTION ROUGHING PUMPS
- METAL SEAL FITTINGS
- FULL CONDUCTANCE VALVES
- AMBIENT FORELINE TRAPS

Literature available (state application) from Ultek or its exclusive sales representative, Kinney Mfg. Div. of the New York Air Brake Co. Sales Offices in major U. S. cities.

ULTEK CORP.

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LETTERS

Sirs:

In emphasizing sexual attraction as the major basis of subhuman primate sociality, Marshall D. Sahlins ["The Origin of Society"; SCIENTIFIC AMERICAN, September] neglected several outstanding features of primate social behavior.

Four types of primate social behavior that appear in greater frequency, strength and duration than sexual bonds are those expressed in maternal behavior, juvenile play, mutual grooming and sleeping behavior. None of these is predominantly sexually motivated or oriented. Field studies that I have recently conducted on rhesus monkeys in northern India indicate that all four of these patterns of social behavior are of greater importance in maintaining sociality than sexual attraction.

In most subhuman primates the mother-infant bond remains a stable unit for approximately one year. The strength of this bond is indicated by the observation in langurs and rhesus monkeys that the mother may still retain possession of a dead infant for many days after death. The strength of this bond is also shown by frequent display of social co-operation between mother and infant....

Infant and juvenile play-groups represent another consistent social force in subhuman primates. This social grouping is based primarily on the development of motor skills rather than on sexual awareness. In both rhesus and howling monkeys, play behavior centers around chasing, jumping and wrestling; not sexual play. Sexual mounting by juveniles is frequently seen, particularly in the rhesus, but it is not clearly associated with the establishment of dominance relationships as stated by Sahlins and suggested by the Japanese primatologists. Sexual play by infants and juveniles obviously does have social significance, but I am convinced that its role in the process of socialization has been overstated.

Mutual grooming is a third type of social behavior of great importance in maintaining group unity. It occupies a major portion of time in the daily routine of adult rhesus monkeys, and is primarily associated with daytime resting behavior. There are no obvious sexual correlations of mutual grooming. It is exhibited by all combinations of ages and sexes, often in groups of three or four. Most mutual grooming does not involve sexual display or sexual excitement; it is not particularly characteristic of the sexual consort pair....

Still a fourth aspect of sociality in rhesus monkeys is the close physical contact maintained in sleeping groups during the cold winters of northern India. Closely huddled subgroups of five to 15 individuals are characteristic of the rhesus sleeping pattern in the winter season in northern India. I believe that the simple adaptive value of this social response may have been a factor in the early evolution of sociality in the rhesus.

In contrast to maternal, play, grooming and sleeping behavior, sexual behavior in most subhuman primates is less frequently observed and definitely less stable. I have observed individual female rhesus monkeys in natural groups in India copulate with three different males within a span of two hours, involving both the most dominant male and the lowest ranking peripheral male in the group. This, of course, is an important factor in socialization, but not always in the direction of group cohesion....

Hence I feel that it is an oversimplification to consider "the powerful social magnet of sex as the major impetus to subhuman primate sociability." To do so immediately biases any discussion of the origin of society into narrow and misleading channels.

CHARLES H. SOUTHWICK

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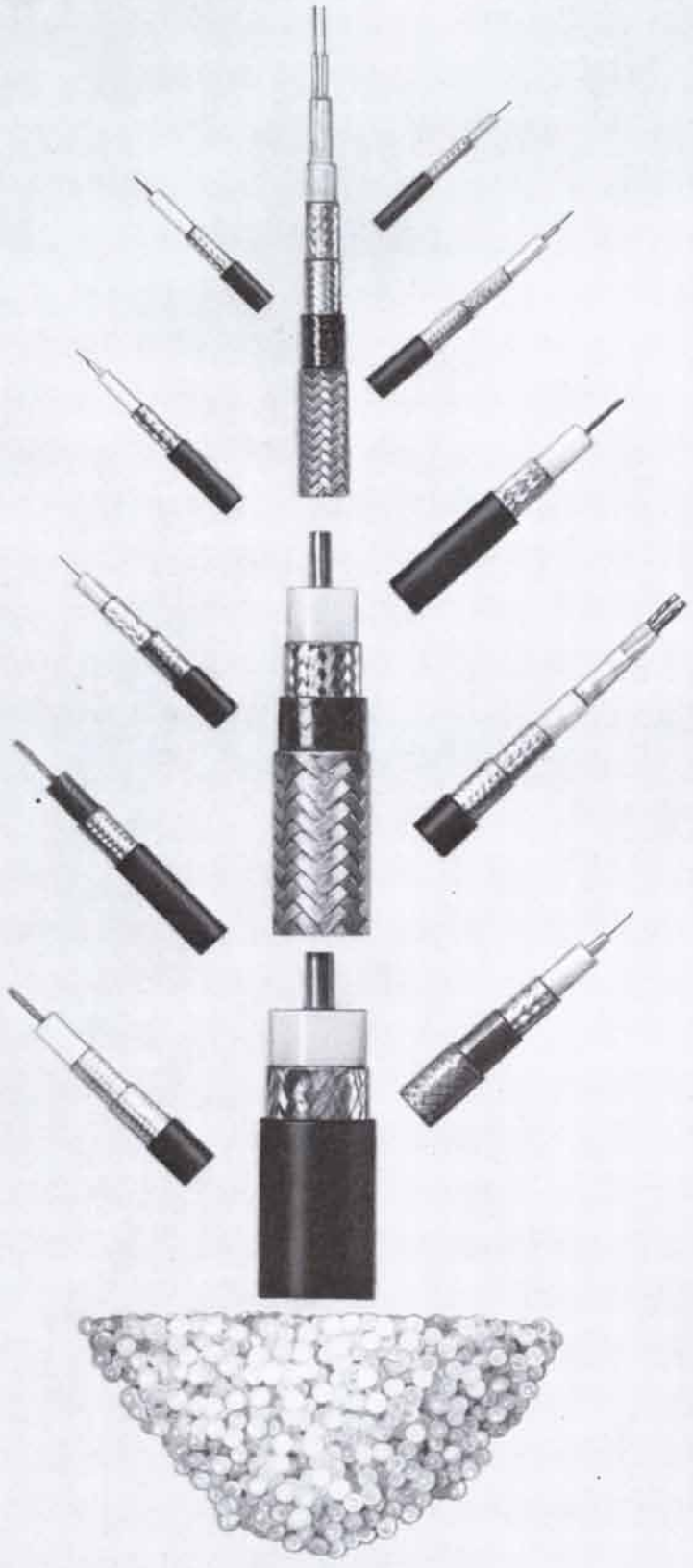

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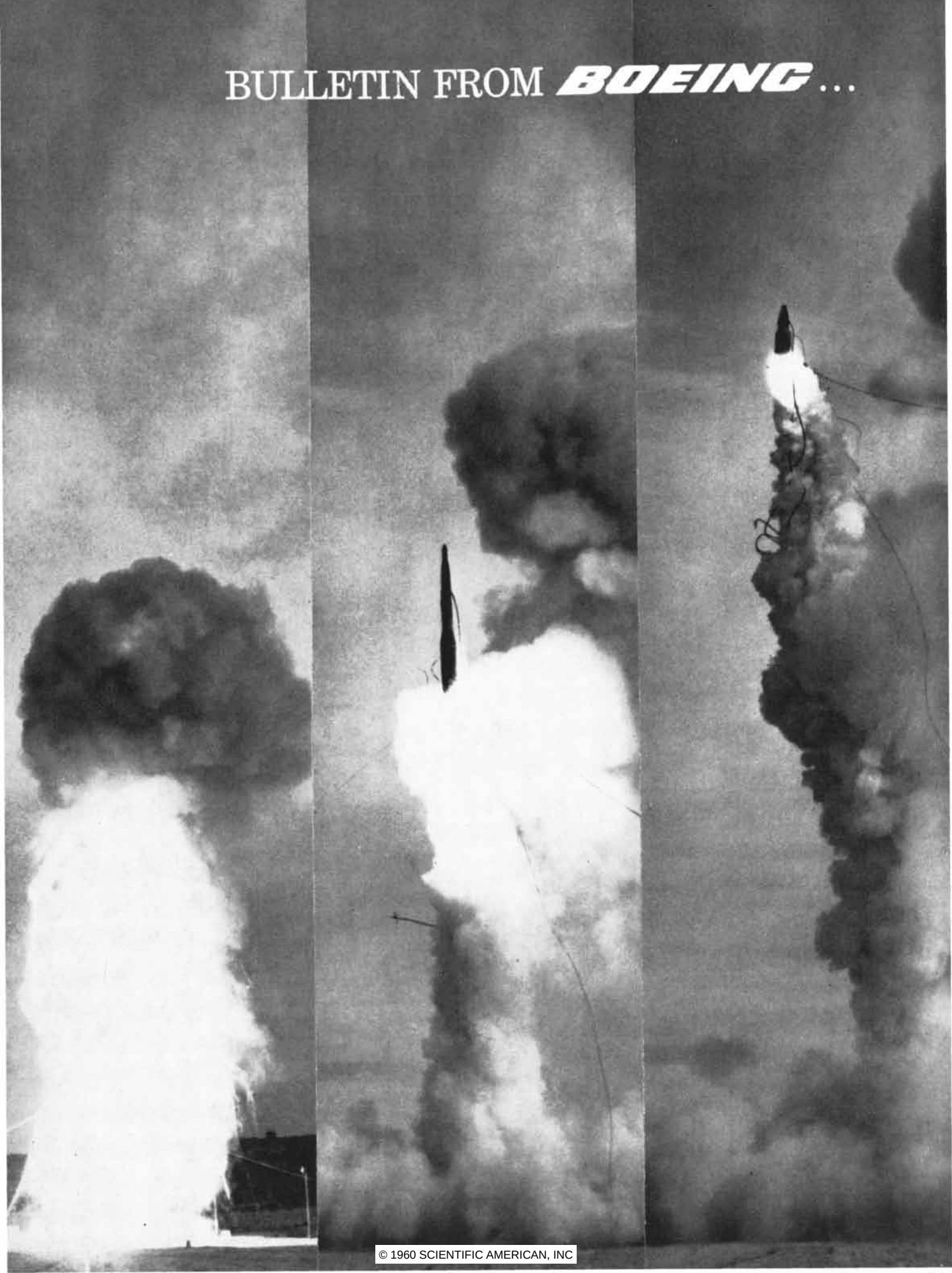

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...WHERE CAPABILITY HAS MANY FACES

Minuteman, the nation's first solid-fuel ICBM, blasts from underground silo, left, in tethered firing test. Successful Minuteman firings cut test program, saving millions of defense dollars. Boeing is weapon-system integrator of the 6000-mile-range Minuteman missile, now under development.

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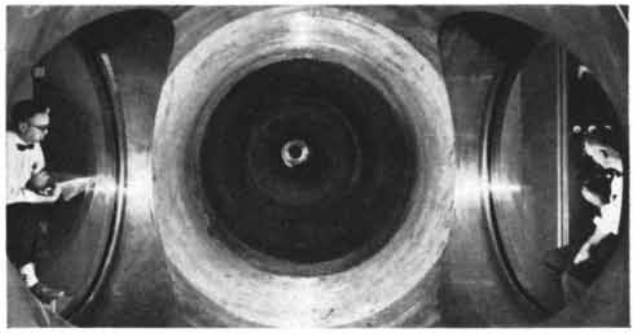

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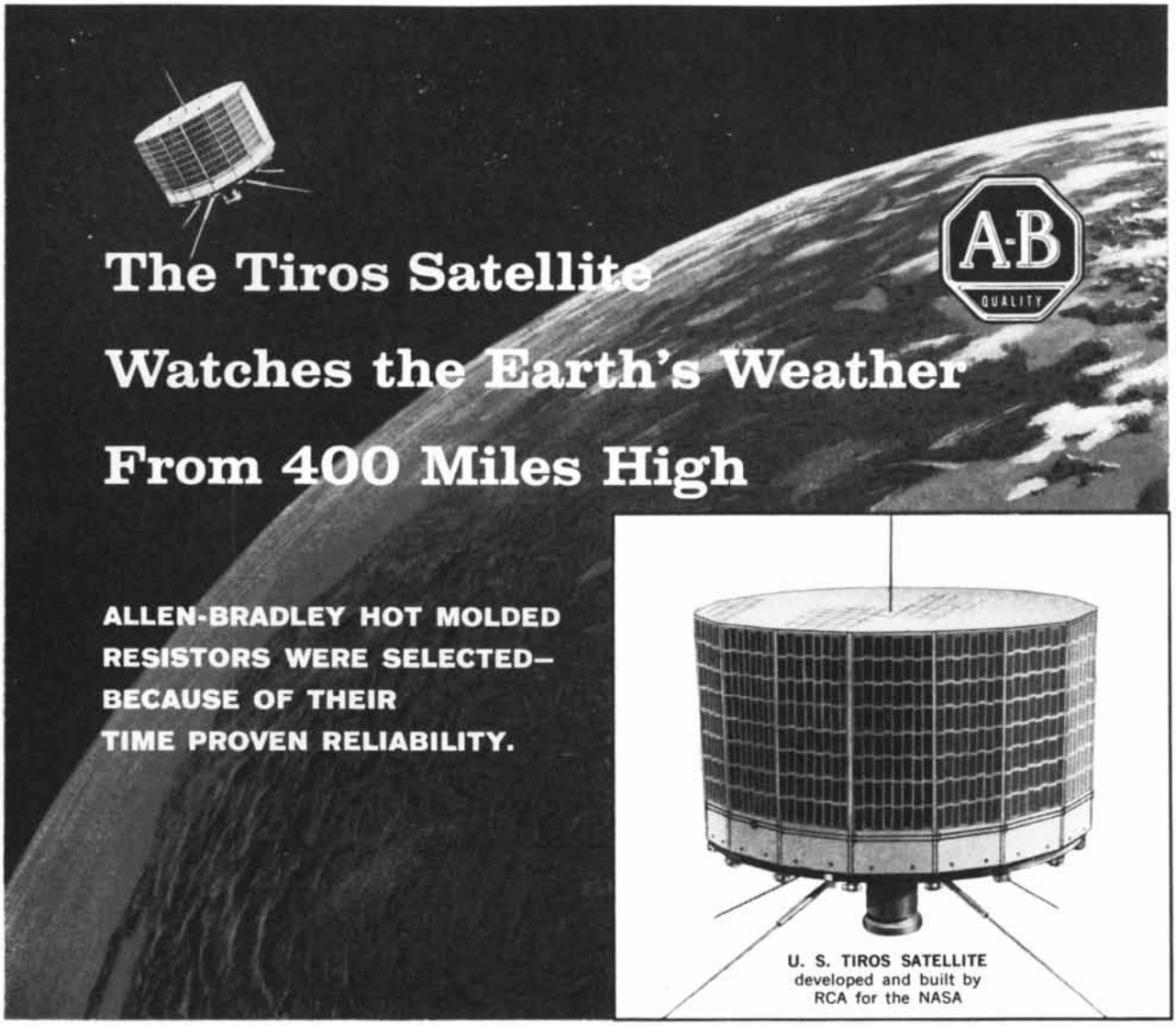

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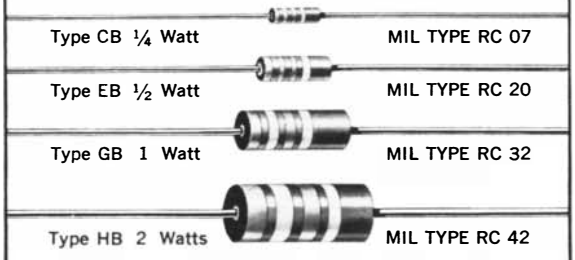

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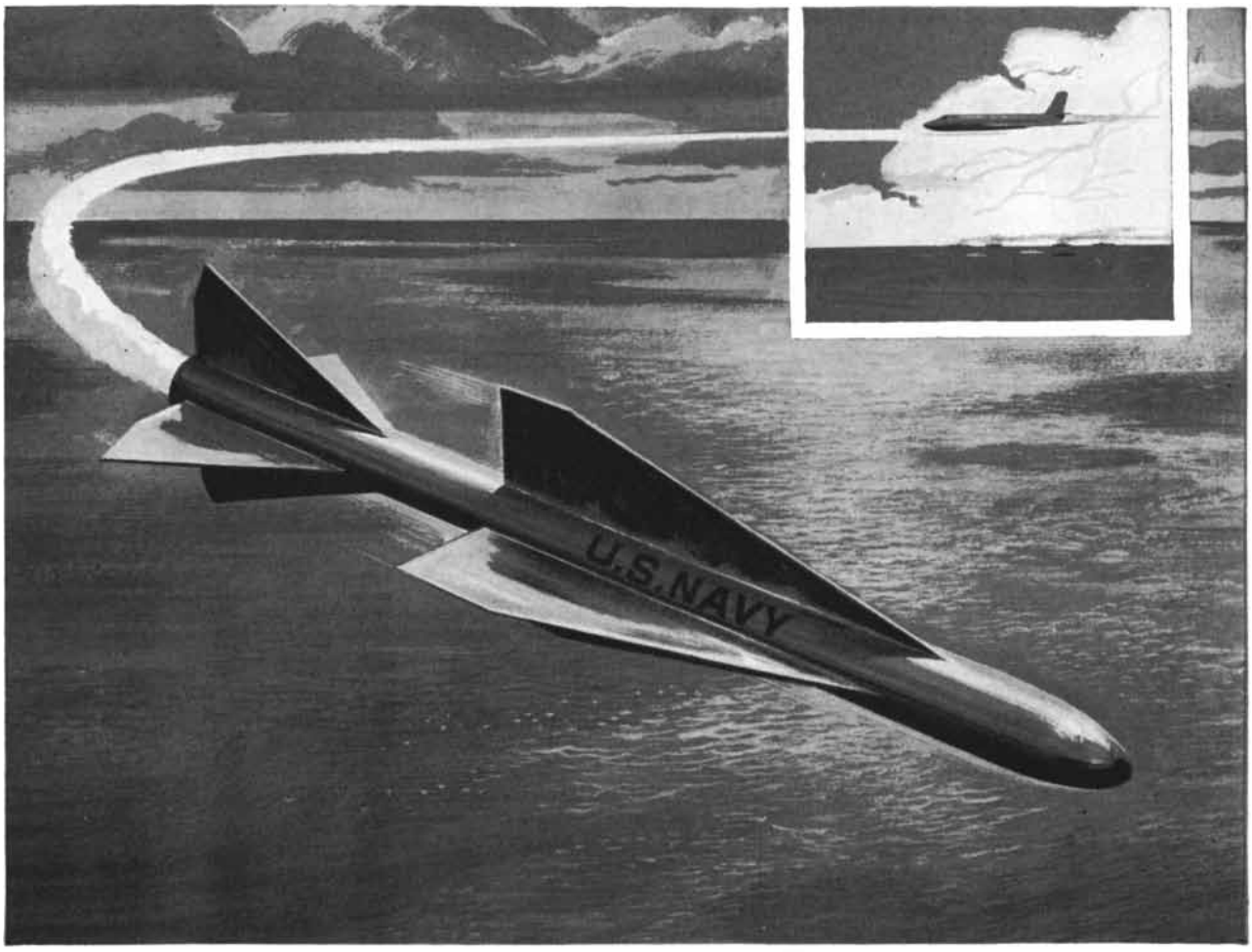

This is an artist's conception of the Eagle—the Navy's latest, long-range, air-to-air missile. It is shown being launched from a fleet aircraft (inset), and on its way to strike an enemy target.

MEET EAGLE—NAVY'S NEW AIR-TO-AIR POWERHOUSE

Eagle—the Navy's latest air-to-air missile for long-range defense—will surround task forces and marine landing operations with a veritable thicket of destructive power poised against any intruding enemy aircraft or aerodynamic missile. It will also make possible extended air control over a wide area beyond the fleet.

Eagle, for which Bendix is prime contractor, represents a new trend in that it can be launched from relatively slow aircraft, since the high performance is built into the guided missile itself rather than into the manned airplane.

Bendix is also prime contractor for Talos — the Navy's long-range surface-to-air missile. It is the principal armament of the new fleet of missile-carrying cruisers that have replaced the battleship.

Bendix is deeply involved in many other phases of this country's missile and space program. We build the inertial guidance systems that help provide the accuracy of Pershing, the Army's new, mobile, ground-to-ground guided missile. The global ground tracking, voice communications, and telemetry systems for Project Mercury—the U.S. man-in-space program—are other important Bendix responsibilities.

Bendix built two of the three U. S. satellite tracking systems and now operates and maintains them for the National Aeronautics and Space Administration. We have developed an ingenious device that steers and controls a satellite in space, and, in addition, helps remove it from orbit and directs it precisely to a designated recovery area; telemetering systems that can transmit 500 channels of information back to ground stations; general purpose digital computers that are widely used for many applications in the missile and space fields.

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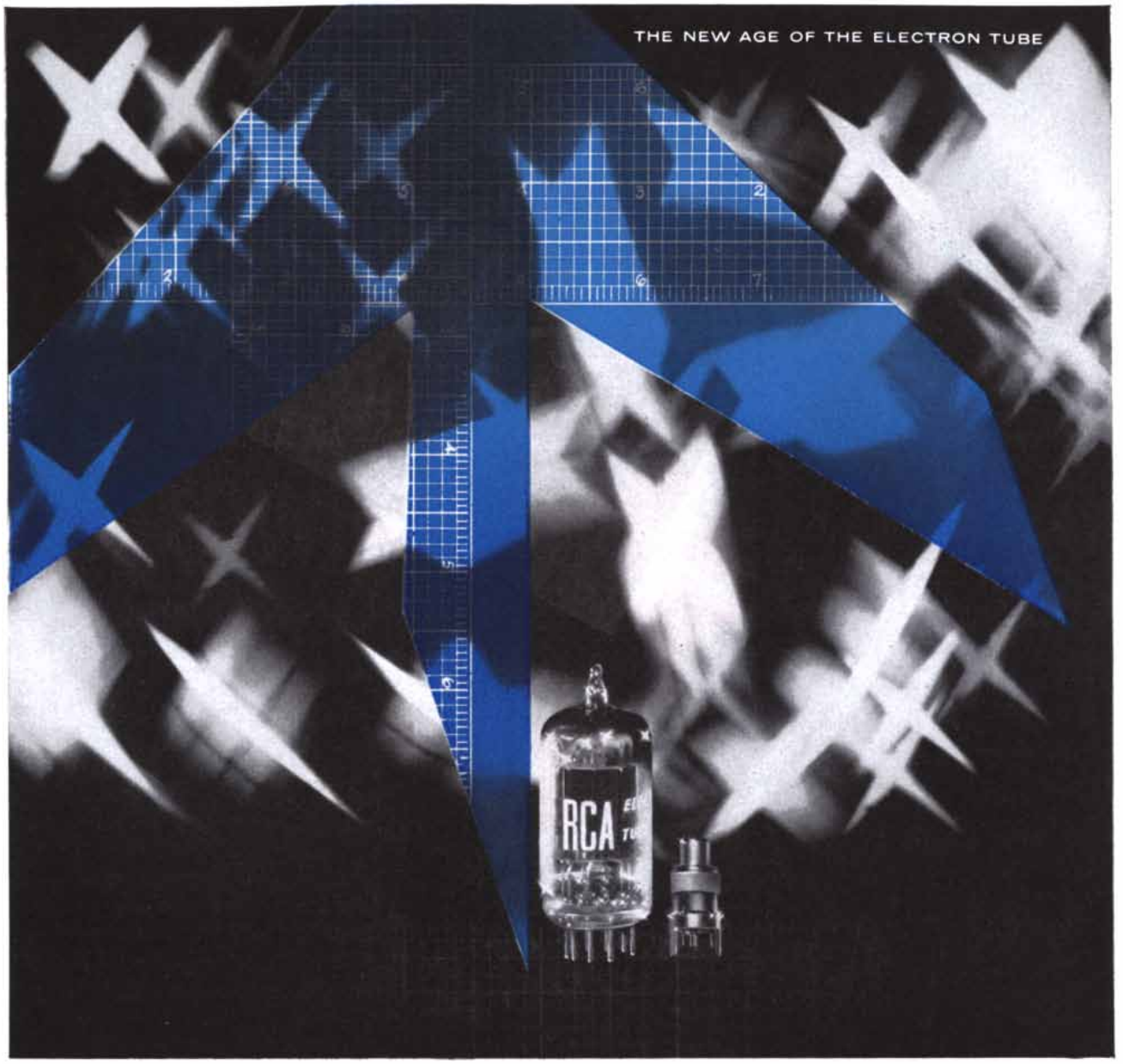

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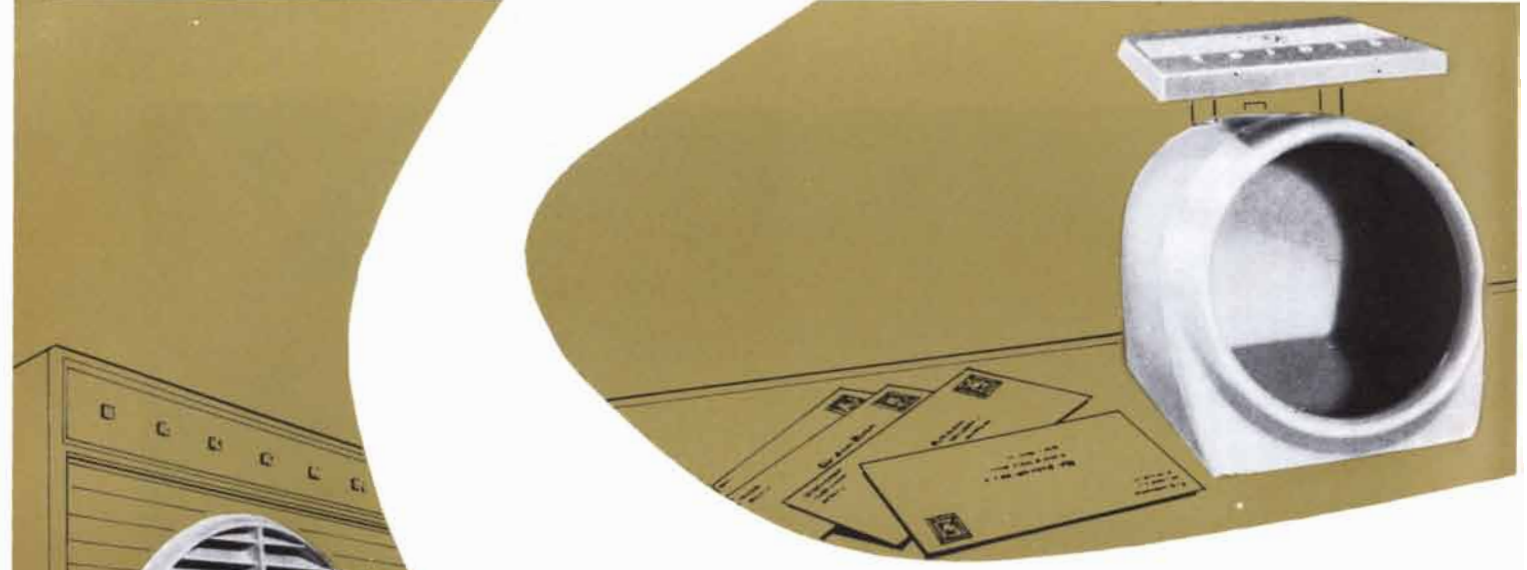

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WILL IT CUT COSTS AND IMPROVE PERFORMANCE?

Molding this air conditioner vent decreased weight, eliminated costly finishing operations and reduced material cost. At the same time, possibility of rust, tarnishing or marring was minimized.

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The re-design and custom-molding of this postal scale in high-impact plastics improved appearance and gained customer acceptance that was immediately reflected in increased sales.

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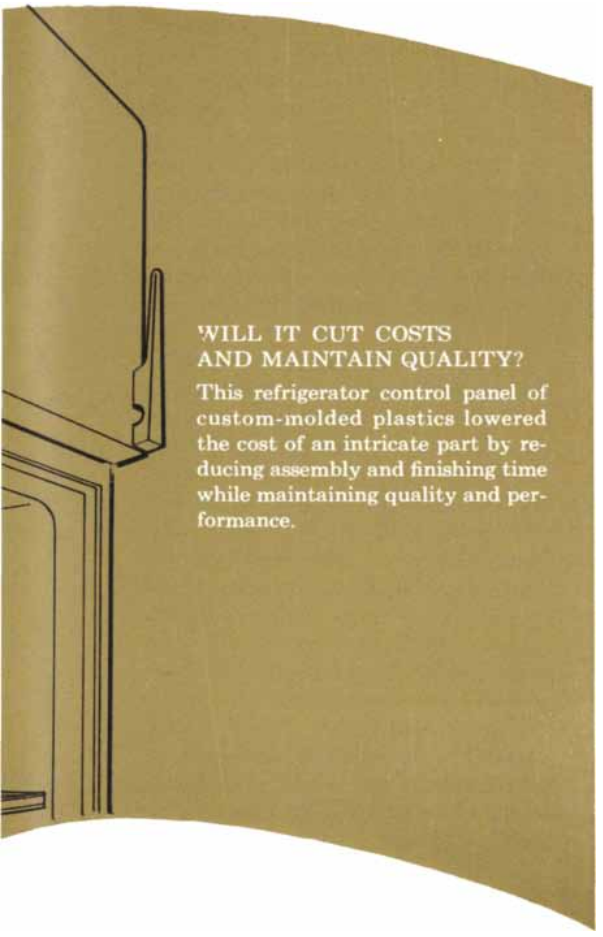

WILL IT CUT COSTS AND MAINTAIN QUALITY?

This refrigerator control panel of custom-molded plastics lowered the cost of an intricate part by reducing assembly and finishing time while maintaining quality and performance.

"Without exception, the adoption of plastic parts over previously used materials is decided only if it makes possible a ❶ reduction in price, with the same quality; or ❷ an improvement in quality, with the price remaining constant; or ❸ a reduction in price and an improvement in quality at the same time."*

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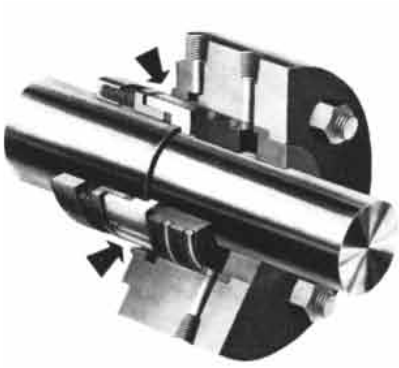

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DECEMBER, 1910: "Considerable opposition has been raised to the admission of Mme. Curie to the French Academy of Sciences. For the first time the question of the eligibility of a woman for any one of the five academies has formally been placed before the central committee."

"The population of the U. S., excluding Alaska and our island possessions, has been announced by the Census Bureau as 91,972,267. This represents an increase during the decade of 21 per cent, which is two and a half millions greater than that of the decade 1890 to 1900. The significance of this will be realized when it is stated that previous to the present decade, the percentage of increase had been falling."

"Comparing naval vessels completed, under construction or authorized, the statistics for the close of this year show that Great Britain possesses 548 vessels, aggregating 2,173,838 tons in displacement; the U. S. has 177 vessels aggregating 878,152 tons; Germany, 255 of 963,845 tons aggregate. In spite of Germany's strenuous efforts to defeat Great Britain's scheme to maintain a navy equal to that of any other two powers combined, the U. S., when all points that make for efficiency are considered, is nearly, if not altogether abreast of Germany."

Scientific American

DECEMBER, 1860: "What will become of the Patent Office if the Union is dissolved? The dissolution of the Union can only be effected by a secession of some of the States. This would not necessarily break up the Federal Government, and for the present its seat of power would remain at Washington. Should the Government acquiesce in the peaceful secession of the States, then to all intents and purposes these States would be regarded as foreign countries, and their citizens treated accordingly. But the business of the Patent Office would still go on, and all applicants for patents would be dealt with according to law. Citizens of a seceding State would, under such circumstances, be subject to all the legal inabilities imposed on foreigners. We believe we have stated the matter fairly and correctly, without reference to any of the political issues that connect themselves with the subject."

"Our attention has been called to a novel mode of buoying steamboats over bars and shoal places in rivers, the invention of no less a personage than the President elect of the United States. Buoyant chambers, with tops and bottoms of boards or metal plates, and the sides of flexible material, are secured at the sides of the vessel under the guards. Stiff rods are secured rigidly to their bottom boards, so that by pushing down these rods the chambers are expanded, and by drawing the rods up, the chambers are folded under the guards snugly. The merits of this invention we are not disposed to discuss; but we hope the author of it will have better success in presiding as Chief Magistrate over the people of the entire Union than he has had as an inventor in introducing his invention upon the Western waters for which it was specially designed."

"Mr. Donald McKay of Boston states that a new epoch has commenced in naval construction which will render our very best frigates obsolete. In France and England they have just built several mail-clad warships, of which Mr. McKay says, 'It is generally acknowledged that no naval power, which will not lose entirely her authority on the seas, should be without a number of these frigates.' And he affirms that, with a few such ships, and 20 screw line-of-battle ships, with as many more frigates, our whole navy could be cooped up by either England or France within the shelter of our land batteries, our whole coast blockaded and our merchant fleet perhaps entirely annihilated."

"The Commissioner of Patents has refused the application of Dr. Morton for a renewal of the patent granted to him and to Dr. Jackson in 1846 for the use of sulphuric ether to promote anesthaesia. Dr. Jackson at that time assigned his share of the patent to Dr. Morton, but he has now protested against its renewal, and the Commissioner decided that when a patent has been originally grant-

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A HISTORIC TELEPHONE EXPERIMENT BEGINS IN AN ILLINOIS TOWN

New technology brings the dream of an electronic central office to reality . . . foreshadows new kinds of telephone service.

Today, the science of communications reaches dramatically into space, bouncing messages off satellites. But an equally exciting frontier lies closer to home. Bell Telephone Laboratories engineers have created a revolutionary new central office. At Morris, Illinois, an experimental model of it has been linked to the Bell System communications network and is being tried out in actual service with a small group of customers.

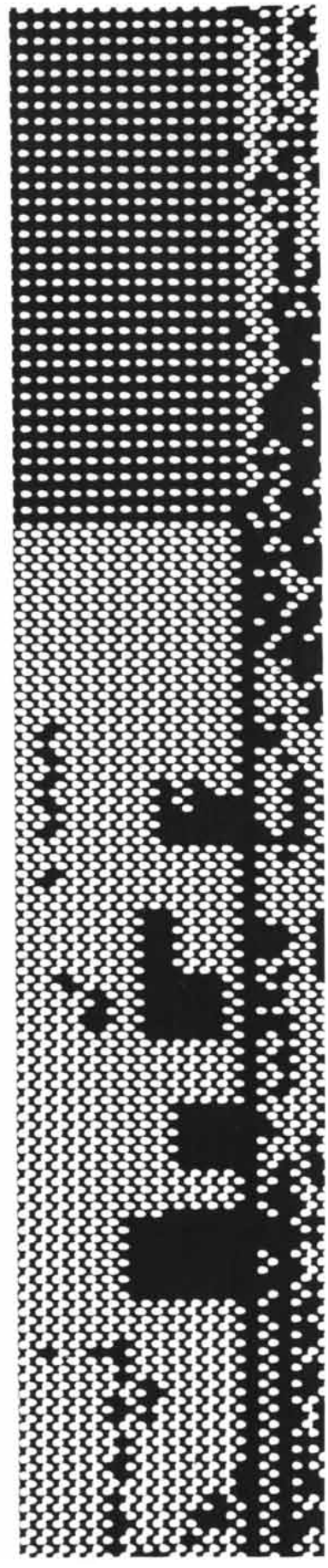
This is a special electronic central office which does not depend on mechanical relays or electromagnets. A photographic plate is its permanent memory. Its "scratch pad," or temporary memory, is a barrier grid storage tube. Gas-filled tubes make all connections. Transistor circuits provide the logic.

The new central office is versatile, fast and compact. Because it can store and use enormous amounts of information, it makes possible new kinds of services that will be explored in Morris. For example, some day it may be feasible for you to ring other extensions in your home . . . to dial people you frequently call merely by dialing two digits . . . to have your calls transferred to a friend's house where you are spending the evening . . . to have other numbers called in sequence when a particular phone is busy.

The idea behind the new central office was understood 20 years ago, but first Bell Laboratories engineers had to create new technology and devices to bring it into being. A Bell Laboratories invention, the transistor, is indispensable to its economy and reliability.

This new experiment in switching technology is another example of how Bell Telephone Laboratories works to improve your Bell communications services.

BELL TELEPHONE LABORATORIES
World center of communications research and development



Part of a memory plate of the new electronic central office is shown at right (enlarged 8 times). Spots are coded instructions which guide the system in handling calls and keeping itself in top operating form. Over two million spots are required. Logic and memory are physically separated in the machine, so new functions can be easily added. The experiment is being conducted in co-operation with the Illinois Bell Telephone Company and the Western Electric Company.

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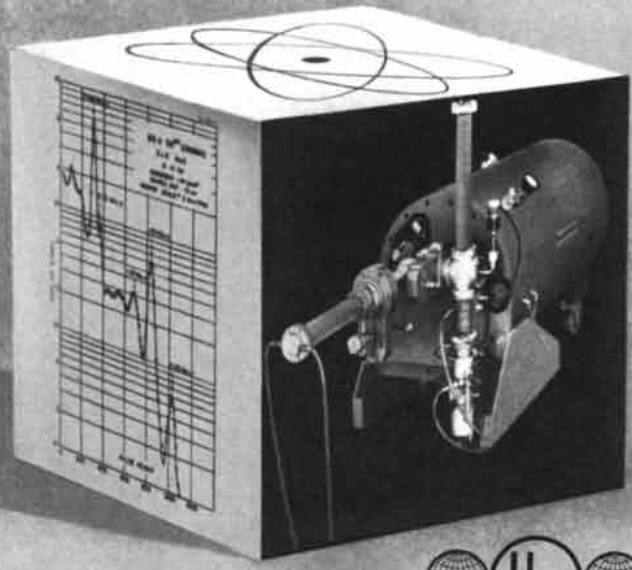

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ed to joint discoverers, they must unite in an application for renewal."

"The new museum (partly built) of comparative zoology at Cambridge, Mass., is to be 360 feet long, with wings each 200 feet long, making the whole 760 feet in length, with a uniform width of 60 feet. The height of that part of the museum already opened is four stories, and is fireproof, with arched ceilings and massive iron supports. This museum was projected by the learned and indefatigable Agassiz. Twice a week it is open to all teachers in the state of Massachusetts, who may seek to gratify their curiosity or improve their minds. This museum already contains a most splendid collection of specimens, there being no less than 3,500 species of fishes, which makes it take the third in rank in this department with the museums of Europe. As our country is so extensive, and the sources so numerous and varied for securing specimens of natural history, we have no doubt but the Cambridge museum, if it had the funds to purchase and transport specimens, would soon be the very first in the world."

"It has been ascertained that our sun is one of an innumerable multitude of stars which are grouped together in one collection or system, separated from other stars in the universe. The general form of this stellar system is an irregular wheel, with a deep notch in one side, and with a portion of another wheel branching out from it. Our sun is situated pretty near the middle of the system. The dimensions are so vast that the plan has been adopted of stating the time which a ray of light would require to traverse them. In applying this measuring rod, it is found that, through the thickness of the wheel the distance is such that light would occupy 1,000 years, and through the diameter not less than 10,000 years, in making its passage! In some directions, indeed, the system stretches away into depths of space beyond the reach of the most powerful telescopes. If we pass through these inconceivable distances out beyond the boundaries of our stellar system, we find a region of empty space. Traversing this void space through distances which appall the mind by their immensity, we find other systems of stars probably similar to our own. And astronomers are now considering the possible relation of these several clusters to each other—whether there is not a system of systems! This is the most sublime problem which has ever engaged the attention of the human mind."

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A LABORATORY IN JOHANNESBURG IS WORKING FOR YOU

Possibly you have never even heard of the Diamond Research Laboratory of Johannesburg. Yet its findings are of great importance to every user of industrial diamonds.

Established in 1947, the Diamond Research Laboratory is sponsored by Industrial Distributors (1946) Ltd. Its work is devoted exclusively to investigations on all phases of the diamond.

In its brief 13 years of existence, the Laboratory's developments have been of great significance. They include:

- increase in efficiency of natural diamond grit in resin and metal-bond grinding wheels
- considerable improvement in design and performance of diamond drill crowns
- development of electrolytic method of resharpening tungsten-carbide-tipped percussion drill bits
- development of diamond thermistors for highly accurate temperature measurements
- vector orientation, by X-ray, of diamond tool stones

Obviously, this intensive—and costly—research cannot be carried on by individual users of industrial diamonds. But Industrial Distributors, world distributors of natural industrial diamonds, has undertaken this responsibility for interested users throughout the world.

The Diamond Research Laboratory is in Johannesburg. But it's working for *you*.

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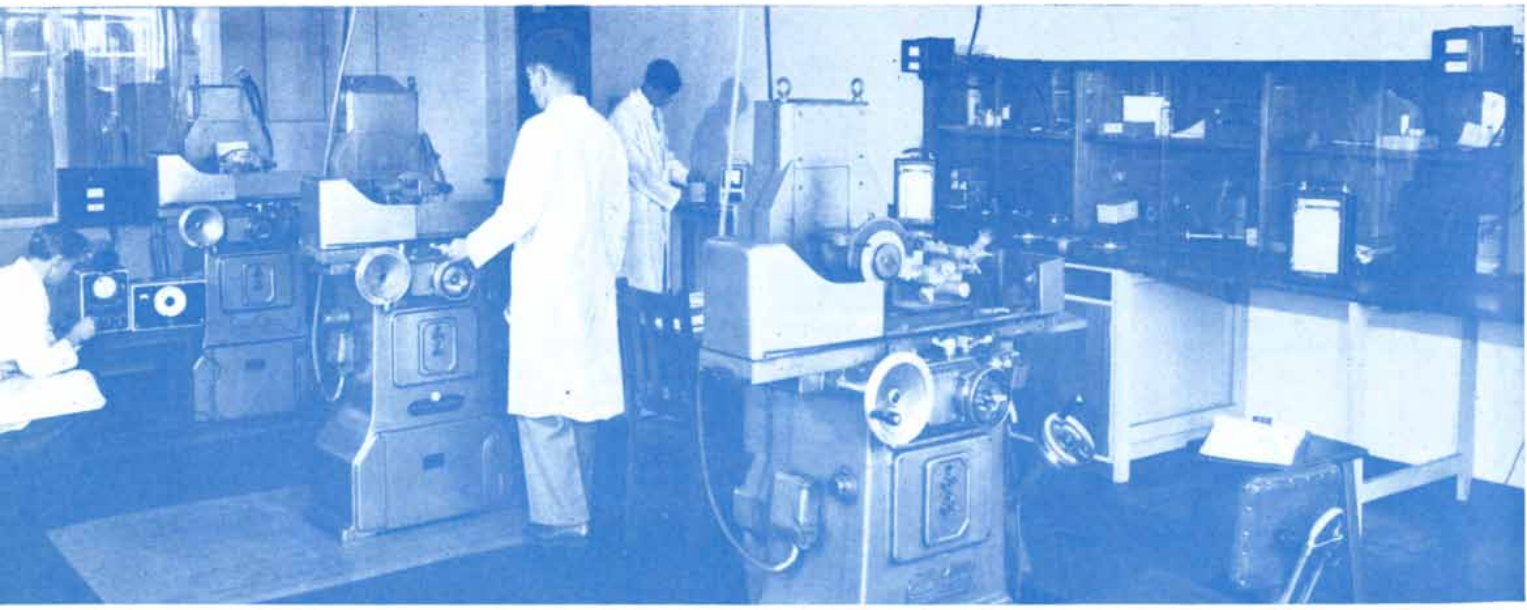
Resin-bonded diamond grinding wheels are tested in a carefully controlled experiment. In two years of testing, 450 separate wheels were used to grind away two tons of carbide.



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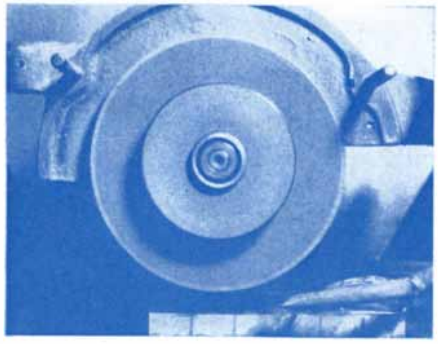
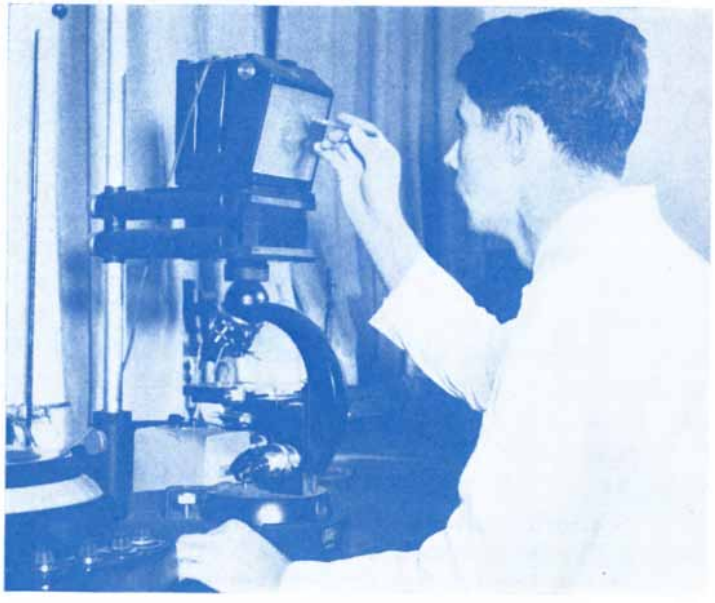
A specially developed type of grit enables resin-bond diamond wheels to grind rapidly and efficiently.

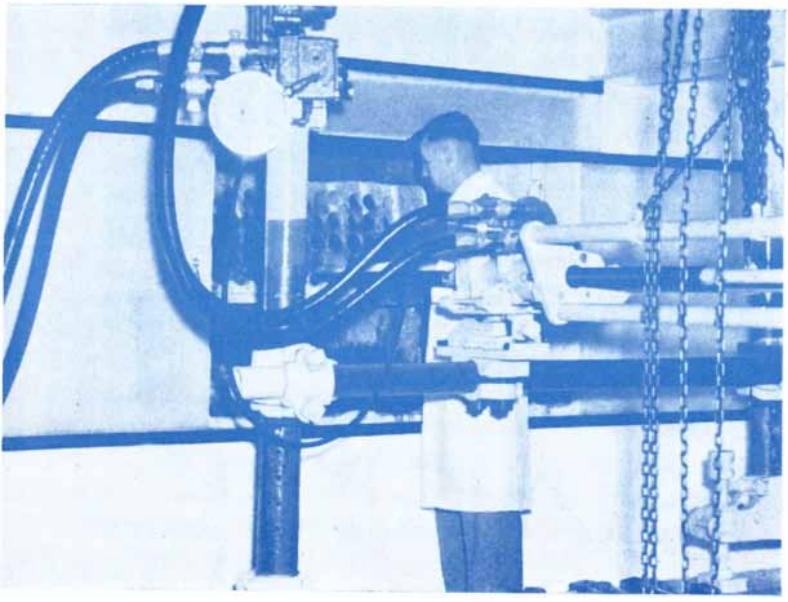


A diamond abrasive wheel is tested at the Diamond Research Laboratory by surface grinding a block of tungsten carbide.

Staff member counts number of diamond grit particles which appear on the screen of a microscope. This instrument was especially developed for checking the shape of diamond grit.



Laboratory drilling machine tests the efficiency of diamond drill crowns in granite.



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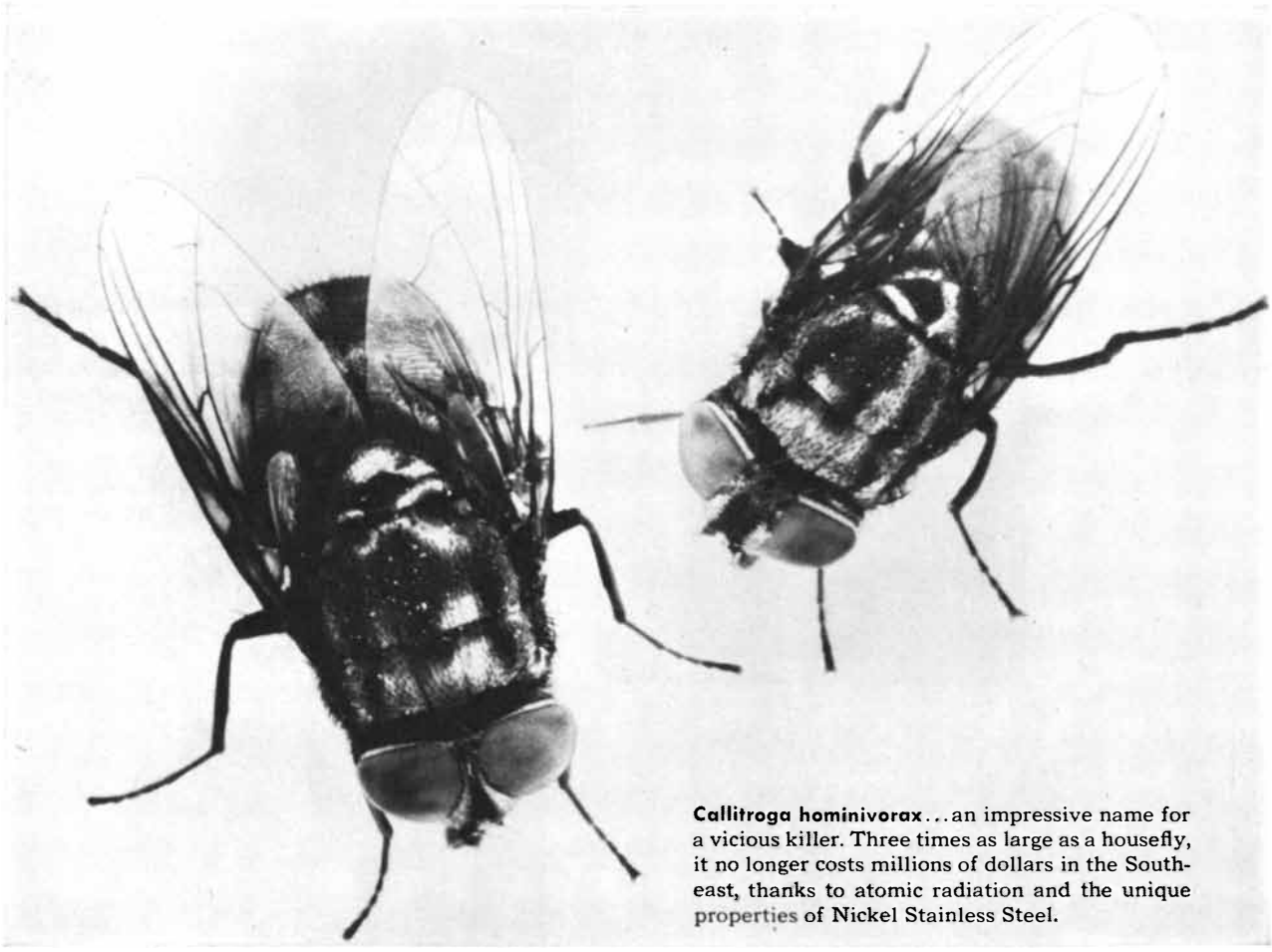

Callitroga hominivorax...an impressive name for a vicious killer. Three times as large as a housefly, it no longer costs millions of dollars in the Southeast, thanks to atomic radiation and the unique properties of Nickel Stainless Steel.

Atoms clobber a $20-million-a-year pest

How Nickel Stainless Steel helped fight costly cattle menace

A few small flies can kill a full-grown steer in ten days.

They call this killer *Callitroga hominivorax,* or screwworm fly. It used to cost Southeast cattlemen 20 million dollars a year.

Thanks to a peaceful use of atomic energy, the U.S. Department of Agriculture reports that *Callitroga hominivorax* was completely eradicated within seventeen months. This achievement may mark a new precedent in modern methods of pest elimination. Over two billion laboratory-raised male flies were sterilized by atomic radiation and then released. Because the females then laid sterile eggs, the screwworm fly population was destroyed.

Sterilization was accomplished by exposing males to gamma radiation from Cobalt 60 within a lead-shielded cask of Nickel Stainless Steel.

Nickel Stainless Steel was chosen by the designers, Knapp Mills Inc., for several reasons. It gives strength and rigidity to the cask's interior for greater handling safety. It stands up to the nitric acid solution used for radioactive decontamination — a cleaning process that plays havoc with less corrosion-resisting metals. And its sanitary, attractive appearance adds sales appeal to any product.

Are you in the atomic energy field . . . or any field where you need a metal with a combination of superior properties? Consider the advantages of Nickel or one of its alloys when planning the construction of your equipment. Help with any metals problem is available from Inco. Just call or write us.

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The Irradiator, nemesis of screwworm flies, is fabricated of Nicrolum*—a Nickel Stainless Steel to which lead has been metallurgically bonded. Six of these machines brought the fly menace under control.

*T.M. of the designer-manufacturer, Knapp Mills, Inc., Long Island City, N. Y.

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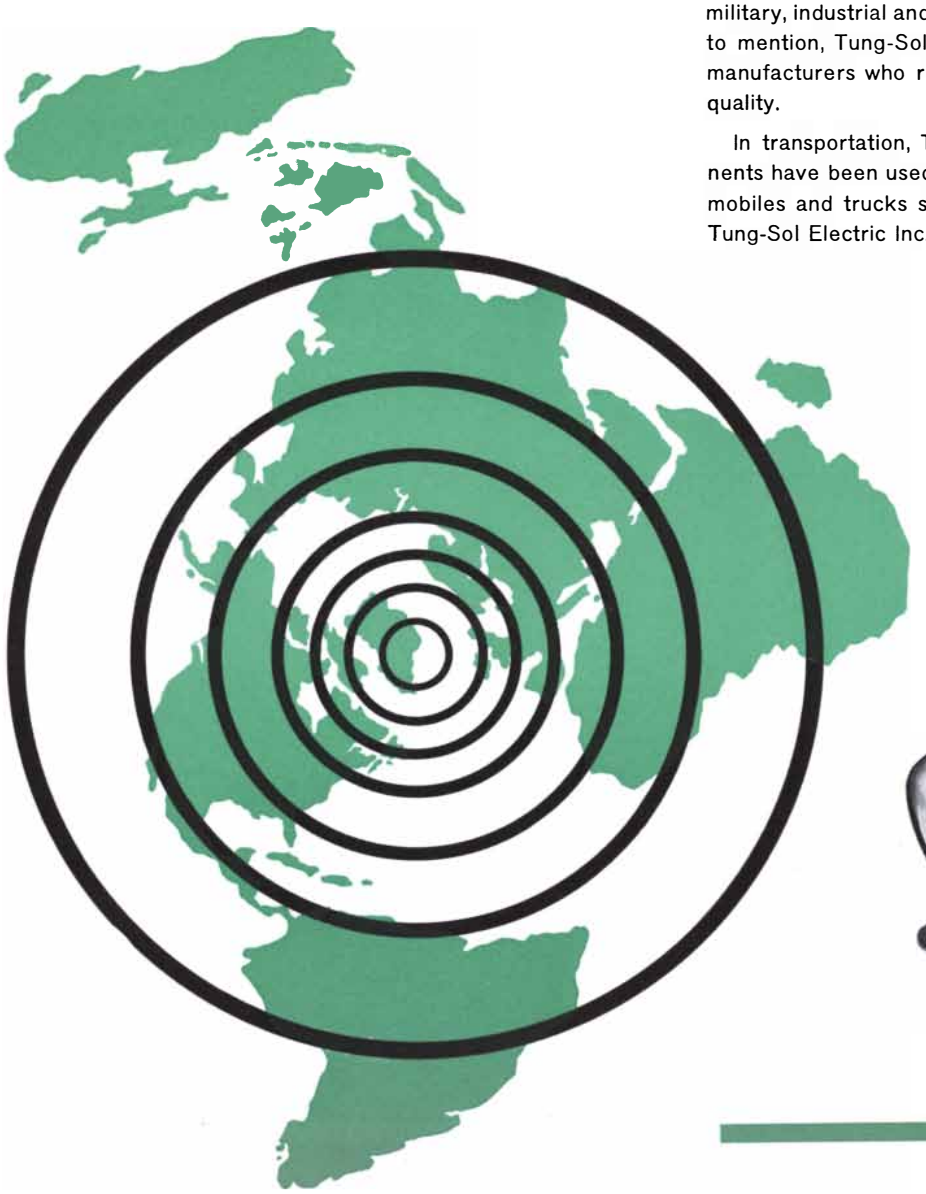
An important component in the scanning element of this world-shrinking facsimile equipment, is an exceptionally stable exciter lamp made by Tung-Sol. Here, as in military, industrial and business equipment too numerous to mention, Tung-Sol low-voltage lamps are chosen by manufacturers who require volume without sacrifice of quality.

In transportation, Tung-Sol lamps and other components have been used by the makers of America's automobiles and trucks since the inception of the industry. Tung-Sol Electric Inc., Newark 4, New Jersey.



Manufacturers of facsimile transmitting equipment use a variety of Tung-Sol exciter lamps.

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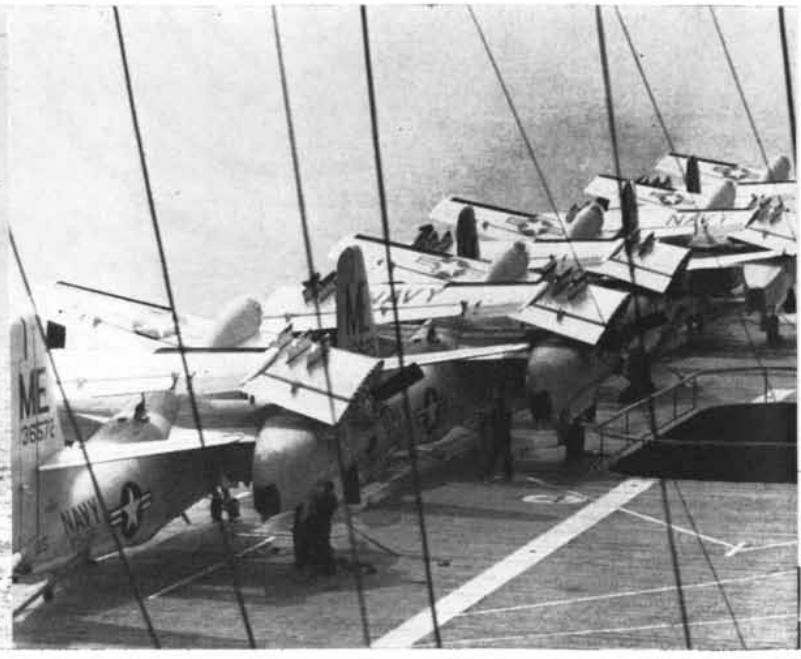
The story of Alfa and the Skunks—

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.

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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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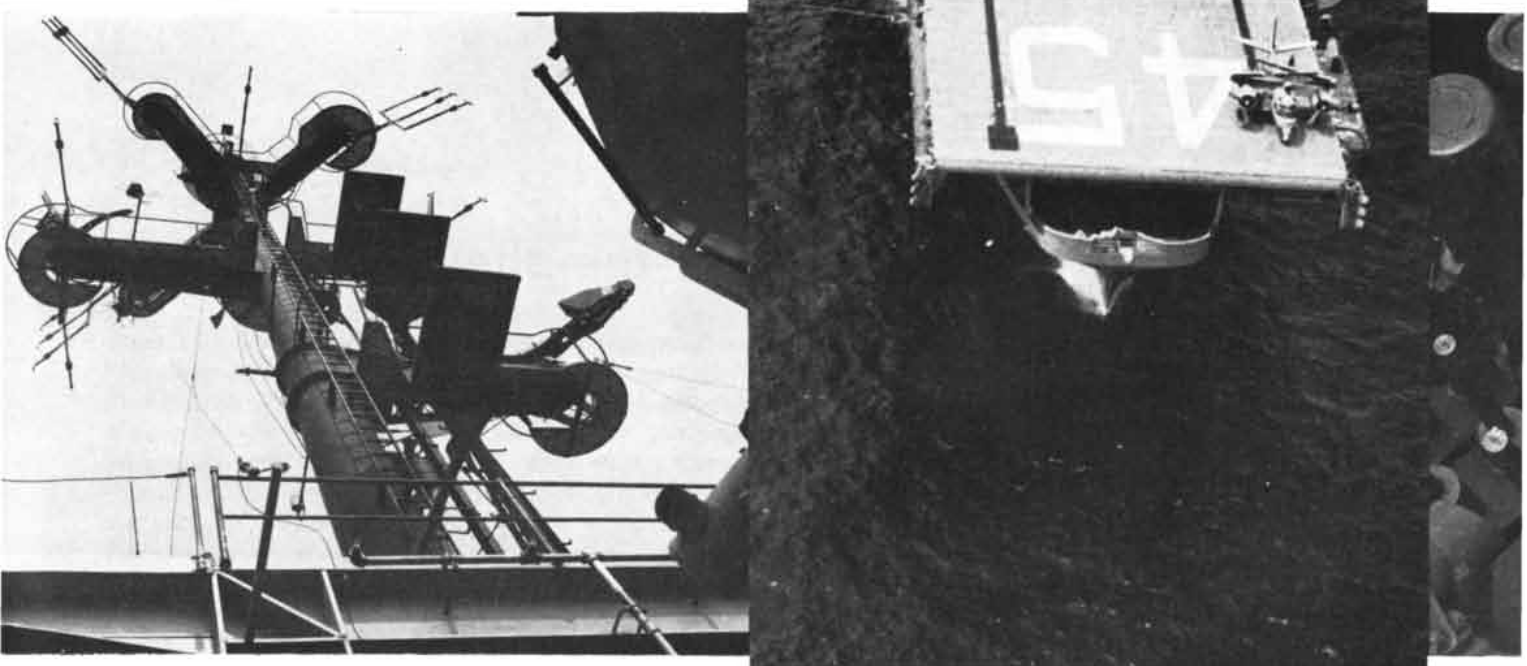

CARRIER VALLEY FORGE's steel mainmast is a maze of electronic devices, including steel radar and radio antennas that keep her in constant touch with all elements of the task group. Her radio can reach around the world. She coordinates all attacks, and has been modified to handle anti-sub helicopters, 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.

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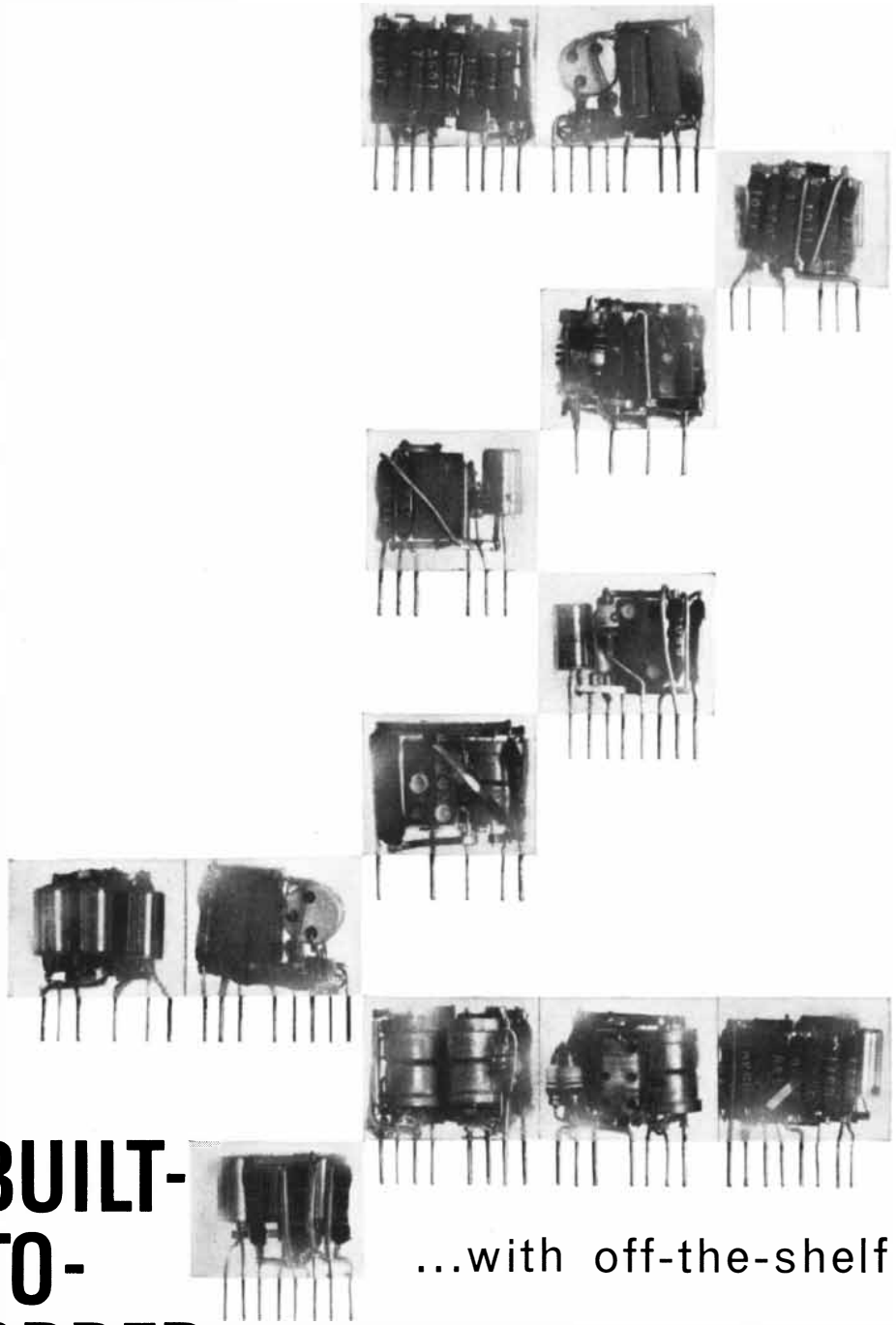

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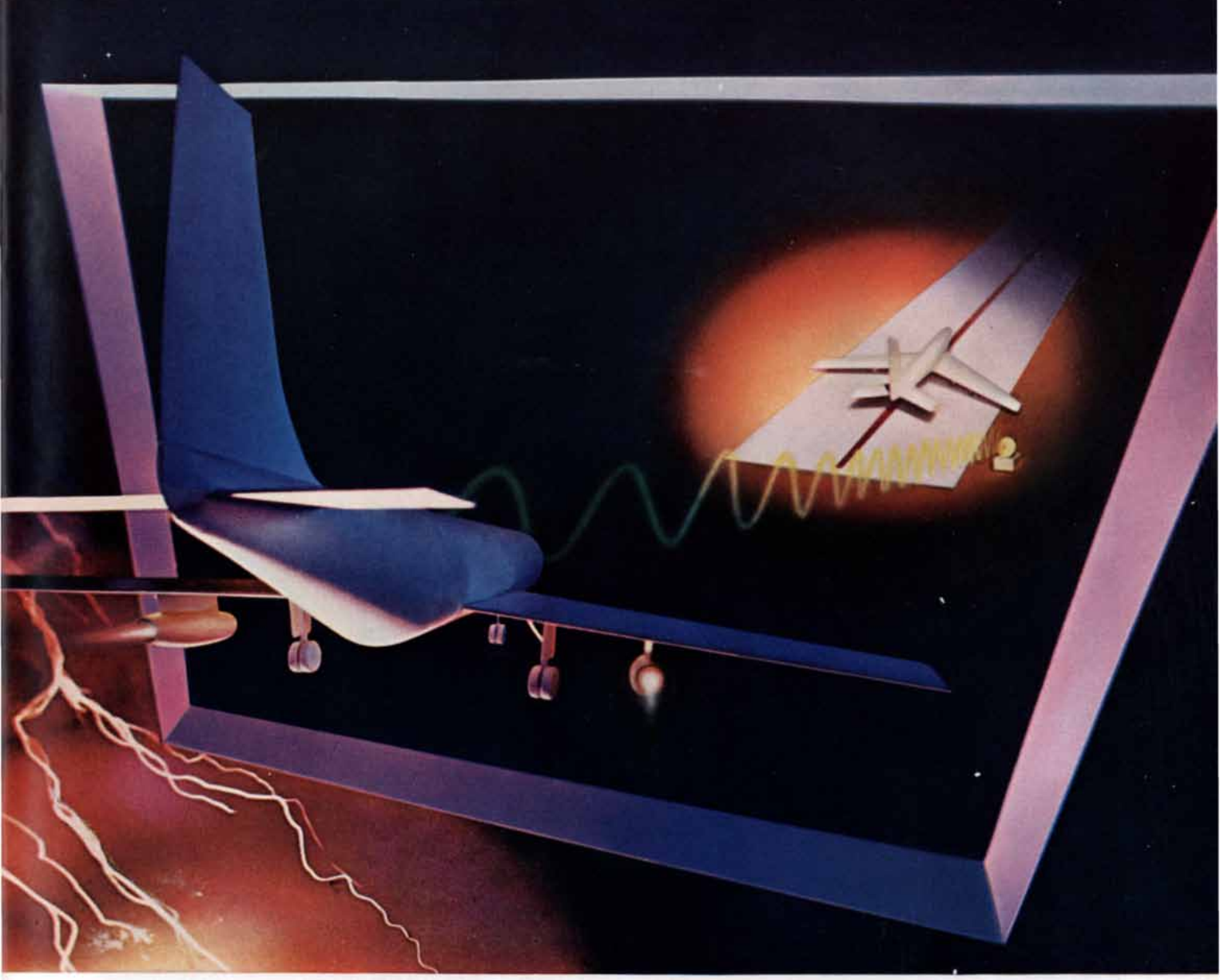

Bell's All-weather Automatic Landing System—symbolized.

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Today's increasing air traffic demands faster and safer all-weather operation at every airport.

Bell brings this goal one important step closer with its All-Weather Automatic Landing System (ALS) which can fly two airplanes to touchdown every minute, even when visibility is absolutely zero.

The Bell ALS takes over when the pilot brings his plane through the electronic "window in the sky" and guides it to a safe and sure landing.

The system has been flight-proved in more than 4,000 landings with all types of aircraft—small private planes as well as airliners from the DC-3 and DC-7 to the huge Boeing 707 jet. It now is being evaluated at FAA's National Aviation Experimental Center, Atlantic City, N. J.

Unlike other automatic landing systems, the Bell ALS is ground-based so a ground observer monitors every approach and landing. It can operate either fully automatically or under pilot control.

Military versions of the ALS have been ordered by the Air Force. The Navy has selected it for installation aboard the nuclear-powered aircraft carrier USS Enterprise as well as for its other large carriers.

The Bell ALS is but one among many contributions which Bell Aerosystems Company is making to the scientific progress and defensive strength of the free world. We invite qualified engineers and scientists to inquire about sharing our challenging and rewarding future.

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INSIDE ACCUTRON: A new timekeeping principle . . . accuracy only the space age could bring.

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Bulova announces a major scientific breakthrough in timekeeping...

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First instrument of the space age you can wear and use!... First microsonic timepiece... It doesn't even tick. It hums!... First timepiece ever guaranteed accurate on your wrist!

This new microsonic timepiece is the heart of a timing mechanism in a U. S. satellite now in orbit. Now it is available as a timepiece you wear on your wrist . . . a timepiece so accurate it carries a guarantee never before possible: ACCUTRON is guaranteed 99.9977% accurate . . . not under laboratory conditions . . . *but in actual use!*

Developed after 8 years of research, ACCUTRON is guaranteed for one full year not to gain or lose more than two seconds a day *on your wrist.* Based on expert opinion of conventional fine-watch performance, ACCUTRON *is 10 times more accurate.*

Built to stand a rocket-launching

ACCUTRON is more dependable, too. Built to withstand the shock of a rocket-launching, it has fewer moving parts (12 as compared to 29 in a self-winding watch), so it will require far less service than conventional watches . . . and it never needs winding.

A new principle in timekeeping

Throughout history, the accuracy of a fine watch has depended almost entirely on skill and craftsmanship. Now science has come to the aid of the craftsman, making possible a new dimension in precision accuracy that human skill could not hope to achieve.

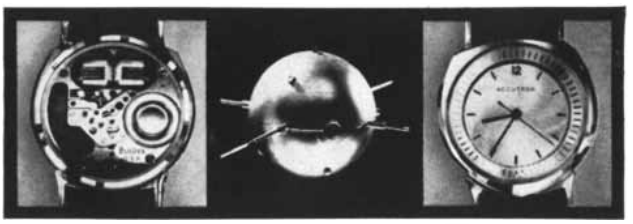
In conventional and electric watches, the springs and balance wheel are only near-perfect components. In ACCUTRON, these and many other moving parts are replaced by a tuning fork. This is oscillated at the rate of 360 times a second by a tiny germanium transistor, powered by a button-size power cell. In place of the conventional tick, you hear a low, almost inaudible hum. It is the new sound of accuracy . . . and you hear it only in ACCUTRON. Because no other timepiece . . . conventional or electric . . . operates without a balance wheel.

The power cell lasts over a year, costs only $1.50, and you replace it as easily as a lighter flint.

Where and when can you buy one?

Each ACCUTRON timepiece is an exquisitely fashioned piece of jewelry. A timepiece so new and so fine can be made only in limited numbers at first; but as production increases we hope to make them available to more and more people. Priced from $175 to $2500*, they'll be sold at official Bulova jewelers only. Look for them. And remember—the same skill and scientific knowledge that developed the world's most accurate personal timepiece make every Bulova a finer watch.

Look for this symbol of your authorized Bulova ACCUTRON *jeweler.*



ACCUTRON...*world's new standard of accuracy*

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THE AUTHORS

SEYMOUR DEITCHMAN and ALFRED BLUMSTEIN ("Air-Traffic Control") are both engaged in research on air-traffic control and related problems at the Cornell Aeronautical Laboratory in Buffalo, N.Y. Deitchman heads the Transportation Systems Section of the Cornell Laboratory's Operations Research Department. Blumstein is a Principal Operations Analyst and a member of the Department's technical staff. Deitchman graduated from the College of the City of New York in 1944 with a degree in mechanical engineering. During the next nine years he served in various capacities with the National Advisory Committee on Aeronautics, the Cornell Aeronautical Laboratory and the Bell Aircraft Corporation. In 1953 he acquired an M.S. in applied mechanics and mathematics at the University of Buffalo. He took up his present position the same year. Blumstein received a degree in engineering physics at Cornell University in 1951, an M.A. in statistics at the University of Buffalo in 1954 and a Ph.D. in operations research at Cornell University this year. He has been associated with the Cornell Laboratory since 1951.

W. L. BUTLER and ROBERT J. DOWNS ("Light and Plant Development") are both employed by the U. S. Department of Agriculture, the former as a biophysicist at the Instrumentation Research Laboratory, the latter as a plant physiologist at the Plant Industry Station. Butler acquired a B.A. in physics at Reed College in 1949. He did graduate work in photosynthesis at the University of Chicago under the Nobel laureate James Franck, receiving a Ph.D. in biophysics in 1955. He joined the Instrumentation Laboratory in 1956. Downs served in the Navy from 1941 to 1947, first as a repair machinist and later as an optical repairman and instructor. He took three degrees at George Washington University, receiving his Ph.D. in botany two years after he joined the Plant Industry Station in 1952. The present article describes the results of a research program that was carried out by a group of workers which included the authors.

JOHN L. MERO ("Minerals on the Ocean Floor") is a staff member of the Institute of Marine Resources at the University of California. He was born in Grand Forks, N.D., in 1929. He remembers having been greatly attracted by mountains and oceans, "although in Grand Forks," he says, "I could hardly have been farther removed from either." This interest led him to study geology and mining at the University of North Dakota, where he acquired a B.S. in mining engineering in 1952. After three years in the Army, Mero did graduate research at California, acquiring his M.S. in engineering science in 1957 and a doctorate in engineering in 1959. He joined the Institute of Marine Resources in 1958, when he was invited to work on the manganese-nodule project discussed in the present article.

CHRISTOPHER HOWARD ANDREWES ("The Viruses of the Common Cold") is deputy director of the National Institute for Medical Research in London. He acquired his B.S. and M.D. degrees at St. Bartholomew's Hospital. In 1927 he became a staff member of the National Institute, assuming his present post in 1952. Though Andrewes is best known for his work on the common cold, he has been interested in other respiratory infections for more than 30 years. His discovery in 1933 (with P. P. Laidlaw and Wilson Smith) that ferrets can be infected with influenza virus provided a great stimulus to influenza research. In 1946 he became director of the Common Cold Research Unit, which had just been built in Salisbury, England. During the following year he also directed the World Influenza Center of the World Health Organization. After his retirement next year, Andrewes plans to devote most of his attention to virus classification and related subjects.

HERBERT A. POHL ("Nonuniform Electric Fields") is a staff member of the Plastics Laboratory in the department of electrical engineering at Princeton University. He took two degrees at Duke University, receiving a Ph.D. in physical chemistry in 1939. Until 1941 he served on the faculty of the Johns Hopkins School of Medicine, and from 1942 to 1945 he was a senior chemist at the Naval Research Laboratory. Before going to Princeton in 1957, Pohl had been a chemist in the Textile Fibers and the Atomic Energy divisions of E. I. du Pont de Nemours & Co., and a visiting lecturer at the University of Delaware.

N. TINBERGEN ("The Evolution of Behavior in Gulls") is Reader in Animal Behaviour at the University of Oxford and a Fellow of Merton College. Born

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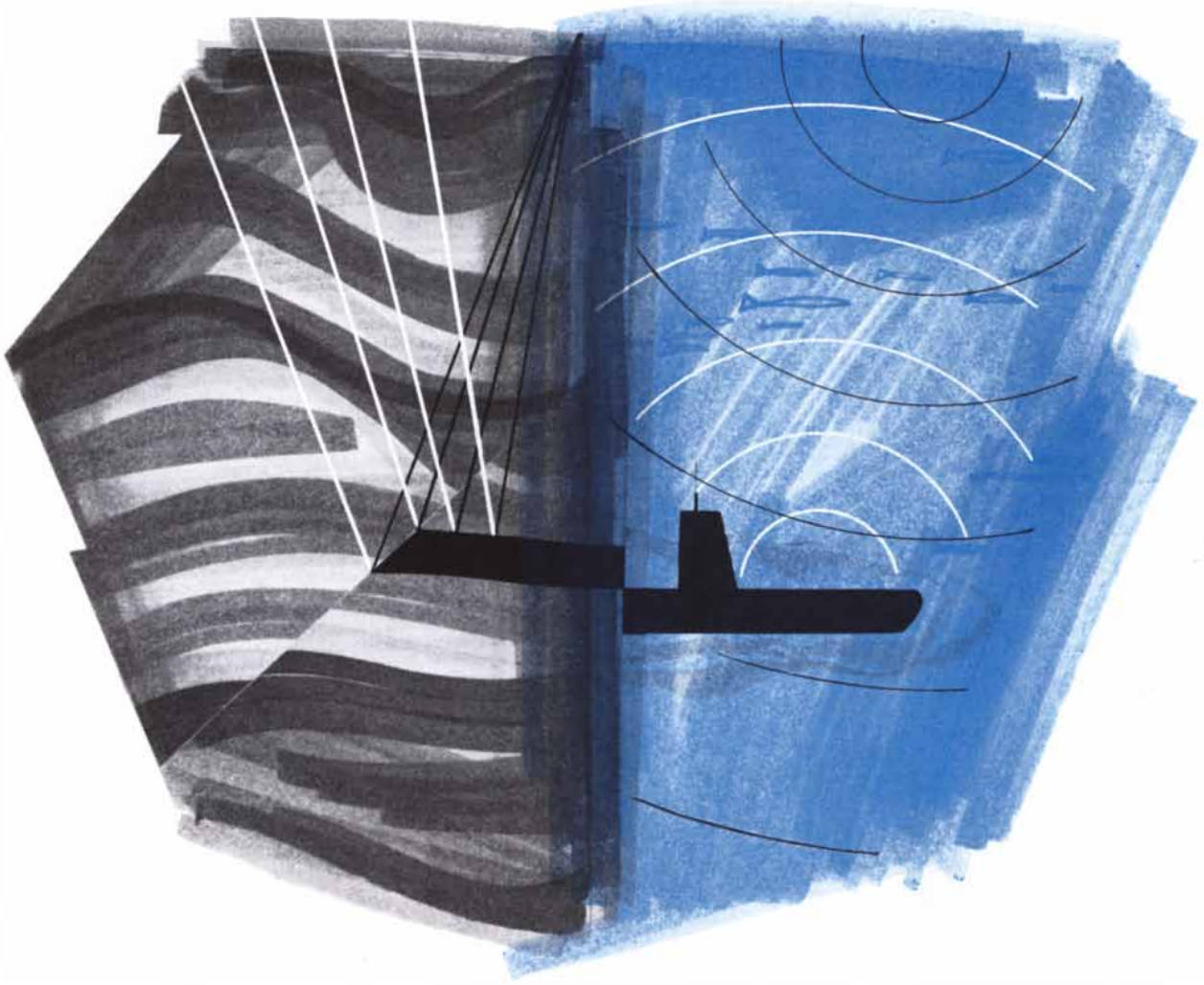

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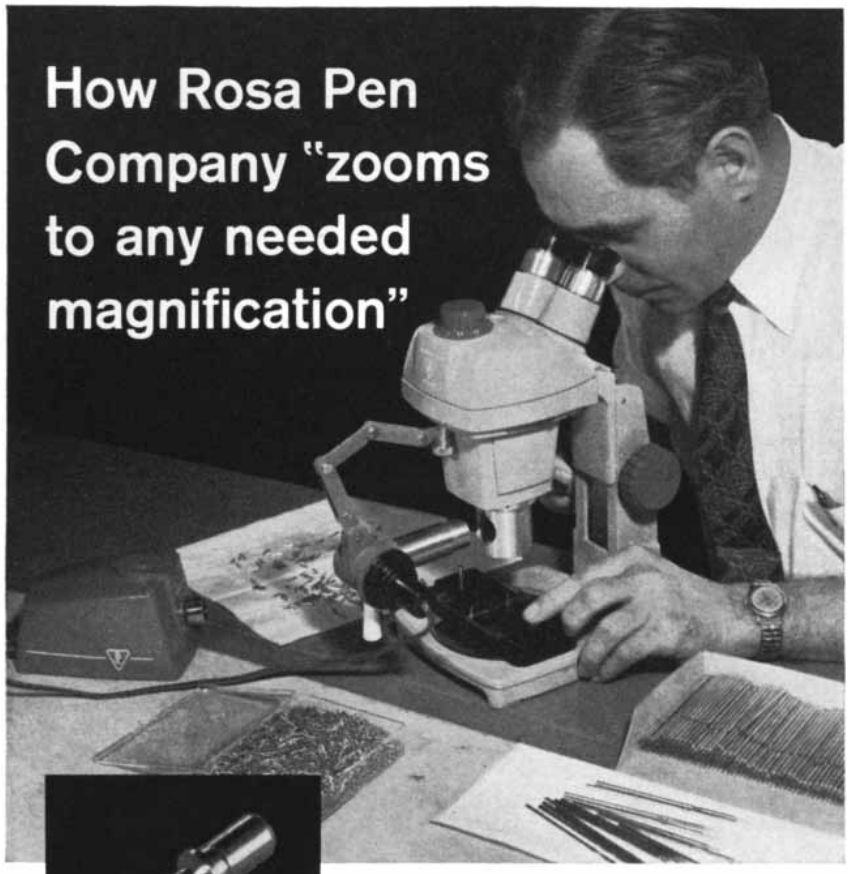
How Rosa Pen Company "zooms to any needed magnification"



Rosa uses B&L StereoZoom Microscopes for internal inspection of socket this size.... , zooms instantly to any power needed for other inspections.

Before spinning the ball (as small as the period at the end of this sentence) into the socket of their fine ball-point pen, Rosa Pen Company, Lyndhurst, N. J., uses B&L StereoZoom® Microscopes for a number of critical checks.

They check the interior finish of the socket (1 mm to .025" diameter, depending on the model), using the B&L Vertical Illuminator for depth lighting. The ink channels inside the socket are checked for uniformity and freedom from flaw. The ball is checked for finish, uniform surface, feather edge. After assembly, ball and socket are inspected for concentricity and free spin, and the ball's feather edge is checked again.

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and raised in the Netherlands, he took his doctorate at the University of Leiden in 1932, and later went to the University of Vienna, where he worked with the noted student of animal behavior Konrad Z. Lorenz. At the end of World War II, Tinbergen, already famous for his lectures at Leiden, was invited to pursue his career at Oxford. He has written several articles for SCIENTIFIC AMERICAN. The most recent was "Defense by Color," in October, 1957.

JAMES MARSTON FITCH and DANIEL P. BRANCH ("Primitive Architecture and Climate") are, respectively, associate professor of history in the school of architecture at Columbia University and a former lecturer in architecture at Columbia now engaged in private architectural practice in Florida. Fitch studied architecture at the University of Alabama and then at Tulane University, where he acquired a B.A. in 1929. Before he went to Columbia in 1950, he had held editorial positions with *Architectural Record, Architectural Forum* and *House Beautiful,* and had directed studies in architectural climatology. Last year, on a William Kinne Fellows fellowship, he studied Byzantine monuments in Italy, Turkey and Greece. He was the author of the article entitled "The Curtain Wall" in the March, 1955, issue of SCIENTIFIC AMERICAN. Branch holds a B.A. in architecture from the University of Florida and an M.A. from Columbia.

ARTHUR K. SOLOMON ("Pores in the Cell Membrane") is associate professor of biophysics at the Harvard Medical School. He graduated from Princeton University in 1934 with a degree in chemistry; then he did graduate work in chemistry under George B. Kistiakowsky at Harvard University, receiving a Ph.D. in 1937. Later Solomon studied the application of nuclear physics to chemical problems under the direction of J. D. (now Sir John) Cockcroft at the University of Cambridge. He returned to the U. S. just before the outbreak of World War II, and until 1941 he did research involving the application of radioactivity to biological problems; his collaborators included James B. Conant, then president of Harvard, Kistiakowsky and A. Baird Hastings. In August, 1941, he went back to England to work on the development of radar. He remained there until 1945, during which time he pioneered the development of short-range anti-aircraft radar. In July, 1946, he joined the faculty of the Harvard Medical School.

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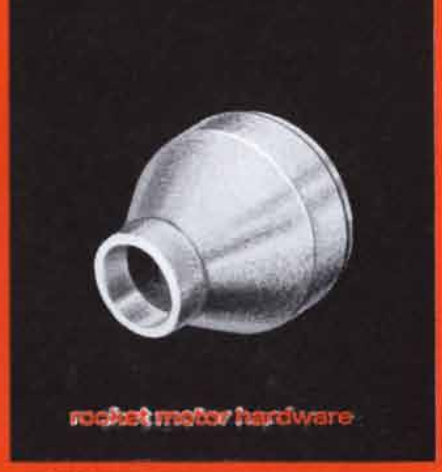

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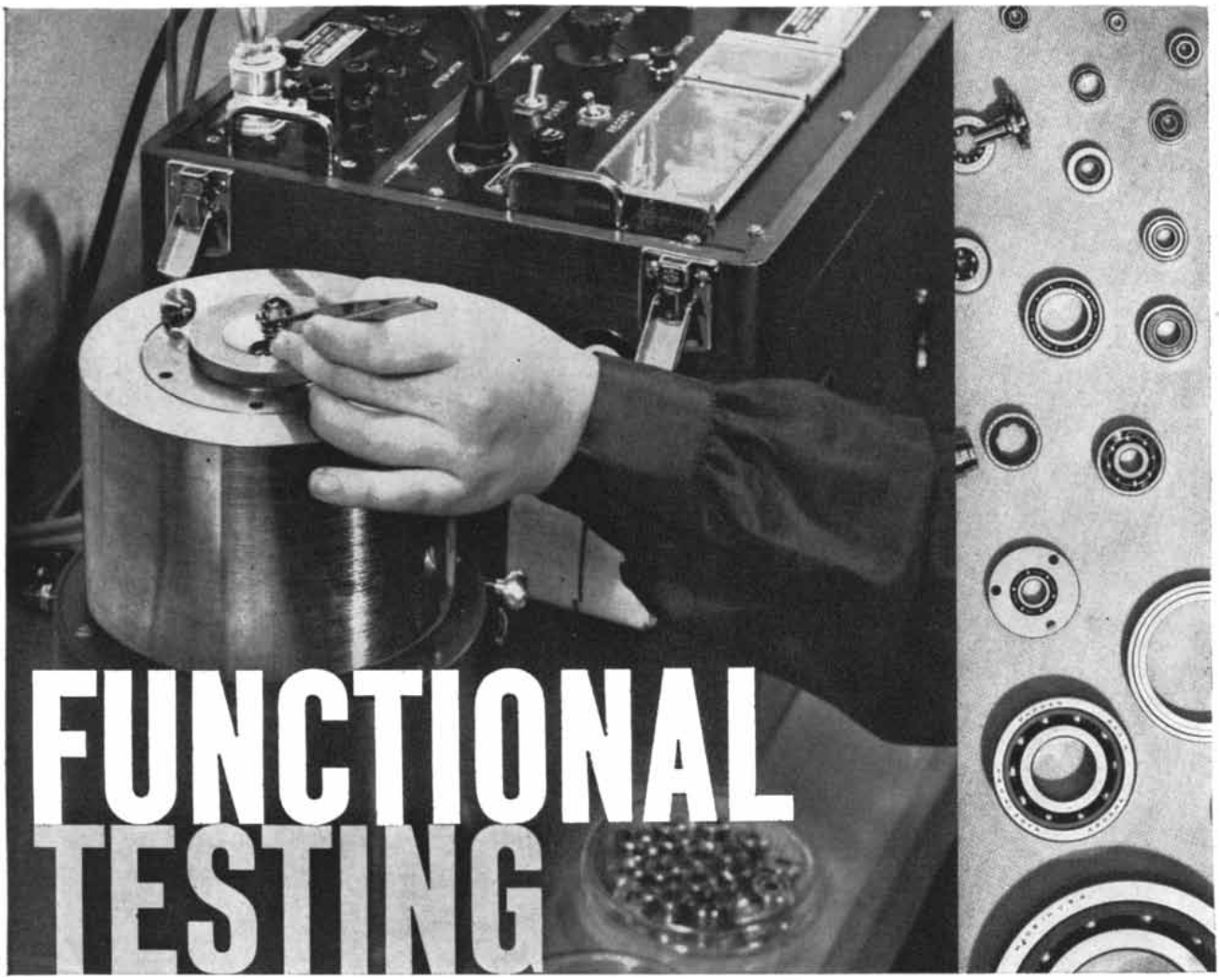

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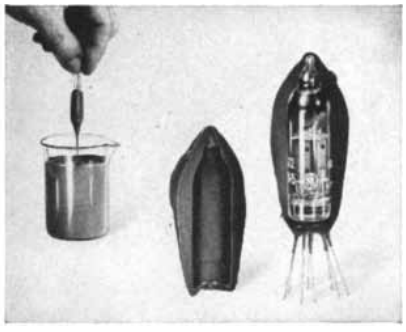
General Electric Silicone Rubber finds dozens of uses in missile systems. How many more will prove vital?

General Electric silicone rubber has the "thermal toughness" to stand up under the searing heat of rocket blast-off or possible atomic attack. Add very good electrical properties and excellent resistance to aging, weathering, moisture, flame, ozone and corona and you can easily see why silicone rubber is now being used in virtually every U.S. missile and space vehicle.

Since both space technology and silicone rubber are relatively new, General Electric believes there are many more areas not yet explored where silicone rubbers can help keep a missile functionally reliable and combat-ready. To help designers in their evaluation work, we list here the principal properties and applications of G-E silicone rubber.



RTV LIQUID SILICONE RUBBER — One of the most versatile materials developed in recent years, RTV is a liquid rubber that cures at room temperatures. Like all silicone rubber, it remains flexible over a wide temperature range and is virtually ageless. Since it comes in a wide range of viscosities, it can be poured, sprayed, dipped, painted or applied with a pressure gun or spatula. It bonds tightly to metal when a primer is used. When not primed, you can readily remove RTV and then reapply more. You can impregnate tightly wound coils with RTV or form sections several inches thick.

You can control cure time from two minutes to 24 hours. These are RTV's typical properties:

Viscosity	from 120 poises (very pourable) to 12,000 poises (paste)
Specific Gravity	1.2 to 1.5
Solids Content	100%
Shrinkage	0.2%
Heat Resistance	from —90°F to 600°F, and as thermal insulation, in 5500°F flame for minutes
Ozone Resistance	Comparable to Mica
Electrical Properties	See last table

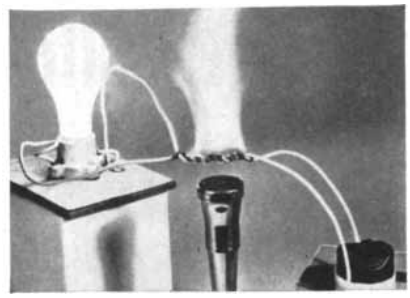
Applications—RTV is used as a high temperature structural sealant in missiles, satellites and space vehicles. It is used to pot and encapsulate electronic components and assemblies for electrical and heat insulation and for protecting delicate components from physical damage. It is commonly used as an impregnating insulation in transformer coils, to pot and hold cable in raceways and to pot cable breakouts. You can make flexible molds with RTV and hence make accurate, duplicate castings from originals.

RTV is an excellent thermal barrier and as such is applied on and around missile nozzles. Tests show RTV's resistance to flame temperatures as high as 5500°F for several minutes. RTV also functions as a flexible ablative material and is used around probe holes, along raceways, and between stages and structural joints on the missile skin.

HEAT CURED SILICONE RUBBER PARTS —Silicone rubber gaskets, port seals, O-rings, shock mounts and other mechanical parts are not only used on missiles but have wide application in ground support equipment. For instance, missile silo doors use silicone rubber seals that will stand up to outside weathering, ozone and abuse for years and which will also resist the heat of missile launching and nuclear attack. Silicone rubber also resists brief exposure to cryogenic materials.

Silicone rubber has long-lasting temperature resistance from —150°F to 600°F, with excellent electrical, weathering, ozone, corona, radiation and non-aging properties at these temperatures. High tensile strength and low compression set are also within its range of desirable properties:

Tensile Strength, psi	800—1500
Elongation, %	100—600
Hardness Durometer (Shore A)	25—80
Compression Set, %	10—80
Tear Resistance lb/in	40—200
Radiation Resistance	1 x 10^8 roentgens
Electrical Properties	See table below



WIRE AND CABLE INSULATION — The long term reliability of silicone rubber when operating in high ambient temperatures and when current over-loads cause the conductor to approach 500°F is an important feature of silicone insulation. In an 1800°F flame, specially constructed silicone rubber insulated cables will continue to insulate for hours, forming a non-conductive ash that gives off no toxic fumes. And short term reliability is obtained even when silicone rubber is exposed momentarily to a direct flame of 5500°F.

Because of this excellent heat resistance, more current can be carried than in conventional cable (or smaller cable can be used). Other features: best compression set of all elastomers at temperature extremes, so that silicone rubber wire and cable does not deform under clamps; high ozone, corona, radiation and weather resistance, low moisture absorption, flexibility down to —100°C. These are the typical properties:

Volume Resistivity	10^{15}—10^{16}
Dielectric Strength, volts/mil	600—650
Dielectric Constant, 60 cps	3.0
Power Factor	.0010—.0050
Radiation Resistance	1 x 10^8 roentgens
Physical properties	Similar to table above

Applications—Wiring harness made of silicone rubber insulation is often found throughout missiles. Cable offers added reliability for use in various places throughout the launch complex below ground from power plant to silos. All combat vessels built for the U.S. Navy during the last ten years, including fleet ballistic missile submarines and the new nuclear-powered cruiser and aircraft carrier, have silicone rubber insulated cable installations in all fixed wireways. In every case, silicone rubber is chosen because it is virtually non-aging, stands up to intense heat better than any other flexible insulating material, and continues to operate even when subjected to fire.

●

There are many more places where G-E silicone rubbers' inherent properties can be vital in missiles, satellites and space vehicles. For further data, call your nearest G-E sales office or write Section U1233, **Silicone Products Department, General Electric Company, Waterford, New York.**

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READING AN INFERNO'S SECRETS...
Missile "silo" concept proved practical—
by Lockheed Electronics

The U.S. Air Force came to Lockheed Electronics with an extremely complex and urgent problem. Could the tremendous shock and heat of a missile blast-off be accurately measured in launchings from an underground silo?

Lockheed Electronics designed and built a special data-gathering system to analyze, through instrumentation, the searing heat and violent shock of more than 40 test firings. During each test more than 200 measurements were made simultaneously.

Results have produced new understanding of missile stresses, acoustics, thermal radiation, shock and vibration. This vital information is already being applied to the design of "hard" launching sites.

The capabilities of Lockheed Electronics, Information Technology Division extend to all phases of data handling—a fact well worth remembering when you encounter tough problems in this field.

CAPABILITIES—INFORMATION TECHNOLOGY DIVISION

Data processing
Data storage • Telemetry systems
Data reduction and display
Special-purpose computers
Traffic control systems • Systems research

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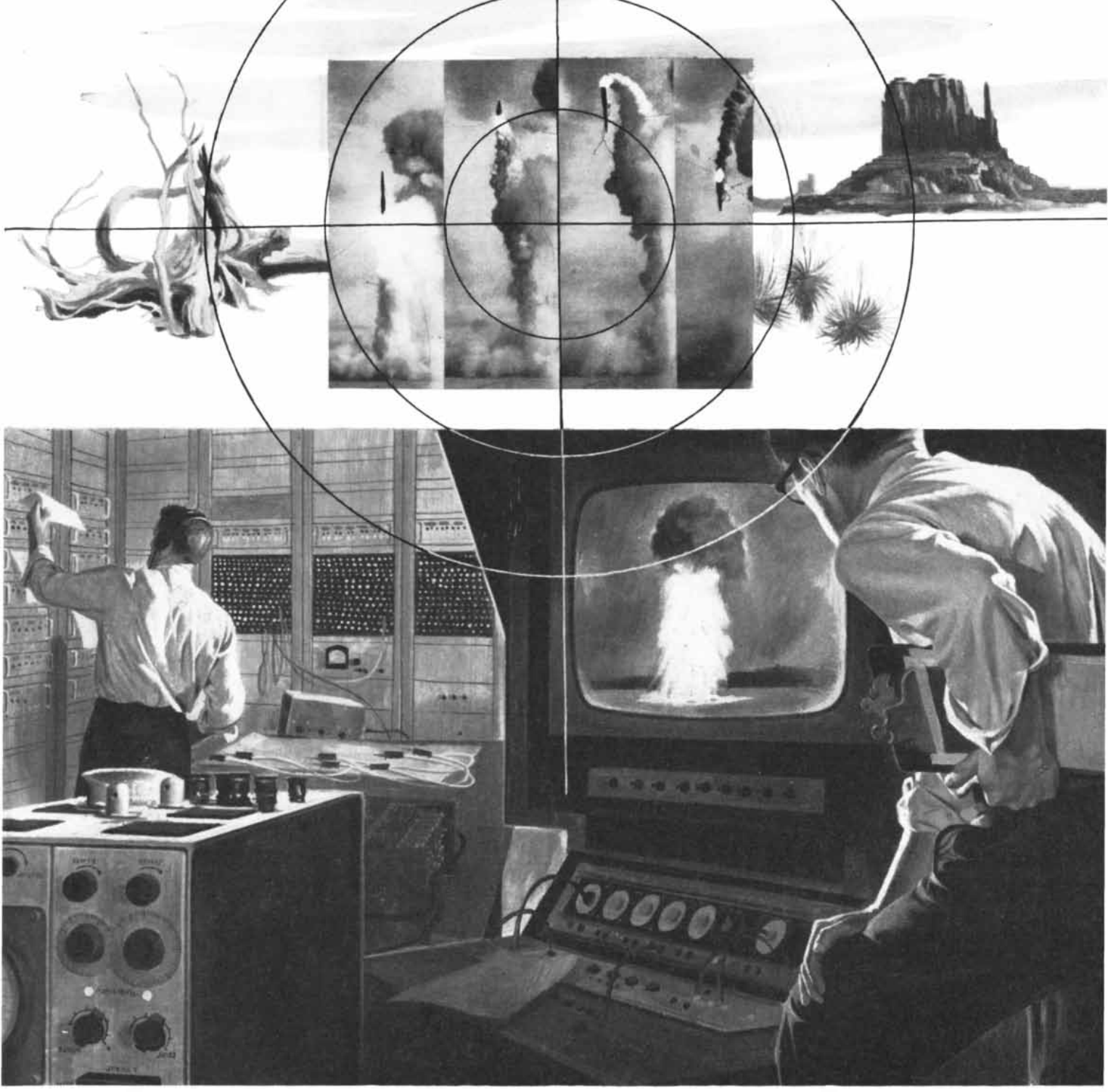

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D'Arcy Wentworth Thompson...on form

"We are apt to think of mathematical definitions as too strict and rigid for common use, but their rigour is combined with all but endless freedom. The precise definition of an ellipse introduces us to all the ellipses in the world; the definition of a 'conic section' enlarges our concept, and a 'curve of higher order' all the more extends our range of freedom. By means of these large limitations, by this controlled and regulated freedom, we reach through mathematical analysis to mathematical synthesis. We discover homologies or identities which were not obvious before, and which our descriptions obscured rather than revealed: as for instance, when we learn that, however we hold our chain, or however we fire our bullet, the contour of the one or the path of the other is always mathematically homologous.

"Once more, and this is the greatest gain of all, we pass quickly and easily from the mathematical concept of form in its statical aspect to form in its dynamical relations: we rise from the conception of form to an understanding of the forces which gave rise to it; and in the representation of form and in the comparison of kindred forms, we see in the one case a diagram of forces in equilibrium, and in the other case we discern the magnitude and the direction of the forces which have sufficed to convert the one form into the other."

—*On Growth and Form, 1942*

THE RAND CORPORATION, SANTA MONICA, CALIFORNIA

A nonprofit organization engaged in a program of research in the physical sciences, economics, mathematics, and the social sciences. RAND scientists and engineers are engaged in the imaginative exploration of frontier areas of science and technology; with the insights gained from this research they seek to create new and improved air and space systems.

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Air-Traffic Control

As aircraft fly faster, they need larger "cocoons" of airspace for safety. To make the cocoons smaller and enlarge the over-all capacity of the airspace requires new automatic control systems

by Seymour Deitchman and Alfred Blumstein

Every air traveler has experienced the frustration of sitting in an airplane while it circles endlessly through the clouds only a few miles from his destination. At the same time the passenger in the crowded terminal, waiting to board the same airplane, reads the sign announcing: All flights subject to air-traffic delays. Though the airspace remains largely empty, critical regions of it—through which many airplanes simultaneously seek passage—have become saturated. These regions cannot accommodate a denser flow of air traffic without increasing the risk of collisions between aircraft. The delays which cost the airline and its passengers money and inconvenience are the price of safety.

To prevent collisions the air-traffic control system maintained by the Federal Government surrounds each aircraft with an inviolable volume of airspace into which other aircraft are forbidden to intrude. The fact that there has never been a collision betwen two aircraft, both operating under air-traffic control, demonstrates the soundness of the system. (In each of some 200 collisions that occurred since the late 1940's at least one of the aircraft was operating outside of air-traffic control.) But the capacity of the system has become ever more inadequate to handle the increasing flow of air traffic.

The number of licensed aircraft in the U. S. has more than tripled over the last 20 years, and the cruising speed of airliners has recently climbed from 300 to 600 miles per hour. Yet with the notable exception of the widespread employment of radar, there has been little change in the technique of air-traffic control. In 1958 the Federal Aviation Agency was organized to take over the competing jurisdictions of the several civil and military agencies in the field and to function as the nation's sole air-traffic control manager. The Research and Development Bureau of this agency is charged with the creation of modern navigation, communication and control systems, and with the definition of what such systems should be and do.

The objective of this research effort is easily defined: The only way to increase the flow of traffic through a given region of airspace is to reduce the airspace reserved for each aircraft. The volume of reserved airspace must be large enough to compensate for error in the location of aircraft, for delays in the processing and interpretation of data, for lag in the response of pilots and aircraft and for uncertainty in the projection of the future position of aircraft in the system. Thus to reduce the reserved airspace ways must be found to reduce such error, delay, lag and uncertainty. It is becoming apparent that this will require changes in the very nature of the air-traffic control system, especially in the vicinity of the airport.

Any air-traffic control system—present or future—must perform the same basic functions. The system ascertains the actual and the intended positions of all the aircraft under its control; it processes these data to bring out present and future relative positions of the aircraft, and it displays the resulting traffic information to the controller. It is this official's responsibility to determine whether any changes in current or projected flight paths are necessary, and to communicate the appropriate instructions to the pilots involved. The controller acts in accordance with a set of doctrines prescribing the separation of aircraft from one another, modified by his own judgment when unanticipated situations arise.

In between airports a nationwide network of airways—a navigational highway system staked out by radio transmitters—furnishes the basis for air-traffic control. Passage over a radio transmitter tells the pilot his exact location, or "fix"; the intersections of the airways are always marked on the navigational charts as fixes. Before taking off, a pilot files a flight plan with the nearest air-traffic control center, indicating the airway route he intends to fly. The control center prepares a "flight progress strip," on which it enters the estimated time of arrival (ETA) of his flight at each of the fixes on his route. A controller assigned to each fix maintains a list of the ETA's and altitudes of all aircraft scheduled to pass there and constantly updates this record as pilots report the passing of successive fixes. When he finds a conflict in ETA's at his fix, he orders one of the

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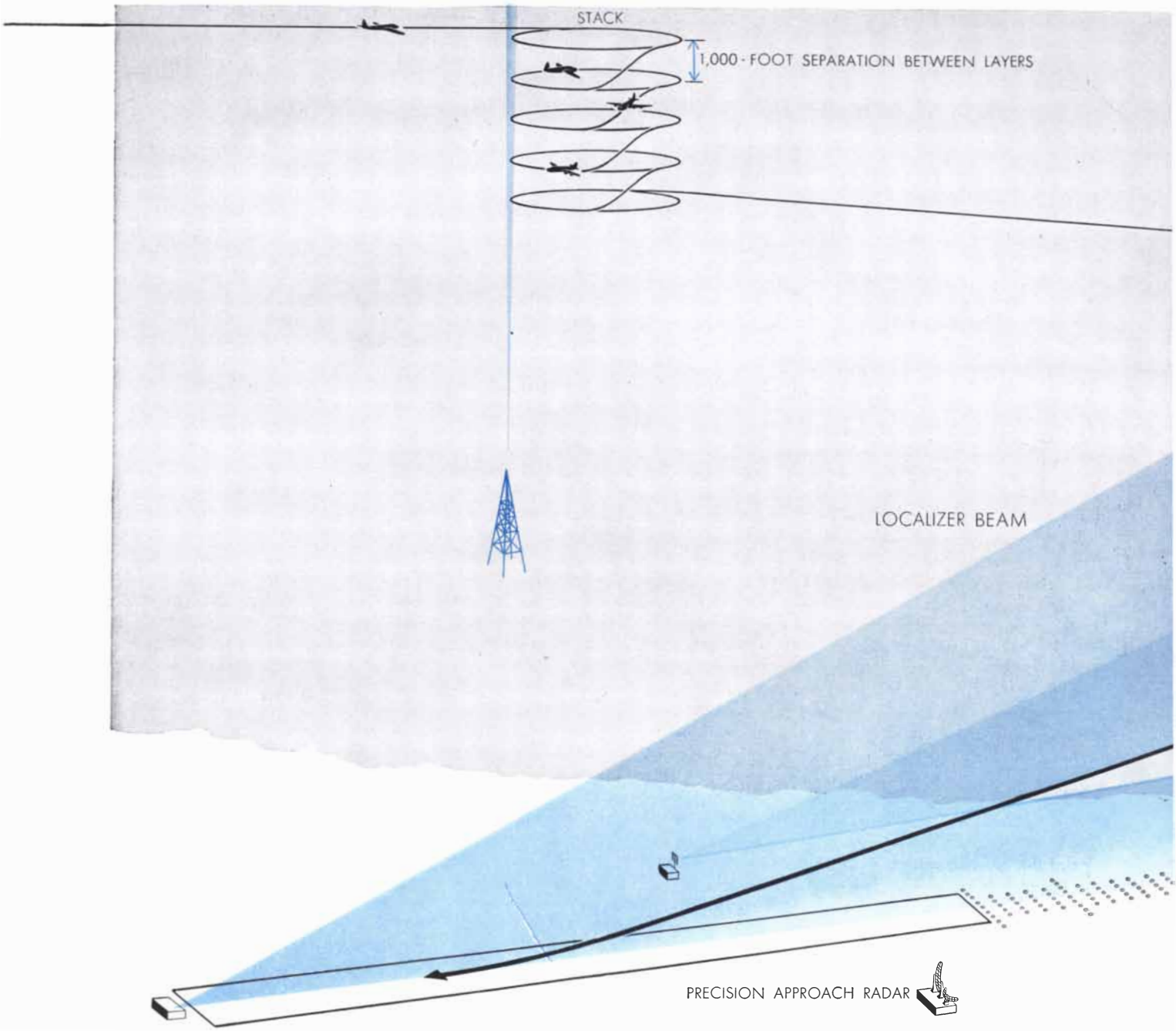
pilots, generally the one with the later ETA, to hold his position by circling over his last fix until the desired separation between the two aircraft is reached; or he may order him to change his route, speed or altitude.

A conflict arises, of course, when one aircraft threatens to enter the reserved airspace of another. Under ordinary conditions on the airways, the ETA's of any two aircraft flying at the same altitude must be separated by a minimum of 10 minutes at a given fix. For 300-miles-per-hour aircraft this means a longitudinal separation of 50 miles; for 600-miles-per-hour aircraft, it is 100 miles. The length of the protective cocoon of air that travels along with each aircraft thus varies with speed; the cocoon's width is fixed at 10 miles and its depth at 1,000 feet below 29,000 feet, and twice these values at higher altitudes. Where radar facilities are available, the controller may permit a separation as small as three miles. The cocoon now becomes a disk of air three miles in diameter and 1,000 feet deep [*see illustration on page 50*].

In cloudy skies all pilots must fly under air-traffic control. In good weather, however, a pilot may take upon himself the responsibility of seeing and avoiding other aircraft. Moreover, clear skies bring out many pilots who have neither the training nor the equipment to operate under the control system; the capac-



PLANES STACK UP (*top left*) during overcast, awaiting permission to land. Craft at bottom lands first, others move down one step in stack, staying 1,000 feet apart. Plane crosses over from stack to come in (*right*) for instrument-approach landing. Localizer radio beam keeps craft aimed at center of runway. Glide-slope beam holds it on sloping approach. Electronic markers are vertical sig-

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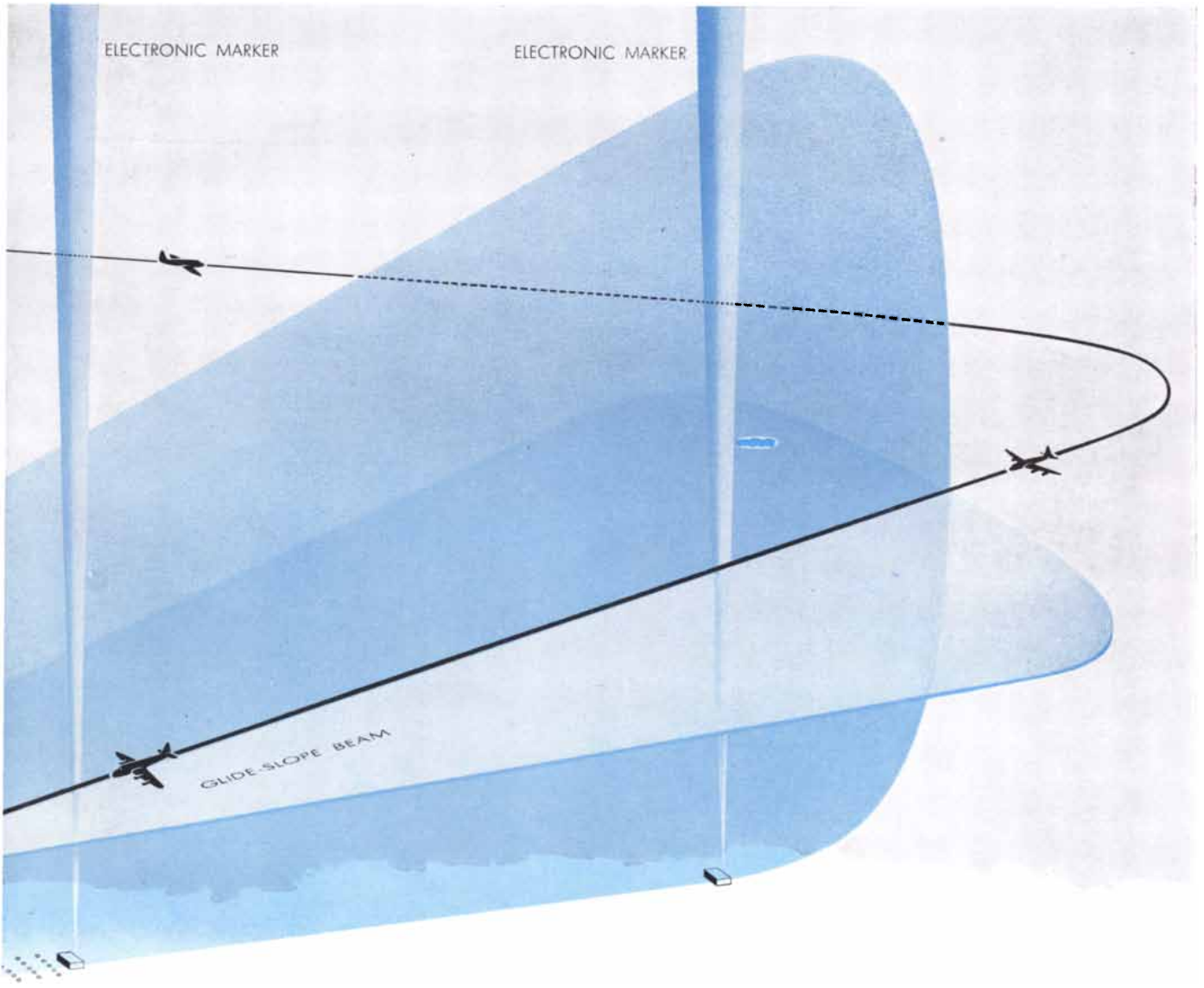
ity of the system allows it to handle only about 20 per cent of the traffic at such times. The numerous aircraft operating outside air-traffic control constitute a hazard to those that seek its protection. Motorists would be exposed to equivalent perils if a large number of drivers were turned loose on the highway with license to ignore traffic signals at will. It took a major air disaster—the collision in April, 1958, near Las Vegas, Nev., between a passenger airliner flying under traffic control and a military jet flying outside the system—to drive home the lesson that the control system can protect aircraft only against other aircraft under the same control. Today, regardless of weather, all aircraft not operating within the system must stay clear of certain "positive control" airways at altitudes from 17,000 to 22,000 feet, and are forbidden to fly in a 110,000-square-mile region of airspace between 24,000 and 35,000 feet over the Midwest.

The airlines, recognizing the danger of operating in skies increasingly crowded with ever faster aircraft, now conduct almost all their flights under air-traffic control in all kinds of weather. Military and business pilots are accepting control to an ever greater extent, and control is mandatory in particularly congested areas and over certain routes. Military and transport jet-aircraft must always fly under air-traffic control. They are so fast that the pilot can no longer



nals that serve as distance reference-points. Pilot must break out of overcast (*gray*) about half a mile from runway and 200 to 300 feet up. New automatic systems will use more accurate electronic position-measurements and computers so that plane can follow the approach path down to the runway without going through difficult transition from instruments to visual control just before landing.

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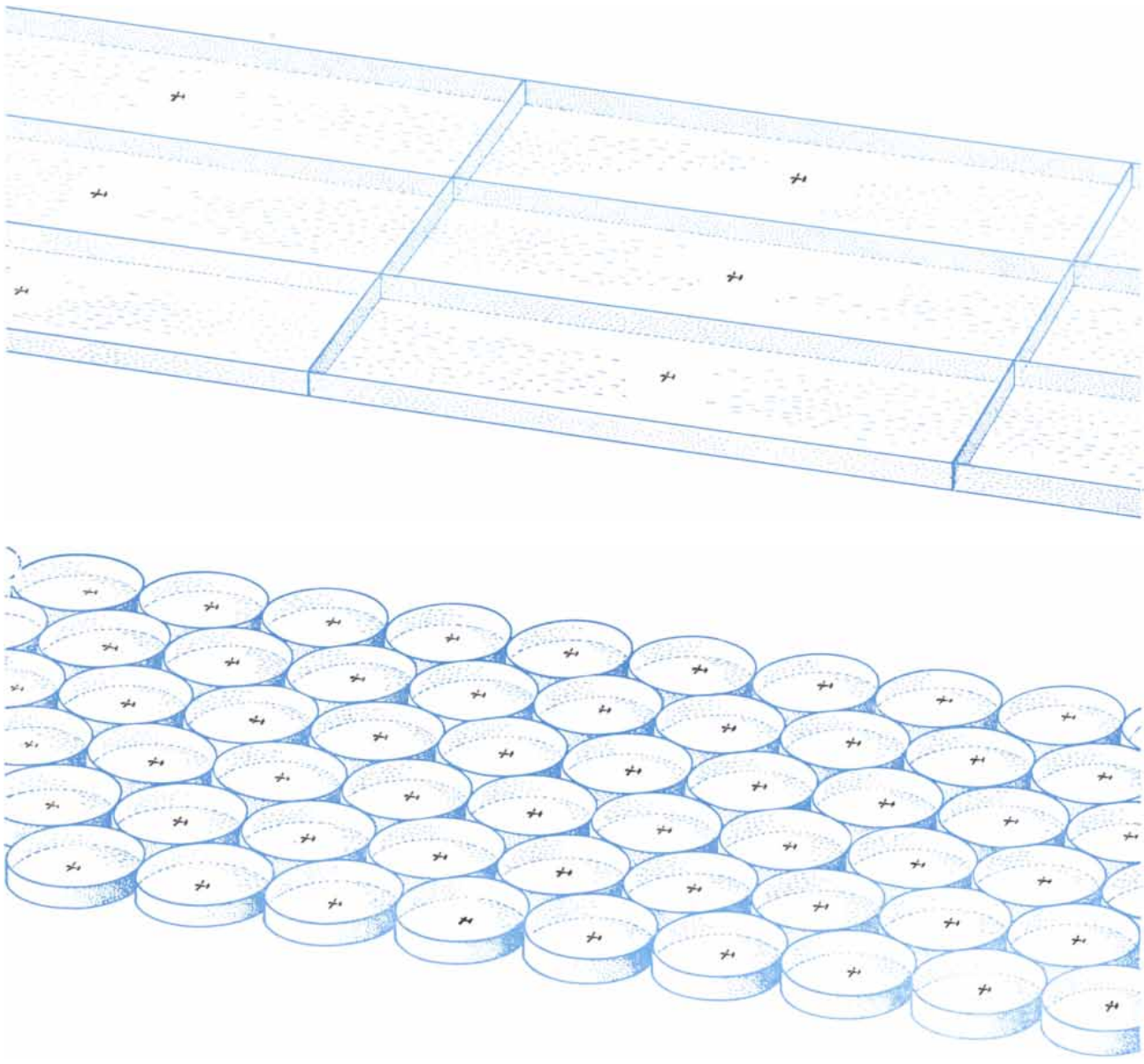
detect another aircraft in time to avoid a collision. The pilots of two jet airliners on a head-on collision course have only 15 seconds to avoid collision when their planes are five miles apart. Ordinarily the time required to see an approaching aircraft, judge whether it is on collision course and maneuver to avoid it may run as high as 30 seconds or more [*see illustration on opposite page*].

Air-traffic control is of course intimately involved with the technique of navigation. The first nationwide system of airways was established by the transmitters of the so-called Low-Medium Frequency Four-Course Radio Range, referred to as the LF/MF system. As the name suggests, directed radio beams create four tracks to or from each transmitter; the tracks mark the center line of the airways, and the transmitters themselves serve as fixes. Since the LF/MF system permits navigation along only four specified radials from each transmitter, it severely limits the number of routes that can be flown, and may occasion excessive detours from a simple straight-line flight path [*see top illustration on page 53*]. To change the orientation of a track, one or more radio towers must be physically relocated. The LF/MF system is still in operation, but for all except minimally equipped aircraft it has been supplanted by the Very High Frequency Omnidirectional Radio Range, or VOR, which provides bearing information in all directions. Planes may thus navigate along direct routes between any origin and any destination by triangulating on two or more VOR sources. Some airline navigating gear does this work automatically, continuously computing the aircraft's position in polar co-ordinates based on the VOR transmitters or in hyperbolic co-ordinates based on other transmitter networks [*see illustrations on page 54*]. A separate set of VOR airways has been created, any number of which may radiate from a given transmitter. To change the airway structure requires promulgation of the



"COCOONS" OF AIR TRAVEL WITH AIRCRAFT at all times. Along the airways (*top*) the inviolable airspace around a plane is as much as 100 miles long (depending upon the speed of the craft), 10 miles wide and 1,000 feet deep. Near the airport, or wherever radar can observe all craft, the cocoon around each craft can become a disk of air three miles in diameter and 1,000 feet deep (*bottom*).

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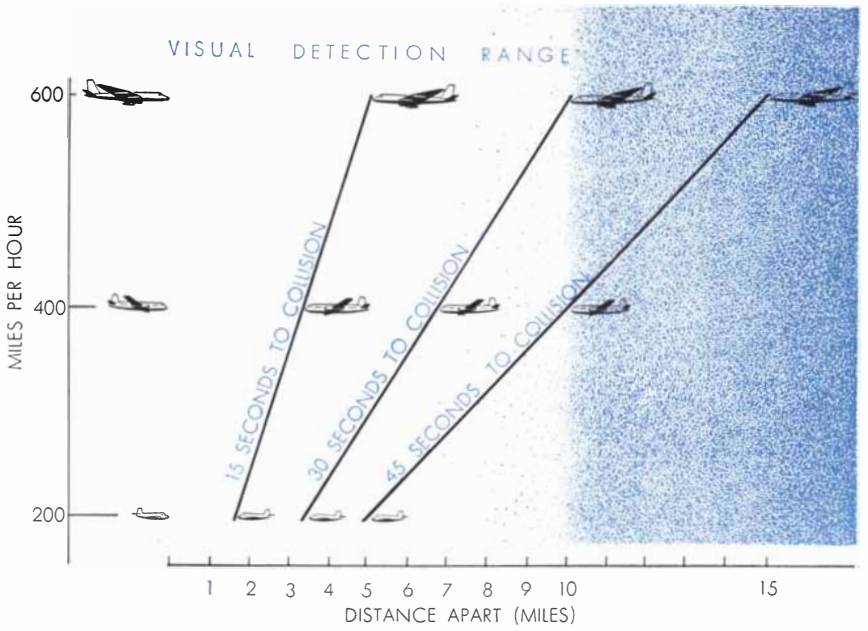
plan, but no physical change in the facility.

Beyond the well-established technology of radio navigation which relies on ground transmitters, engineers are developing new systems that will be wholly self-contained aboard the aircraft. These apply the basic concepts of celestial navigation and of dead reckoning, that is, navigation by the record of the time flown along a known heading from a known initial position. The hardware involved includes such devices as artificial earth-satellites and the inertial guidance systems by which rockets are navigated.

Navigation can also be directed by sources external to the aircraft. The radar techniques used to control traffic at most major airports have recently been extended to the en route control of high-altitude jet flights. A ground controller, watching the plane's position on the radar scope, "vectors" the flight from the ground, giving the pilot heading instructions.



RANGE OF VISUAL DETECTION of approaching aircraft is illustrated. Pilots usually need about 30 seconds to avoid head-on collision when not under traffic control. With reasonable visibility and vigilance approaching planes can be seen about four miles away. Detection becomes virtually impossible beyond 10 miles, as indicated here by the shading.

Even though navigation systems now provide many pilots with the capability for direct origin-to-destination flying, air-traffic control continues to rely on the airway network. Pilots must accordingly put up with longer flight paths and flight times; they encounter congestion and delay at the fixes on major routes, and they cannot exploit the full speed of the aircraft. But without the airway system the task of data-processing would become entirely unmanageable. On the airways, conflicts arise only at fixes, and comparison of ETA's at these points is relatively simple. If all aircraft were to fly direct courses, on the other hand, the air-traffic pattern would change from that of a single file of vehicles on a highway to the random pattern of drivers moving about in a large and relatively empty parking lot. On the highway, traffic lights are needed only at intersections; in the parking lot, a collision can occur anywhere [*see illustration at top of page* 55]. Continuous computation of projected flight paths, plus constant comparison of the changing relative positions of the aircraft, would be necessary to prevent conflict and collision. Such omniscient control of the airspace exceeds the capability of the data-processing system presently in existence.

The system is a manual one, and it is already stretched to the breaking point by the rising demand for air-traffic control. This is especially the case in the control centers at major air terminals. Since position reports from the pilots are neither sufficiently accurate nor frequent enough to maintain the characteristically heavy traffic flow, the controllers at these points have long since come to rely upon radar to provide the basic control-data. Radar, supplemented by radio for identification of the aircraft, yields much more accurate information at a high rate. The controller's problem is how to manage and make sense of the flux of data.

The Federal Aviation Agency is pressing the development of equipment to reduce the data-processing load on the controller. In addition to improvements in radio and radar gear for more automatic communication, the program includes an automatic computer to mechanize the preparation and processing of flight-progress strips and the prediction of conflict. The human controller will continue to make the decisions that resolve the conflicts. It is hoped that the mechanization of data-processing will free him for this primary task.

The always-qualified reliability of automatic equipment, however, sets a limit on the increase in traffic flow that can be achieved by such means. An air-traffic control center that employs it will have to be ready at all times to resume manual data-processing in the event of equipment failure. The controller's nightmare is to have his radar scope go dead when he is controlling a dozen closely spaced aircraft all moving in different directions. A controller who may suddenly face the need to work without automatic equipment cannot be expected to take cognizance of more aircraft or to permit smaller separations between them than he could manage unaided.

There is also the prospect that a substantial increase in the flow of information may exceed the rate at which the controller can make decisions. Part of the decision-making function—the selection and ranking of the alternative changes in flight paths that would resolve a given conflict, and the computation of optimal sequences of aircraft in the traffic flow into the terminal—might then be shifted to automatic computers. The question of reliability, however, comes even more urgently to the fore. The installation of redundant units of critical components and of whole machines, plus automatic switching to replace a faulty unit with a sound one, could provide a reasonable margin of safety. But against the possibility of having to revert to manual control there would have to be standard procedures for reducing traffic density and increasing the separation between aircraft in a short time. And the controller would always need some ineradicable record of the current positions and courses of all aircraft under his cognizance available for such an ultimate emergency. Until repairs were completed, the system would obviously have to operate at a low level of capacity.

The mechanization of air-traffic control also presents some difficult equip-

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ment management problems. Military and large transport aircraft can be expected to carry all the airborne gear necessary for operation in a sophisticated control system. But most of the aircraft used for business, training and pleasure—70 per cent of all licensed aircraft—cannot bear either the weight or the expense of such equipment. These aircraft can, however, carry radio-communication and navigation gear suitable by current standards. All air traffic may someday be brought, of necessity, under a dual system of control, with a more sophisticated, direct-flight system open to those that can benefit by it, and with other aircraft restricted to the present airways system. The two control systems would share data-processing and control equipment, and would accept flight plans and position reports and issue instructions by any means appropriate to the skill and equipment of the individual flyer. Compatibility among the different parts of this dual system will have to be assured.

An air-traffic control system must also be prepared to cope with the willingness as well as the ability of pilots to operate within its confines. Pilots generally prefer flexibility in planning and operation, with freedom to detour storms, for example, or to change their plans at any time on other than transport flights. The system must also permit pilots to take occasional independent action based on their own knowledge of the traffic situation at the moment. Presently they depend upon the controller and their own eyes to learn about the presence of other aircraft. Airborne proximity indicators and collision-avoidance devices may eventually give each pilot a more secure orientation in the traffic pattern.

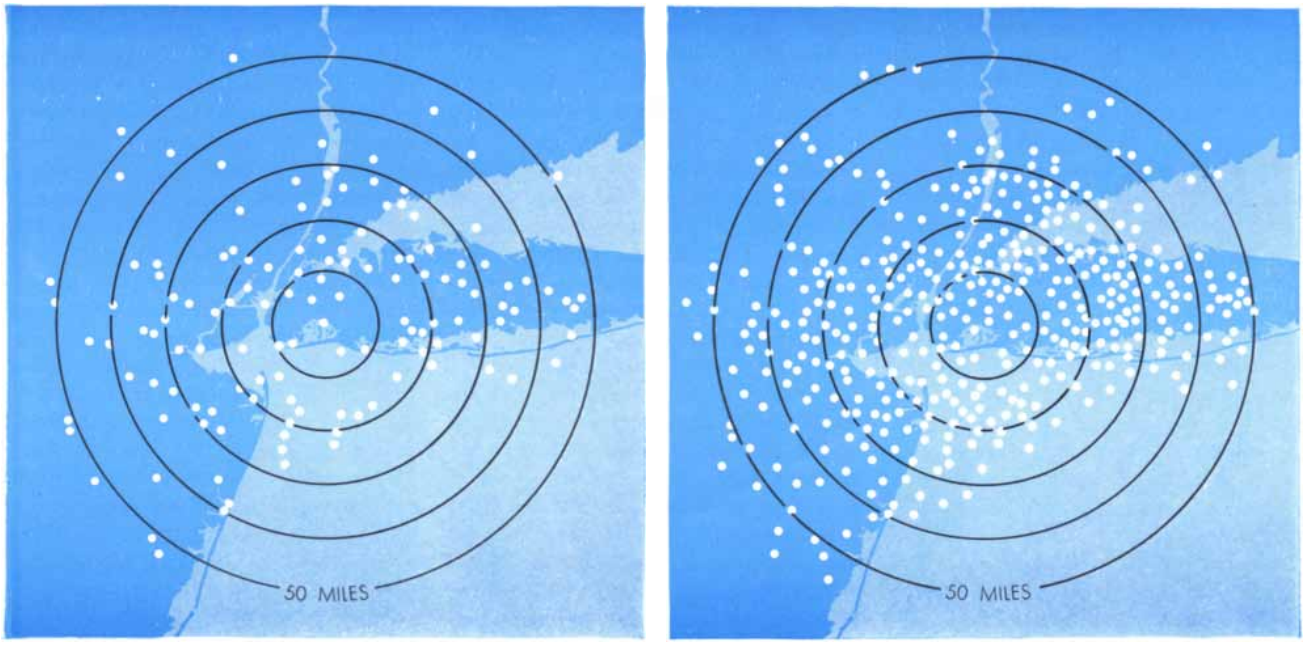
But even after the automatic data-processing and control system is operating to the maximum of its capability, it will not necessarily increase the traffic capacity of the crowded portions of the airspace. That capacity is ultimately limited by the separation in space and time required between aircraft. Experience and intuition indicate that the primary bottleneck is to be found in the approaches to the airport, and that most of the delay is suffered by aircraft waiting to land.

This suspicion was confirmed by studies recently conducted under the sponsorship of the Federal Aviation Agency. The staff of the International Business Machines Corporation programmed a digital computer to yield data representing two hours of heavy air-traffic in the New York metropolitan area. With two hours of operations reduced to six minutes of computation, the investigators were able to study the effects of many variations in route structures, in flight plans and in the rate at which aircraft could be accepted at the airports. It was found, when the results were analyzed at the Cornell Aeronautical Laboratory in Buffalo, N.Y., that landing delay accounted for three quarters of the total delay time accumulated during the sample period. Delay in waiting for clearance to take off and to proceed to the first fix accounted for half of the remainder. A simulated doubling of the landing capacity of the airports in the area reduced the landing delay by 60 per cent. With the principal cause of delay plainly identified, further study at Cornell was centered on the task of speeding traffic through the approaches to the airport.

When the weather is good, aircraft can usually be cleared for landing as soon as they report in to the controllers. Since speeds are relatively low in the terminal area, and approach paths are rather precisely defined, see-and-be-seen operation (in which pilots retain responsibility for avoiding other craft) can frequently be permitted. Under these circumstances the airspace reserved to each aircraft can be much reduced, and traffic flows at a high rate.

As soon as visibility falls, however, the control system, with its more restrictive standards, assumes jurisdiction over all traffic. When aircraft arrive more frequently than they can be landed, they are ordered to wait their turn in a "stack." The aircraft assemble over radio beams which the pilots use to help them fly a precise "holding pattern" with planes separated from one another by 1,000-foot intervals of altitude. As aircraft are removed from the bottom of a stack for landing, the remainder are laddered down.

At the runway all aircraft, especially in bad weather, must follow a single final



AIRCRAFT IN THE AIR near New York at 10:30 a.m., July 14, 1956, are seen (*left*) in simulated radar view centered on New York International Airport. There are 123 planes. A Federal study has forecast that by 1975 there will be 350 planes in the air (*right*).

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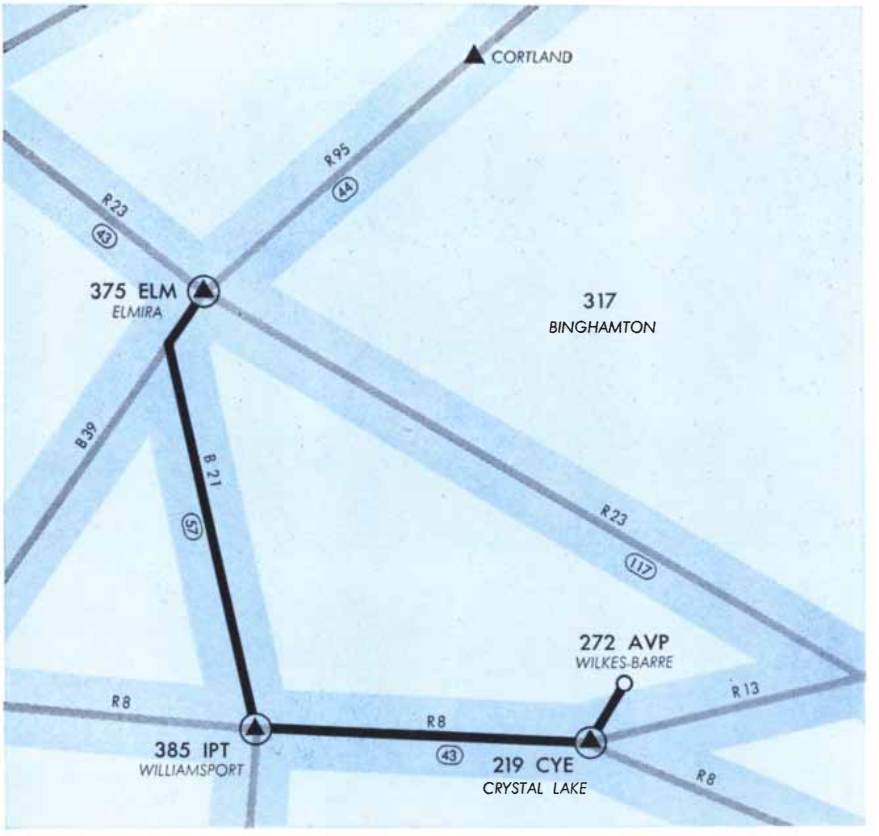
approach path that is marked out in the airspace by radio signals [*see illustration on pages 48 and 49*]. They must maintain the standard three-mile radar separation along the path, at least at its beginning. Since no two aircraft may occupy the runway at the same time, an aircraft cannot land until its predecessor has left the runway. Similarly, no departing aircraft may enter the runway if the next one scheduled to land is within two miles of the runway threshold.

On the basis that most of the delay is experienced in the stacks, some hypothetical control-systems go to great pains to eliminate the stacks. But this is like removing the chairs from the doctor's waiting room in the hope of removing the wait. Rather, the need is for increased service capacity so as to reduce delay.

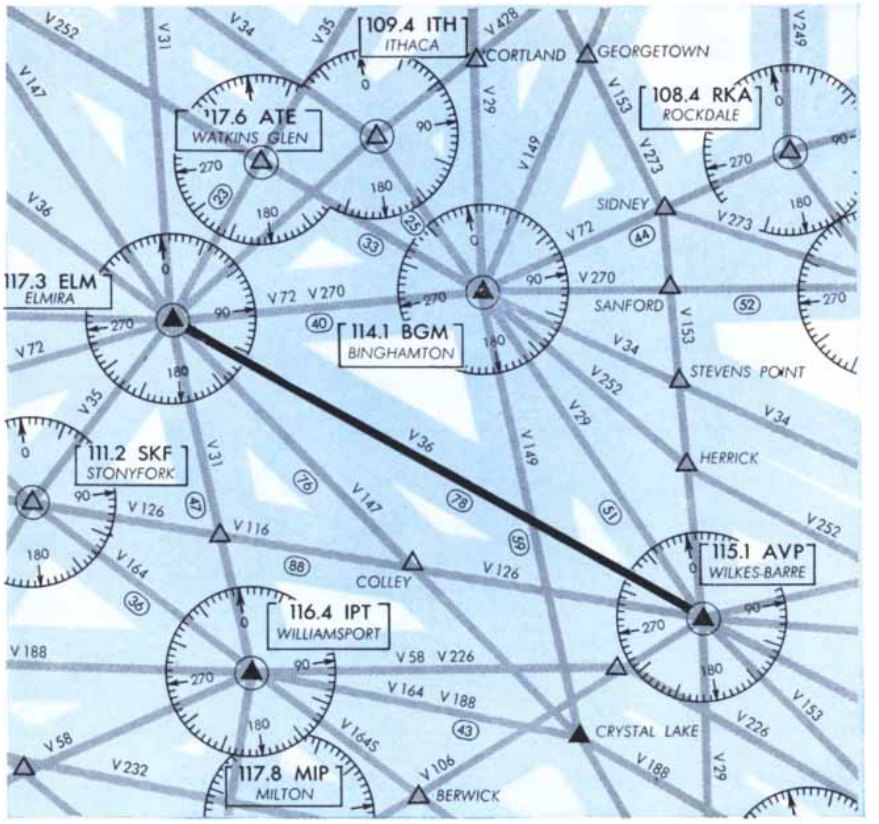
Analytical models were formulated recently at the Cornell Aeronautical Laboratory to assess the effect of the airport, the air-traffic control system and air-traffic characteristics on runway capacity. The principal quantities in the equations that constitute these models stand for the length of the final approach path, the required separation between planes at the beginning of the path, the maximum runway-occupancy time and the statistical distribution of the velocities of the arriving aircraft. The studies indicate that the landing capacity of a runway in bad weather under the present control system is on the order of 35 landings per hour, in accordance with actual experience, and is most severely restricted by the minimum separation required on the common landing path.

The three-mile standard is based upon the use of radar, and was established 10 years ago as an optimum consistent with the demands of safety and of service. It may be that the safety record could be maintained with less airspace reserved to each aircraft; this would require more accurate radar and reorganization of the controller's work load to allow him to police the smaller separation. If the separation could be reduced to two miles, landing capacity could be increased 25 per cent.

This analysis helped to dispel some persistent misconceptions. For example, it has been proposed that landings might be cleared from the runway faster if banked exits were provided, permitting the planes to swing off the runway at higher speed and thus sooner after they touch ground. Landing capacity, it is argued, would increase accordingly. Some increase might in fact be secured in clear weather, when aircraft can line up be-



AIRWAYS ARE LIMITED to four tracks originating at each transmitter in LF/MF system. The route between Elmira, N. Y., and Wilkes-Barre, Pa. (*black line*), is 120 miles long.



UNLIMITED NUMBER OF TRACKS is theoretically possible from each VOR transmitter. Twelve pass through Elmira; trip to Wilkes-Barre can take direct route 78 miles long.

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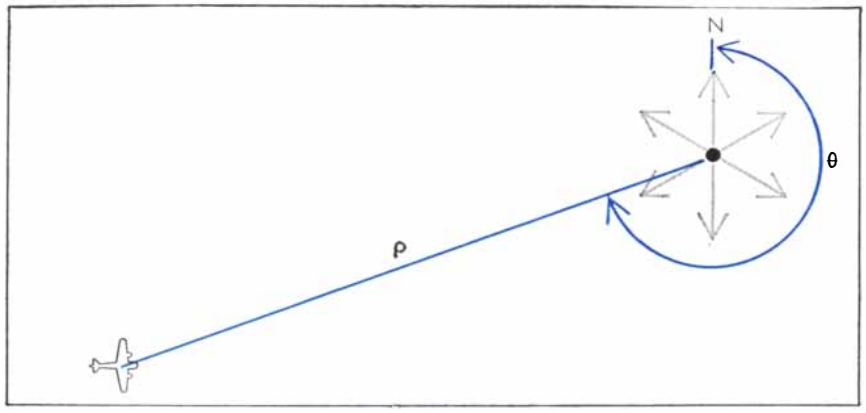
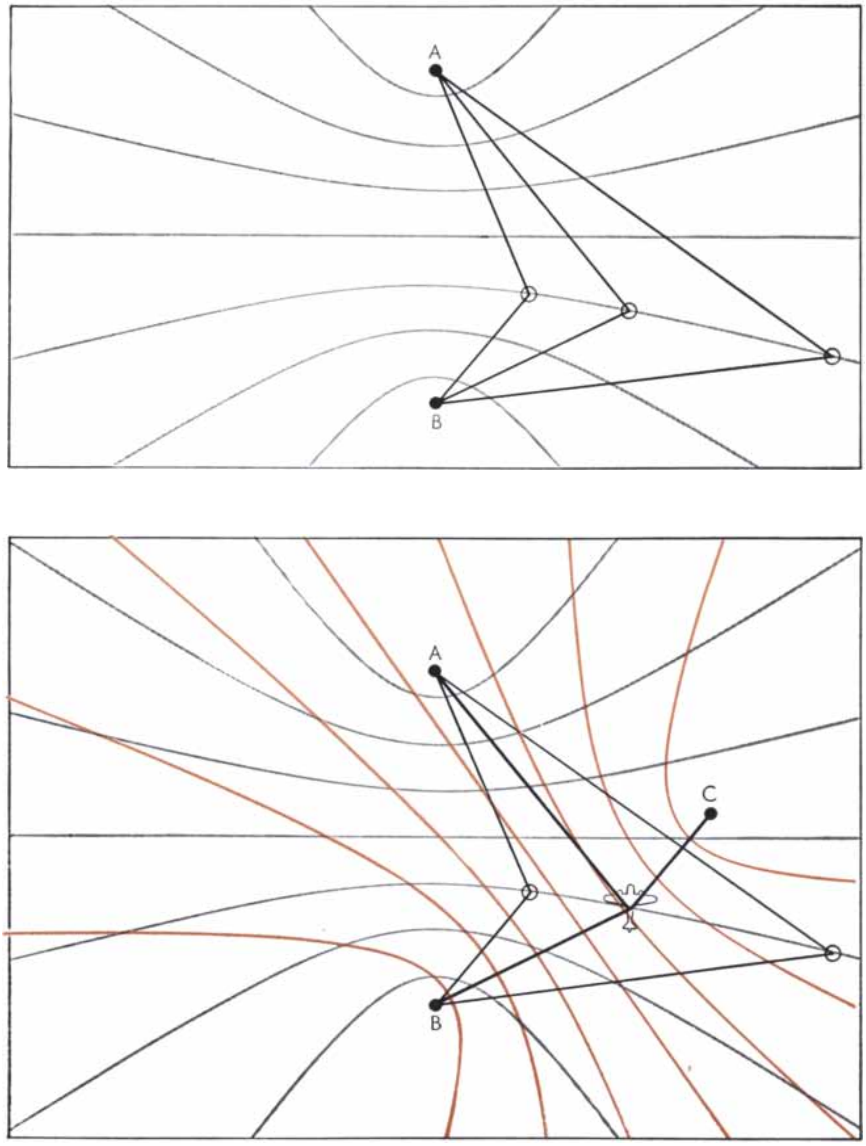


POLAR-COORDINATE SYSTEM for navigation continuously computes aircraft position from angle (θ) and distance (ρ) to known radio transmitter, indicated by dot at upper right.



FAMILIES OF HYPERBOLAS make up another system of navigation. Transmitters at A and B are common foci for one family (*gray*), which actually consists of radio signals. The difference in the distance from A and B is the same at every point on one line. Open circles (*top diagram*) indicate three of the possible positions of a craft on a line. Transmitters at C and B (*bottom diagram*) are foci for a second family of hyperbolas (*color*). Intersection of two lines, calculated automatically from radio signals, locates the aircraft.

hind one another in close formation and the next one can touch the runway the moment the preceding one is off. Under such conditions, with conventional runways, planes can now land about one minute apart; banked turnoffs might cut this interval in half. But the capacity problem is most serious in bad weather. The three-mile limit—equivalent to 1½ minutes for a 120-mile-per-hour aircraft—is then the dominating consideration. Only with the separation distance reduced below two miles can fast turnoffs yield great advantage in landing rate.

Rearrangement of the landing sequence to take advantage of the different speeds of different aircraft has also been proposed. Aircraft are now landed in first-come-first-served sequence. If a jet, a slow-moving DC-3 and another jet arrive in the stack in that order and land in the same order, there is a large time lag between the first jet and the DC-3, and the second jet has to wait out a relatively expensive delay. It might appear that some increase in traffic flow would accrue from landing the planes in some optimum sequence instead of in the present more "democratic" order. Analysis showed that the gain would be small, on the order of 10 to 20 per cent in the ideal case. The gap that now appears between the first jet and the DC-3 would reappear between the second jet and the DC-3, negating most of the gain. With automatic data-processing and control equipment available for other reasons, however, the gain might be worth working for.

Any consideration of runway capacity must reckon with take-offs as well as landings. In saturation situations take-offs are simply interposed between landings wherever possible, and the total operations rate represents the combined effect of the two. Most measures proposed in the interest of speeding up the rate of landing by closer spacing result in less opportunity for interposing take-offs. In this case the high-speed turnoff can raise the total operations rate by removing the landing from the runway earlier, thereby making possible a take-off before the next landing gets too close. Similarly, rearrangement of the landing sequence can increase the take-off rate by creating long intervals of proper length between landings for the interposition of planes waiting to take off.

Under some conditions, therefore, a large separation on the final approach path may help increase the total rate of operation, even though a smaller separation offers the greatest improvement in the rate of landing. Clearly the fixed

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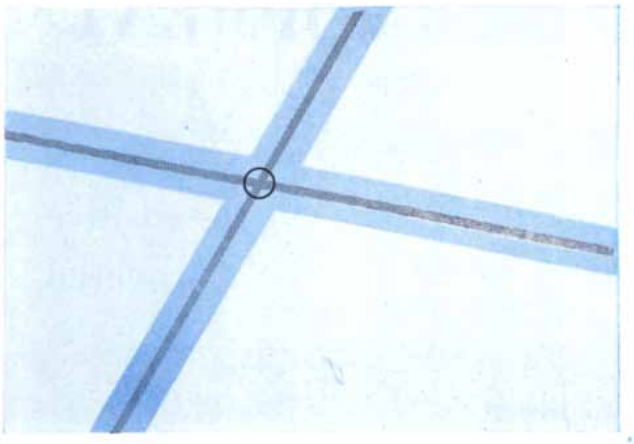
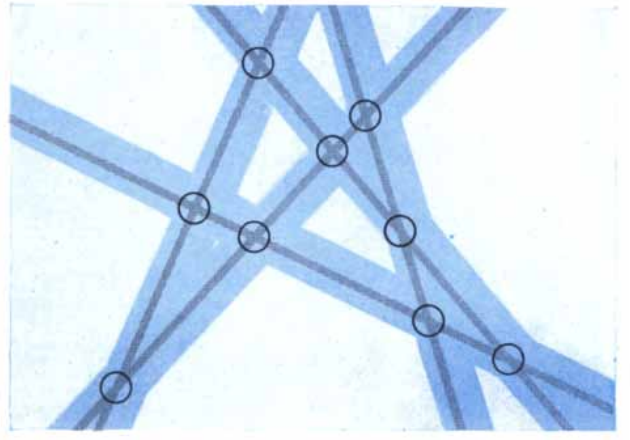
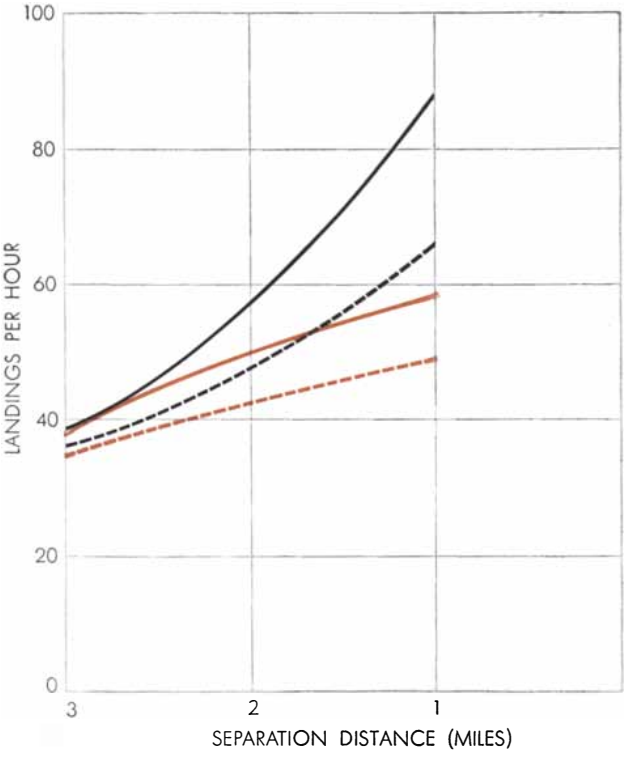


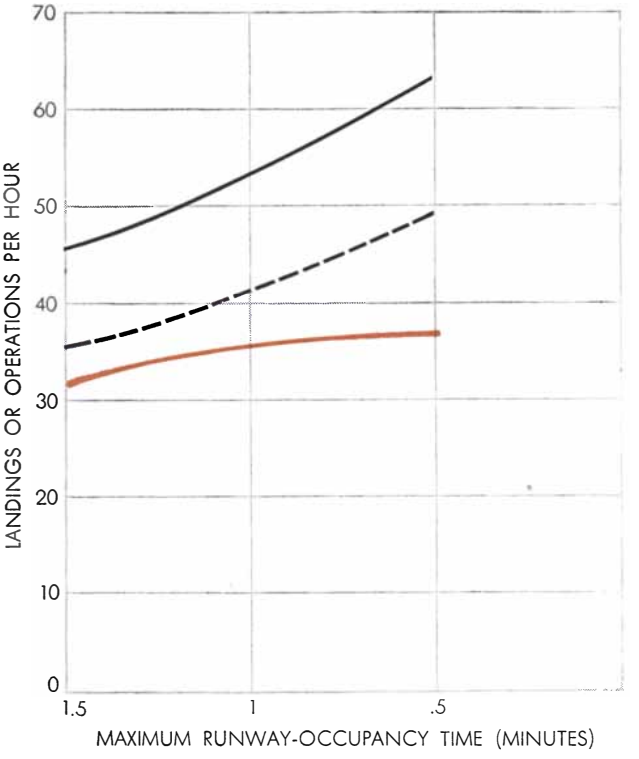


CROSSROADS IN THE AIR (*left*) are created by airways system. If five craft are flying the two routes, collisions can occur only at the one intersection. Five planes, each traveling its own path (*right*), create nine intersections where collisions become possible.

minimum-separation standard must give way to a flexible one. An important approach to such flexibility is to reduce errors in position-sensing equipment. By giving the pilot more assured control of his aircraft, and the controller a better picture of the traffic situation, this may permit more accurate adjustment of the space between aircraft.

But with aircraft closer together in space, small speed differences assume much greater importance. The controller will then be concerned with rates of closure between aircraft as well as the distance between them. He will have to be equipped with a whole new mode of control that will enable him to include in his judgments relative velocities as well as relative positions. Such information would eliminate many of the uncertainties in the picture of the traffic pattern as now presented to the controller. This in turn would permit further increase in the rate of traffic flow that the controller can manage. Such transformation of method as well as the engineering of equipment promises to increase the capacity of the airspace and reduce delay while maintaining the present high level of safety.





LANDING CAPACITY OF AIRPORT is affected by several factors. Graph at left shows theoretical capacity at La Guardia Airport in New York when instruments must be used. Black curves indicate capacity if planes are on runway 30 seconds; colored curves, if they are on runway one minute (as at present). Solid lines are for final approach path of four miles; broken lines, 10 miles. Curves show that reducing the space between planes would be most effective in increasing the landing rate. Graph at right, for same airport, shows theoretical landing capacity (*color curve*) and operations capacity (sum of landings and take-offs) in instrument weather. Top curve is for minimum take-off intervals of one minute between planes; broken curve is for take-off intervals two minutes long.

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LIGHT AND PLANT DEVELOPMENT

Events in the life of a plant such as flowering are responses to a change in the length of the night. The light-sensitive enzyme that mediates these responses has now been discovered

by W. L. Butler and Robert J. Downs

Various kinds of plant germinate, grow, flower and fruit at different times in the year, each in its own season. Thus some plants flower in the spring, others in the summer and still others in the autumn. And in the autumn, trees and shrubs stop growing in apparent anticipation of winter, usually well before the weather turns cold. What is the nature of the clock or calendar that regulates these cycles in the diverse life histories of plants? Some 40 years ago it was discovered that the regulator is the seasonal variation in the length of the day and night. Since this is the one factor in the environment that changes at a constant rate with the change of the seasons, in retrospect the discovery does not seem so surprising. But how do plants detect the change in the ratio of daylight to darkness? The answer to this question is just now becoming clear. It appears that a single light-sensitive pigment, common to all plants, triggers one or another of the crises in plant growth, from the sprouting of the seed to the onset of dormancy, depending upon the plant species. This discovery is a major breakthrough toward a more complete understanding of the life processes of plants, and it places within reach a means for the artificial regulation of these processes.

The pigment has been called phytochrome by the investigators who discovered it at the Plant Industry Station of the U. S. Department of Agriculture in Beltsville, Md. It has been partially isolated, and it has been made to perform in the test tube what seems to be its critical photosensitive reaction: changing back and forth from one of its two forms to the other upon exposure to one or the other of two wavelengths of light that differ by 75 millimicrons. (A millimicron is a ten thousandth of a centimeter.) Phytochrome appears to be chemically active in one of its forms and inactive in the other. In the tissues of the plant it functions as an enzyme and probably catalyzes a biochemical reaction that is crucial to many metabolic processes.

The first step toward the discovery of phytochrome was taken in the 1920's, when W. W. Garner and H. A. Allard of the Department of Agriculture recognized "photoperiodism" [see "The Control of Flowering," by Aubrey W. Naylor; SCIENTIFIC AMERICAN, May, 1952]. They showed that many plants will not flower unless the days are of the right length—some species flowering when the days are short, some when the days are long. Indeed, some plants seem to react not simply to seasonal changes but to changes in the length of the day from one week to the next. Photoperiodism explained why plants of one type, even though planted at different times, always flower together, and why some plants do not fruit or flower in certain latitudes.

Other investigators soon reasoned that if a plant needs a certain length of day to flower, then keeping it in the dark for part of the day would inhibit its flowering. They tried to demonstrate such an effect in the laboratory. Nothing happened: the plants always bloomed in the proper season. The riddle was solved when the reverse experiment was tried, that is, when the night was interrupted with a brief interval of light. Chrysanthemums, poinsettias, soybeans, cocklebur and other plants that flower during the short days and long nights of autumn and early winter remained vegetative (*i.e.*, nonflowering). Moreover, they could be made to bloom out of season, when the night was lengthened by keeping them in the dark at the beginning or the end of a long summer day.

Conversely, a brief interval of light interrupting the long winter night induced flowering in petunias, barley, spinach and other plants that normally bloom in the short-night summer season. Artificial lengthening of the short summer night kept these plants vegetative. Interrupting or prolonging the nighttime darkness correspondingly affected stem growth and other processes as well as flowering in many plants.

It was evident that light must act upon a photoreceptive compound, or compounds, to set some mechanism that runs to completion in darkness. As a first step toward elucidating the chemistry of the process H. A. Borthwick, Marion W. Parker and Sterling B. Hendricks of the Department of Agriculture in 1944 set out to determine the wavelength or color of light that is most effective in inhibiting flowering in long-night plants. They exposed each of a series of Biloxi soybean plants, from which they had stripped all but one leaf, to different wavelengths of light from a large spectrograph [*as in middle illustration on opposite page*]. Several days after the treatment the plants were examined for the effect of this exposure upon the formation of buds. Red light with a wavelength of 660 millimicrons proved to be by far the most effective inhibitor of flowering. The cocklebur and other long-night plants gave the same response. By plotting on a graph the energy of light required to inhibit flowering at various wavelengths, the investigators obtained the "action spectrum" of the mechanism that inhibits flowering. This showed that to interfere with flowering, much more light energy is required at, for example, 520 or 700 millimicrons than at (or very near) 660 millimicrons [*see illustration at bottom of page 62*]. The wavelength at which the unknown substance absorbs light

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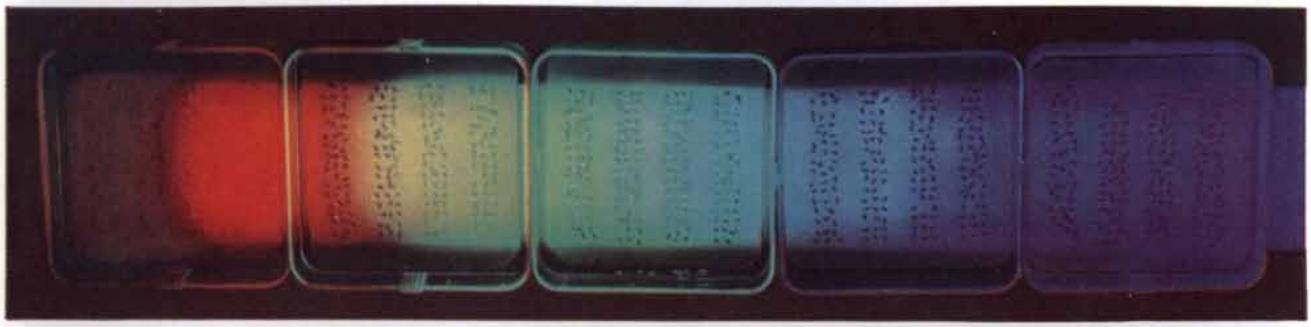

LIGHT FROM SPECTROGRAPH exposes lettuce seeds to different wavelengths. Only 2 per cent of those in far-red light at far left will sprout, while 90 per cent of those in red will germinate. In this photograph only a few of seeds in red region are visible.

CATALPA TREE SEEDLINGS, kept on short days and long nights, are exposed to this spectrum in the middle of the night. Those seen in red will grow. Seedlings in far-red light at far left and all of the others will stop growing and become dormant.

CHRYSANTHEMUM PLANTS at left have had long nights interrupted by period of red light. This divides night into two short dark periods, and plants will not bloom. Chrysanthemums at right also had nights interrupted by red light, but they were irradiated with far-red, as seen here. Far-red light reversed effects of red light, and the plants bloomed just as if nights had been uninterrupted.

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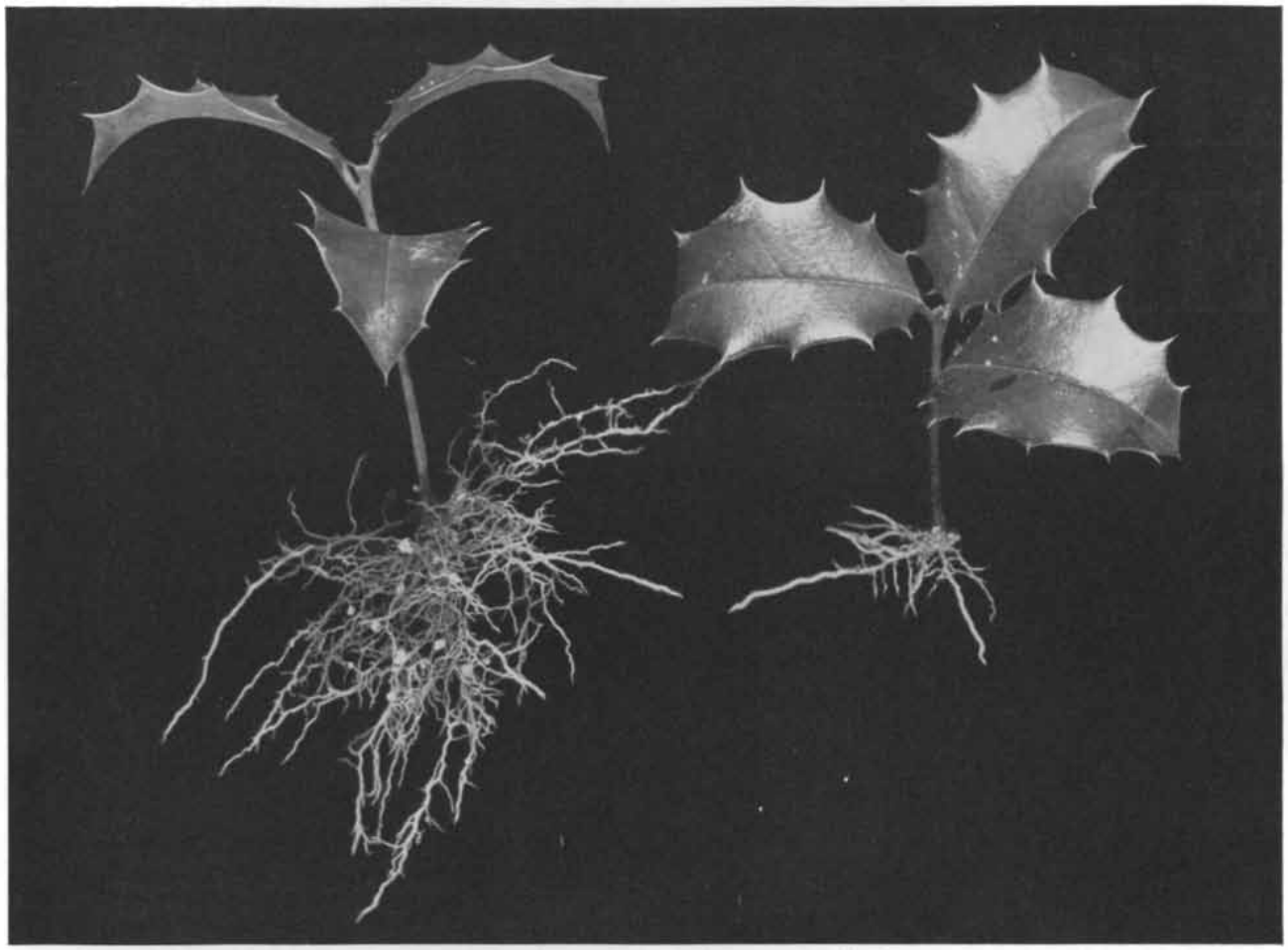
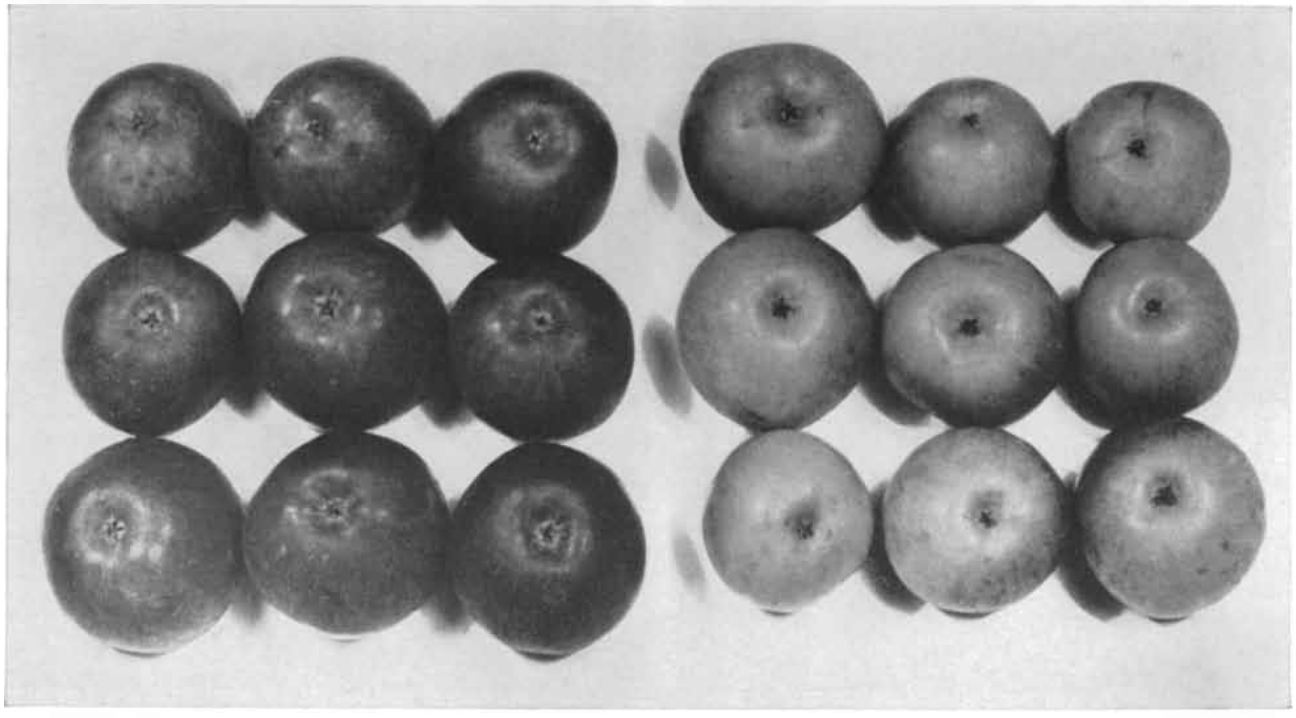


ROOTS OF AMERICAN HOLLY show response to light. Both cuttings were rooted during winter. That at right was kept on natural days and nights. Long nights were interrupted with 30 foot-candles of light for plant at left; its roots grew prodigiously.



MATURE APPLES do not turn red if they are kept in the dark while ripening (*right*). Ethyl alcohol collects instead of red pigment. The apples can manufacture anthocyanin, the red pigment, only if they are exposed to light when they are mature (*left*).

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most efficiently was thus shown to be 660 millimicrons.

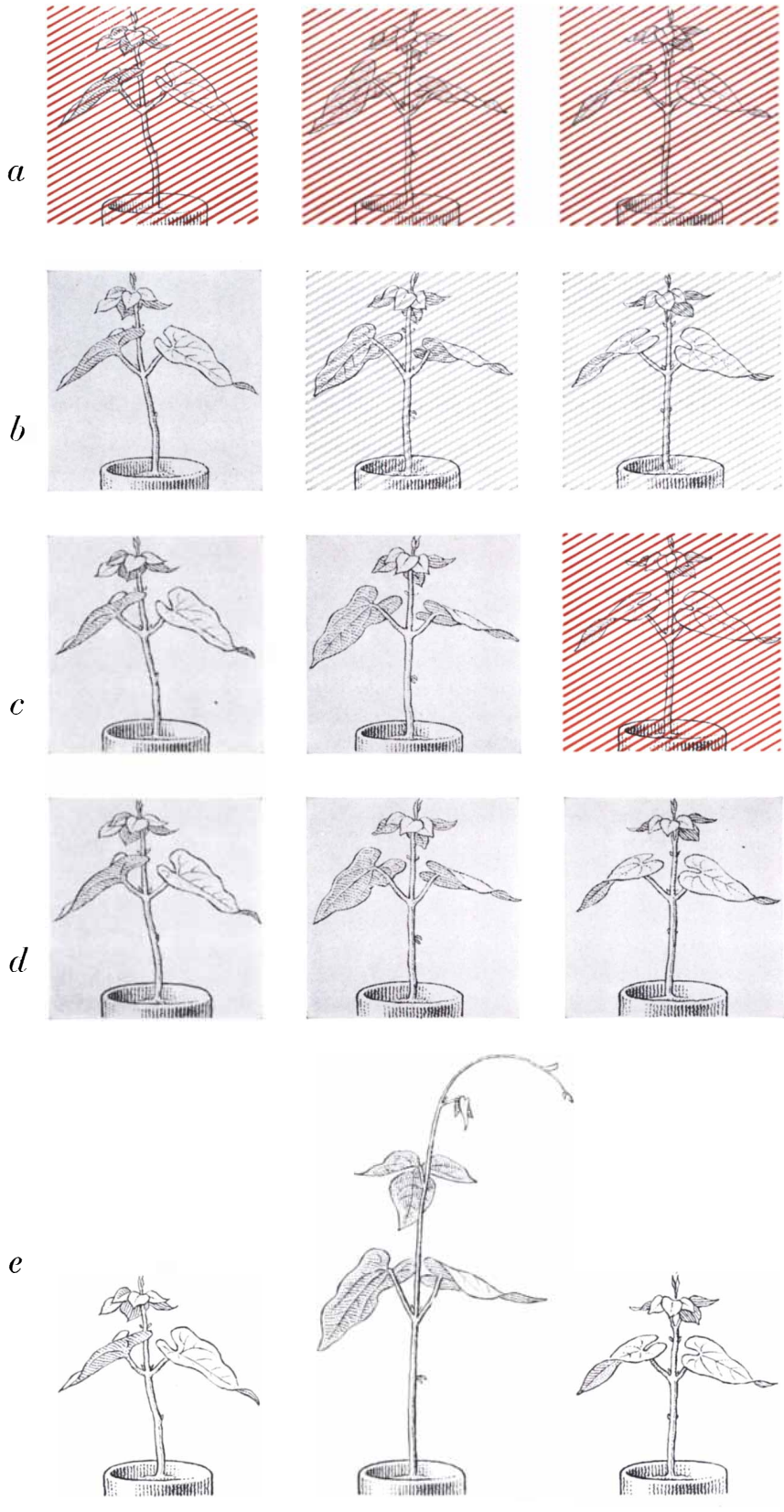
Borthwick and his associates then turned to short-night plants. The same spectrographic experiments yielded exactly the same action spectrum. But in this case the effect of the exposure was to promote—not inhibit—flowering! Since the same wavelength of light caused the greatest response in both cases, the investigators could only conclude that a single photoreceptive substance was involved in these two diametrically opposed responses.

Subsequent experiments implicated the same compound in the control of stem elongation and leaf growth. Recent work has shown that light at 660 millimicrons also acts upon mature apples to turn them red by enabling them to make the pigment anthocyanin. The same red light controls the production of anthocyanin in a number of seedling plants.

With the collaboration of a research group headed by Eben H. Toole, Borthwick and his associates next set out to determine which wavelengths of light trigger germination in those seeds that must be exposed to light in order to grow. Many weed and crop seeds are of this type. The action spectrum for the promotion of seed germination turned out to be essentially the same as that established for other plant responses. Whereas about 20 per cent of the seeds germinated in the dark or when they were exposed to green, blue and other shorter-wavelength colors, more than 90 per cent sprouted after irradiation by red light at 660 millimicrons.

This finding led the two groups of investigators to the study of an entirely different effect of light upon germination. It had been observed in the late 1930's that germination was inhibited when seeds were exposed to the longer wavelengths of far-red light which are invisible to the human eye. That observation was speedily confirmed. In fact, seeds that had been pushed to maximum germinative capacity by exposure to red light failed to germinate when they were subsequently irradiated with far-red light. The plotting of the action spectrum for this effect showed that far-red light at 735 millimicrons wavelength is the most potent in inhibiting the germination of seeds.

Still more interesting was the discovery that the diametrically opposed effects of red and far-red light upon germination are fully reversible. After a series of alternate exposures to light of 660 and 735 millimicrons, the seeds re-



STEM ELONGATION in pinto-bean seedlings is promoted by exposure to far-red light on four successive evenings. All three plants are in red-irradiated condition at end of each day (*a*). Second and third plants are exposed briefly to far-red light (*b*); third plant is given dose of red light, which reverses effects of far red (*c*). Then all three have normal nights (*d*). Some days later first and third plants are still short, but center plant is tall (*e*).

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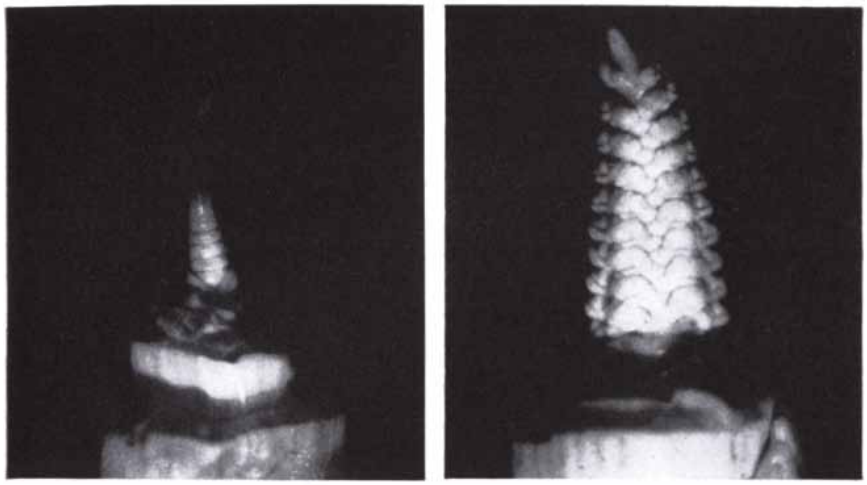


GROWING TIPS OF BARLEY, photographed through dissecting microscope at magnification of 20 diameters, show effects of long and short nights. Tip at left, dissected out from leaves, displays only leaf buds and little growth after being kept on long nights for two weeks. Plant at right had short nights; its tip has grown long and produced many tiny flower buds.

sponded to the light by which they were last irradiated. If it was red, they germinated; if far-red, they remained dormant [*see illustrations at top of pages 62 and 63*]. Now all of the phenomena of growth and flowering had to be re-examined for the effect of far-red as well as of red light. In each case the experiments demonstrated that irradiation by far-red light reversed the effects obtained by irradiation with red light.

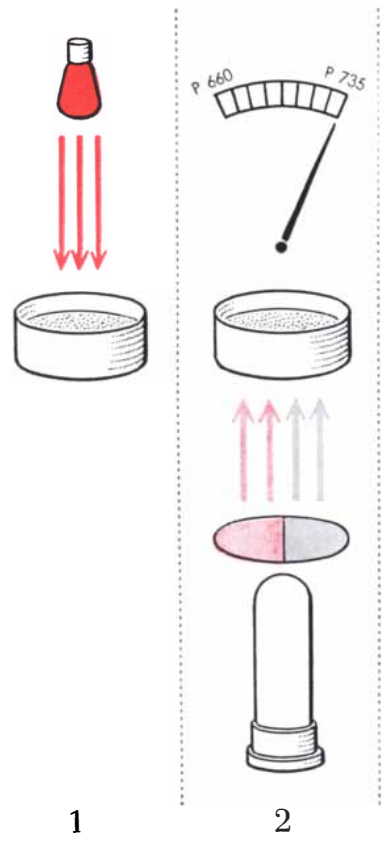
The reversibility of these reactions and the clear definition of their action spectra strongly suggested that a single light-sensitive substance is at work in every case, and that this substance exists in two forms. One form, which was designated phytochrome 660, or P_{660}, absorbs red light in the region of 660 millimicrons. When P_{660} is irradiated at this wavelength, it is transformed into phytochrome 735 (P_{735}), which absorbs far-red light at 735 millimicrons. When P_{735} is irradiated with light at 735 millimicrons, it reverts in turn to the P_{660} form.

In order to substantiate these deductions phytochrome had to be extracted from the plant. This required a method for detecting the presence of the compound other than the responses of a living plant. Since those responses occur at sharply defined wavelengths, there was reason to expect that phytochrome itself would prove to be more opaque, or "dense," to light at the wavelengths of 660 and 735 millimicrons when examined in a spectrophotometer—an instrument that measures the intensity of transmitted light at discrete wavelengths. The transformation of phytochrome from one form to the other would also show up well.

Measuring the very small amounts of phytochrome present in plants was not a simple task. K. H. Norris and one of the authors (Butler), respectively an engineer and a biophysicist in the Department of Agriculture, had been studying the pigment composition of intact plant-tissue, and had developed some sensitive spectrophotometers that measured the absorption of light by leaves and other plant parts. With Hendricks, a chemist, and H. W. Siegelman, a plant physiologist who had been investigating the chemistry of phytochrome, they formed a research group to look for the reversible pigment. Initially the absorption of light by plant parts failed to reveal the presence of phytochrome. The plant tissue, however, contained large amounts of chlorophyll, which absorbs strongly at 675 millimicrons. Apparently the absorption of light by chlorophyll—at a wavelength so near the phytochrome absorption peak of 660 millimicrons—was masking the absorption by phytochrome.

It was no great problem, however, to get around this obstacle. Seedlings can be sprouted in the dark and can grow for a while on the food energy stored in the seed; they do not begin to synthesize chlorophyll until they are exposed to the light. Corn seedlings were accordingly grown for several days in complete darkness. They were then chopped up and exposed to red light to put the phytochrome into the P_{735} form in which it absorbs far-red light. In the spectrophotometer a weak beam of light at 735 millimicrons was projected through the sample, weak light being used so that the phytochrome would not change form. The absorption spectrum showed that the phytochrome was indeed absorbing light at 735 millimicrons; the same sample passed light at 660 millimicrons. On the other hand, after exposure to relatively bright far-red light the chopped seedlings were found to absorb more light at 660 millimicrons and less light at 735 millimicrons. Repeated demonstration of this reversibility fully confirmed all that had been predicted from the responses of whole, growing plants. No doubt remained that a single compound was responsible for the reversible changes in growing plants.

The spectrophotometer measures the changes in "optical density" with such high sensitivity that it can be used to assay the amount of phytochrome in plant tissue. Thus with the help of this instrument a search was instituted for a plant that would supply phytochrome in sufficient abundance for chemical separation. Certain plant tissues, such as the flesh and seed of the avocado and the head of the cauliflower, showed a relatively high concentration of phytochrome. The cotyledons (the first leaves,



SPECTROPHOTOMETER TESTS, diagrammed here, show effects of red and far-red light on chopped corn seedlings in glass-bottomed dish. Dish is exposed to bright

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which feed the seedling) of most legumes synthesize phytochrome, and the concentration reaches its maximum about five days after the seeds start soaking up water. The growing shoot, or hypocotyl, as well as the first leaves of the legumes, contain less phytochrome than the cotyledons. In cabbage and turnip seedlings that have been sprouted in the dark the cotyledons are also a good source of phytochrome. However, five-day-old, dark-grown corn seedlings proved to be the best source, because they develop a high phytochrome content, have large stems and are easy to grow and harvest.

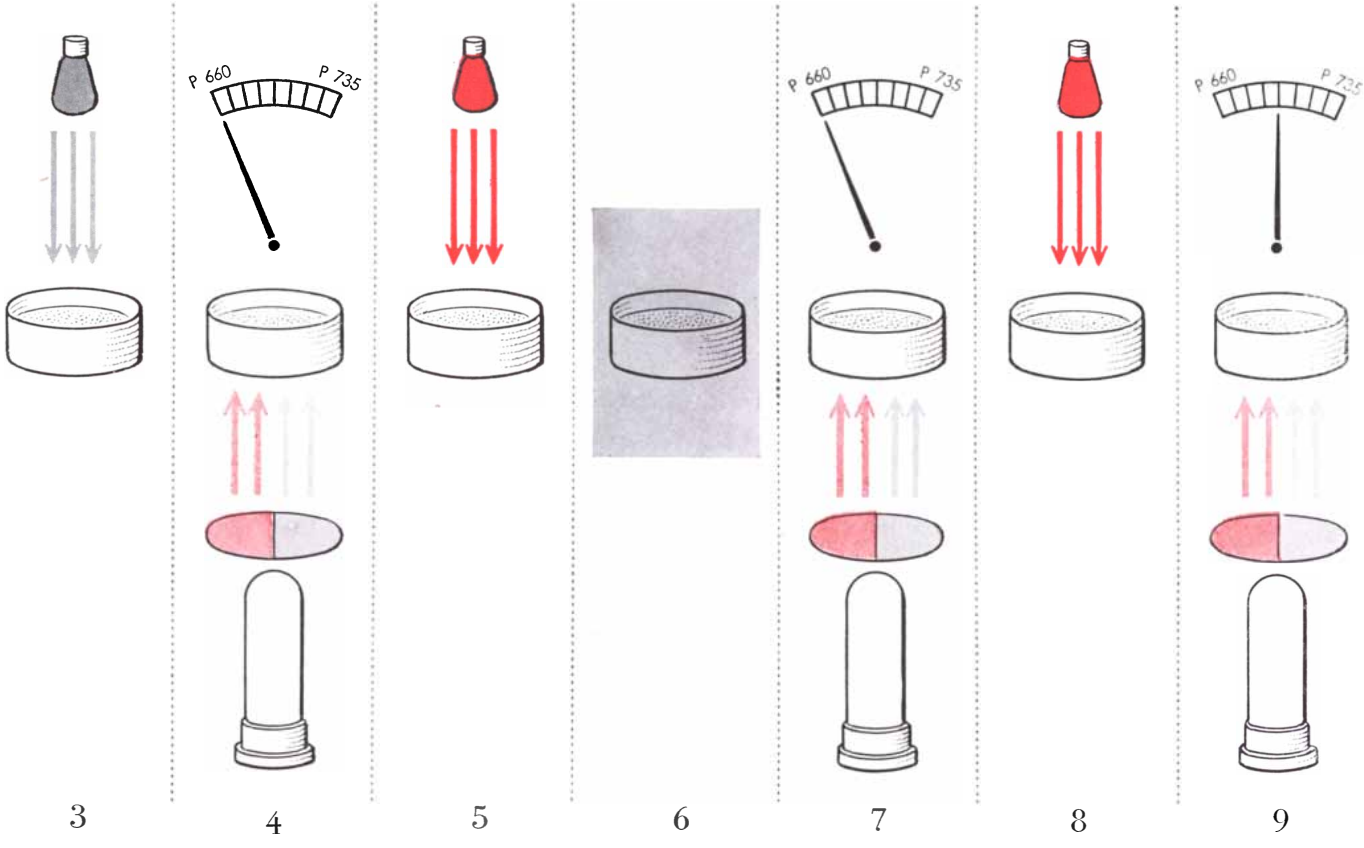
The preliminary and partial chemical isolation of phytochrome was easily accomplished. Corn shoots were ground up in a blender along with water and a mild alkaline buffer, and a clear solution was separated from the solid material by filtration. This extract exhibits exactly the same reversible optical-density changes at 660 and 735 millimicrons as the chopped seedlings themselves. Thorough study of the partially purified material has developed no evidence that any compound other than phytochrome participates in the photoreaction.

Though phytochrome has not yet been isolated in pure form, the outlook is favorable. The compound shows all the properties of a relatively stable soluble protein, and Hendricks and Siegelman are now using the techniques of protein chemistry to purify it. They have subjected it to dialysis (diffusion through a porous membrane), and it has retained its photochemical activity. Oxidizing and reducing agents do not affect it. Moreover, the photoconversion occurs at zero degrees centigrade as readily as at 35 degrees, as would be expected of a strictly photochemical reaction. Higher temperatures denature the protein and destroy its photochemical activity.

Measurements of the amount of red and far-red light necessary to bring about the conversion show that P_{660} consumes only one third as much energy in being transformed to P_{735} as P_{735} consumes in being changed into P_{660}. In both cases, however, the energy consumption is relatively small, indicating that the phytochrome absorbs light efficiently. The pigment should turn out to be a blue or blue-green, the colors complementary to red, but the concentration achieved so far has been too low to make the color visible.

Experiments with growing plants had indicated that P_{735} slowly changes back into P_{660} in darkness, whereas red-absorbing P_{660} is stable. Direct measurement of the changes in the form of phytochrome in intact corn seedlings have confirmed these indications. In seedlings that have never been exposed to light, phytochrome occurs entirely in the red-absorbing, or P_{660}, form. These seedlings are exposed briefly to red light to convert the P_{660} to P_{735}. They are then returned to the darkroom and are examined with the spectrophotometer at intervals thereafter. Such measurements show that it takes about four hours at room temperature for the P_{735} to change back into P_{660}.

This conversion in the absence of light is apparently mediated by enzymes. It is markedly retarded by lowering the temperature, and it does not occur at



red light (1). Filters are used in spectrophotometer to project weak red and far-red light through dish (2); dial shows absorption at wavelength of 735 millimicrons. Now dish is exposed to bright far-red light (3). Next test (4) indicates phytochrome has changed to form that absorbs light at 660 millimicrons. After second exposure to bright red light (5) seedlings are placed in dark for four hours (6), and P_{735} again changes to P_{660} (7). Exposure to red light (8) shows that phytochrome lost half its activity in dark (9).

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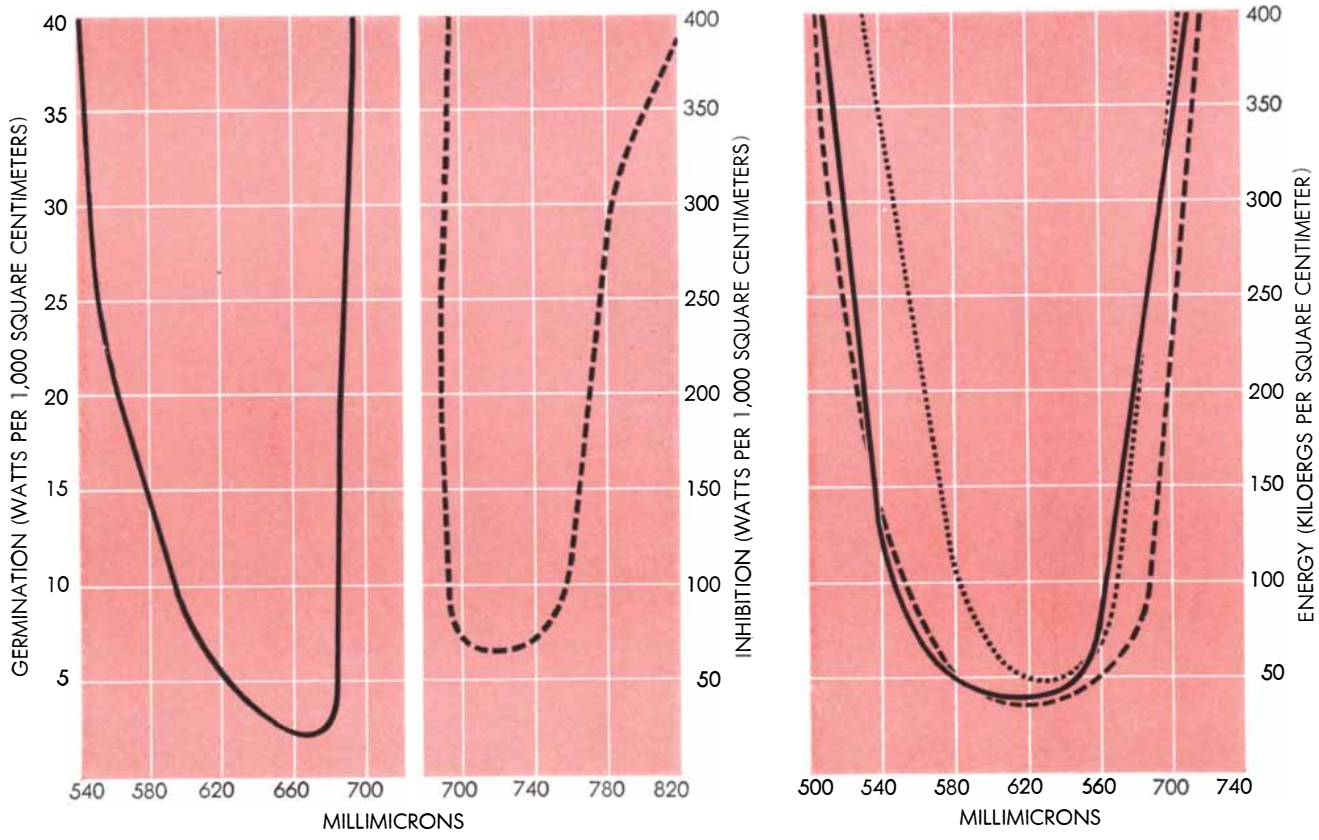
GERMINATION OF LETTUCE SEEDS placed on moist disks of blotting paper is promoted by exposure to red light. "R" indicates an exposure to red light; "F," to far-red light. The last type of light given in the series determines whether the seeds sprout.

all in the absence of oxygen. In the partially purified clear liquid extracts of seedlings, however, P_{735} is stable in the dark, indicating that the dark-conversion enzyme system has been removed. Half the phytochrome activity is lost in intact seedlings during the dark-conversion of P_{735} to P_{660}. After a second illumination with red light, total phytochrome activity declines still more. In continuous light, phytochrome activity is quite low, but is still detectable. It was fortunate that the presence of chlorophyll made it necessary to grow seedlings in darkness for the early experiments. If the seedlings had received even small amounts of light, the unstable P_{735} would have formed and would have soon lost its activity to such an extent that phytochrome might never have been detected.



ACTION SPECTRA for the promotion (*left*) and inhibition (*middle*) of germination in lettuce seeds show energy of light required (*vertical scale*) at each wavelength (*horizontal scale*) to produce the desired effect in 50 per cent of the seeds. Curves at right are spectra for the promotion of flowering in barley (*solid line*), and for the inhibition of flowering in soybeans (*long dashes*) and cockleburs (*short dashes*). Barley flowers during short nights, and the other two flower when the nights are long.

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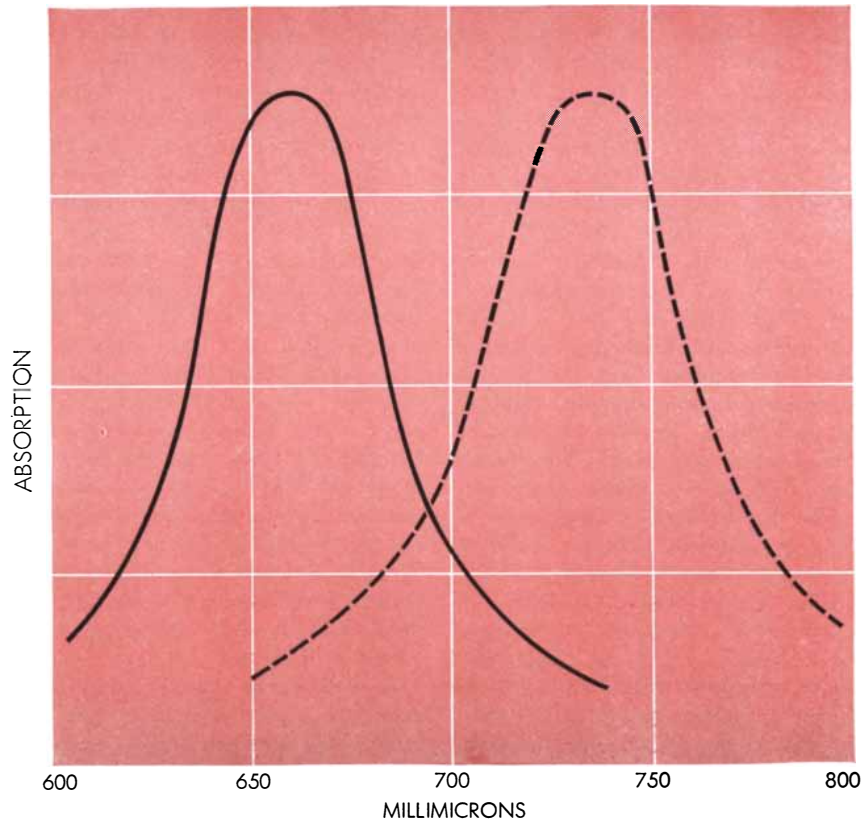
GERMINATION IS INHIBITED by irradiation with far-red light. While the great majority of seeds germinated after final exposure to red light (*opposite page*), practically none of the lettuce seeds irradiated last with far-red light will ever be able to germinate.

How phytochrome exerts its manifold influences on plant growth is still unknown. P_{735} seems to be the active form, while P_{660} appears to be a quiescent form in which the plant can store the potentially active compound. At the close of any period of exposure to light, phytochrome is predominantly in the far-red-absorbing form. The rate at which P_{735} is then carried through the dark conversion back to P_{660} provides the plant with a "clock" for measuring the duration of the dark period. The rate of conversion probably varies from one plant to another, and must depend in part upon such factors as temperature. The effective dark period might be the time required for the complete conversion, or it might be the time in darkness after the conversion is finished. In either case a brief interval of light in the middle of the dark period would cause a plant to respond as though the dark period were short.



ABSORPTION SPECTRA for the two forms of phytochrome are shown here. The form known as P_{660} (*solid line*) absorbs the most light at a wavelength of 660 millimicrons, while P_{735} (*broken line*) is far more absorbent, or opaque, to light at a wavelength of 735 millimicrons. The reactions of plants to these wavelengths indicate that P_{735} is the active form.

Phytochrome is undoubtedly an enzyme—a biological catalyst. Its ability to control so many kinds of plant response in so many different tissues suggests that it catalyzes a critical reaction that is common to many metabolic pathways. Several reactions of this kind are known. One is the reaction that forms the so-called acetyl coenzyme-A compounds. These compounds are essential intermediates in fat utilization and fat synthesis, in cellular respiration and in the synthesis of anthocyanin and sterol compounds. The regulation of the supply of acetyl coenzyme-A compounds would provide an ideal control for growth processes. More than three fourths of all the carbon in a plant is incorporated in this coenzyme at some stage or other.

The extraction and partial purification of phytochrome is the starting point of a major forward movement in the understanding of plant physiology. Further research on this remarkable protein, ubiquitous in the plant world, should answer many questions concerning germination, growth, flowering, dormancy and coloring. It should also provide a means to control all of these plant processes to the great benefit of agriculture.

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Minerals on the Ocean Floor

The depths of the ocean are strewn with curious nodules that are rich in manganese, copper, cobalt and nickel. Special devices may make it possible to mine the bottom for these valuable substances

by John L. Mero

Many of the rich deposits of essential minerals that have supported the industrial growth of the U. S. have been so heavily mined that they are near exhaustion. Today ores of lower grade are being mined and processed at constantly higher cost, and a number of vital metals are being imported. But even low-grade deposits are becoming difficult to find, and as the underdeveloped nations proceed to industrialize, this country's overseas suppliers will be using their raw materials at home. One potential source of low-cost minerals, however, remains virtually unexplored and untapped. It is the sea.

Sea water itself has some promise; some 60 elements have been identified in it. By conservative estimate the water in all the oceans holds 15 billion tons of copper, seven trillion tons of boron, 15 billion tons of manganese, 20 billion tons of uranium, half a billion tons of silver and 10 million tons of gold. In absolute terms these are large figures, but in relation to the amount of water they are small. Thus sea water must be considered a lean "ore," except perhaps in the case of magnesium and a few other substances that are already being extracted from it. Still, the ocean basins do contain minerals that in my opinion could be profitably mined by applying techniques that are available today. These ores are simply lying on the ocean floor waiting to be dredged up.

From an economic standpoint the most promising ore is manganese dioxide. In deep-sea sediments it takes such forms as grains, slabs, coatings on rocks and impregnations of porous materials. Most important, it also occurs in a strange product of sea-water chemistry: the so-called manganese nodules, which incorporate not only manganese but also several other important metals. But the sediments and oozes of the sea floor also constitute promising sources for such a common bulk material as portland cement.

Sea-bottom nodules were first brought to the surface in the 1870's by the famous expedition of the British oceanographic vessel *Challenger*, which dredged them up throughout the deep parts of the Atlantic, Pacific and Indian oceans. Nodules from various locations have distinctive appearances, and the *Challenger* investigators learned to tell where one or another came from by simple inspection. At the turn of the century Alexander Agassiz, aboard the *Albatross*, dredged up nodules at many spots in the eastern Pacific, and concluded that in this part of the ocean they cover an area larger than that of the U. S.

From then until the International Geophysical Year in 1957 and 1958, however, Great Britain and the U. S. did very little deep-sea dredging. During the I.G.Y., investigators from the Scripps Institution of Oceanography dredged and made many deep-sea photographs through the eastern Pacific. They found nodules almost everywhere. The photographs showed high concentrations of these objects in most locations, and have provided the first reliable method of calculating the number of nodules per square foot. On one occasion the Scripps ship *Horizon* pulled up about 500 pounds of nodules that assayed over 30 per cent manganese and contained commercially significant amounts of cobalt, nickel and copper. Considering the possible economic value of this material, Henry W. Menard and Charles D. Wheelock of the Scripps Institution sought to establish a co-operative project involving the Institute of Marine Resources and the Department of Mineral Technology (both part of the University of California) to study the commercial possibilities of mining nodules. I have been associated with this project since its inception in 1957, and this article is a summary of some of our findings.

Manganese nodules have a wide variety of shapes, but most often they look like potatoes [*see illustration on page 66*]. Their color varies from earthy black to brown, depending upon their relative manganese and iron content. The nodules are porous and light, having an average specific gravity of about 2.4. (Specific gravity is the ratio of the density of a substance to the density of water.) Generally they range from one to nine inches in diameter. The largest nodule ever recovered was about four feet long and three feet in diameter; it weighed 1,700 pounds. A British ship brought it up in 1955 in a loop of an old telegraph cable that was being salvaged from a depth of 17,000 feet in the Philippine Trench. After sketching it and breaking off a sample for chemical analysis, the crew cast it back into the ocean. The Scripps expedition also brought up a big nodule in 1955 in a tangle of wire; it measures two feet across, 20 inches thick and weighs 125 pounds. Such large nodules are seldom brought up, because the opening of the dredges presently used to recover sediments will not admit objects more than a foot in diameter.

In cross section nodules display thin, onion-like layers, indicating that they form by the accretion of very small particles rather than by direct precipitation of ions from the water. The nodules usually form around a bit of red clay, of basalt, of pumice or, oddly enough, around a shark tooth or a bone from the ear of a whale. The manganese in the nodules enters the sea from rivers, from

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springs in the ocean floor, from submarine volcanic eruptions and from the decomposition of manganese-rich volcanic deposits on the sea floor. In certain areas the decomposition of organic matter can give rise to reducing "atmospheres" in localized bottom waters, causing the manganese in exposed rocks to go into solution. As the manganese ion migrates away from the local reducing area it enters the general oxidizing atmosphere of the water. There it combines with oxygen and precipitates as molecules of manganese dioxide which have a tendency to clump into submicroscopic colloidal particles. Iron seems to react in a similar manner. Studies made by Edward D. Goldberg of the Scripps Institution indicate that, as these colloids of manganese and iron filter down through the ocean, they "scavenge," or pick up, nickel, copper, cobalt and other metallic ions from the water. The particles carry an electric charge and are attracted to hard-surfaced electrically conductive objects on the sea floor; in this way they tend to form nodules around some nucleus instead of forming a uniform layer of sediment on the ocean floor. Clay particles are frequently trapped in the growing nodules.

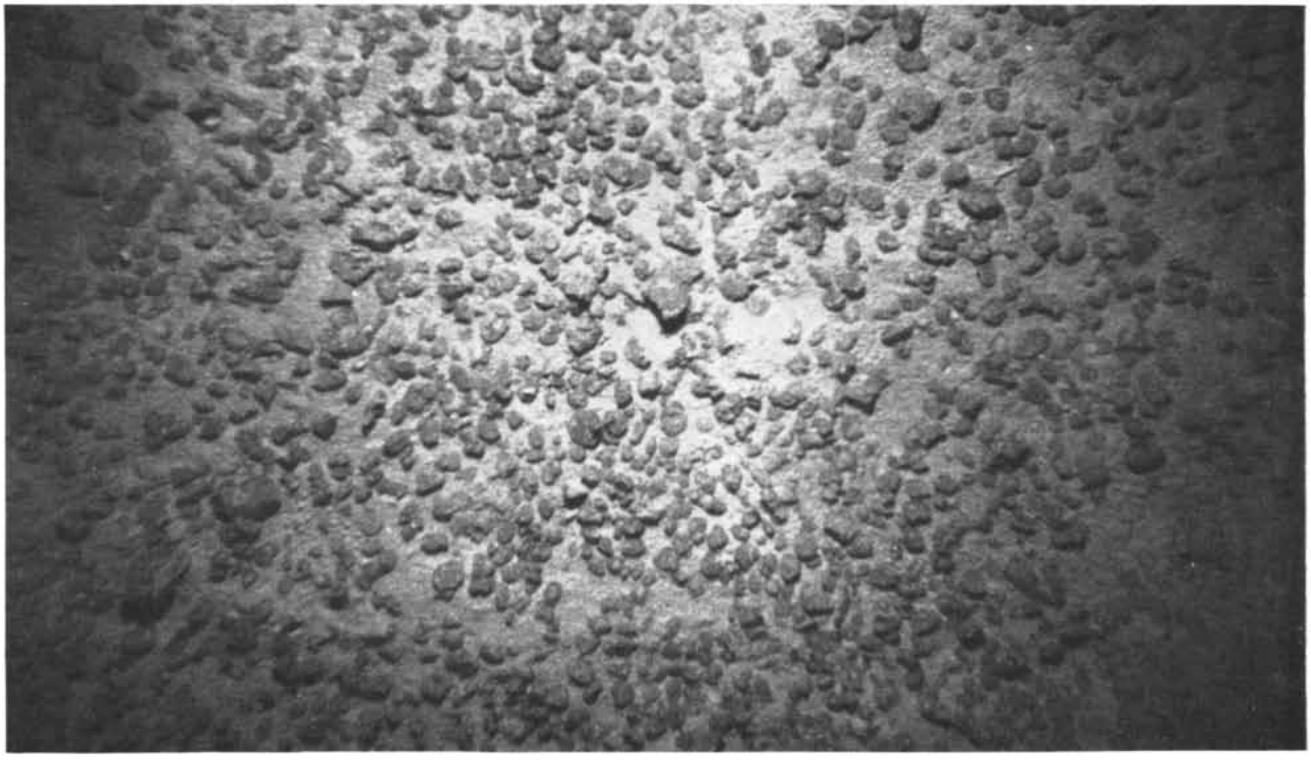
The colloidal particles also scavenge radioactive isotopes from the water. These furnish a means of dating various sections of a nodule and of determining rates of growth. Measurements made by Hans Pettersson of the University of Göteborg in Sweden show that some nodules grow about one millimeter per 1,000 years to one millimeter per million years.

It may be that manganese nodules occur in layers more than one nodule thick on the ocean floor, but as yet the only evidence that they do appears in deep-sea photographs which hint at lumps beneath a thin covering of fine sediment. The tubular samplers that allow oceanographers to recover vertical "cores" of sediment from the bottom of the ocean sometimes cut through beds of the nodules at discrete horizons within the sea-floor sediments. A prime environmental condition for the formation of the nodules is a very low rate of sedimentation. If the sediments should form faster than the nodules, the nodules would be buried, and, cut off from sea water, they would cease to grow. Photographs frequently reveal "scour marks" on the sea floor around nodules; these suggest that small ocean-floor currents tend to sweep away extraneous fine sediment, leaving the nodules exposed and able to attract charged particles of manganese and iron oxides.

Sea-floor manganese oxides chemically resemble the impure fresh-water manganese oxides found in swamps throughout the world. Although nodules from individual deposits assay as high as 80 per cent manganese dioxide, the average composition of 30 samples of nodules from all the oceans was found to be by weight 32 per cent manganese dioxide, 22 per cent iron oxides, 19 per cent silicon dioxide and 14 per cent water, with smaller quantities of aluminum oxides, calcium and magnesium carbonates and such metals as nickel, copper, cobalt, zinc and molybdenum. Some of the minerals in nodules have no names, because their exact crystalline structures have never been encountered before.

From an economic standpoint, manganese, nickel, cobalt and copper are the interesting metals in the nodules. The maximum amounts of these metals found thus far in nodules are 50 per cent manganese, 2 per cent cobalt, 1.6 per cent nickel and 1.9 per cent copper. Nodules from 45 locations in the eastern Pacific have been analyzed for these four metals. Although this is admittedly a small sample of such a vast area, it is significant because sea-floor sediments tend to be rather uniform over large regions. The 45 samples seem to delineate several "ore provinces" of manganese nodules [*see map on page 67*].

A belt of nodules that is especially rich



MANGANESE NODULES on the floor of the eastern Pacific ocean were photographed by N. L. Zenkevitch of the Soviet Institute of Oceanology in Moscow. The photograph shows that there are approximately 3.7 pounds of nodules per square foot of ocean floor.

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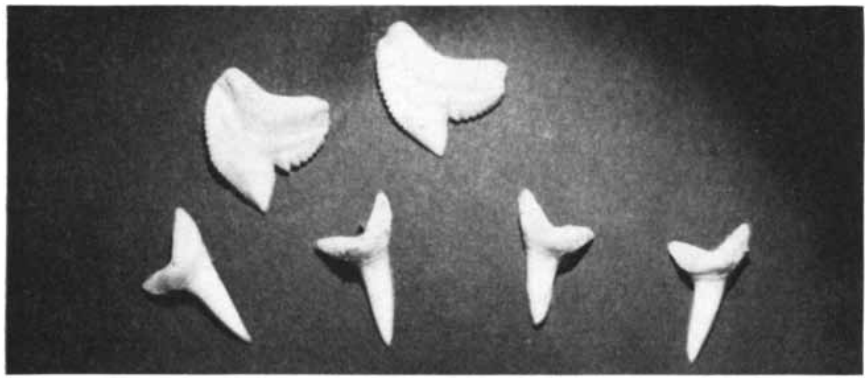
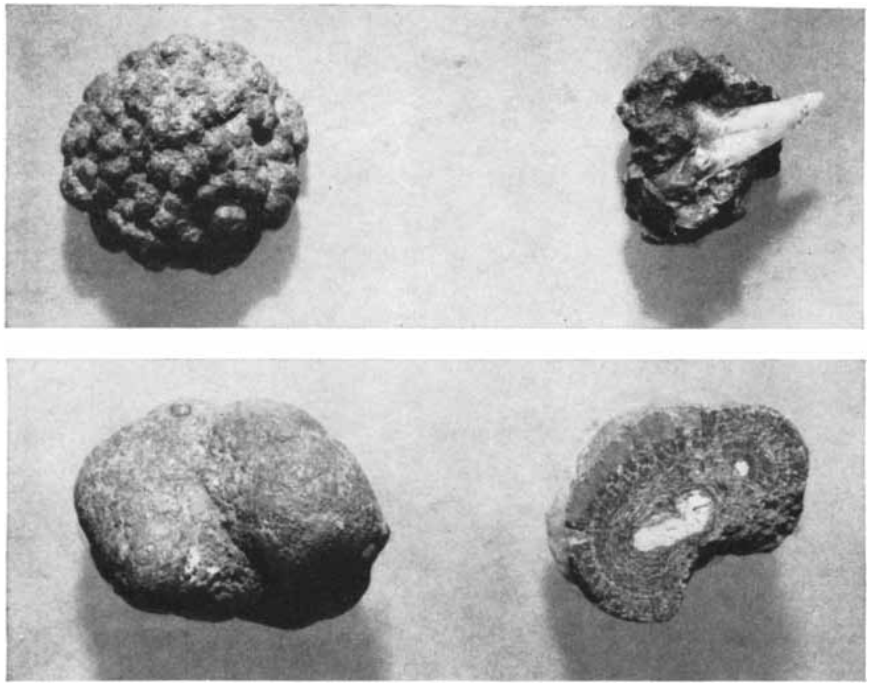
WHALE EAR BONE, shown here about three fourths natural size, consists mostly of tricalcium phosphate and is relatively insoluble. Many such ear bones lie on the floor of the ocean.



SHARK TEETH, shown at same scale as ear bone, are also primarily tricalcium phosphate. Most of a dead shark dissolves before it can sink to the sea floor, but teeth remain intact.



MANGANESE NODULES take various forms, but they usually resemble potatoes (*lower left*). Nodule at upper right formed around a shark tooth. At lower right a nodule has been cut in half and polished, revealing its growth rings and its nucleus of claylike material.

in manganese, though it is poor in other metals, follows the coasts of North and South America about 300 to 500 miles offshore and covers an area of about two million square miles. The two photographs made in this belt indicate concentrations of five and seven pounds of nodules per square foot of sea floor. In my opinion it would be economic to mine an area bearing one pound of nodules per square foot. At that concentration this submarine ore province would bear about 26 billion tons of nodules.

Nodules rich in nickel and copper seemingly predominate in the central part of the southeastern Pacific, an area of about 14 million square miles. Nodules from this area grade as high as 37 per cent manganese, 1.6 per cent copper, 1.6 per cent nickel and .3 per cent cobalt, all in the same nodule. At an average concentration of only one pound of nodules per square foot this region would bear 200 billion tons of nodules. The five photographs from the area show five, eight, three, four and seven pounds of nodules per square foot.

The mid-Pacific rise, which lies just west of Hawaii and includes the Society Islands in the South Pacific, seems to harbor high-cobalt nodules. Some containing 31 per cent manganese, 2 per cent cobalt and .8 per cent nickel have been found in this region. This four-million-square-mile area would hold about 57 billion tons of nodules at a concentration of one pound per square foot. Two sea-floor photographs each show about five pounds per square foot. This area possesses a number of advantages from the mining standpoint, because much of the bottom is less than 5,000 feet deep, compared with an average depth in other areas of about 14,000 feet. Also there are many islands in this part of the Pacific which could conveniently serve as supply bases.

No one is likely to invest in a deep-sea mining venture on the basis of this sparse sampling of the Pacific Ocean basins, but the data certainly indicate that the manganese nodules are worth further study. The U. S. must certainly look seriously into such a promising alternative source for the manganese, nickel, cobalt and copper it now imports in large quantities.

Of course the question whether the Pacific floor deposits will prove to be ores, in the economic meaning of the term, remains to be seen. Ores are generally defined as aggregates of metalliferous minerals, more or less mixed with a worthless "gangue," which can be mined, processed and sold at a profit.

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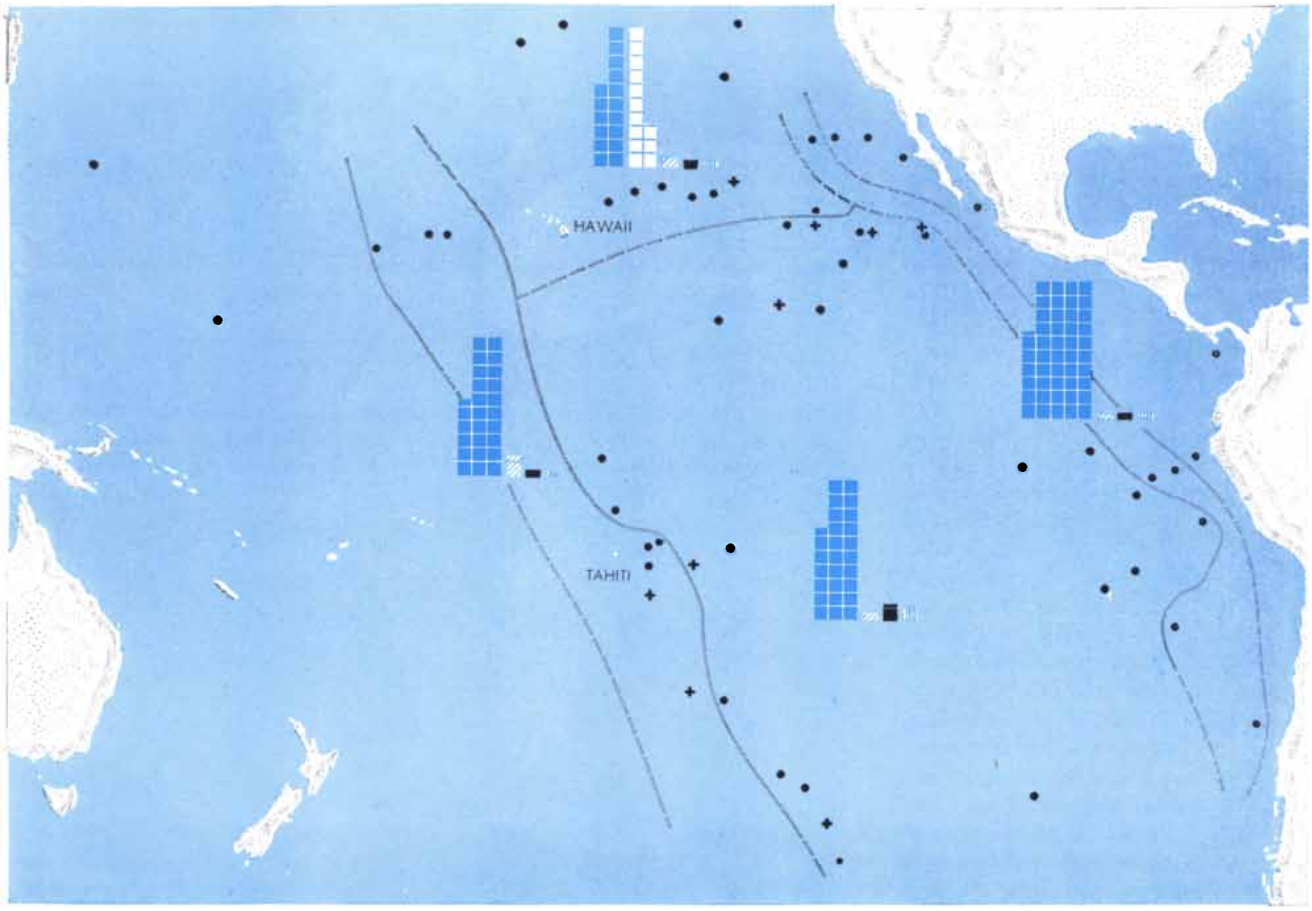

● DREDGE SITES
✚ PHOTOGRAPH SITES
MANGANESE
COBALT
COPPER
IRON
NICKEL

"ORE PROVINCES" of the eastern Pacific are delineated on this map. Broken line indicates that border of province is uncertain. Bar charts show average composition of nodules in the province, each block representing 1 per cent of weight of nodules. The nodules in the area parallel to coast of North and South America are rich in manganese. In eastern Pacific nodules are relatively rich in copper and nickel. Nodules of the mid-Pacific rise, which includes Tahiti, assay higher in cobalt than the others.

The gross value of a metallic ore is the amount of metal that can be recovered from it in salable form, multiplied by the market value of the metal. Such factors as transportation, political conditions, climate and unforeseen technical difficulties can make "gross value" very misleading. Some mineral deposits with a gross value of several hundred dollars a ton are not economic to mine, while some worth $5 a ton yield a profit.

The cobalt-rich nodules have a gross recoverable value of more than $100 a ton at present prices, and the gross value of the nodules of the southeastern Pacific basin would average about $60 per ton. The low-grade nodules of the northeastern Pacific would be worth perhaps $40 a ton. In a large-scale operation, processing would cost about $20 to $30 per ton of nodules. Transportation and overhead would add $10 a ton. If a mining method can be designed to bring nodules into the hold of a ship for less than $5 or $10 per ton, most of the eastern Pacific deposits could be classed as ore-grade.

Manganese nodules are found in the Atlantic Ocean, but they seem to be of a much lower grade than those in the southeastern Pacific. Typical samples of Atlantic nodules assay 18 per cent manganese, 18 per cent iron, .4 per cent cobalt, .6 per cent nickel and .4 per cent copper. Because the sedimentation rates in the Atlantic are much higher than those in the Pacific, Atlantic nodules trap a good deal of clay and other contaminating material.

Near the continents high sedimentation rates usually prevent nodules from growing to an appreciable size. Small manganese dioxide grains are found in sediments near shore, but the grain deposits are too dilute to be of commercial interest. One deposit near shore in the Atlantic, however, does consist of nodules. They lie on the Blake Plateau, an area of about 75,000 square miles off the coast of the Carolinas and Florida. The plateau is only 500 to 3,000 feet down. Apparently nodules grow to appreciable size there because the Gulf Stream flows through the area and sweeps away much of the sedimentary material coming from the continent. Unfortunately the nodules on the Blake Plateau seem to be no richer in metals than the other manganese deposits in the Atlantic.

While manganese nodules are probably the most important ores on the sea floor, they are by no means the only ones. The sediments also contain materials of potential economic importance. Ocean sediments are broadly classified as terrigenous and pelagic. The former are coarse-grained materials washed down from the continents; they lie on the continental shelves and slopes and at the margins of the deep-sea basins. The pelagic sediments, fine-grained materials that are usually light reddish brown, cover the deep-sea floor. They generally

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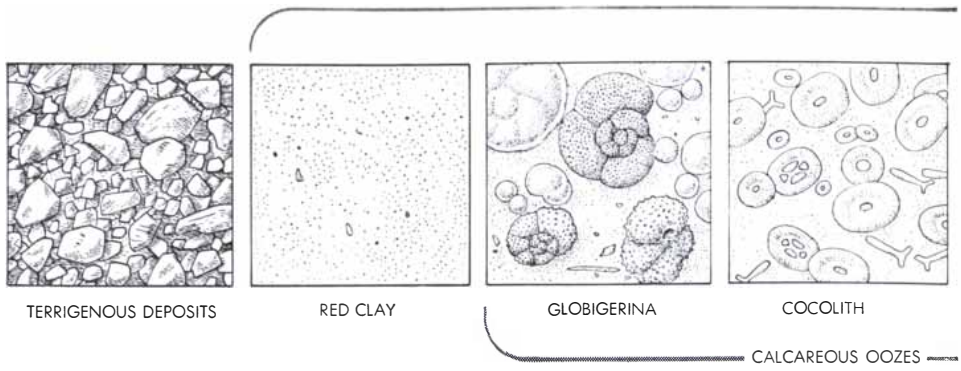
contain the skeletons of tiny planktonic plants and animals. When such organic remains constitute more than 30 per cent of a sediment, it is called an ooze and is named according to the type of planktonic remains that predominate. If the animal and plant materials make up less than 30 per cent, the sediment is called red clay.

Red clay covers about 40 million square miles of the ocean floor. It is about 50 per cent silica, 20 per cent aluminum oxide, 13 per cent iron oxide, 7 per cent calcium carbonate, 3 per cent magnesium carbonate and 6 per cent water, with minor amounts of manganese, nickel, cobalt, copper and vanadium. Although copper makes up only .2 per cent of the clay, this is 10 times as much as in igneous rock on land. Like all deep-sea sediments, the clay is fine-grained and in an unconsolidated state. It has no solid overburden and would probably be a more attractive source of copper and aluminum than a similar grade of rock on land. At a conservative estimate the sediment is 300 feet thick. All the red clay in the oceans must hold some 10^{14} tons of aluminum and some 10^{12} tons of copper. If aluminum and copper can ever be extracted economically from such material, these deposits would last for about a million years at present rates of consumption.

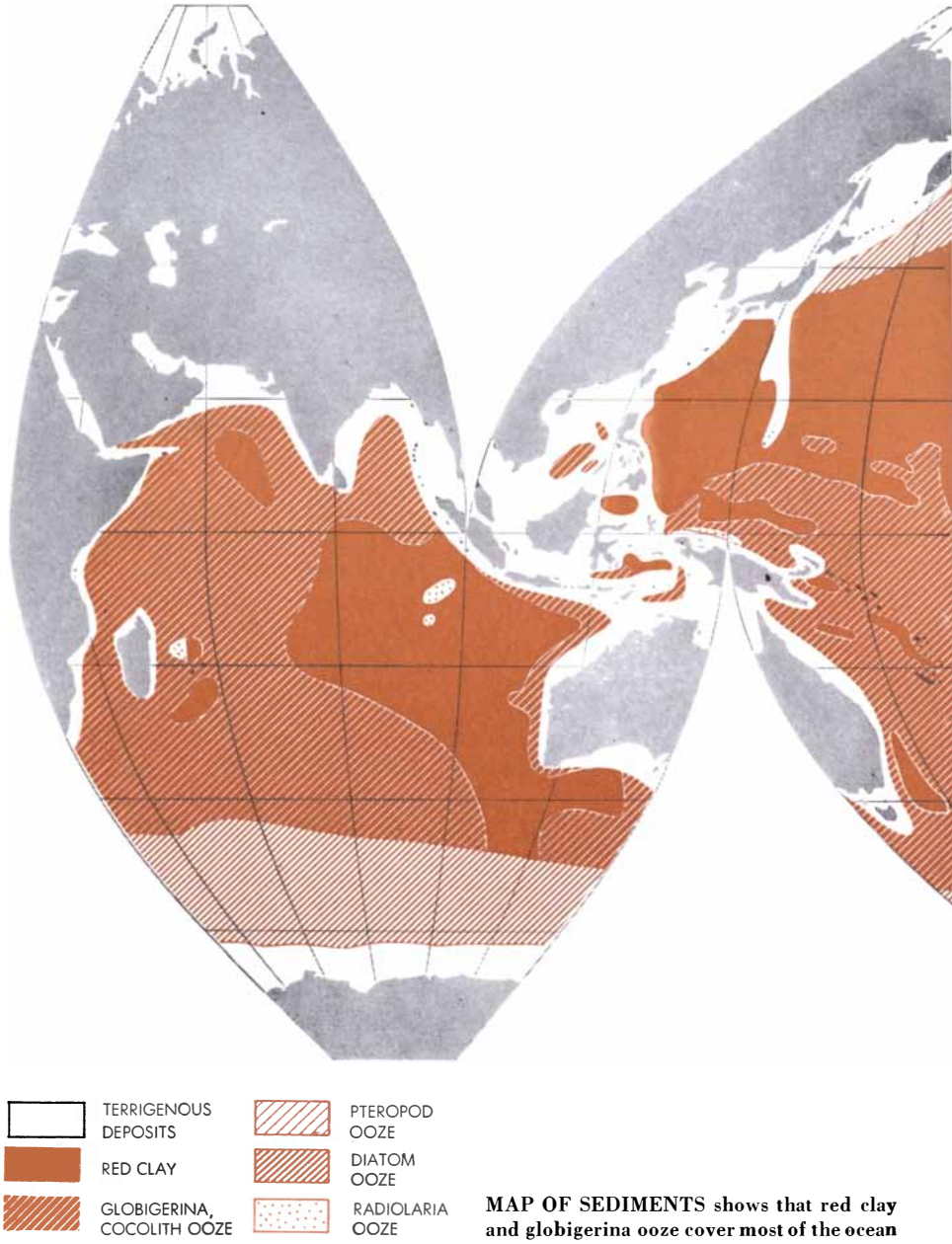
Diatomaceous earth, a relatively pure silica material found in some places on land, consists primarily of the skeletons of the planktonic animals called diatoms. It serves as a filtering agent, as a heat and sound insulator, as a dusting agent to prevent caking of fertilizers, as a filler in lightweight concrete and in many other applications. Wide belts of this material, known as siliceous ooze, stretch across 11 million square miles of the north and south sides of the Pacific. One disadvantage of these deposits is that they lie relatively far from any market.

A common constituent of the pelagic sediments are the tiny nickel-iron spherules which originate with meteorites [see "Cosmic Spherules and Meteoritic Dust," by Hans Pettersson; SCIENTIFIC AMERICAN, February]. They are magnetic and could easily be separated from the red clay or from oozes. Although spherules are widespread, they do not occur in any known high concentration and could only be recovered as a by-product of some other mining operation.

Globigerina ooze, a type of sediment consisting mainly of skeletons of protozoa, covers about 50 per cent, or 50 million square miles, of the ocean floor. It assays as high as 95 per cent calcium



OCEAN-FLOOR SEDIMENTS, most of them magnified, are illustrated here. Terrigenous sediments are coarse grained. Pelagic sediments are fine grained. Red clay contains less than 30 per cent remains of planktonic plants and animals. Calcareous oozes are primarily cal-



MAP OF SEDIMENTS shows that red clay and globigerina ooze cover most of the ocean

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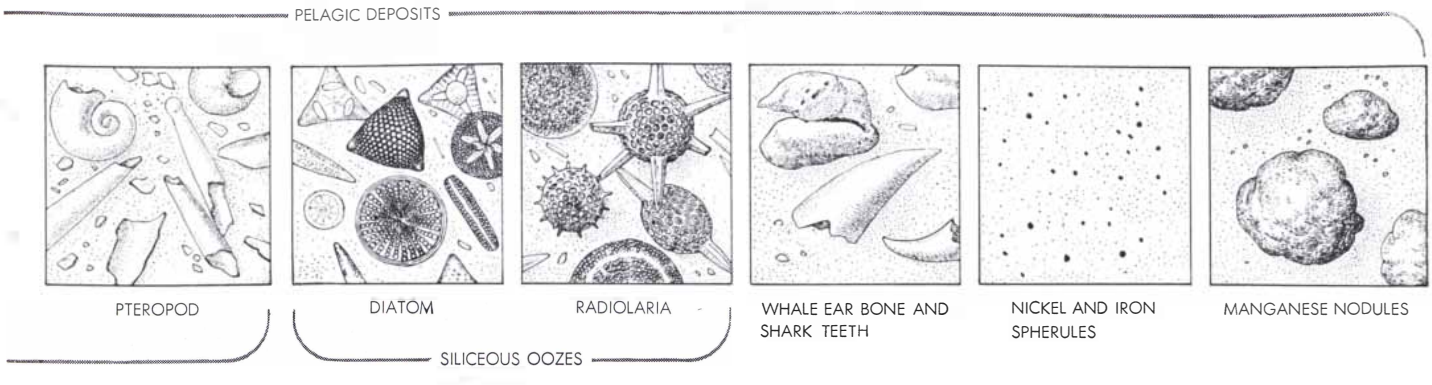
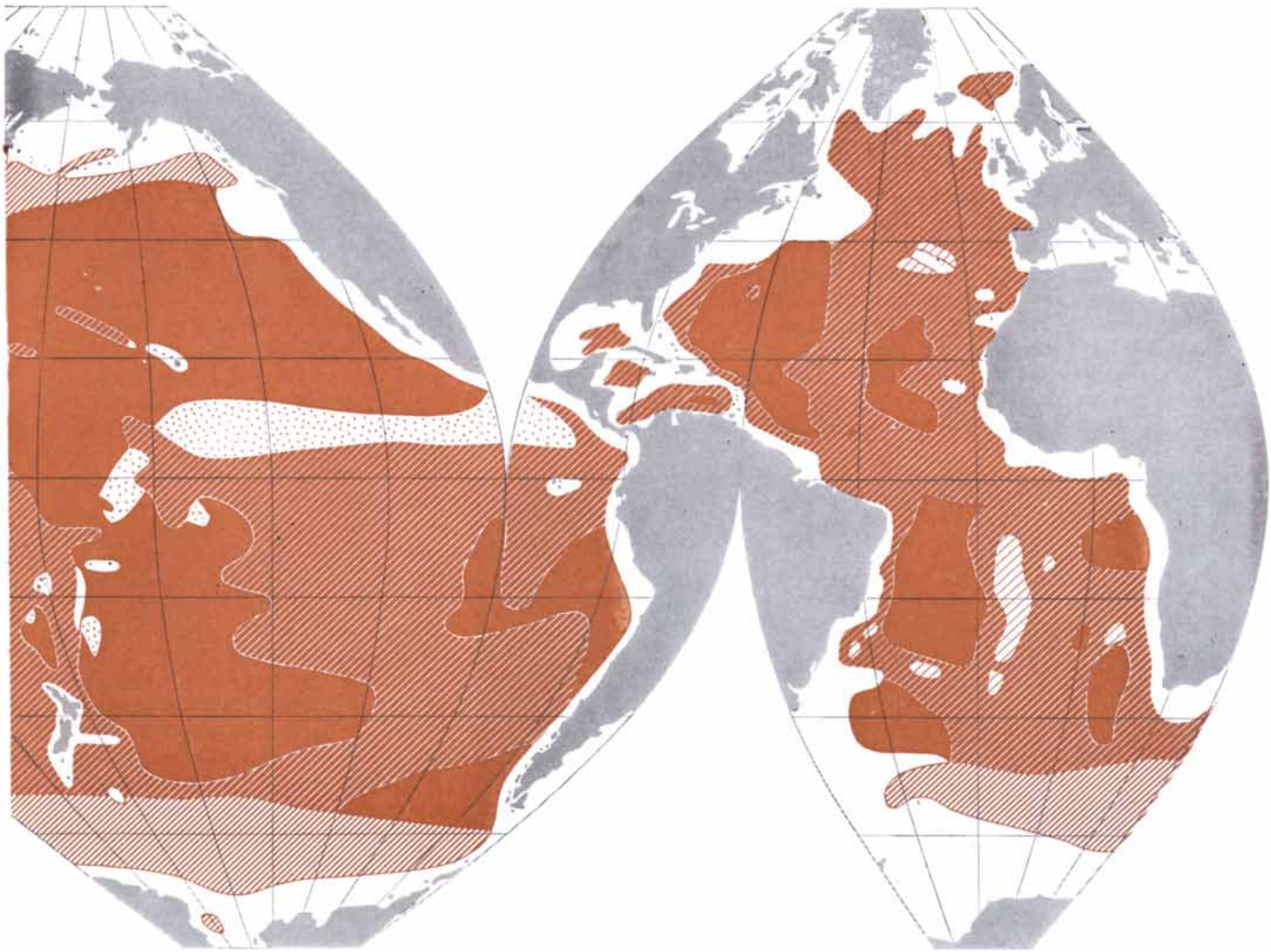


cium carbonate; siliceous oozes are silicon substances. The particular oozes are named for the life forms that furnish most of the materials. Microscopic views of oozes shown here are not drawn to same scale. Whale ear bone and shark teeth as well as the nodules are somewhat reduced. The terrigenous deposits and several of the oozes often display beautiful pastel colors in their natural state.



bottom. They are characteristic of the deepest parts of the ocean. Manganese nodules are found lying on all types of deep-sea sediment. Globigerina ooze can be made into cement, and the diatom and radiolaria oozes can be employed in a number of capacities.

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carbonate. The average content of many samples is as high as that of the limestone from which almost all of the world's cement is made. If only 10 per cent of the globigerina ooze is cement-grade, then at a 300-foot average thickness this sediment would contain about 10^{14} tons of usable material. Extensive deposits lie within a few hundred miles of most of the countries that have sea coasts, and the ooze may someday serve as a source of cement for those nations with no domestic deposits of cement-grade limestone.

Shark teeth and the ear bones of whales are remarkably common on the deep-sea floor. When a larger marine animal dies, its remains are eaten or dissolve before they sink to the bottom. Shark teeth and whale ear bones, however, consist primarily of the relatively insoluble tricalcium phosphate, and thus remain intact on the sea floor. They contain about 34 per cent phosphorous pentoxide, which is used to make fertilizer. Although they would not be mined alone, they could be recovered as a by-product from any deep-sea mining operation.

Certain sea animals extract elements from sea water and concentrate them in various parts of their bodies. Some of the simple animals known as tunicates contain 50,000 times as much vanadium by weight as does sea water. Oysters effect a 200-fold concentration of copper. Analyses by Gustaf O. S. Arrhenius and his co-workers at the Scripps Institution have shown that some skeletal remains of fish contain appreciable amounts of zinc, copper, tin and rare-earth elements. Nickel and silver also concentrate in the bones of fishes. The data are so sparse, however, that it cannot be said whether this material will ever have economic significance.

Oceanographers have dredged up one material that is almost certainly destined for commercial exploitation. This is phosphorite, a source for the economically important phosphate fertilizer. On the sea bottom phosphorite occurs in flat slabs and irregular masses ranging from grains to chunks more than a yard in diameter. Generally found near the shore in shallow water, sometimes less than 300 feet deep, these nodules are found off Australia, Japan, Spain, South Africa, the west coast of South America and both coasts of the U. S. Phosphorite nodules which have a phosphorous content similar to ores of this element now mined in Florida and Idaho have been brought up at 125 locations off California, from north of San Francisco to south of San Diego.

California has no commercial-grade phosphorite deposits and each year imports more than 100,000 tons of phosphorous pentoxide to meet its needs. Phosphate rock sells for as much as $15 a ton, half the price representing freight charges. It has been calculated that $3.5 million would pay for the design and construction of a system to mine 400,000 tons of sea-floor phosphorite a year. The mining cost would be about $4.50 a ton, and transportation about $1.50 a ton. At a selling price of $13.50 per ton in California, the annual return on the investment would be 52 per cent after taxes.

The drag dredge would furnish the easiest method for mining phosphorite nodules and the shallower manganese nodules. It is simply a bucket which is dragged along the ocean bottom by the ship [*see illustration on page 72*]. Oceanographers have used it for almost 100 years to recover material from depths as great as 30,000 feet. The relatively long time needed to raise and lower the bucket would generally make it uneconomic in depths greater than 4,000 feet. The estimated production costs of the drag dredge range from $5 per ton of nodules in 1,000 feet of water to $20 per ton in 5,000 feet.

Any large-scale operation in deep water, where most manganese nodules are found, would require the far more complex hydraulic dredge: a giant vacuum cleaner capable of removing a thin layer of material from the sea floor while disturbing the floor itself as little as possible. Its major parts would be a float, a pipeline, a pump, a motor and suction heads. The pump and motor must be submerged for proper operation of such a dredge. Careful control of the ratio of nodules to water in the pipeline must also be maintained to keep the nodules from jamming in the pipeline. To control the fluid-solids ratio, the suction heads would be designed to allow rapid lowering or raising at the sea floor, and relief water valves could be built into the heads. Television cameras near the sea floor would watch the operation of the suction heads.

Floats about 200 feet beneath the turbulent surface of the water would carry the bulk of the weight of the dredge, and gyroscopes and a small stabilization float at the surface would provide vertical stability. Such a dredge could be moved through the water by propellers attached at regular intervals along the pipeline. Where the nodules are concentrated at one pound per square foot, the dredge would have to move across the sea floor at three feet per second for efficient operation. It would take about 3,000 horsepower to provide this speed and another 9,000 horsepower to pump nodules to the surface at a rate of 5,000 tons of nodules a day from a depth of 14,000 feet.

A less complicated, and probably less efficient, machine would be the vertical-float hydraulic dredge. Its pump and motor would be near the surface in the float tank. Sea-water ballast in the

PHOSPHORITE NODULES, which are up to 30 per cent phosphorus pentoxide, are seen underwater off California in this photograph made by the Naval Electronics Laboratory in San Diego. Phosphorus pentoxide is generally used in manufacture of phosphate fertilizers.

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bottom of the float could be pumped out to bring the tank up for servicing. The whole dredge would rotate around its central axis; two suction arms reaching out at the bottom of the pipeline would sweep around the ocean floor in a circle so that the dredge could mine a relatively large area without having to move rapidly along the floor. Vanes along the pipeline would make the whole machine creep along, attacking a new area on each rotation. Ocean currents might very well move it without any vanes.

Mining with hydraulic dredges should cost approximately $2 per ton of nodules in water 3,000 feet deep, and about $4 per ton at 14,000 feet, the average depth at which manganese nodules lie. The delivery rate of a hydraulic dredge depends on the diameter of the pipeline and the velocity of the fluid flow in it, and is almost independent of the depth of the water. Since 90 per cent of the capital cost of a deep-sea mining system would be in the surface equipment, which costs the same regardless of the depth, the cost of pumping would go up only about 15 cents per ton of nodules for every 1,000 feet of added depth.

Designing and building a deep-sea hydraulic dredge would cost about $4 million. This includes auxiliary equipment such as Diesel generators and barges to receive the ore. But it does not include a maneuverable surface ship of 2,000 tons displacement, which would cost an additional $5 million.

Some of the materials from the deep-sea floor would require very little processing. The oozes, for example, would not have to be crushed or ground; only dried. Phosphorite nodules would be marketable after crushing, grinding and drying.

Some manganese nodules have a manganese dioxide content of 80 per cent or more and would need little processing in order to produce a salable product. Because they are formed by the agglomeration of colloidal particles, manganese nodules have a very large surface area. Gas-absorption measurements have shown surface areas in excess of 200 square meters per gram of nodule material. It may therefore be useful as a battery-grade manganese dioxide or in similar applications in which materials with a large, chemically reactive surface area are important.

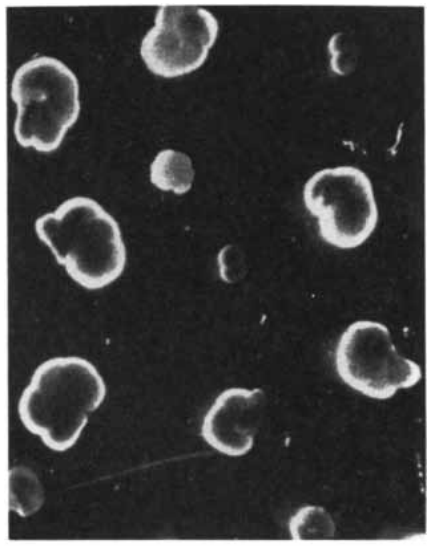
Manganese is essential in the manufacture of high-grade steel. The U. S. has no sizeable deposits of manganese minerals that are economic to mine; however, it has very large reserves of low-grade manganese ore. The Federal Government has spent millions of dollars over the past 40 years in developing processes that might make possible exploitation of the manganese deposits in the U. S. Several of these processes could be used to recover manganese from the nodules.

Once the manganese goes into solution in one of these recovery processes, the copper, nickel and cobalt in the nodules can easily be recovered. Calculations based upon techniques now used to separate copper, nickel and cobalt from lean ores indicate that it will cost about $25 a ton to process manganese nodules into marketable materials. Adding $5 for mining and $10 for marketing, transportation and overhead, the profit would still be $20 per ton of nodules from the southeastern Pacific. On paper this would allow an annual return of 30 per cent, before taxes, on a capital investment of $100 million in a mining and processing plant able to handle 5,000 tons of nodules a day.

Such calculations do not, however, excite any great enthusiasm among mining men. From the business point of view there are still too many unknowns in deep-sea mining. It is unlikely, for example, that the government would allow the 22 per cent deduction against resource depletion in the computation of taxable income. The nodule deposits are so vast as to be nearly inexhaustible and so easy to find that there is little gambling in exploration.

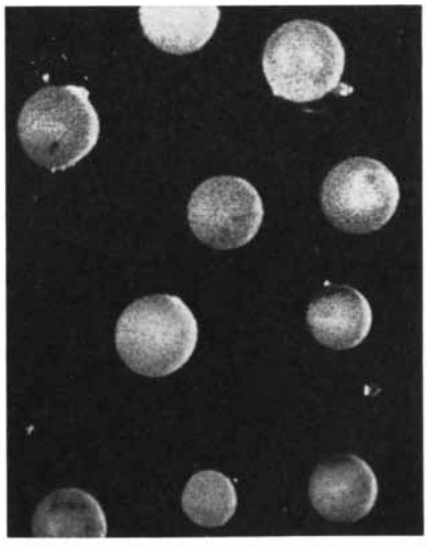
Mining of nodules from the deep sea may be attended by legal complications, because marine law is quite vague. It has been kept so by the implied mutual consent of the nations of the world. Traditionally the U. S. has held that national sovereignty extends only three miles offshore. At the 1957 Geneva conference on the Law of the Sea, it was argued that a nation might be permitted to control the ocean floor wherever economic exploitation of minerals is found to be feasible. Such a law could lead to great difficulty, because the first country to mine nodules on a commercial basis might lay claim to tens of millions of square miles of the floor of the world's oceans.

A more rigid law should probably be written defining the line on the ocean floor at which national boundaries end. This could be some specified distance offshore, or a certain depth of water, or a combination of both. The offshore boundaries for control of mineral recovery might be set at 10 miles off-



SHELLS OF FORAMINIFERA, enlarged 28 diameters, occur in globigerina oozes.

PTEROPOD SHELLS form oozes only in the Atlantic. Magnification is 23 times.



RADIOLARIA are represented by shells magnified here approximately 48 diameters.

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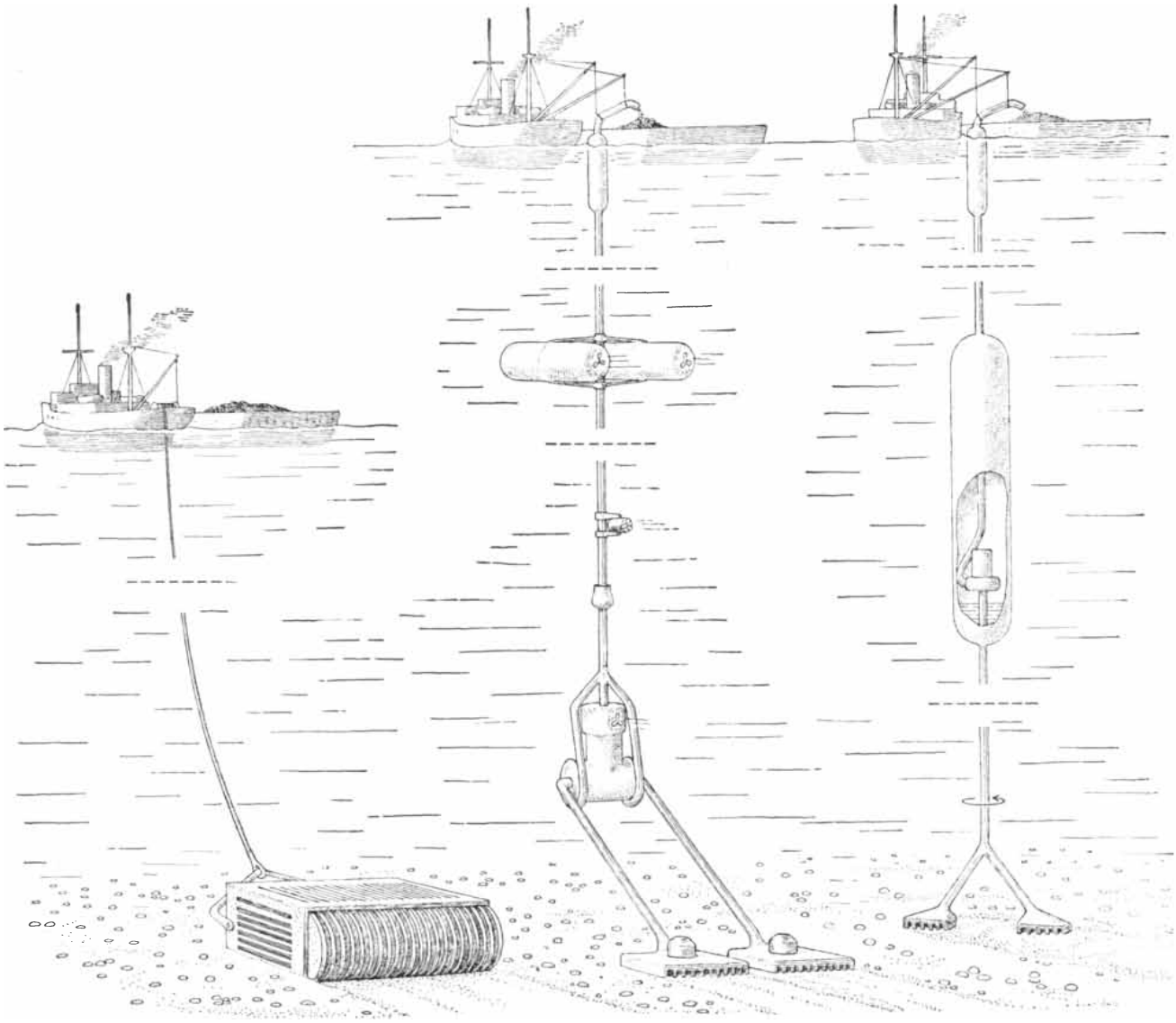

THREE DEEP-SEA DREDGES that might be used for mining manganese nodules are shown in this diagram. At left is a simple drag dredge: a "carpet-sweeper" device that can be used in shallower water. The hydraulic dredge in center will work like a giant vacuum cleaner. Horizontal tanks on pipeline are floats to buoy it. Propellers on floats will move it in straight path along ocean bottom. Pumps and motor are near bottom, above suction heads. Vertical-float hydraulic dredge at right is simpler, contains motor and pump in single float. Suction heads sweep around in circles. In many places ocean currents would move dredge along sea floor.

shore, or a depth greater than 100 fathoms (600 feet), whichever is farthest from the shore. The rest of the ocean floor would be part of the general domain of the world.

An international ocean-mining law could then be formulated, perhaps through the United Nations, which would spell out the exclusive rights of the discoverer to mine for a definite length of time in his discovery area, or to grant him a franchise to mine a certain area surrounding his point of discovery. The law might require the discoverer to invest a certain amount of time and money in developing his claim and to produce on a profitable scale within a reasonable length of time, or lose his claim.

Once the technical and legal problems are overcome, ocean mining will offer many advantages over traditional land mining. Oceanic ores have no overburden except water. They can be discovered without explosives and expensive drilling. With deep-sea cameras, the complete deposit can be explored before mining, and every ton of ore can be accounted for before mining starts. In developing a deep-sea mine there will be no drifts to drive, no shafts to sink or townsites to build.

Handling costs will be low. Inexpensive sea transportation would carry the ore directly to most of the world's markets. Almost 50 per cent of the material, and more in some cases, would be marketable, in contrast to the 2 or so per cent of today's copper and nickel ores. Moving the ore from mine to mill and around the mill adds a great deal to costs, and it is just as expensive to move a pound of gangue as a pound of valuable material. When an ore is 50 per cent valuable material, handling costs can be charged against a much wider base. Because it is a new industry, not bound by old traditions, ocean mining can have equipment designed from the start for automatic control. The cost of labor will not be an item of great importance.

Any new enterprise such as deep-sea mining should succeed or fail on its economic merits. I believe that, all things considered, the sea-floor nodules will prove to be a cheaper source of manganese, nickel, cobalt and even copper than the present sources on land.

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Kodak reports on:

aiming information into the eyes . . . a camera for a progressive Christmas . . . polyester electrically upgraded . . . new black-and-white film speed numbers

The final transfer

For an honest purpose these able gentlemen have consented to the indignity of posing a tableau in supercharged staring. Because they and numerous unpictured coequals are personally involved, they wish to call attention to a certain technical area in which we think we are good. It deals with the art of projecting information into human eyes, the final transfer from machine to man.

The black rectangle labeled "Special Kodak screen" stands for a multitude of possibilities, some which we have already demonstrated and others needing more study. Study, as is well known, costs money. It would be smarter use of the money to do the studying in the context of specific viewing and display requirements—review of vast volumes of reconnaissance photography, for one currently popular example. The composition and design of the screen should not be considered in isolation from the projectors, the eyes, the restrictions on their location, the ambient light, the nature of the visual task, and all the other pertinent factors.

On this broad and subtle subject we have neither off-the-shelf literature nor off-the-shelf products, but we are anxious to be in contact with those whose interest in it is more urgent than academic. Such persons should communicate with Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.

Inverse squares are square

Christmas is coming, a time when one can quit being obnoxiously logical about all things, a time of fun and acquisition for kin and self. Maybe the family needs a new camera. Cameras nowadays must be automatic. A non-automatic camera suggests lack of respect for progress.

The *Kodak Motormatic 35 Camera* is the most automatic of automatics. Energy for advancing the film and cocking the shutter for ten pictures is supplied from a spring wound in loading the camera. You can fire all ten in ten seconds, then rewind the spring and fire off ten more. Not only is the *f*/number photoelectrically set for ASA Indices of 10 to 800 and shutter speeds from 1/40 to 1/250, but for flash the act of focusing adjusts the opening to the guide number. There is no need to trouble the little woman with the law of inverse squares.

Less than $110 at most Kodak dealers'. You can also get a generator flash holder for less than $14.

New recipe

Polyester in sheeting means strength with thinness. Chemically it means a polymer condensed from alternating units of dibasic acid, usually terephthalic, and a glycol, usually ethylene glycol until we went to cyclohexane dimethanol in Kodel Polyester Fiber.

With the switch, some isophthalic acid added to the recipe, and six years of cleaning up details, there emerges a polyester resin that keeps its dielectric constant really constant up to 130° C, which could not be said of earlier polyester. Its dissipation factor is 0.3% at 100° C, where the old ran to 1.2%. Since it also better resists humidity, acid, and bases, it is excellent for insulation and frozen food wraps. As a capacitor film at 2000 v/mil, it outlasts the old 8 to 1.

Eastman Chemical Products, Inc., our subsidiary, sells the resin. Acme Backing Corporation, Canal and Ludlow Streets, Stamford, Conn., turns it to what others call film and we (for whom "film" has another meaning) call sheeting. Acme will gladly expatiate.

Too conservative

Only conservatives sit on committees that formulate standards for specifying film speeds. They set their lips in thin lines when they overhear enthusiasts trying to top each other with speed numbers. In the '40s they fixed the enthusiasts for fair. They defined the index so as to result in 2½ times the least exposure that even a stern judge would already have to accept as producing negatives of the highest pictorial quality.

They now confess that they leaned over backward too far for minimum grain and maximum sharpness from modern black-and-white films, modern practices, and modern equipment. The following speed numbers are derived from the revised American Standard:

KODAK PANCHROMATIC FILMS	
Sheet Films	**ASA**
Panatomic-X	64
Portrait Panchromatic	125
Super-XX Panchromatic	200
Super Panchro-Press, Type B	250
Tri-X Panchromatic	400
Royal Pan	400
Royal-X Pan	1250
Roll Films	**ASA**
Panatomic-X	40
Verichrome Pan	125
Plus-X Pan Professional	160
Tri-X Pan	400
Royal-X Pan	1250
35mm Films	**ASA**
Panatomic-X	40
Plus-X Pan	160
Plus-X Portrait	160
Tri-X Pan	400

Note that only one figure is given for each film because most meter cells have about the same spectral response as panchromatic film. Two are needed for:

Kodak Blue-Sensitive and Orthochromatic Sheet Films	ASA Daylight	Tungsten
Commercial	50	16
Commercial Ortho	80	25
Super Speed Ortho Portrait	125	64
Royal Ortho	400	250

Prices subject to change without notice.

Kodak
TRADE MARK

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

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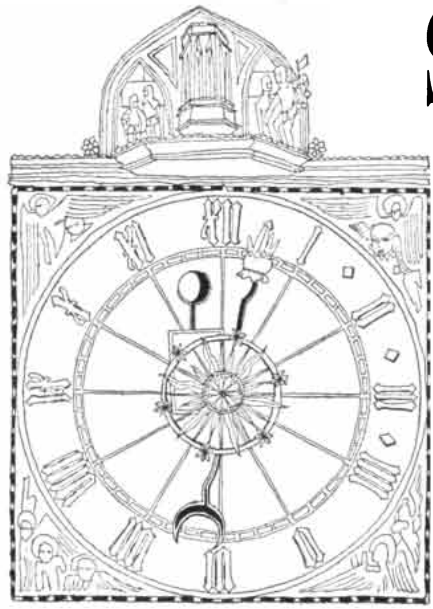
SCIENCE AND



The Nobel Prizes

The 1960 Nobel prizes in science were awarded to two Americans and, jointly, to an Englishman and an Australian. Each of the awards this year is equivalent to $43,625. Donald A. Glaser, 34-year-old professor of physics at the University of California, won the physics award for his invention of the bubble chamber, a device that reveals the path taken by a charged particle [see "The Bubble Chamber," by Donald A. Glaser; SCIENTIFIC AMERICAN, February, 1955]. While it does much the same job as the cloud chamber (which won C. T. R. Wilson the Nobel prize in 1927), the greater density of the liquid it contains makes it a much more efficient detector of events involving high-energy particles. Thus Glaser's device has teamed well with modern high-energy accelerators, and has contributed much of the knowledge gained about elementary particles in the last half-dozen years. The bubble chamber contains a liquid (often liquid hydrogen) that is almost at its boiling point for a given pressure. When the pressure is suddenly released, there is a brief period before the liquid starts to boil. If, during this time, a charged particle passes through the liquid, it will leave a path of tiny bubbles in its wake. As in the cloud chamber, the speed, mass and charge of the particle can be deduced from the density of the bubble track and its deflection in a magnetic field. Glaser's first chamber, on which he started work in 1952 while at the University of Michigan, was the size of a test tube. The later models are up to six feet long and contain hundreds of gallons of liquid.

Willard F. Libby, professor of chemistry at the University of California at Los Angeles and former member of the U. S. Atomic Energy Commission, won the chemistry prize for devising the method of radiocarbon dating. The radioactive isotope carbon 14 is continuously produced from nitrogen in the atmosphere by the impact of cosmic rays and, in the form of carbon dioxide, enters the life cycle of plants. From plants the isotope is incorporated in the bones and tissues of animals. So long as they live, plants and animals contain a constant ratio of carbon 14 to the more abundant nonradioactive isotope carbon 12. But when they die, the carbon 14, no longer replenished, begins to diminish through radioactive decay. After some 5,600 years a piece of wood or bone will contain only half as much carbon 14 as it did originally; at 11,200 years, only a quarter as much, and so on. With the precise methods developed by Libby, it is possible to date with reasonable accuracy the remains of organisms that lived as much as 30,000 years ago.

The prize in physiology and medicine went to Sir Macfarlane Burnet of the University of Melbourne and Peter Brian Medawar of University College London for "the discovery of acquired immunological tolerance." The discovery has brought a fundamental revision in the theory of immunity. This is the mechanism of "self-recognition," by which an organism distinguishes between its own tissues and anything else, including bacteria and viruses and grafts of tissue from another organism. In 1949 Burnet proposed that immunity is not inherited, but is gradually acquired during the embryonic period. The developing embryo "learns" to recognize its own cells and tissues and, up to a critical point in development, to tolerate foreign biological substances. Any cells and tissues introduced after this point are treated as foreign [see "How Antibodies Are Made," by Sir Macfarlane Burnet; SCIENTIFIC AMERICAN, November, 1954].

Medawar and his co-workers confirmed Burnet's theory in 1953 in a series of skin-graft experiments with mice. They found that mice of one strain that had been inoculated in embryo with

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THE CITIZEN

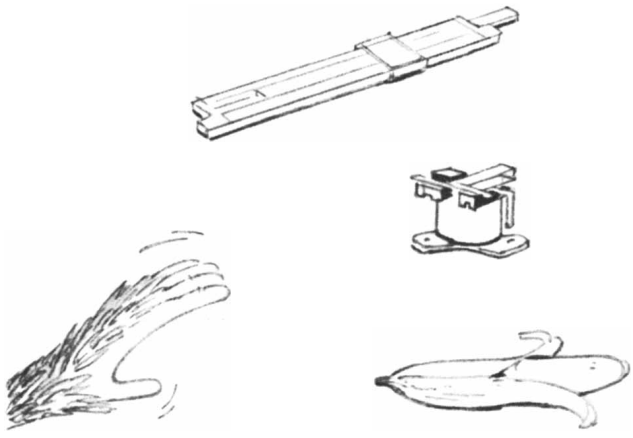
spleen cells from a second strain accepted skin grafts from that same strain after birth. They had acquired a tolerance to the foreign tissues [see "Skin Transplants," by P. B. Medawar; SCIENTIFIC AMERICAN, April, 1957].

Constant Standards

The wavelength of the orange-red light of krypton 86 has replaced the platinum-iridium meter bar (kept in the vault of the International Bureau of Weights and Measures in Paris) as the world standard of length. Formerly the wavelength of this light was defined as a fraction of the length of the meter bar. Now the meter is defined as a multiple (1,650,763.73) of the wavelength of the light.

The new wavelength standard has several advantages over the metal one. It is a constant of nature, indestructible, immutable and reproducible anywhere in the world; it can be determined within an error of one part in 100 million, and so permits measurements to an error of one part in 10 million. Krypton 86 correspondingly has several advantages over mercury 198, the also-ran in the competition for an atomic standard that was closed by the present decision of the 11th General Conference on Weights and Measures in Paris. Like mercury 198, krypton 86 is an isotope with an even mass number; as such it has no nuclear spin, and so emits a cleanly defined spectral line. For sharpest definition, however, the thermal motion of the atoms must be reduced to a minimum by cooling. Krypton has a much higher vapor pressure at extremely low temperature, and the krypton-filled gas-discharge lamp employed for length-calibrating purposes produces a bright light at only 64 degrees centigrade above absolute zero. In the interferometer—the instrument used to measure wavelengths of light or to apply them to the calibration of a meter bar—the krypton lamp produces sharp interference fringes over a longer optical path.

The adoption of the new standard does not mean that the meter bars will be melted down. They are sufficiently accurate for most purposes and are convenient to use. Although it is no longer necessary to return national meter bars to Paris for periodic checkups,



Will he make the right choice and find True Happiness?

With enough expertly "programmed" and ingeniously dispensed training by a machine, even monkeys can be taught all sorts of marvelous things. (There are those who say that for the rewards illustrated, even a monkey would know enough not to pick the Sigma relay. At times we too wonder if some of our customers wouldn't have been better off if they'd chosen a banana instead of one of our relays.) At any rate, we salute the hard-working souls who try to get other people to think; if their "teaching machines" lack human fervor and originality, as some say, perhaps the critics are confusing the methods with the accomplishments.

Continuing our discussion of Sigma relays vs. bananas (we've decided that *they're* our real competitive threat, not transistors), it is the Application that decides all. We can't hold a candle to their enclosure, and while heat improves them up to a point it's apt to make relays dry up and get lethargic instead of just squishy. What hurts the most, though, is that if a banana doesn't work in the application you had in mind, you can always eat it; in 20 years, we've never been able to offer customers that consolation.

There's a ray of hope for relays, however, from one quarter where slide projectors, electric shocks, peanut butter and other assorted elements are being used in teaching machines. In one device relays and photocells "read" the student's answer to a slide-projected question, via selected light beams passing through holes in the edge of the slide. This particular programmer uses twelve Sigma Series 11 relays, noted for their compatibility with both monkeys and people. The machine can handle up to 4096 different questions (12 relays x 2 positions $= 2^{12}$), and its output from the relays' contacts can run a congratulatory or reprimanding indicator, reward dispenser or some other electrically-actuated device. To the "student" using the machine, the fruits of his labors may be either literal or figurative, depending on what's connected to the machine. This, in turn, is usually determined by whether the student is a smart monkey or just a human being. Another good feature is that the inventor* is Sigma's Sales Manager's cousin's husband, which assures us a certain degree of customer sympathy and prompt payment of account.

This educationally-oriented advertisement is one in a series of public-spirited messages from Sigma, wholeheartedly devoted to fostering greater awareness among relay users. For those not yet ready to buy, Sigma once again offers a small remembrance gift. If you've got 26¢, send it to Sigma's Advertising Manager today, for your Big Application Boon of Oblige Noblesse (address "BABOON Branch"). Quantities limited by our patience; act now.

*Davis Scientific Instruments, 12137 Cantura St., Studio City, California

SIGMA INSTRUMENTS, INC.

40 Pearl Street, So. Braintree 85, Mass.

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Sheer listening pleasure for you and your family. The delights of the original performance are recreated in accurate detail and perspective. Every nuance of tonal shading and phrasing is clearly delineated without hum, noise, or distortion.

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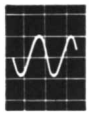
To assemble your own DYNAKIT is a uniquely rewarding experience. Easy . . . fun . . . educational . . . satisfying your creative interests.



TECHNICAL
The superiority of premium components and the functional simplicity which typify the advanced engineering and design of DYNACO high fidelity equipment add a special satisfaction for you who appreciate excellence. Building your own makes you intimately aware of the *quality* of DYNACO equipment.

FINANCIAL
The unexpected bonus—*substantial savings* on high fidelity components of unquestioned technological superiority and unparalleled listening satisfaction.

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the International Bureau of Weights and Measures will continue to calibrate them for those countries that do not have adequate standards laboratories.

The Paris Conference also adopted a new standard of time. The second, hitherto reckoned as 1/86,400 of the mean solar day, is now defined as 1/31,566,925.9747 of the year 1900. For astronomical purposes the period of the earth's rotation on its axis has proved to be too variable; the period of the earth's revolution on its orbit is more nearly constant, and the specification of the year 1900 takes care of the small variations observed. The new time standard is nonetheless a stopgap. It is to be replaced in a few years by one based upon a securer constant of nature: the period of vibration of an atom.

Community of Fear

A grim assessment of the arms race and of the consequences of its perpetuation has recently been published by the Fund for the Republic, Inc. The authors of the study, entitled "Community of Fear," are Harrison Brown, professor of geochemistry at the California Institute of Technology, and James Real, both of whom are consultants to the Fund's Center for the Study of Democratic Institutions, in Santa Barbara, Calif.

Brown and Real begin with a brief review of the technological advances that have transformed the weapons of war in the past 20 years. They suggest what might happen if one of today's 10-megaton hydrogen bombs, delivered by intercontinental ballistic missile, were exploded over Los Angeles. "The blast effects would exterminate virtually all but the most deeply sheltered living things within a radius of five miles. . . . A good proportion of the . . . area's three and a half million cars and trucks would be lifted and thrown like grotesque Molotov cocktails. . . . In an instant most underground gasoline and oil tanks would rupture and explode." Beyond the blast area tens of thousands of homes and the brush-covered hills that comprise 50 per cent of greater Los Angeles "would break into intense flame simultaneously. . . . There would be virtually no survivors."

To destroy the U. S., in its present state of preparedness, would require an attack of "considerably less than 20,000 megatons," which could be carried out by fewer than 4,000 (and perhaps fewer than 2,000) intercontinental missiles. Such an attack, the authors believe, is presently beyond the capability of the U.S.S.R., "but the revolution in delivery systems may well bring the Soviet Union to that point [of capability] in a few years." An unspecified time after that, but perhaps not long after, "very large bombs (about 1,000 megatons) will be built which, when exploded at an altitude of about 300 miles, could sear six Western states." (If placed in orbit, such weapons could be exploded effectively without having to be launched toward earth.)

Brown and Real see scant hope of a letup in the arms race. Instead, they believe, a forceful case will be made "within the next two or three years" for a crash program of shelter-building. They concede that "in principle" shelters can provide protection as effective as desired, "at least until such time as we learn how to make explosives capable of pulverizing the earth to great depths." But this is some time off, and meanwhile Americans will be persuaded that war is not obsolete. "Once the people are convinced that they can survive the present state of the art of killing, a broad and significant new habit pattern will have been introduced and accepted, one grotesquely different from any we have known for thousands of years—that of . . . living in holes. From that time onward it will be simple to adjust ourselves to living in *deeper* holes."

A major factor in the arms race, the authors believe, is the importance of the huge military budget in supporting the U. S. economy. Few Americans have much incentive for seeing the arms race ended. In fact, Brown and Real see an "alliance . . . between the scientist-technician on the one hand and the military on the other." The former "are in every sense the paramilitary—civilian soldiers. . . . Their sympathy for and concurrence with their uniformed colleagues are often marked and open."

Paradox Proved

For the past year or so physicists have been busily trying out one of the most accurate and sensitive tools that has ever come into their hands: the sharply defined radiation of nonrecoiling atomic nuclei [see "The Mössbauer Effect," by Sergio DeBenedetti; SCIENTIFIC AMERICAN, April]. Now it appears that, almost incidentally, their experiments have settled the famous problem of the clock paradox in the theory of relativity.

In his original paper of 1905 on the special theory of relativity Albert Einstein discussed the case of two identical clocks initially at rest in an "inertial"

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Problem: How to Microfilm Old Drawings So They Can Be Read

Microfilming is widely used for recording and storing the mountains of drawings and data individual companies must maintain. But to anyone who works with microfilmed drawings, they know the condition of the original is very critical in order to obtain a readable microfilm print. Faint lines, weak lettering and dimension markings, creases, and dirt smudges become impossible handicaps when the originals are first reduced 16 to 29 times and then enlarged for reading or reproduction. Today's advanced drafting techniques avoid this problem in new drawings, but what about a company's old drawings? Few are ever suitable for microfilming without extensive, meticulous restorative work. Yet, something must be done with these old drawings if the microfilm file is to be complete and useful.

Dietzgen answers this problem with a number of products and techniques developed for restoring old drawings

Dietzgen's "wash-off" process puts new life into old drawings quickly and inexpensively.

preparatory to microfilming. The Dietzgen "wash-off" process is preferred by many because no darkroom work is involved. Corrections are easily made on the "wash-off" media eliminating the tedious retouching of a photographic negative. Backgrounds come clean with a wipe of a brush or sponge so that even the finest line stands out sharp and clear.

Today thousands of old drawings which appeared hopeless subjects for microfilming have been salvaged by Dietzgen products and techniques . . . and it's this experience which can prove invaluable to you if old drawings have handcuffed your company's microfilm program.

JETS, MISSILES AND DIAZOS

A large manufacturer of components for jet aircraft and guided missiles complained: "We're having trouble getting all the prints we need each day with our present printmaking facilities. We must step up our printing speed. However, we want to standardize on blueline diazo prints and would like to run our printers at very nearly a constant speed. Also, we have to work with a wide range of reproducibles, which really complicates the problem."

Four companies coating diazo papers were given the problem. Two immediately said it was impossible. The third submitted a specially coated stock which provided the speed but not the print quality required.

Dietzgen had answered similar problems before. With a slight formula change in one of the regularly catalogued Dietzgen diazo papers, the extra speed was added to all the other needed characteristics already in formulation. This custom-engineered product was tested and immediately adopted. It has since been used continuously for the company's large volume needs and is pronounced "perfect." Print production soared.

Dietzgen's long and broad experience with Diazo coatings and equally long and broad research program frequently combine to provide both counsel and advanced products not obtainable elsewhere.

Drafting-Printmaking Booklet reports new techniques for solving engineering and production problems

This new 36 page booklet describes a wide variety of engineering and production problems that have been solved with advanced techniques in drafting and printmaking pioneered by Dietzgen. The concise, problem-solution approach suggests ways in which you may improve the efficiency within your engineering department or eliminate production bottlenecks. Write today on your company letterhead for the Mechanics of Modern Miracles. Ask for Publication SPD2-M239. Eugene Dietzgen Co., Chicago 14, Illinois.

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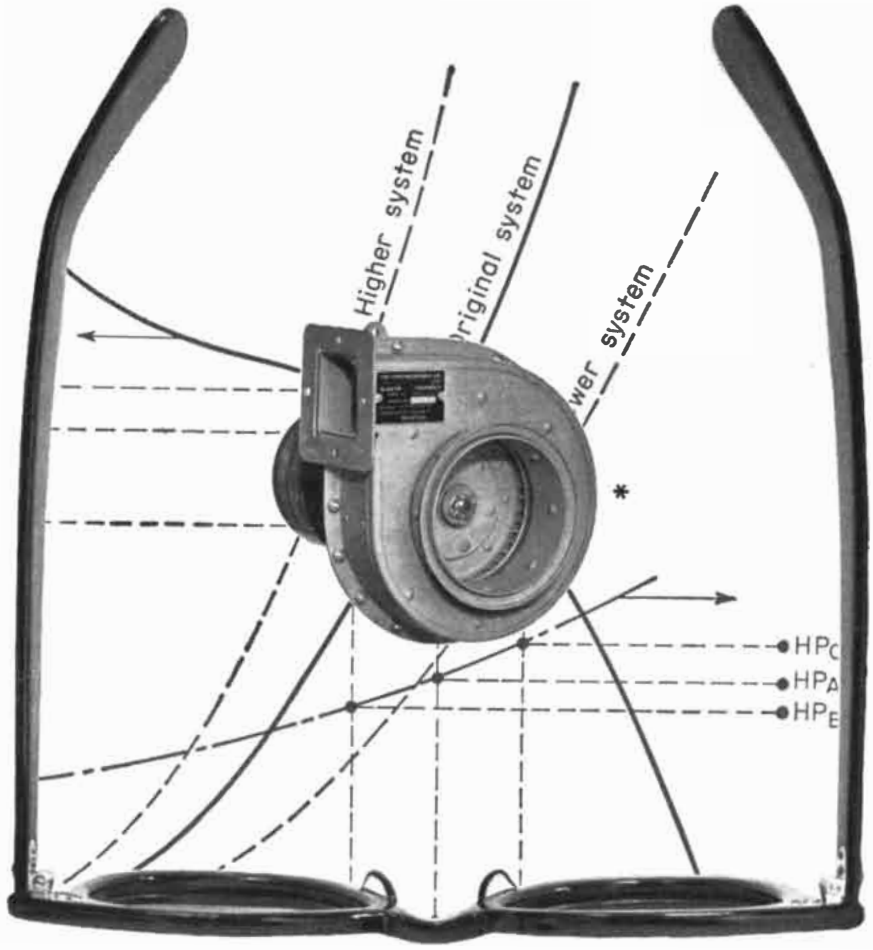
A CRITICAL LOOK AT THE PROBLEMS OF EFFICIENT ELECTRONIC COOLING UNITS. There's a lot of solid engineering in the business of cooling electronic equipment efficiently, quietly, to precise requirements.

It takes more than a catalog and the best wishes of the supplier.

Torrington capabilities in this highly specialized field of air moving requirements offer the most extensive experience and the finest facilities available... plus service. **THIS MEANS** Torrington technical service representatives in the eastern, central and western areas — at your beck and call. **IT MEANS** upward of a million dollars of investment in laboratory, design and experimental facilities — yours to utilize. **AND IT MEANS** a complete engineering approach to your problem of tailoring the **right** cooling unit to the **total** electronic system design.



*MSA-7861 centrifugal blower unit used on B52 bomber and Boeing 707 transport

THE TORRINGTON MANUFACTURING COMPANY
SPECIALTY BLOWER DIVISION Torrington, Connecticut

system; that is, a system undergoing no acceleration. If one clock were then taken on a round trip to another part of space and back, Einstein said, it would prove to have lost time compared with the one that remained behind.

The paradox transcended the theory from which it arose. The special theory of relativity deals with systems moving at uniform velocity with respect to one another. It predicts a simpler "time dilation" phenomenon, in which a clock in one such system appears to run slow to an observer in another. This effect has been experimentally verified in a number of ways, for example in the reduced decay-rates of unstable particles moving at high speed. It is a symmetrical relationship: To an observer riding on a moving particle, the decay rates of what to us are stationary particles would seem retarded.

The case of the round trip is different. In order to return to its starting point, the traveling clock must at some point change its direction, if not also its speed; in other words, it must be accelerated. And the theory states unequivocally that it is the accelerated clock that slows down.

Almost all physicists have long accepted the prediction. In the absence of experimental proof, however, they have felt obliged to defend it against a small but vehement minority that insisted that all motion is purely relative, and that all its effects must therefore be symmetrical. If there is no way of deciding which clock has actually moved, the argument goes, then each has an equal claim to run slow. Hence when reunited after the trip, they can only show the same elapsed time.

In a recent article in *The Physical Review*, C. W. Sherwin of the University of Illinois declares that the experiment has now in effect been performed. The "clocks" were nuclei of the radioactive isotope iron 57. When held in a crystal lattice so that they cannot recoil, these nuclei emit and absorb gamma radiation in an extremely narrow band of frequencies. The band is so narrow that, if the frequency of emitter or absorber varies by as little as one part in a million billion (or, in other words, if one clock runs this much slower than the other), a lack of resonance between the two can be detected.

Sherwin points to the studies of R. V. Pound and Glen A. Rebka, Jr., of Harvard University, who have discovered that differences in the temperature of the crystals containing the emitting and the absorbing nuclei produce shifts in frequency. Furthermore, the hotter ma-

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3M COMPANY CHEMICALS

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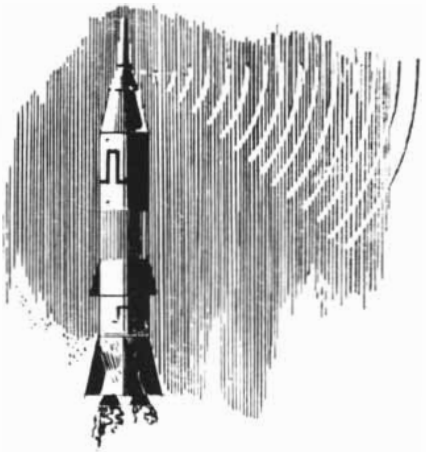
How a 3M fluorochemical cushion keeps voice of Atlas "on the air"

A mighty Atlas missile blasts off on a scientific mission carrying a top-priority passenger—a delicate telemetering device. It will record conditions the missile encounters, then report back. To do its job, this sensitive instrument must survive abrupt acceleration, violent vibration . . . even a fast fall back to earth. Its "cushion"—a completely inert 3M fluorochemical liquid called FC-75!



Inside the sealed telemetering device is a continuously operating magnetic tape recorder. It picks up such preselected conditions as temperature, air pressure, vibration, strain and stress... then reports this data to observers below. Also inside the sealed unit is 3M Brand Inert Fluid FC-75. This fluorochemical isolates and cushions the working parts—protects them during the missile's rampaging ride through extreme environments.

No chemical or electrical changes

Because FC-75 is completely inert, it is compatible with metals, plastics, elastomers, all other materials used in the telemetering unit. *It will not* chemically attack the magnetic tape or other components . . . *will not* interfere with their electronic operation. At the same time, FC-75 remains stable through a wide temperature span. It has a pour point of less than —100° F., will not break down even after long exposure at +750° F. In addition, FC-75 is nonexplosive, nonflammable, nontoxic, and provides high dielectric strength.

In other electronics applications, FC-75 does a remarkable job of keeping equipment cool so designers can make it smaller. In an airborne high-frequency amplifier, for example, the great heat transfer efficiency of FC-75 enabled weight reduction from a half-ton-plus to less than 200 pounds.

Talented family from 3M

Other members of the new and talented 3M family of fluorochemicals are similarly serving missiles and electronics with materials that perform well beyond conventionally accepted limits.

KEL-F® Brand Plastic, for example, provides unusual endurance for missile wire coatings and jackets, circuit encapsulations, lip seals and other components for valves, fuel lines and additional assemblies. This plastic resists violent chemical attacks . . . even from fuming nitric acid, yet has an operating range from —320° to +390° F.—excellent dielectric and compressive strengths—zero moisture absorption.

Another news-making 3M fluorochemical is Fluorel® Brand Elastomer 2141, used for O-rings, grommets, seals, other high-performance rubber parts. It withstands heats up to 600° F. —is unaffected by most fuels, lubricants and hydraulic fluids. An unmatched Mooney scorch rating permits processors to make fast, economical cures—safely allows repeat processing to meet tough military specifications.

More than 300 specialty chemicals

Can the 3M family of chemicals help you? More than 300 of them are at work today in electronics, missiles, textiles, plating, aircraft, automotive, rubber, plastics, packaging, other fields as well. For technical assistance or detailed information, write today on your letterhead, specifying area of interest, to 3M Chemical Division, Dept. KAM-120, St. Paul 6, Minn.

"KEL-F" and "FLUOREL" are reg. TM's of 3M Co.

CHEMICAL DIVISION

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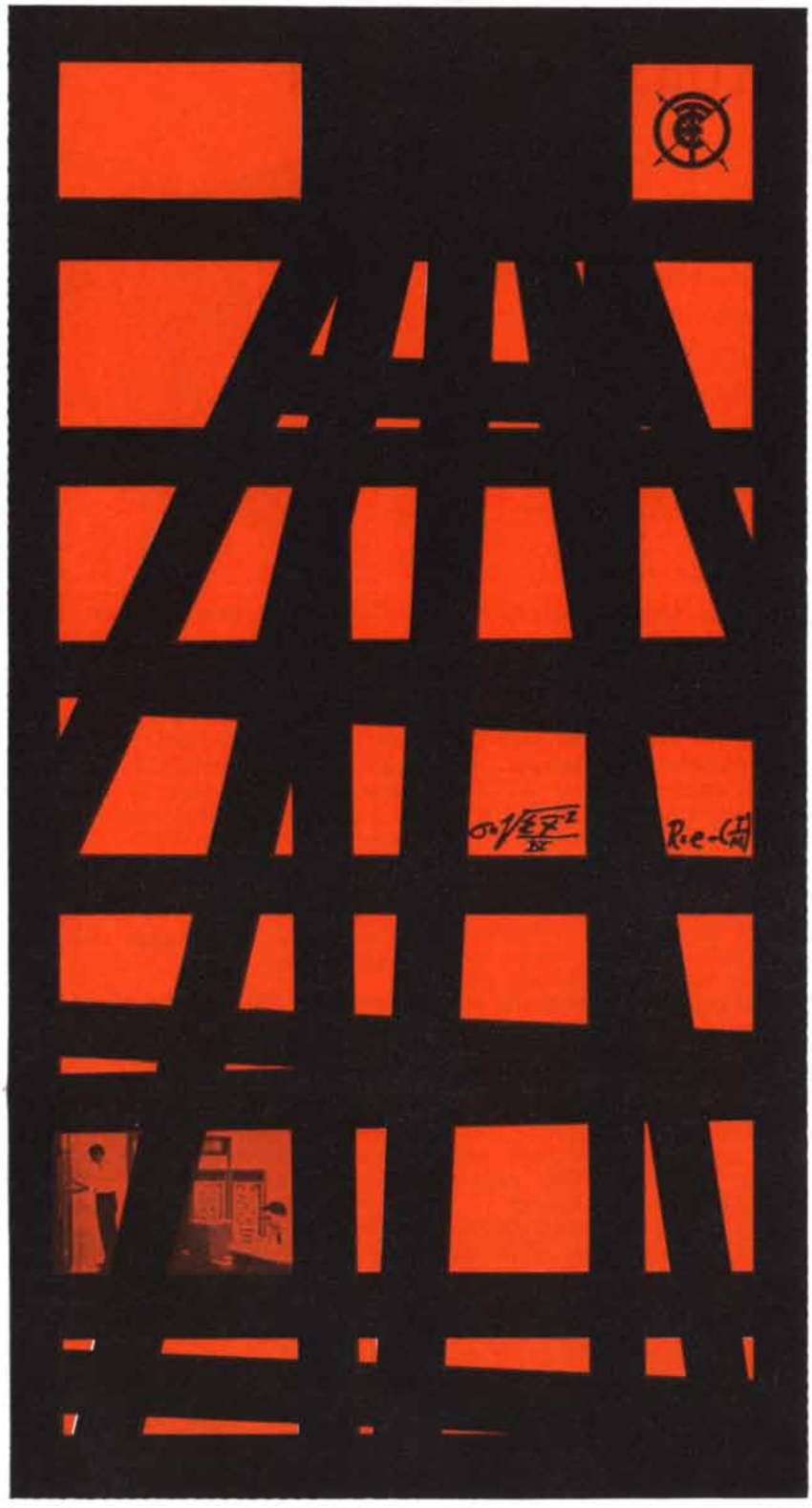

terial has the lower frequency. Thus the accelerated motion imparted to the nuclear clocks by thermal vibration does slow them down, and by an amount that agrees with Einstein's calculations, within limits of experimental error.

Sherwin concedes that the experiment is not identical to the one originally proposed. Instead of a single round trip, the heated atoms make many rapid oscillations over a short distance. But the emitter and absorber remain the same net distance apart as they travel, so the clocks are compared while they are relatively at rest, as they are in Einstein's example.

Sherwin concludes: "Whatever its theoretical difficulties may be, pure relativism is untenable experimentally."

Optical Maser

A novel method of communication, and unfortunate addition to the U. S. vocabulary, is promised by an optical cousin of the microwave amplifier called the maser. An optical maser, which seems destined to bear the name "laser," has been used by A. L. Schawlow and his colleagues at Bell Telephone Laboratories to transmit a narrow beam of light over a distance of 25 miles, with a spread of only about eight feet per mile. Similar results have been achieved by T. H. Maiman of the Hughes Aircraft Company.

The Bell device is a cylindrical rod of synthetic ruby an inch and a half long and a fifth of an inch in diameter, its parallel ends coated with a thin layer of silver. When the synthetic ruby —crystalline aluminum oxide in which chromium atoms take the place of a small proportion of the aluminum atoms —is exposed to light, the chromium atoms emit a red fluorescence. The portion of this light emitted parallel to the axis of the rod is reflected back and forth by the silvered ends, and, on each passage, it stimulates a further emission. When the brightness of the input light is raised above a certain threshold, a beam of red light bursts through the thinly silvered ends.

The beam, composed of very nearly a single wavelength, is more than a million times brighter than the sun. Moreover, it is "coherent"; that is, its light waves are in phase, as are the waves emitted by a radio transmitter. Accordingly it should be possible to modulate the light beam, as radio waves are modulated, to carry a signal.

This has not yet been accomplished, because present optical masers emit light in discrete bursts rather than con-

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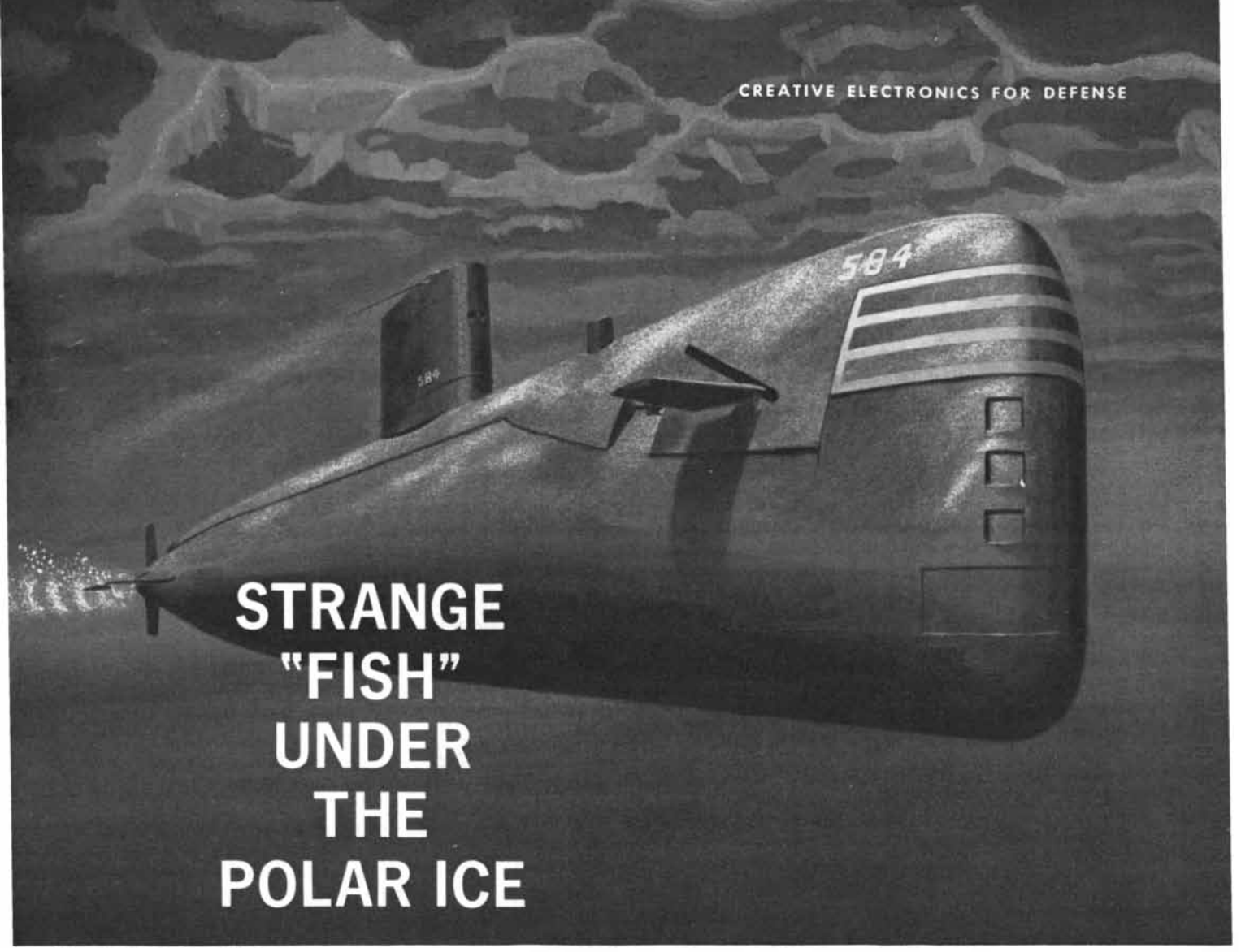

Revolutionary RCA Magnetic Video Tape Recorder to Speed Navigation Training of Submariners

Aboard the nuclear submarine Sea Dragon, the first undersea magnetic video tape recorder will record and store data on under-the-ice characteristics from externally installed TV cameras. Upon return to base the recorded information will be displayed for the benefit of undersea service trainees.

The RCA undersea recorder is a marvel of compact design (dimensions 20″ x 20″ x 100″). It nestles in a torpedo rack, and represents a 60% space reduction over existing video tape equipment.

Among the exclusive RCA developments are: the now famous "Tiros" satellite recorder; a radar system designed to take the first pictures of a nose cone re-entry vehicle; a unique tape cartridge completely adaptable to any size recorder. For literature describing new RCA defense and commercial products developments, write Defense Electronic Products, Radio Corporation of America, Camden, N. J.

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tinuously. When a continuous emitter is developed, it might be used to transmit telephone messages through "light pipes" filled with a highly refracting transparent material, such as carbon disulfide, which could trap the light. The pulsed device may find application in a highly accurate form of optical radar.

Progress in Fusion

Physicists at the Livermore laboratory of the University of California have reported a significant step forward in the control of hydrogen fusion. Frederick H. Coensgen of Livermore described a fusion reaction that reached 35 million degrees centigrade and lasted about a thousandth of a second. One physicist in another fusion laboratory calls it "the most encouraging thing yet reported. It is positive evidence that magnetic confinement of a hot gas is possible—and that's encouraging for all of us."

The Livermore work was done in a "multi-stage magnetic compression mirror machine." It uses a type of magnetic container in which ionized particles of deuterium plasma are magnetically reflected back into the reaction zone by higher magnetic fields when they try to wander out of it. The reaction zone is roughly the size and shape of a football. The recent experiment indicates that the magnetic-mirror confinement principle may not be subject to instabilities that were theoretically predicted, and which have been frustrating designers of fusion machines. In defiance of theory the Livermore plasma stayed confined as long as the magnetic field was on. The real test of the machine will come when a third stage of magnetic "compression" is added to it in an effort to achieve still higher temperatures and longer confinement times.

Venus Observed

A rare astronomical coincidence has recently provided the best look at Venus anyone is likely to get before space craft arrive there for a first-hand inspection. On July 7, 1959, the bright star Regulus passed directly behind Venus. For a few seconds on either side the light of the star was seen through the outer layers of gas surrounding the planet. From the points at which the light faded, astronomers obtained the first direct evidence as to the density of the upper Venusian atmosphere and the variation of this density with height.

Combining this result with previous

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MICROCHEMISTRY OF SURFACES

Surface impurities of less than half a monolayer can have a marked effect on semiconductor performance. Because these impurities—residual oxides and adsorbed gases—occur in such minute amounts, highly sophisticated techniques are required to detect their presence. The preparation of optimum semiconductor surfaces requires detailed microchemical data.

To investigate the oxidation and adsorption kinetics of germanium and silicon, Raytheon researchers designed and constructed a vacuum microbalance system. The vacuum microbalance reproducibly detects weight differences of less than three-billionths of an ounce in single crystal oriented samples, 0.002 to 0.004 inch thick, weighing a hundredth of an ounce.

All measurements and analyses are performed in an ultra-high vacuum system in which pressures of 10^{-10} mm Hg are achieved. The initial oxygen concentration is less than one ten-billionth of the gas ambient in the apparatus. Experiments can be performed at temperatures ranging from 1200° C. to -195° C. A combination of an "omegatron" mass spectrometer and the microbalance provides information concerning changes both in the weight of a sample and the composition of the system ambient. Raytheon has made substantial contributions to the development and understanding of the omegatron.

Information obtained from these investigations will guide the development of advanced semiconductor designs. Among the scientists responsible for this unusual research endeavor are Dr. S. P. Wolsky and Dr. E. J. Zdanuk of Raytheon's Research Division.

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SILICONE NEWS from Dow Corning

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SPECIALISTS IN FREQUENCY MANAGEMENT for space exploration programming, high speed navigation, and spectrum conservation in the growing communications field.

measurements of the temperature at various levels also provided a sharper view of how far the atmosphere of Venus extends below the opaque clouds that hide the solid body of the planet. According to the new calculations, reported in *Nature* by Gérard de Vaucouleurs and Donald H. Menzel of the Harvard College Observatory, the radius of the planet proper is 6,089 kilometers (3,783.5 miles) plus or minus six kilometers, which represents a tenfold reduction in the probable error of earlier estimates.

Calculations of the paths of stars and planets across the celestial sphere show that the July eclipse of Regulus by Venus comes only once in more than 1,000 years. (The star is also eclipsed in October at an interval of about 500 years.) Moreover, this is the only bright-star-and-planet pair with intersecting courses.

"Gyplure"

Investigators at the Beltsville center of the U. S. Agricultural Research Service have not only isolated and identified the compound secreted by the female gypsy moth to attract the male, but have synthesized a closely related substance that may open up a new way to control this forest and shade-tree pest. For several years entomologists have been employing a crude extract prepared from the female moth to lure male moths into traps, where they could be counted as an aid to forecasting areas of heavy moth infestation. Last summer the attractive constituent of the extract was chemically identified by Martin Jacobson, Morton Beroza and William A. Jones of the Agricultural Research Service; the isolated substance is so powerful that a ten millionth of a millionth of a gram is detected by male moths at distances up to a quarter of a mile.

Jacobson and his associates were able to synthesize one form of the compound in a modest quantity and to produce more than a pound of an easily manufactured, closely related compound. The latter they have called Gyplure; it is so powerful that the amount already made would suffice to bait traps for 400 years of gypsy-moth surveying. But the creators of Gyplure have a more ambitious objective. Next year they hope to test the feasibility of controlling the gypsy moth by putting the males out of effective reproductive circulation. In strategic places they will spread large sheets of sticky paper with a bit of Gyplure in the center.

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HOW TO AVOID DEVELOPING A COMPULSIVE DESIRE FOR A DIGITAL COMPUTER

The computer we're warning you about is called Recomp. It looks innocent enough at first. Yet one glance can be enough to arouse your acquisitive instincts. Recomp is a handsome piece of equipment. Like fine architecture or jet plane design, it looks right because it is right; form fits function.

Something else that will appeal to your practical sense is the compact size of Recomp. It's solid state, of course; in fact, it was the first fully transistorized computer on the market. There are no voluminous rows of vacuum tubes; no ventilating problems. Yet many times Recomp can match the performance of computers that literally fill rooms.

Now, to indulge your natural desire to find out more about the finest computer in its class, just imagine you have a Recomp handy. First, plug it in; any wall socket will do, and it takes no more electricity than an ordinary electric toaster. After an appreciative look at that distinctive keyboard, try a few sample problems. You will have a full scale compiler named SALT (that's Recomp's own Symbolic Algebraic Language Translator) to help you, or you can use Recomp machine language which is the simplest of any computer on the market today. If you do not know how to operate the keyboard, never mind; in a few hours you can become an expert at programming Recomp. It doesn't even demand specialized talents; anyone with computer problems can be taught to do it.

While you're enjoying yourself at the keyboard, why not try a problem using floating point arithmetic? Of course, Recomp has it built-in; in fact Recomp is the only compact computer on the market today in which this is a standard feature. It is rather astonishing how much greater capacity this gives you to handle a wide range of problems. Cuts down on that frustrated feeling.

If, at this stage, you can already feel the first stirrings of an irresistible urge to possess Recomp for your very own, let us counsel you: this is just a premature impulse. First you should read this unembellished list of facts:

1] Exclusive built-in floating point arithmetic.

2] Easy to program.

3] Efficient programming; 49 basic instructions expandable to 72.

4] Fast access time due to high-speed loops.

5] Magnetic disk memory with large capacity—up to 8192 instructions.

6] Large word length of 40 binary bits.

7] Each word contains two instructions.

8] Solid-state reliability.

9] Built-in square root command.

10] Large sub-routine and program library.

11] Active users group.

12] Built-in automatic conversion from decimal to binary.

13] Visual display of any word in memory.

14] Simple correction of errors.

15] Easily installed anywhere.

16] Can use conventional teletype equipment.

17] Low cost per computation.

18] High-speed input and output.

19] Programming training provided.

20] Large program exchange.

21] Coast-to-coast sales & service.

No doubt you have read of other computers that claim many of these advantages, but you see, Recomp is the only one that can claim them all. This can be very disquieting when you think about it.

Now, as to how you can avoid developing a compulsive desire for a digital computer: don't see Recomp in action. For on seeing the performance of Recomp, it is quite likely you will insist on owning one. However, if you find that the insidious Recomp has made an ineradicable impression on you, it would be as well to face facts. The truth is, you need Recomp. We'll be glad to help. Our address is AUTONETICS INDUSTRIAL PRODUCTS, Dept. 121, 3400 E. 70th St., Long Beach, California. **The Autonetics Division of North American Aviation, Inc.**

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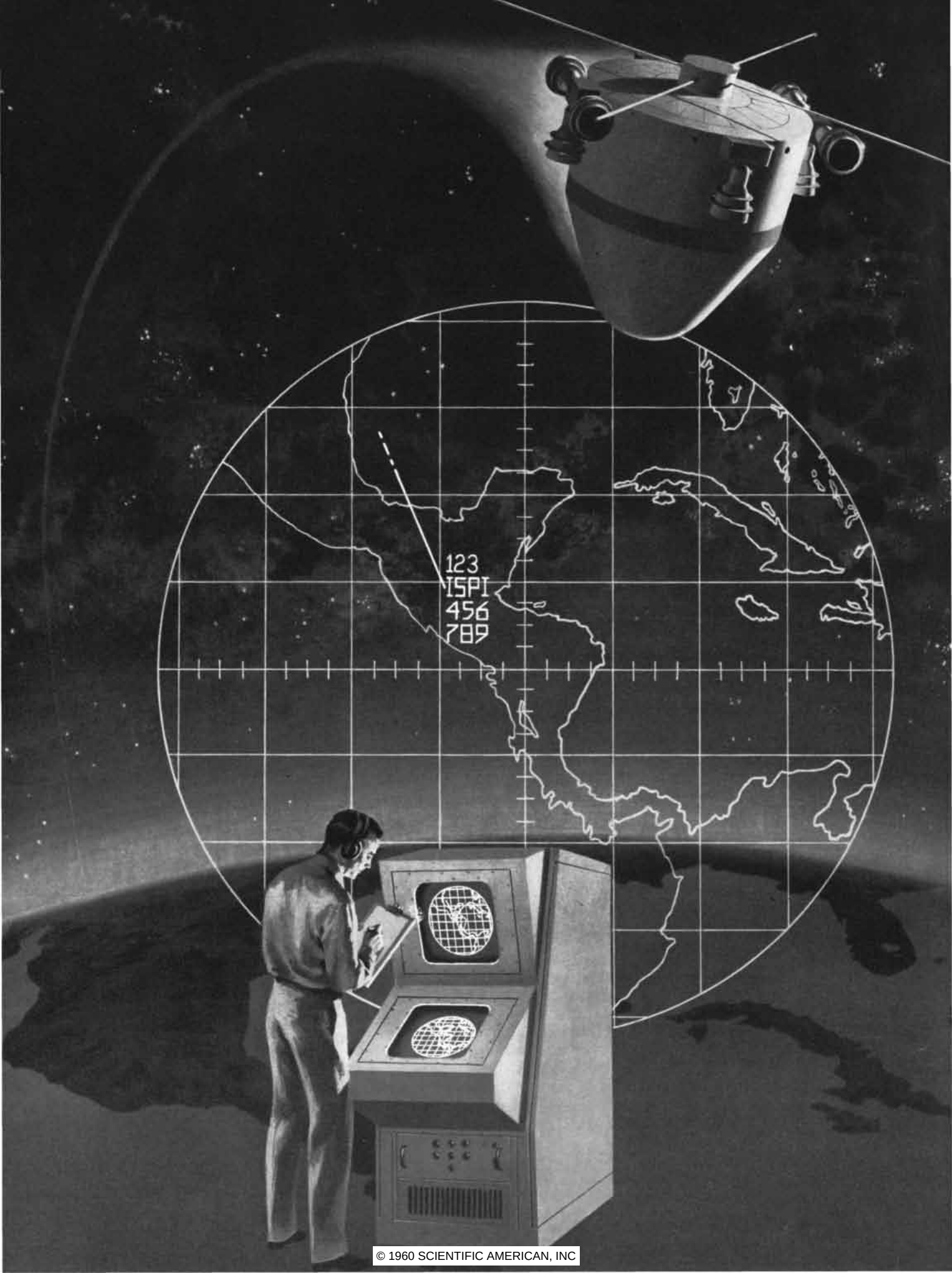

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NEW MARQATRON

BY MARQUARDT/POMONA

Produces Instant Visual Read-Out From High Speed Processed Data

Now, any eye—skilled or unskilled—can read the true, meaningful answers of the fastest, most complex computer, and do so at the push of a button! This is made possible by the MARQATRON, an automatic data processing and display development by the Pomona Division of The Marquardt Corporation. MARQATRON establishes the basis of human understanding—instantly—of the vast data provided by computing systems. It establishes a comprehensive human-machine relationship by converting collected data into readable alpha-numeric and geometrical patterns. By this, the viewer can quickly adapt human intelligence, decision and control over any and all conditions that are reported.

The MARQATRON presents commercial and military situation data in visual images on a cathode ray screen. Operators view this reporting and are able to control or alter the characteristics of the test or operation.

In MARQATRON's original application in the U.S. Army Missile Master Program, surveillance information was converted into readable displays on screens enabling defense officers to make immediate decisions in relation to the use of all missile ordnance.

A modified MARQATRON is currently being used by Bendix on the Eagle Program, helping to determine the behavior of an experimental aerodynamic vehicle under specified operational conditions.

The adaptability and the uses of the MARQATRON are limitless in the field of data processing and display and large scale projection systems. New applications are now in development by Marquardt's Pomona Division. For detailed data, contact Dr. Wendell B. Sell, Vice President, Pomona Division, The Marquardt Corporation, 2709 North Garey Avenue, Pomona, California.

Engineers and scientists experienced in these or related fields will find it rewarding to discuss their career futures with Marquardt. The company's growth is a parallel to the atmosphere of challenge and accomplishment that has existed since the firm's beginning.

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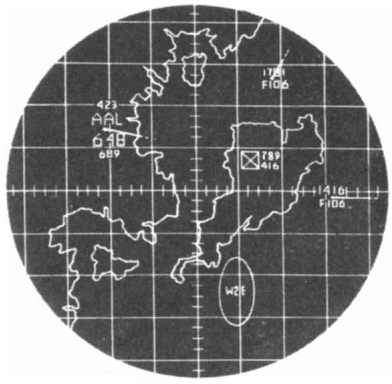
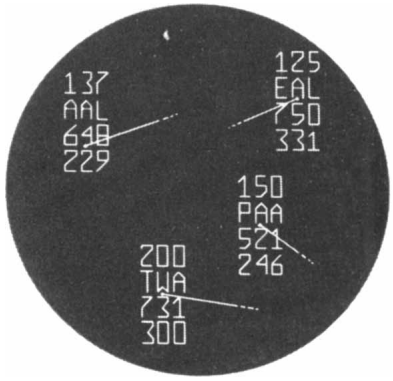


COMMAND CONTROL
Visual displays for satellite tracking, defense intercept and missile training.



AIR TRAFFIC CONTROL
Accurate positional data for enroute approach, ground control, and for identification of air traffic.

PAGE PRINTING FORMATS
Temporary readout of multichannel data for visual program verification.

A Portable Marqatron—no larger than a motion picture projector—is available for field use.

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The Viruses of the Common Cold

For years the cold virus stubbornly refused to multiply in tissue culture. Now, with new techniques, researchers have been able to culture some 20 strains of the virus

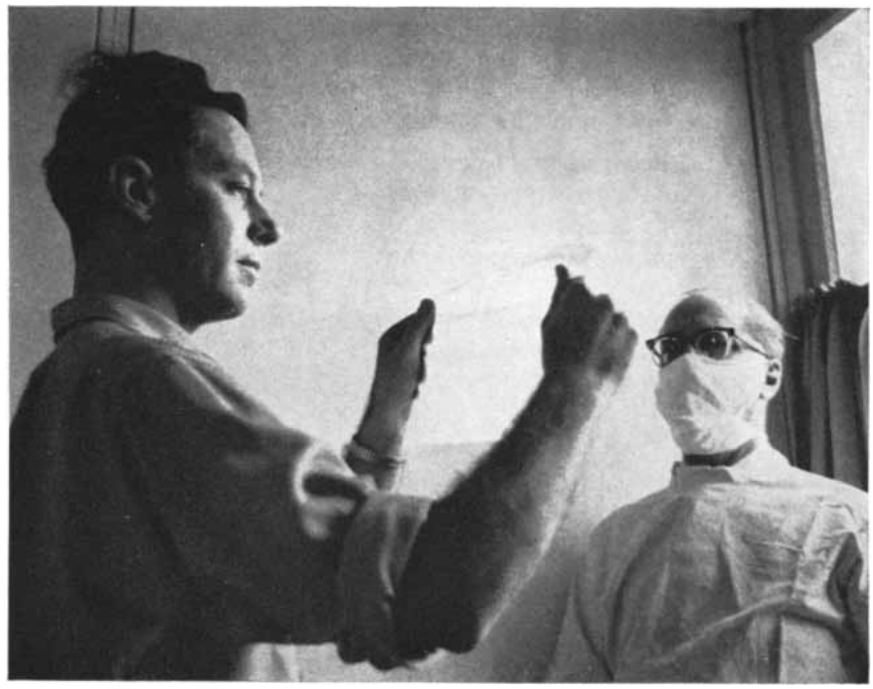
by Christopher Howard Andrewes

Few authorities nowadays would dispute that the commonest kinds of common cold are caused by viruses. As long ago as 1914 Walther Kruse of Germany transmitted colds to volunteers by means of bacteria-free filtrates of nasal secretions from people with colds, and since then numerous investigators have done the same thing. But for years no one was able to recognize the presence of the virus by any laboratory test, and there seemed to be no reliable way to grow the virus outside the human body in laboratory glassware. Until that could be achieved there was little hope of getting the virus concentrated enough or pure enough to be studied in detail, as so many other viruses have now been studied. We believe that this barren and frustrating period has now been brought to a close. Within the last two years research workers at the Common Cold Research Unit in Salisbury, England, have enjoyed a series of heartening successes in growing cold viruses in tissue culture, and in devising laboratory schemes for showing that the viruses are indeed present and have multiplied without assistance from a human host. It is perhaps too early to say with absolute conviction that our Salisbury strains, as we have dubbed them, are the chief viruses causing the commonest colds, and that they differ significantly from all viruses previously isolated, but we feel that the evidence is now quite impressive. While we have not yet got electron-microscope pictures of the Salisbury viruses, we are confident this will come in due course.

Readers of this magazine who have a sufficiently long memory may recall an article entitled "The Common Cold," published in February, 1951, in which I described the first four years of work at the Common Cold Research Unit. The Unit was established by the British Medical Research Council in 1946, and is housed in buildings put up in World War II by the Harvard School of Public Health and the American Red Cross.

The main objective of our work was simple enough. We knew that we could detect the cold virus by dropping filtrates up the noses of volunteers and waiting to see whether or not a cold developed, but this was a clumsy, slow, unreliable and expensive way of working. We needed a laboratory test that would detect the presence of the virus and enable us to study it in a quantitative way. But until we had that, we needed a constant flow of volunteers, willing to let us drop our test materials up their noses, thus giving us information that would guide us to this major objective. It has meant hard work to keep up this steady flow—articles in papers, talks on the radio and television, much correspondence; but in 14 years more than 6,600 volunteers have passed through our hands. We usually manage to keep our 12 "isolation flats" full through the summer and about half full in the winter. Volunteers come and live in pairs, usually married couples or pairs of friends. We pay their fares (within limits), give them a little pocket money and look after them for 10 days.

An essential part of the planning of



EVIDENCE OF COLD, a soggy tissue, is held up for inspection by volunteer at Common Cold Research Unit in Salisbury, England. Physician who checks various symptoms is not told whether volunteer has been exposed to cold virus or is simply serving as a control.

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all the work has been to have the occurrence or nonoccurrence of experimental colds assessed "blind," that is, by someone who does not know the nature of the inoculated material. In borderline cases it is not easy to decide whether a person has a real cold, so neither the volunteer nor the clinical observer must know what has been used: whether active filtrate, "control" (harmless saline solution or broth) or an unknown. By regularly giving material free from virus to a proportion of volunteers, we keep a constant check on the significance of our results. A low percentage of people receiving such control material do in fact develop colds. We are not sure why.

The Common Cold and Its Vagaries

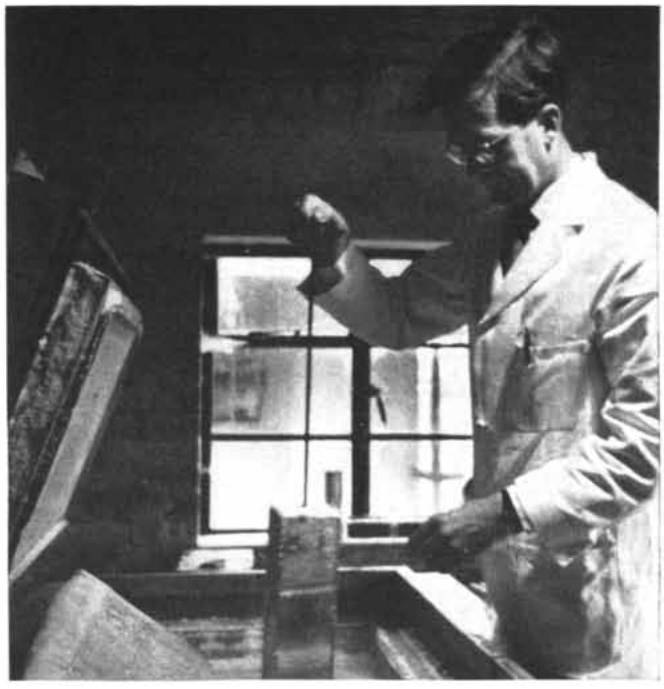
In my 1951 article on the common cold I summed up the first four years' work at the Salisbury Unit. By then we had convinced ourselves that colds could not be transmitted to any one of about 20 animal species, with the solitary exception of the inconvenient and expensive chimpanzee. Several investigators had claimed to have cultivated cold virus in hens' eggs, but we were not able to duplicate this work. Thus we were left with our human volunteers. Unfortunately we found that when one deliberately tries to give a person a cold, one can expect to succeed a good deal less than half the time—about a 30 to 40 per cent incidence of success would be a good long-term figure. We surprised ourselves, as well as many amateur experts on colds, when we discovered that we could not raise our success level even when we obliged our volunteers to take hot baths and then stand about in a drafty passage in wet bathing suits for half an hour. In not one instance did chilling alone produce a cold, and in several instances chilling plus inoculation with a cold virus actually produced fewer colds than inoculation alone.

Women, we still find, are a little more susceptible to colds than men are. Age seems to make little difference. The incubation period of a cold is two to three days. The first symptom is usually a sore throat, fever is rare, and the predominant symptom of the full-blown cold is increased flow of nasal mucus. The mucus of the common cold is clear: when the secretion gets thick and yellow, it means that bacteria of various sorts have joined in and have made things much more unpleasant. The mixed catarrhal vaccines that, in Britain at least, are often advocated for preventing colds can only act against these "secondary invaders," not on the virus infection itself, and even so their value is debatable. The same applies to the use of antibiotics in colds, and many doctors think it is wiser not to use them indiscriminately for fear of encouraging the development and spread of antibiotic-resistant strains of bacteria. (As for antihistamine preparations, which had not yet become popular in 1951, we have found them almost worthless in ameliorating the symptoms of the common cold. I believe this has also been the experience of U. S. investigators.)

A Pandemonium of Viruses

We were well satisfied almost from the first that we were dealing with a virus, or, more likely, several strains of viruses. We knew that the virus was stable when it was kept frozen at 50 degrees below zero centigrade. We found that it passed with little loss in potency through membranes with an average pore size of 120 millimicrons (less than half the wavelength of violet light), and in one instance the virus survived passage through a filter with pores of only 60 millimicrons. So we guessed rather early that the cold virus was well under 60 millimicrons across, and therefore that it was decidedly smaller than the influenza virus, which is some 100 millimicrons in diameter. As we shall see, this early estimate of size has stood up remarkably well.

Ten years ago we had no more than a hint that the virus could survive in cultures of some human tissues. A tremendous stimulus to further work came with the advances in tissue-culture techniques reported in 1949 by John F.



FROZEN SAMPLES of cold virus keep indefinitely in dry-ice chest. The sample, held by D. A. J. Tyrrell, an associate of the author, may be nasal washings or a broth obtained from tissue culture.

TISSUE-CULTURE EXPERIMENT begins when nasal washing from volunteer is pipetted into test tube under ultraviolet light to prevent bacterial infection. With tissue added, tubes are incubated.

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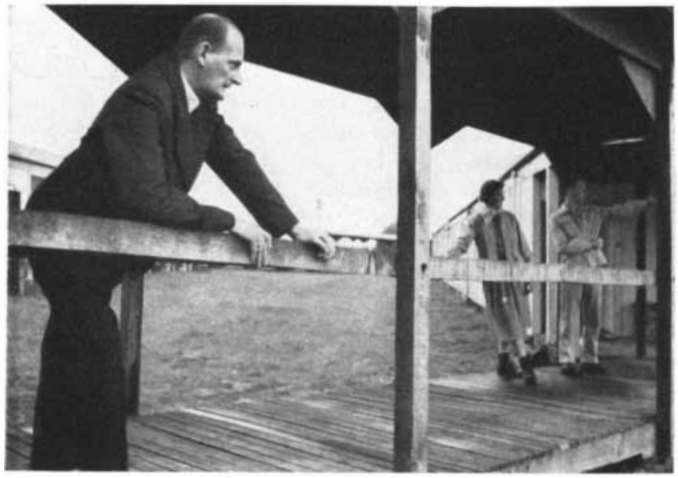


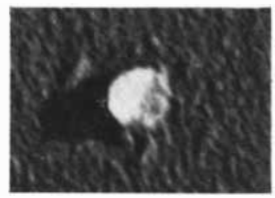
CONFINED TO ISOLATION for two weeks, volunteers are allowed to chat if they stay at least 30 feet apart. Exceptions are volunteers such as husband and wife in background, who share one of 12 flats.

CHESS BY TELEPHONE is evening recreation of one volunteer; his opponent is quartered nearby. Salisbury volunteers receive travel expenses and pocket money, regard the visit as a holiday.

Enders, Thomas H. Weller and Frederick C. Robbins of the Harvard Medical School, who subsequently received a Nobel prize for their contribution. These men worked out effective methods for growing poliomyelitis virus in animal as well as human tissue cultures. An important part of their achievement was the development of a simple and effective test for showing that poliomyelitis virus was indeed present in their cultures, and multiplying vigorously. The test was based on the so-called cytopathic effect, a pronounced degeneration of the tissue-culture cells, easily visible with a low-power microscope.

Largely as a result of Enders's work, virologists in all parts of the world have in the last decade discovered more than 300 new animal and human viruses. A great many of them can be classified into the six main families in the table at right. Members of three of the families—the myxoviruses, the adenoviruses and the enteroviruses—have been found capable of producing a variety of respiratory and coldlike symptoms. Each time a new respiratory virus was reported by one laboratory or another, we would wonder if this, at last, was the virus—or one of the viruses—of the common cold. After testing and examining practically all of the coldlike viruses found by others, we now think that none has all the proper qualifications, although they are important and insidious viruses in their own right. Here is a brief description of the three candidates that came closest to meeting the test.

The first of the candidates are the new myxoviruses. One old and well-known member of this family produces mumps. Most of the newer members, largely discovered since 1953, produce minor respiratory infections, chiefly in young children. Myxoviruses get their name from the fact that they have an affinity for mucins on the surface of red blood cells, and thus cause the cells to agglutinate, or clump. (The prefix "myxo" is derived from the Greek word for mucus.) The true influenza viruses, A, B and C, form a compact group (together with a near-relative that causes fowl plague); other myxoviruses, rather larger, stand a little apart from them. Three newly described



FAMILY	POX VIRUSES	HERPES VIRUSES
EXAMPLES	SMALLPOX	HERPES CHICKEN POX
SIZE (MILLIMICRONS)	200-350	100-175
NUCLEIC ACID COMPOSITION	DNA	DNA
RESISTANCE TO ETHER	MOSTLY +	0
EXCRETION IN FECES	0	0

HUMAN VIRUSES fall into six major families plus a tentative seventh: the new common-cold viruses (*far right*) recently isolated. Electron micrographs show viruses in correct relative size (magnification 75,000 diameters); no pictures of cold viruses yet exist.

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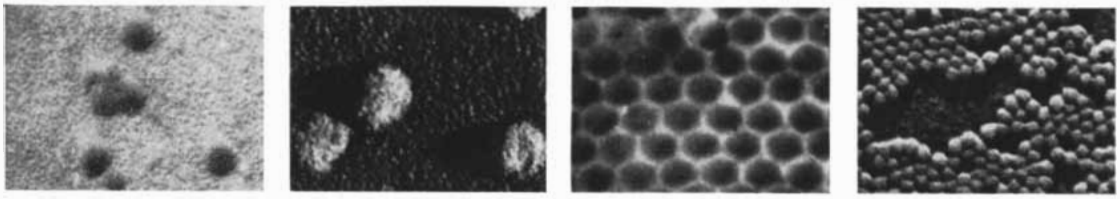
WAITING FOR COLD TO DEVELOP, or perhaps not to, husband and wife pursue hobbies: she sews; he tinkers with radio. Statistics show she is more likely to develop cold than her spouse.

WHEN FORTNIGHT ENDS, couple leaves Salisbury having contributed their bit to knowledge of common cold. In last 14 years Salisbury investigators have been host to over 6,600 volunteers.

members of the family have been named para-influenza 1, 2 and 3. Para-influenza 2 has mostly been associated with outbreaks of croup, or acute laryngotracheitis, in children. The other two types have been recovered by R. M. Chanock, Robert J. Huebner and their colleagues at the National Microbiological Institute in the U. S., from minor respiratory infections among children in an orphanage. Similar viruses have turned up in Britain, Denmark, France and Japan. We have given cultures of para-influenza 1 and 3 to volunteers at Salisbury and have produced some colds. They may well be considered, therefore, as among the causes of colds, but they usually cause somewhat atypical colds according to our criteria. For example, we have never been able to find such viruses in nasal washings taken from adults who have



ARBORVIRUSES	MYXOVIRUSES	ADENOVIRUSES	ENTEROVIRUSES	COMMON COLD VIRUSES
YELLOW FEVER	INFLUENZA MUMPS	PHARYNGITIS	POLIOMYELITIS COXSACKIE AND ECHO DISEASES	
25-80	90-120	70-80	20-30	40
RNA	RNA	DNA	RNA	?
0	0	+	+	+
0	MOSTLY 0	+ 0	+	0

Arborvirus is short for "arthropod-borne virus." (Common arthropod virus carriers: ticks, mosquitoes.) The larger viruses usually have cores of deoxyribonucleic acid (DNA); the smaller ones, of ribonucleic acid (RNA). Certain strains of myxo-, adeno- and enteroviruses are known to produce coldlike symptoms. Conceivably the common-cold viruses are related to enteroviruses.

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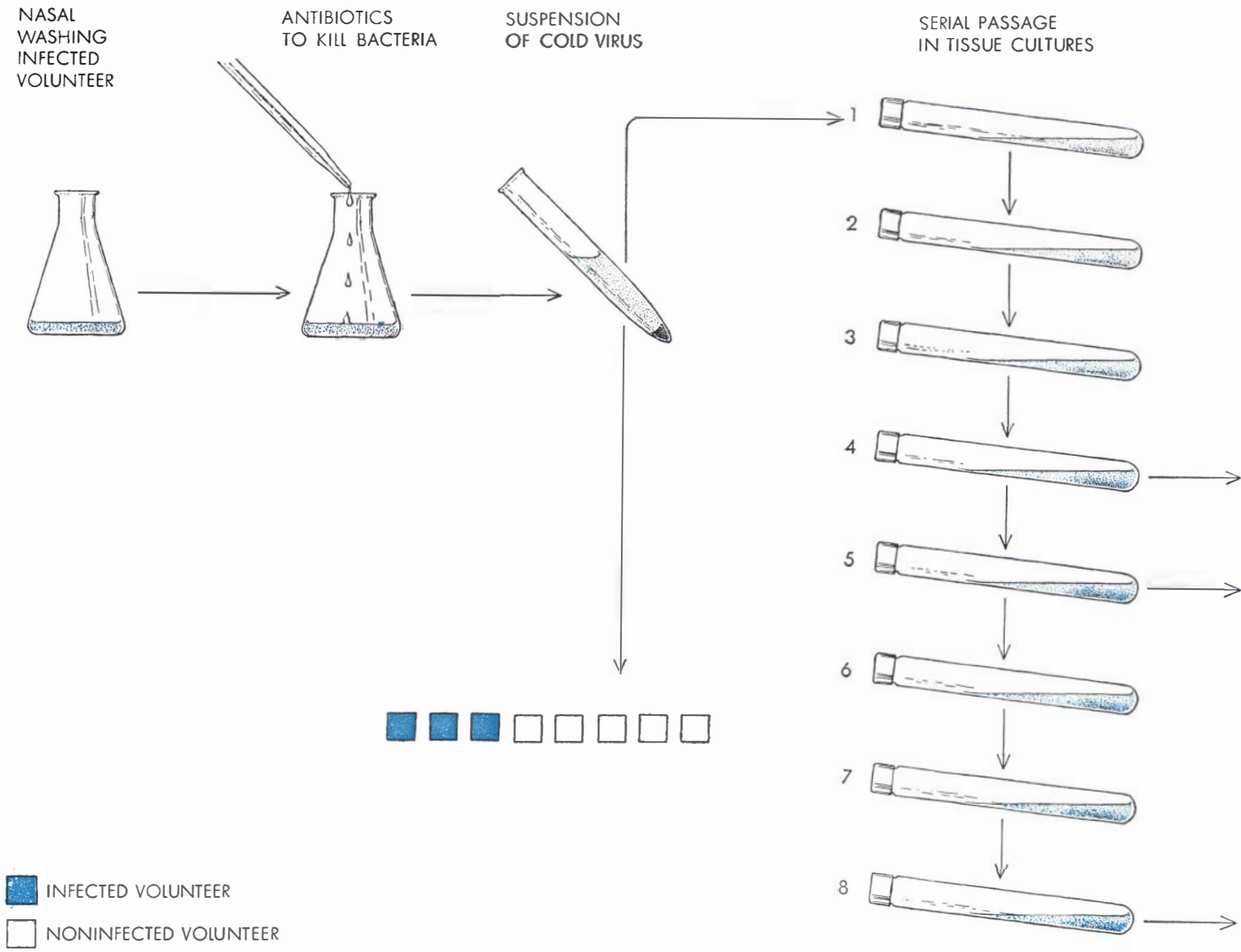

COLD-VIRUS ASSAY, which once could be done only with human volunteers, can now be carried out in tissue culture. By passing the virus through successive cultures, virologists hope to increase the purity and potency of a given strain. Interference test depends

what we regard as common colds. We have thus been reluctant to consider the para-influenza type of myxovirus as very important in causing colds.

The second of the candidates are the adenoviruses. ("Adeno" is a prefix referring to glands.) The viruses of this family commonly produce acute sore throat, or pharyngitis, as well as other respiratory ailments, and one strain causes conjunctivitis, or "pink eye." A virus causing liver damage in dogs (canine hepatitis) has lately been found to fall in the same family. The first adenoviruses were discovered independently in 1953 and 1954 by two groups of workers: by Wallace P. Rowe, Huebner and their colleagues at the National Microbiological Institute and by Maurice R. Hilleman and J. H. Werner at the Walter Reed Army Medical Center. The adenoviruses, like myxoviruses and enteroviruses, react with a blood substance called complement in a serological test known as complement-fixation. (Complement participates with antibodies in combatting infectious agents that enter the bloodstream.) The adenoviruses are all very similar in size and shape and in their behavior in tissue culture. We have found that volunteers infected by adenoviruses feel a good deal more uncomfortable than others who have been given common colds; the former usually develop very sore throats.

The last of the candidates, the enteroviruses, have perhaps the strongest credentials of all. They are the smallest of the known viruses, being only about a third to a quarter the size of the adeno- and myxoviruses, and by one recent count they embraced 57 varieties. They are a hardy lot, and as their name indicates, they flourish in the intestine. The most familiar and destructive enteroviruses are the three strains causing poliomyelitis (Types I, II and III). Another family, the Coxsackie group (first discovered in the feces of two children in the small town of Coxsackie, N.Y.), is responsible for a wide range of illnesses accompanied by fever, usually mild. Still other members of the enterovirus family bear the curious name of ECHO viruses: "enteric cytopathic human orphan" viruses. The word "orphan" simply indicates that these viruses were regarded as "orphans" when they were first encountered in the course of research on poliomyelitis. ECHO 9 has been associated with extensive epidemics in Europe and North America. The ECHO-9 disease ranges from mild to moderately severe; its symptoms include eruption of the skin and fever; at its worst, it may resemble meningo-encephalitis.

Some enteroviruses, it now seems, tend to attack the respiratory tract, and

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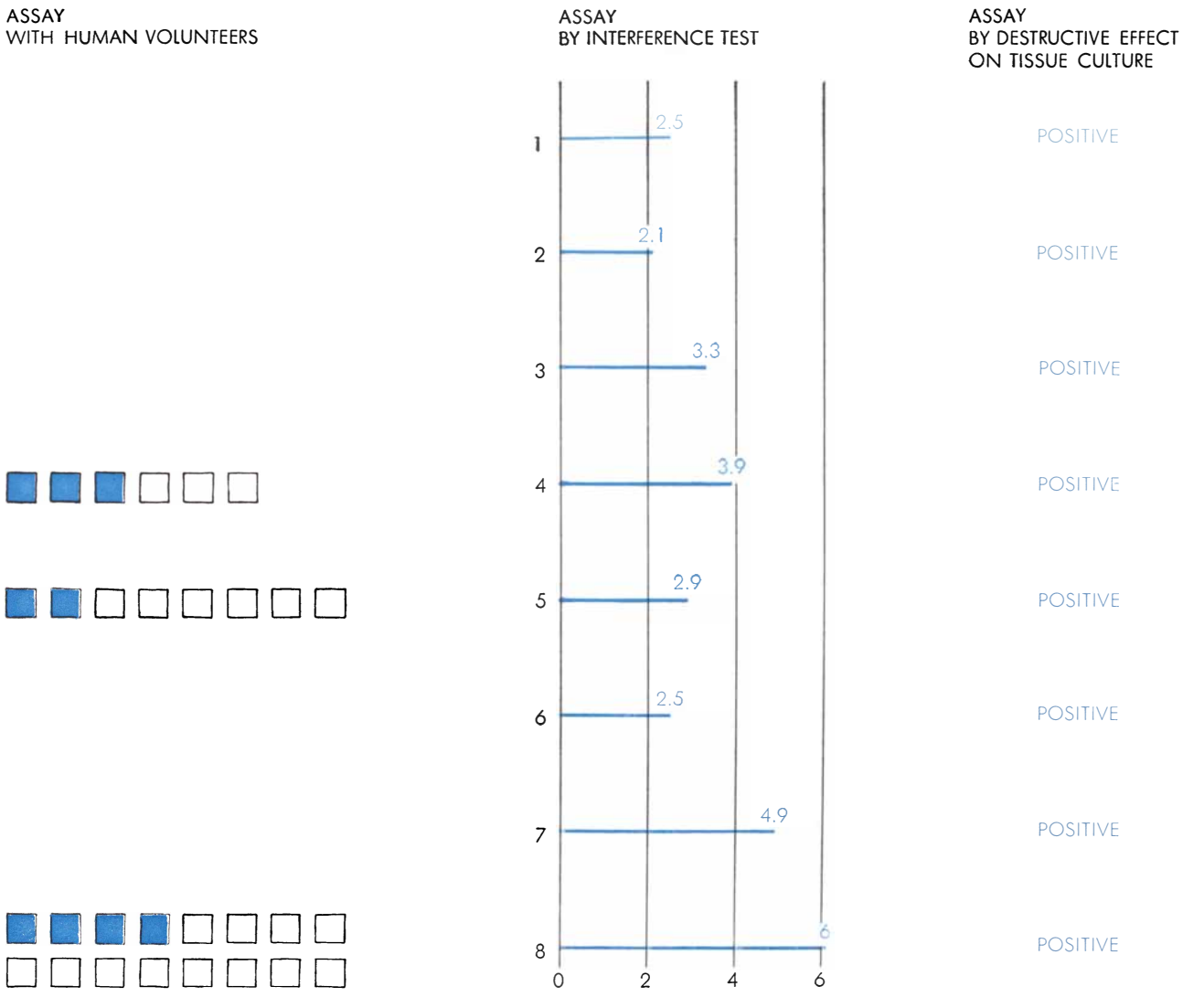

on ability of cold virus to interfere with growth of a second virus (a "challenge" virus) added to the culture (*see illustration on next two pages*). Newest, simplest assay method followed discovery that cold virus would cause tissue degeneration, or "cytopathic effect."

have been isolated from people with colds, though not by our group at Salisbury. Two of the ECHO types, 11 and 20, were tested in volunteers at Salisbury, and though some coldlike symptoms developed, they were usually accompanied by intestinal disturbances, and sometimes by fever. Another strain, consisting of two very similar viruses (called JH and 2060), has been reported by others to produce colds in a rather small proportion of volunteers, but we have not been able to get a clear-cut confirmation of this result in our own volunteers.

Another virus called Coe, isolated recently in California, has, however, regularly produced rather typical common colds in our volunteers, but in tissue culture its behavior marks it as a somewhat atypical member of the enterovirus family. Finally there is a virus, formerly called ECHO 10, which has been associated with colds in chimpanzees, but it is so atypical that it is no longer regarded as an enterovirus.

Thus it is fair to say that a number of enteroviruses, especially the atypical Coe virus, have some right to be called viruses of the common cold, but in our own investigations we have never been able to find them in naturally occurring colds in adults. We have therefore maintained that the *major* cause of the commonest colds has not been proved to lie among the myxo-, adeno- or *typical* enteroviruses.

The Virus that Disappeared

With this introduction to the problem, let us go back and retrace the last decade of research at the Common Cold Research Unit, which has led to our present convictions. It was a period of many frustrations and disappointments. The very fact that the cold virus takes hold only with difficulty in the mucous membranes of the human nose and throat—and then causes only a mild sort of inflammation—should have warned us that it would be uncommonly difficult to find the right sort of tissue and the proper physical and chemical conditions for growing the virus in glassware.

We are still mystified by one of our earliest experiences in culturing the cold virus. In 1952 a Brazilian physician, H. G. Pereira, came to Salisbury to take charge of our tissue-culture work. Human nasal tissues removed at operation proved quite useless for the purpose. Then, in 1953, we had better luck: we were able to grow a strain of cold virus, the D.C. strain (named from the initials of the subject who provided it), in human embryonic lung-tissue. (Human embryos have at times to be removed at about the fourth month of pregnancy,

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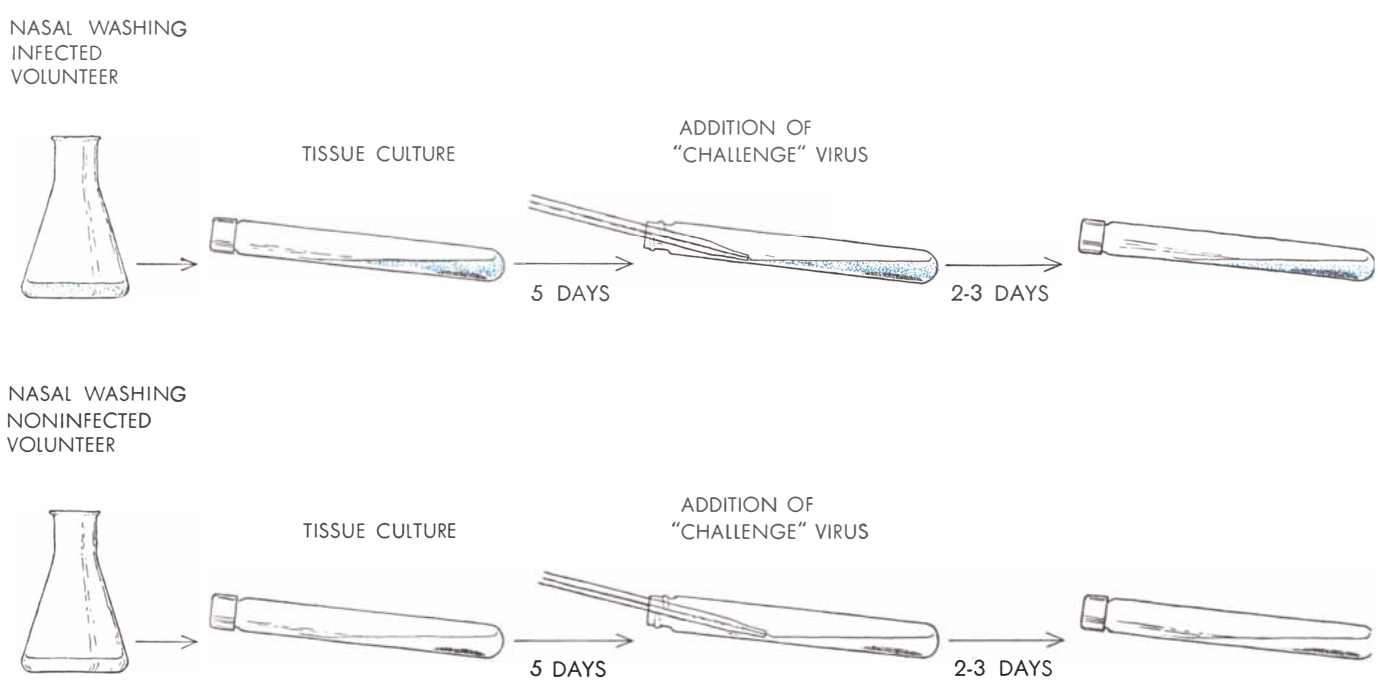

INTERFERENCE TEST replaces human volunteers in establishing whether cold virus is present in sample of nasal washing. If cold virus is present (*color*), it interferes with the growth of a challenge virus, selected for ability to agglutinate (clump) red blood cells.

usually when there is some threat to the mother's life or health.) When grown in human lung-tissue, the D.C. strain of cold virus maintained its activity through 10 cultures in series; that is, it would still produce colds in volunteers. We could not, however, detect its presence except in human hosts; no destructive effects on the cultures were evident, nor could it be revealed in any other way. We had therefore still not attained one of our crucial objectives: a simple laboratory test for virus. Still, we had made a little progress, and we reported this at the International Microbiological Congress in Rome in September, 1953. That apparently finished it! From then on we failed to produce any colds at all with cultures of that strain, even by going back to the original washings of the subject D.C.—washings that had been preserved in a dry-ice chamber.

Pereira and his colleagues spent much of the next three years in varying every bit of technique, every constituent of the culture medium, in hope of finding out why we had been able to grow this strain of virus in the early months of 1953 but not afterward. The matter remains as mysterious as ever.

How Lowering the Temperature Helped

Early in 1959 our tissue-culture prospects began to brighten once more. Two or three strains of virus cultivated in human embryonic kidney had produced reasonable numbers of colds—but only in primary cultures and the first subcultures. This was not enough to prove that multiplication had occurred, and until this was definitely happening, we could not expect to perceive any striking changes in our cultures. Assuming, nevertheless, that limited virus multiplication was occurring, D. A. J. Tyrrell, who in 1957 had succeeded Pereira in the Salisbury laboratory, applied all sorts of techniques—immunological, cytological and biochemical—in the hope of detecting some change, however slight, in the infected cultures.

After innumerable failures a ray of light appeared. Cultures previously treated with cold virus were found to have greatly diminished ability to support the growth of some other virus added later, particularly one of the parainfluenza viruses and one of the ECHO viruses. This was an example of the "interference phenomenon," an occurrence very familiar to virus workers: tissues of living animals, infected with one virus, often resist for a time infection with a second, perhaps quite unrelated, virus [*see illustration at top of these two pages*]. Here at last was an entering wedge, a way to detect the presence and activity of cold virus without having to test its infectivity in human volunteers.

Further advances now came quickly. Use of the interference test soon showed that virus grew much better at the relatively cool temperature of 91 degrees F. than at the customary 97 to 99 degrees, and that the culture medium could be improved. The addition of a little more glucose with a little more bovine albumin led to more consistent results, and eventually made it possible to produce colds with one strain of virus (from subject F. E. B.) that had been passed serially through up to eight cultures [*see illustration on preceding two pages*]. There was no longer any likelihood that

HEALTHY CELLS in this photomicrograph show appearance of tissue when there is no

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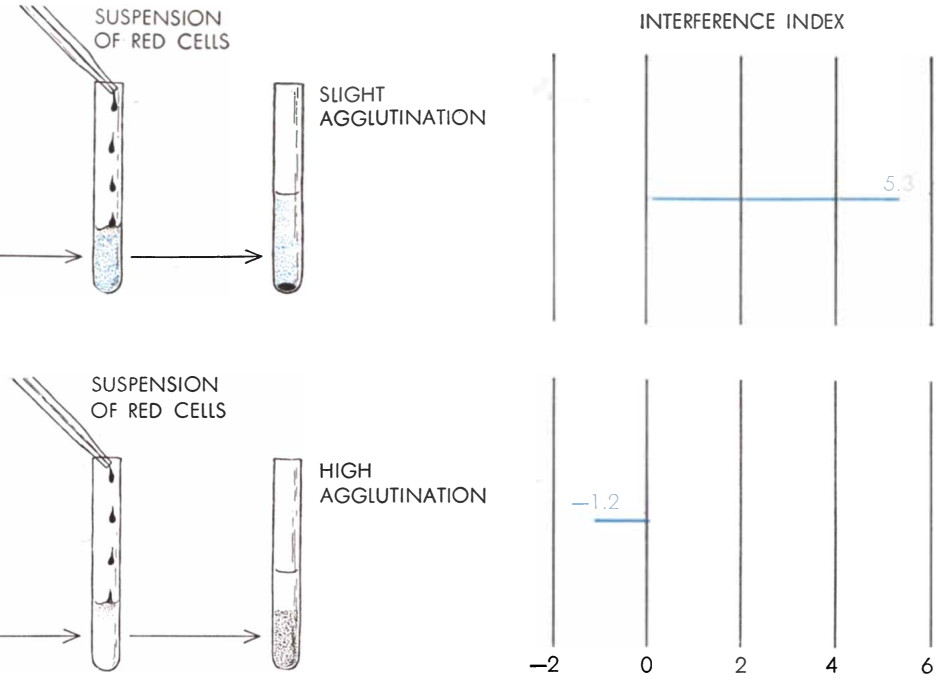


Thus if challenge virus fails to flourish, agglutination is slight, and this is reflected in high "interference index." Opposite is true when cold virus is absent from sample.

colds so produced were caused by a virus that had merely survived without multiplying.

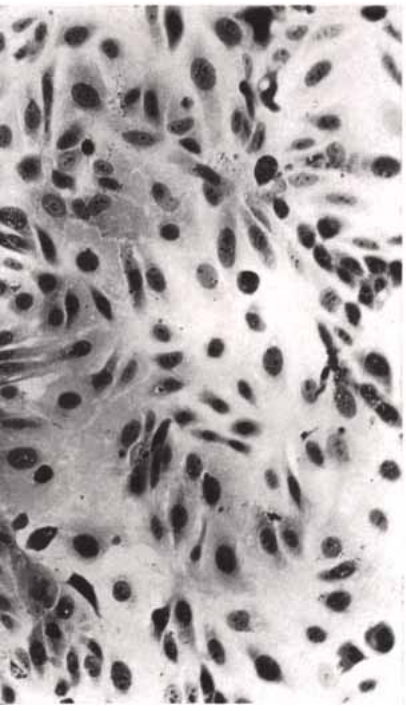
Then came a most fortunate "disaster." One of the constituents of the culture medium was a complex mixture of salts, vitamins and other ingredients, known as 199. One week in 1959 something went wrong with all our 199, and cells would not grow at all satisfactorily. Tyrrell feared that we were facing a repetition of Pereira's baffling experience. In desperation Tyrrell borrowed supplies of 199 from several other laboratories, and was soon able to get our cultures growing again. But along the way he and his co-workers also observed something new and quite exciting.

In one batch of cultures the tissue cells showed signs of degeneration. This was the cytopathic effect that Enders had used in assaying his virus cultures, but which we had never been able to reproduce with our cold viruses. There was little doubt that the cytopathic effect had been caused by the virus, because the control cultures containing snips of the same tissue had remained perfectly healthy [*see illustrations at bottom of these two pages*]. The particular batch of 199 medium that had been used in this experiment was carefully analyzed and was found to be slightly more acid than were the batches we normally used. Evidently the increased acidity, combined with the relatively low temperature of 91 degrees F., was exactly what the virus needed to flourish. It now appears that these are in fact the conditions that prevail at the surface of the nasal mucous membrane.

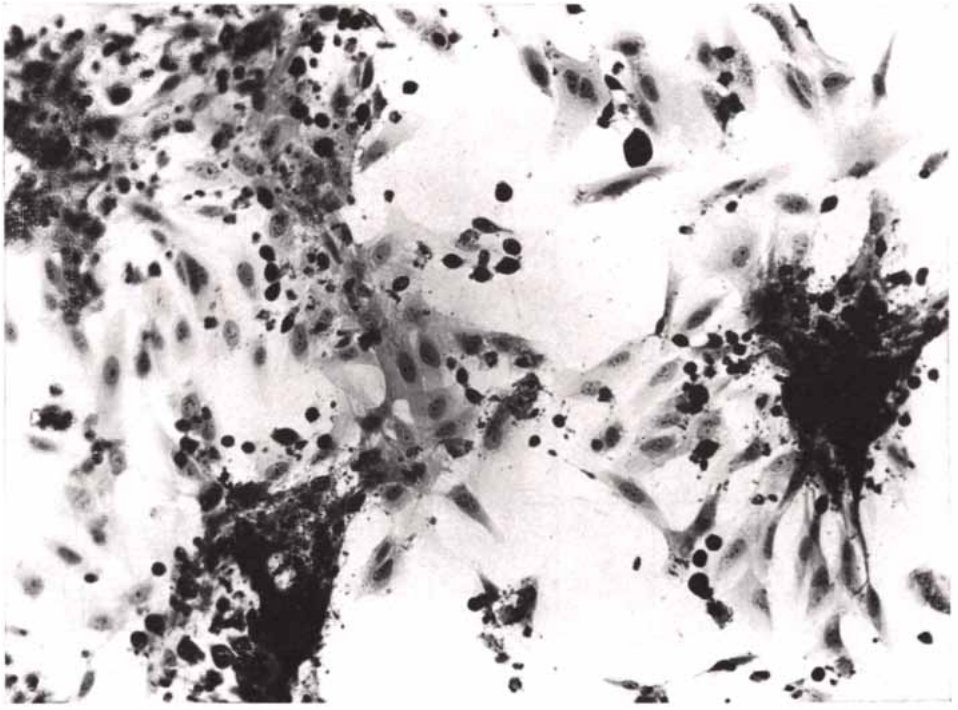
The New Salisbury Viruses

Now that a cytopathic effect—a destruction of tissue-culture cells—could be produced at will with our cold viruses, we had at last attained our first main objective, the simple laboratory test for cold viruses which had been sought for about 13 years. Many questions could now be posed.

Were our agents *the* important common-cold viruses or just a few more addi-



virus infection. Culture shown here consists of human-embryo tissue.



DEGENERATE CELLS appear in human-embryo tissue culture a few days after inoculation with cold virus. This is the "cytopathic effect." Magnification of each picture is 150 diameters.

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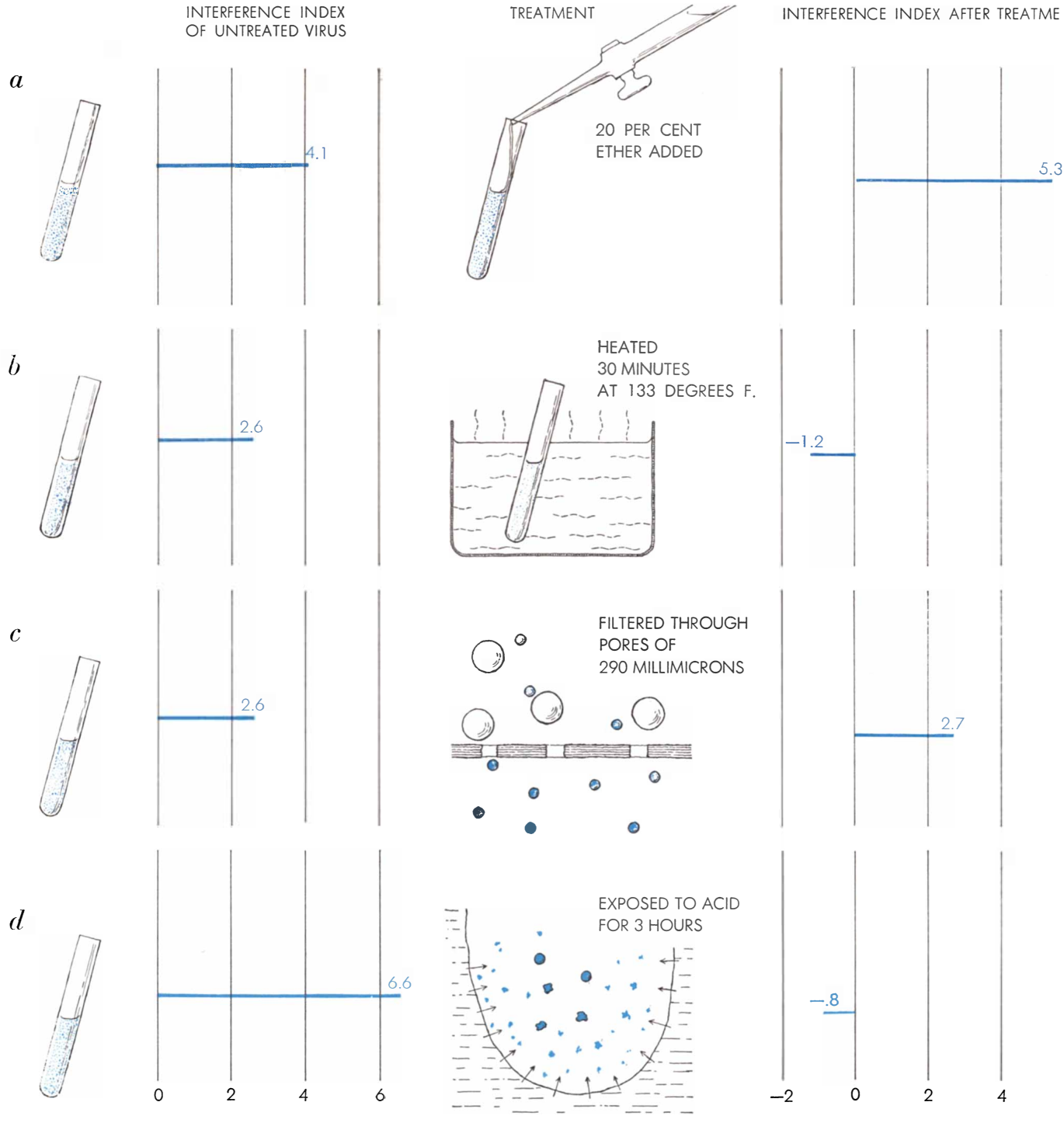
tions to the list of miscellaneous viruses that can at times cause colds? We still do not know the answer, but we have isolated some 20 strains from typical colds in adults. There have, however, been a few washings from colds which have produced colds in volunteers, and yet have yielded no virus in tissue culture. Perhaps the test in the human guinea pig is more sensitive than the culture technique in its present state of development.

Will these cold viruses grow only in embryonic human tissues? If so, progress must needs be slow, for this is not a material that is readily available. There have fortunately been a few strains isolated that are able to grow in monkey-kidney cultures. With these strains it has been possible to make relatively fast progress. Most of our strains, however, prefer the human-embryo tissue. One hopes that this tiresome state of affairs will soon pass, and that we shall learn



PROPERTIES OF COLD VIRUS are adduced by measuring interference index before and after various treatments. Acid-test rules out possible presence of protein called interferon, a natural cell-defense substance, which might have mimicked cold virus in producing a high interference index. Unlike cold virus, interferon would not have been destroyed by acid treatment. Subsequent tests

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how to grow such strains more easily. We recall that for more than a year influenza virus could be grown only in live ferrets, but once we got a start, it became surprisingly easy to propagate it in mice, and later in fertile eggs and in tissue culture.

Are all these viruses immunologically

CONCLUSIONS

ETHER RESISTANT
(HENCE NOT MYXOVIRUS)

DESTROYED BY HEAT
(CHARACTERISTIC OF VIRUSES)

FILTERABLE
(HENCE < 290 MILLIMICRONS)

DESTROYED BY ACID
(HENCE NOT INTERFERON)

using tissue-culture degeneration as assay method show cold virus passes a filter with pore size of 70 millimicrons, but not smaller.

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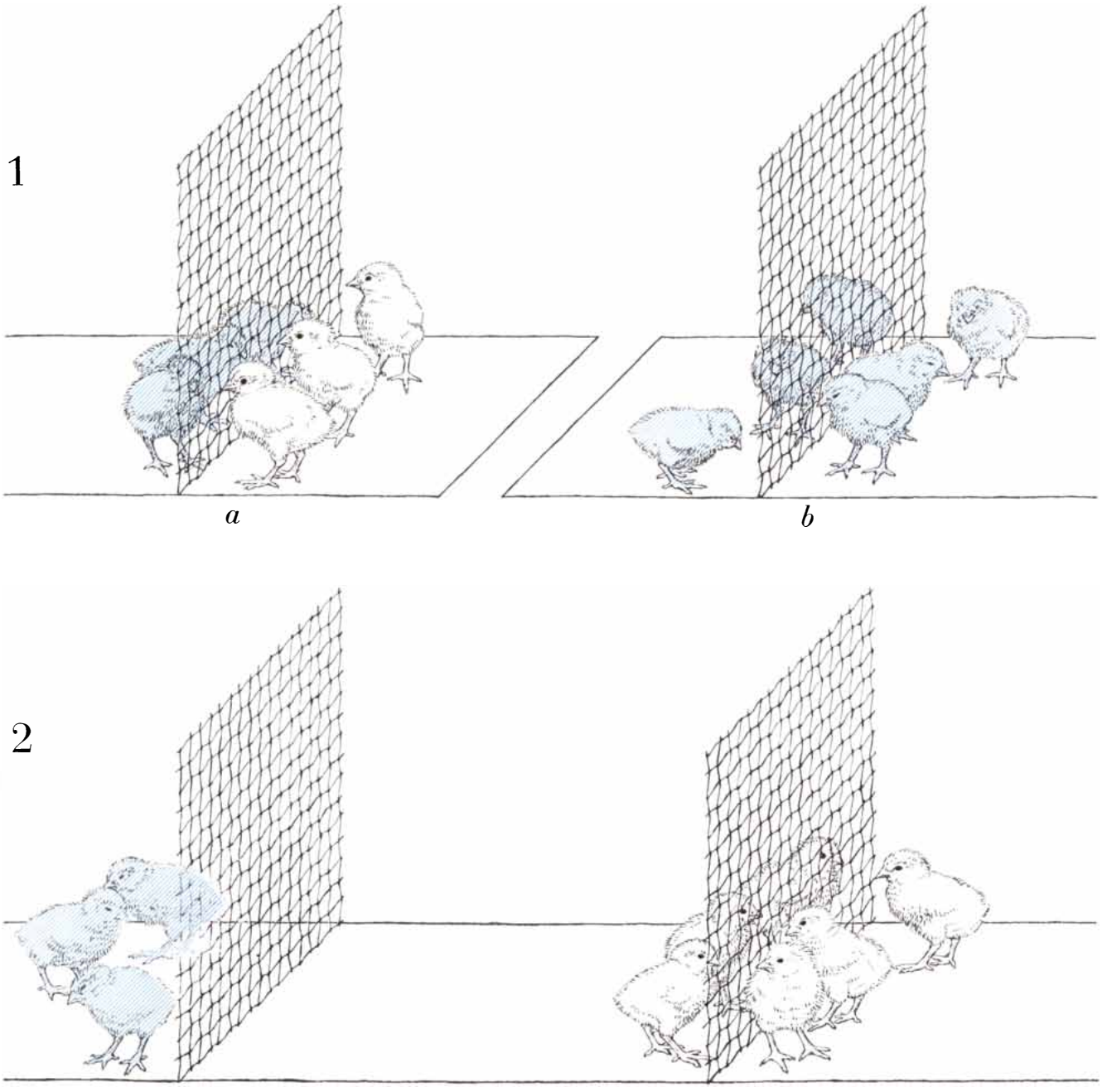

RESISTANCE OF CHICKS to a potent myxovirus, that of Newcastle disease, is influenced by social behavior. When healthy chicks have only sick chicks (*color*) for company (*1a*), they crowd against wire screen and are infected by virus evidently carried on large airborne droplets. The healthy chicks quickly fall ill (*1b*). Given a choice of social partners (2), the healthy chicks in center pen avoid the sick ones and stay well. Tiny airborne droplets that travel substantial distances are evidently poor carriers of viruses.

alike, that is, will an antibody that neutralizes one be active against the others? Such a finding would be very welcome, as it would raise the possibility of making a vaccine with one strain able to protect against all the others. Unfortunately it does not seem to be coming out that way. The few strains that will grow in monkey-tissue cultures seem, in neutralization tests with antibodies, to be different from those that grow only in human tissues; and even among the few "monkey" strains there are at least two serological races. Similarly, "human only" viruses are of several types, a fact to which we will return shortly in discussing immunity to colds.

What are the properties of the viruses that we know grow in tissue culture, and how do these properties compare with those worked out in earlier years for the active agents in cold washings? So far as we can tell, the cultivated viruses are like those in the washings. They resist the action of 20 per cent ether; they pass a filter with pores of an average diameter of 70 millimicrons, but not a filter with smaller pores (indicating that the true diameter of the virus is about 40 millimicrons); they are inactivated by heating to 133 degrees F. for 30 minutes, or by acidification at pH 2. We have not yet been able to find them in the feces of people with colds, and the viruses do not agglutinate any red cells yet tested. We feel sure that when we obtain high

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enough concentrations of the Salisbury viruses, they will react with the blood substance called complement (as do the myxo-, adeno-, and enteroviruses), but we have not been able to demonstrate this as yet.

All of this provides several lines of evidence that distinguish our cold viruses from the known myxoviruses, adenoviruses and enteroviruses. The myxoviruses are two to three times larger, do not survive ether treatment and readily agglutinate red cells. The adenoviruses are also rather larger than our viruses. Finally, the typical enteroviruses seem too small, most of them agglutinate red cells, and of course they turn up regularly in feces.

We still have some reservations about the size of 40 millimicrons we have assigned to the cold virus. Since concentration will often affect the filtration readings, the filtration experiments need to be repeated with fluids containing the virus in higher concentration. There is, moreover, at least one test in which our cold viruses display properties very like those of the enteroviruses, and that is in the character of their cytopathic effect on tissue cultures. We thus seem to be left with two alternatives. Either the cold viruses may ultimately prove to be members of the enterovirus family, or, as we gain further knowledge, we may wish to place the cold viruses in a family of their own.

The Prospects for a Vaccine

It has been our hope from the beginning that we might one day find a way to protect people from the common cold. Where do we stand? One obvious route to protection would be through a vaccine. For this to be an attractive route, we would have to show first of all that people who recover from colds have some degree of immunity to subsequent infection. Our evidence suggests that antibodies have not yet appeared in the bloodstream when a cold is at its height. We have, however, some slight evidence for the presence of antibodies in serum obtained during the convalescent stage, that is, about 12 days after the worst symptoms have passed [*see illustration on next page*].

The results in other laboratories have been conflicting. Harry F. Dowling and George G. Jackson of the University of Illinois College of Medicine recently reported observations on five strains of colds obtained in different years. They inoculated volunteers with the nasal washings of one or another of the five

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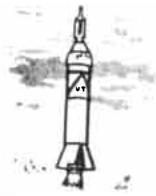

It is anticipated that in the period through 1970, motor cases will have to withstand substantial internal pressures and high temperatures within ever lower weight allowances and with increasing reliability. Thrust vectoring systems and nozzles also will operate under more extreme environmental conditions with flame temperatures as high as 7300°F and greater tendencies toward erosion. Promising materials for this type of operation appear to be an alloy of high melting point metal carbides, which can withstand temperatures of more than 7000°F.

Another most important area for investigation is that of design and fabrication techniques which will allow the use of very large, multi-million pound-second solid boosters as well as long duration high mass ratio solid motors for space applications. As the available energy of solid propellants becomes greater, the design and fabrication problems of such motors become critical with lightweight joints and minimum insulation assuming great importance relative to effective overall motor performance.

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strains. On "challenge" (reinoculation) some months later, the volunteers proved resistant to the same strain, but were susceptible to any of the other four. This result conflicts with an earlier one reported by John H. Dingle and his colleagues at the Western Reserve University School of Medicine, who found no immunity to the same strain of virus when the challenge followed as little as three weeks later.

Our own results are in harmony with those of Dowling and Jackson in that we find evidence for a number of distinct immunological strains; it would be a formidable task to produce a vaccine effective against all of them. Further complication is suggested by the evidence from the study of the influenza virus that changes are taking place in the make-up of the virus from year to year, so that people immune to last year's influenza virus may be unable to stand up to the next one to come along. Very possibly similar changes take place in our cold viruses, the strains being far more numerous than with influenza and perhaps less stable, so that the whole picture is more complex. The net result may be that the common cold will always be with us. If so, specific vaccines cannot have a promising future.

Interferon: A Powerful New Substance

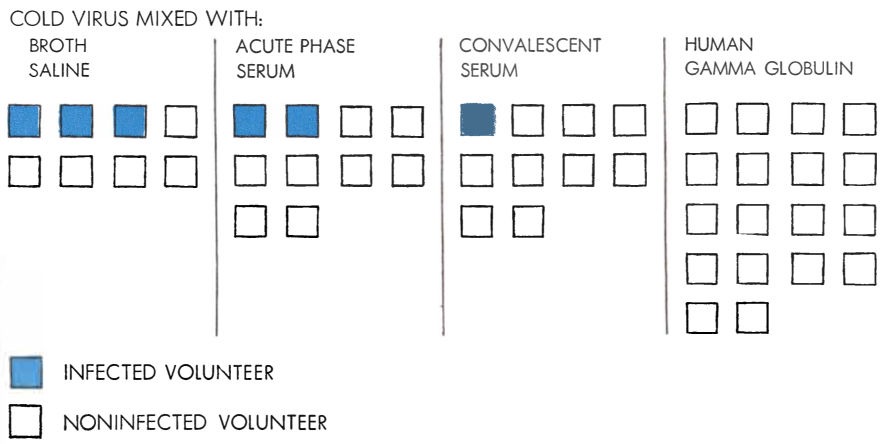
On the other hand, it is conceivable that we might find ways to enhance a nonspecific immunity to colds in general. It is well known that colds of particular ferocity may sweep through an isolated community when its isolation has been broken by a visitor from the outside world. Antarctic explorers who return to civilization after a long absence also seem especially vulnerable to colds. One cannot but feel that frequent exposure to cold viruses of varying kinds keeps up our resistance to at least a certain level, so that we manage to escape the viruses' worst onslaught; and this immunity may not be highly specific. Here a part may be played by the substance interferon, recently discovered by Alick Isaacs and his associates in my laboratory at Mill Hill in London.

Interferon is a protein, probably a cell product present normally in minute amounts, but turned out in quantity as a result of stimulation by viruses. It seems to have the power to stop virus multiplication. In the ordinary course of virus infection the cell may produce enough interferon after a day or two to stop the virus infection in its tracks, even before specific antibodies have had time to develop and play their part. Interferon produced by the action of one virus is active against a whole range of other viruses, including unrelated ones.

Interferon can be extracted from virus-infected cultures or tissues, concentrated, to some extent purified and titrated by seeing how effective it is in stopping the growth of a suitable test-virus in tissue culture. It also works in the living animal, although this is harder to demonstrate. Whether it will prove practically useful as a form of therapy is an intriguing question in which many people are becoming interested.

The Chicks that Remained Well

Experiments reported in the early years of our work at Salisbury led us to conclude that rather close contact was



IMMUNITY TO COLDS is evidently conferred by gamma globulin, a blood fraction rich in antibodies, but not by blood serum from a volunteer with cold in acute phase. Convalescent-phase serum is hardly better in producing immunity. Broth saline is used as control.

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How to get accurate data on a small recorder

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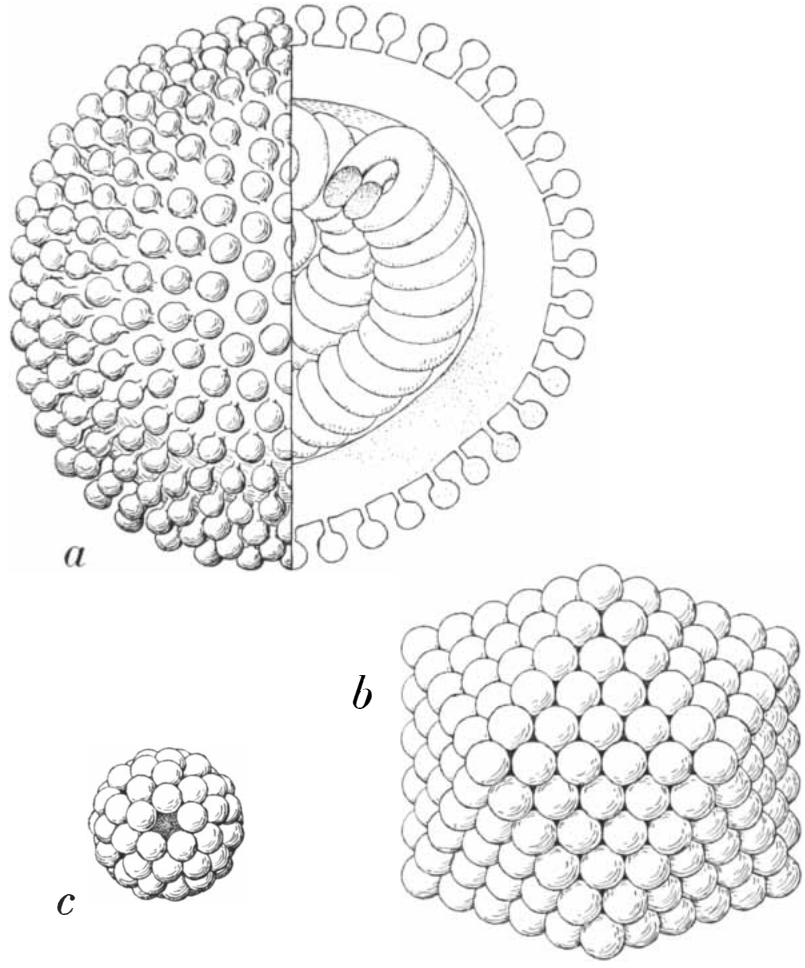

THREE VIRUSES that sometimes cause coldlike ailments are myxovirus (*a*), adenovirus (*b*) and enterovirus (*c*), here enlarged about 800,000 times. Last two, based on studies by H. G. Pereira, have shells of protein units (*balls*) surrounding core of nucleic acid. Myxovirus seems to consist of double coils of nucleoprotein inside a fatty, knobby membrane.

needed to allow cold infections to spread; the tinier "droplet nuclei" floating in the air for long periods seemed less important. I have lately carried out experiments with Anthony C. Allison on a model system that may throw light on the matter. Day-old chicks were infected with a particularly virulent strain of Newcastle disease (a myxovirus) and were found to spread infection quite readily to other chicks in the same cage. When the infected and "contact" chicks were separated by barriers of various kinds, it became clear that infection was transmitted only when the contacts were able to inhale coarse particles; the infection would not spread over a distance of more than a few inches.

Moreover, the social behavior of the birds was an important factor. When separated from infected birds by a wire barrier, normal chicks would pick up infection, but if another group of normal chicks was placed on the other side of them [*see illustration on page 98*], they lost interest in the sick birds and collected against the partition separating them from the other normals. As a result the healthy chicks, thus sandwiched between the sick and the well, failed to pick up infection.

The chick experiment gives us food for thought concerning the spread of colds. Why, for instance, are colds so much more prevalent in winter than in summer? Infection may well be airborne and carried by coarse rather than fine particles. The effect of cold weather may be an indirect one, acting through changes in the social behavior of people.

Thus there are still things to discover about the behavior of the common-cold virus. We cannot hope to control it without understanding as much as possible about it. After 14 years of hard work, those in the Salisbury laboratory feel they are now firmly on the right road.

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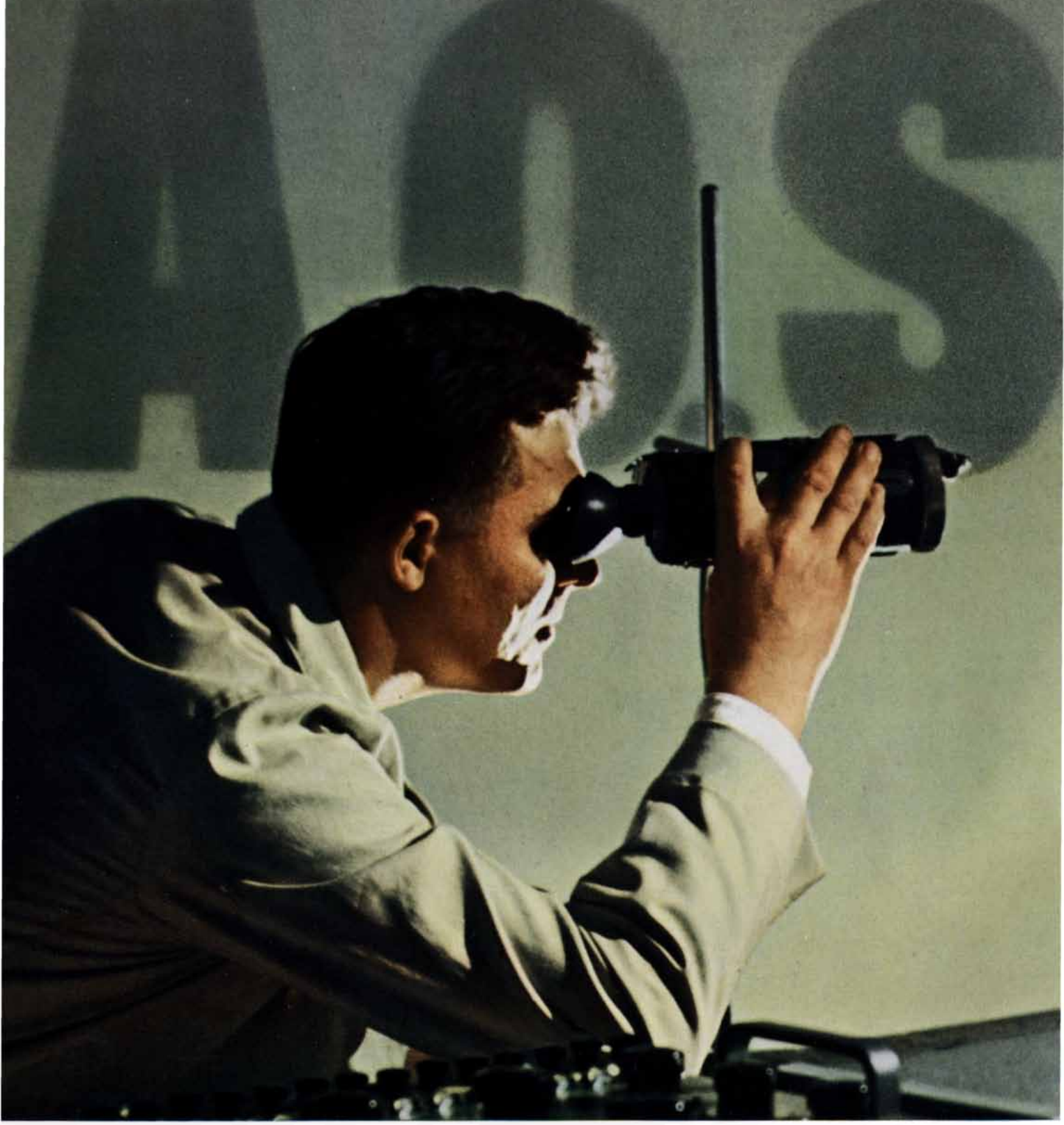

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NONUNIFORM ELECTRIC FIELDS

They act not only on charged particles but also on uncharged ones. Their long-neglected effects are now being investigated in the laboratory and may soon find applications in technology

by Herbert A. Pohl

When a piece of iron jumps toward a magnet, it is responding to a nonuniform field. In approaching the pole faces it travels in a direction of increasing magnetic strength. Placed in a uniform field, no matter how strong, it would not move at all.

While this latter fact may not be generally appreciated, magnetic action is familiar to everyone. Much less familiar is an analogous effect of nonuniform electric fields. They too can set matter in motion. Of course any electric field exerts a force on charged bodies. The significant point about nonuniform fields is that they act on uncharged bodies as well. The phenomenon is well known to physicists, but they have not paid much attention to it. Our group in the Plastics Laboratory at Princeton University is now finding a number of interesting and useful ways to exploit it.

The behavior of a nonuniform field can best be understood by considering first the simpler case of a uniform field, such as the one between a pair of flat, parallel metal plates that are oppositely charged [*see top illustration on next page*]. A charged body freely suspended between the plates—for example, in a nonconducting liquid—will move parallel to the field, toward the plate bearing the opposite charge. A neutral body, on the other hand, is not impelled in either direction; it stays put.

Even though it appears to ignore the field, however, the neutral body is not completely unaffected. It acquires, in effect, a negative charge on the side facing the positive electrode and a positive charge on the side facing the negative electrode. The reason for this polarization, as it is called, is that the atoms composing the neutral body are made up of separate electric charges—positive nuclei and negative electrons. Under the influence of the outside field the electrons and nuclei are pulled in opposite directions, so that the center of negative charge no longer coincides with the center of positive charge. The amount of separation produced by a given electric force (the "polarizability") varies widely for different materials, but all are influenced to some degree.

The net effect is an excess of positive charge on one half of the body and an equal excess of negative charge on the other. Therefore the two sides of the gross body are also pulled in opposite directions by the field. Since the charges are equal and the field is the same on both sides, the opposing forces exactly cancel.

If, however, the field is made stronger on one side than on the other, the forces are no longer in balance, and the body is pulled in the direction of the stronger field. The effect can be demonstrated with electrodes in the form of a pair of concentric cylinders [*see bottom illustration on next page*]. In running from the larger to the smaller electrode the lines of electric force converge. This means that the field grows stronger from the outside in. An uncharged body suspended in the space between is seen to move toward the inner electrode.

Note that it travels the same way no matter which electrode is positive and which is negative! The polarity of the field makes no difference; the only thing that matters is how its strength varies. Thus an alternating voltage applied to the electrodes produces the same result as a direct voltage. This is because the polarization induced in the body switches with the field. Each half is always charged oppositely to the electrode it faces, and the pull of the inner electrode is always greater than that of the outer one.

The motion of electrically polarized matter in nonuniform fields is called dielectrophoresis. Compared to the movement of charged particles (electrophoresis), it is a mild effect, which is why it has been so long neglected. Fields with a strength of a few thousand volts per centimeter are usually required to set up an appreciable force. On the other hand, the force has some useful characteristics. In particular it depends very strongly on polarizability. As has been mentioned, the polarizability (otherwise known as the dielectric constant) of different materials varies over a wide range. This suggests that mixtures could be efficiently separated by nonuniform electric fields.

Shortly before the war the writer made some theoretical calculations on the magnitude of dielectrophoretic forces. The effect on individual molecules turned out to be inconsequential. However, the calculations also showed that the force should increase directly with the volume of the particles. (For one thing, the larger the particle, the greater the range over which it extends in the nonuniform field, and therefore the greater the difference in field strength between its polarized ends.) It seemed as if larger particles such as mineral grains could be sorted by dielectrophoresis.

When the idea was first tried out, World War II had already begun. Working at the Naval Research Laboratory, some colleagues and I succeeded in pull-

PUMP with no moving parts appears in photograph at left. Spray of carbon tetrachloride is thrown upward by a nonuniform electric field. Field is set up by electrodes that are connected to Van de Graaff generator. Part of the generator appears at bottom center.

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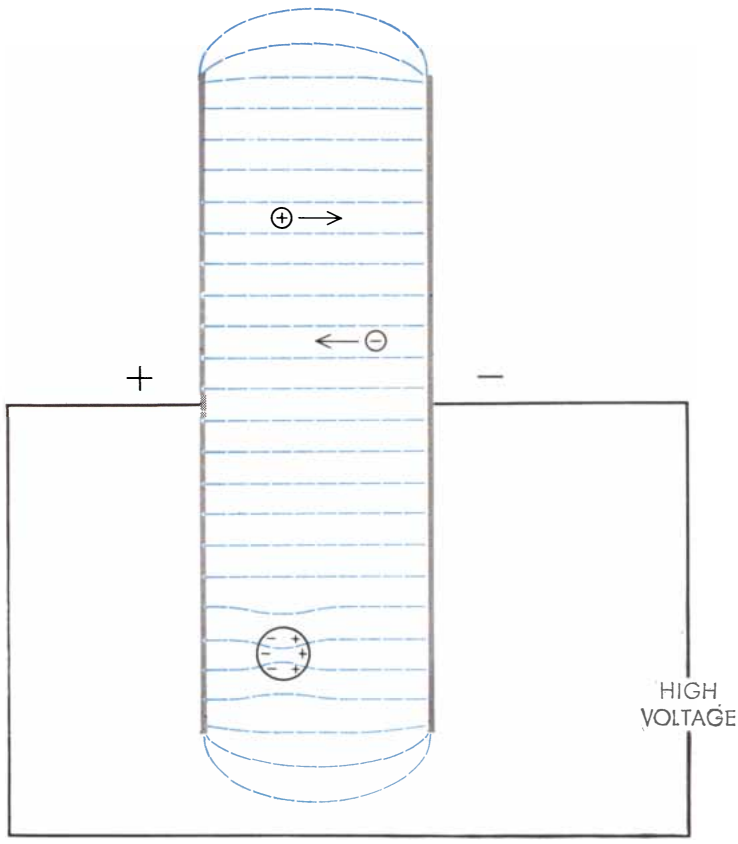
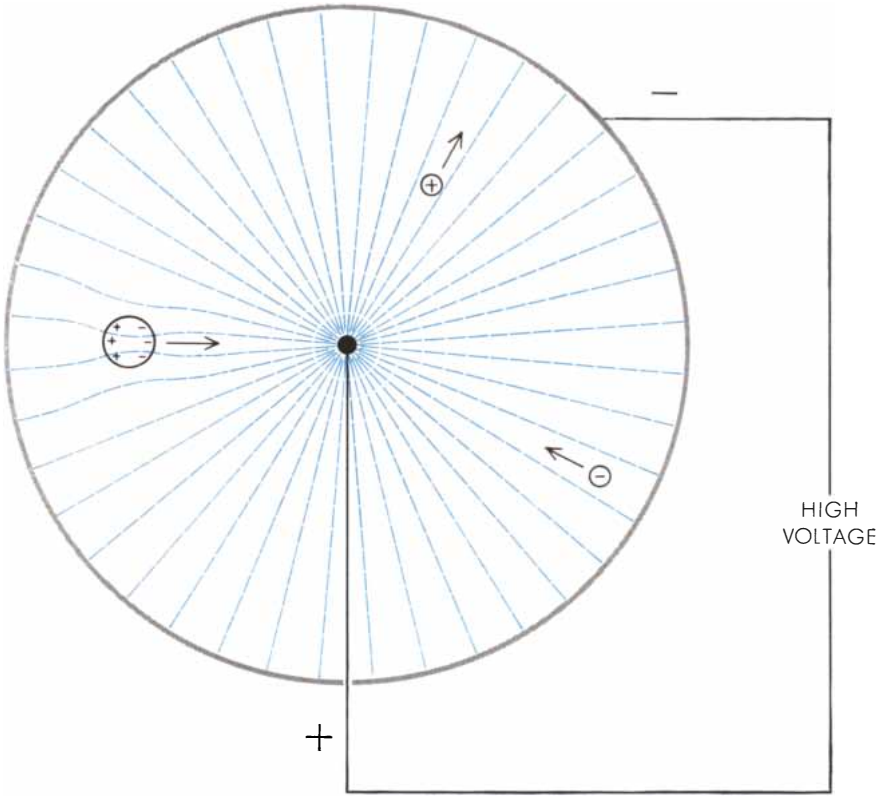


UNIFORM ELECTRIC FIELD exists between parallel metal plates that are oppositely charged. Charged particles (*top center*) suspended in field move toward plate bearing opposite charge. Neutral particle (*bottom center*) does not move, but becomes polarized.



NONUNIFORM ELECTRIC FIELD exists between oppositely charged cylindrical electrodes (*black dot and gray circle*). Lines of electric force (*color*) converge toward electrode at center, indicating that field grows stronger from outside in. Nonuniform field acts on both neutral and charged particles. Neutral particles move to strongest part of field.

ing apart different types of suspended particle with cylindrical electrodes. But more pressing matters prevented our following up the work at that time.

Later we learned that the experiment had also been performed in Germany, with rather poor results, and that our own success had been due to a fortunate accident. Simple theory indicated that the separation would be most efficient if the inner electrode were made as thin as possible, producing a very highly nonuniform field. Accordingly the Germans had used an extremely fine wire for their inner electrode. Because of wartime shortages, we could not get our hands on really fine wire, so we used ordinary wire instead. The reason for the superiority of this apparently crude apparatus has emerged in more recent studies at Princeton by James P. Schwar and the author.

When the central electrode is extremely thin, the field immediately around it reaches very high values. The molecules of the suspending liquid can no longer stand the electrical stress; they break down, becoming charged. In effect the concentrated charge on the wire is diffused over a much larger region in a sort of incipient corona discharge. Particles entering the region acquire a charge themselves and are then pushed away from the electrode rather than attracted toward it. A similar breakdown occurs if the applied voltage is too high. Thus there is a critical minimum for the diameter of the electrode and a critical maximum for the voltage.

A properly designed electrophoretic cell has proved quite effective in precipitating fine powders from liquid suspensions. Generally speaking, the solid particles have a higher dielectric constant than the liquid, so they tend to clump around the central wire. In the few cases where the order of polarizability is reversed, the powder collects near the outer cylinder and the wire is surrounded by pure liquid.

Experience has disclosed a number of factors that influence the efficiency of operation. The electrical conductivity of the liquid must be low; that is, it must contain few ions, or charged molecules. Otherwise the powder particles pick up charges from the ions and may be repelled by the collecting electrode. For the same reason it is preferable to insulate the central wire. Particles clustering around a bare conductor tend to acquire a charge from it, and again are repelled. Since dielectrophoresis is a relatively mild effect, it works fastest in liquids of rather low viscosity. The force is general-

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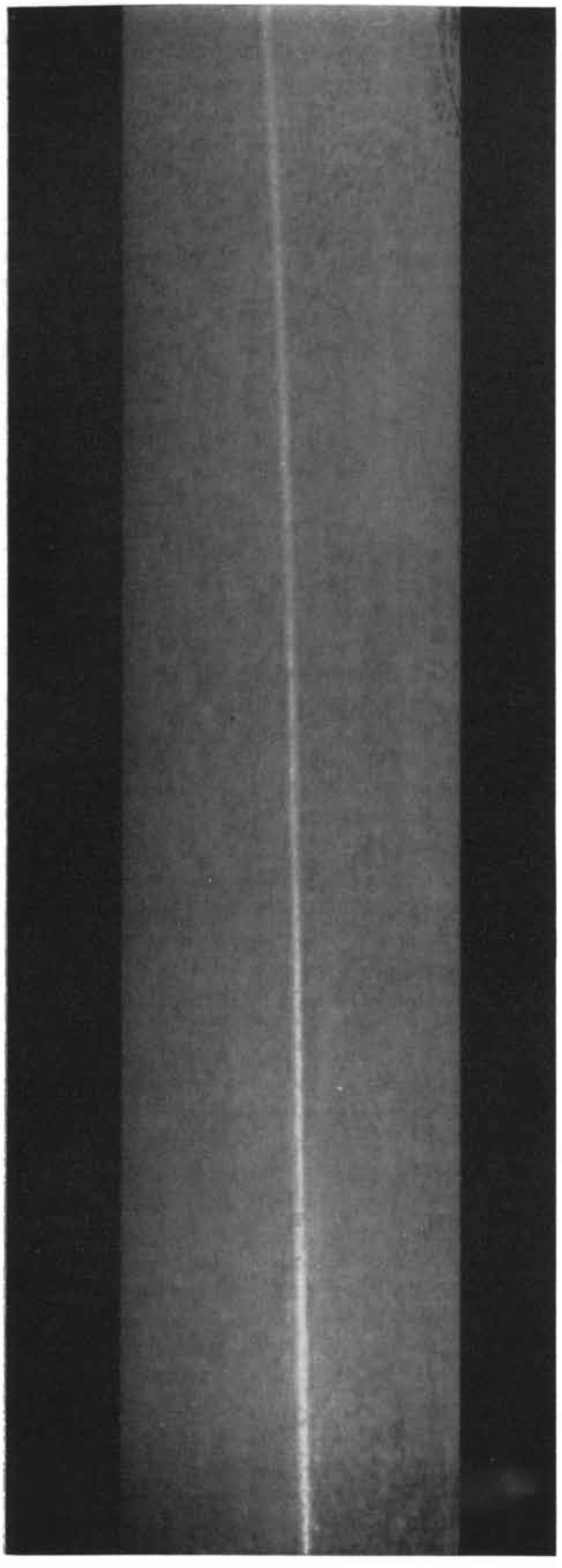

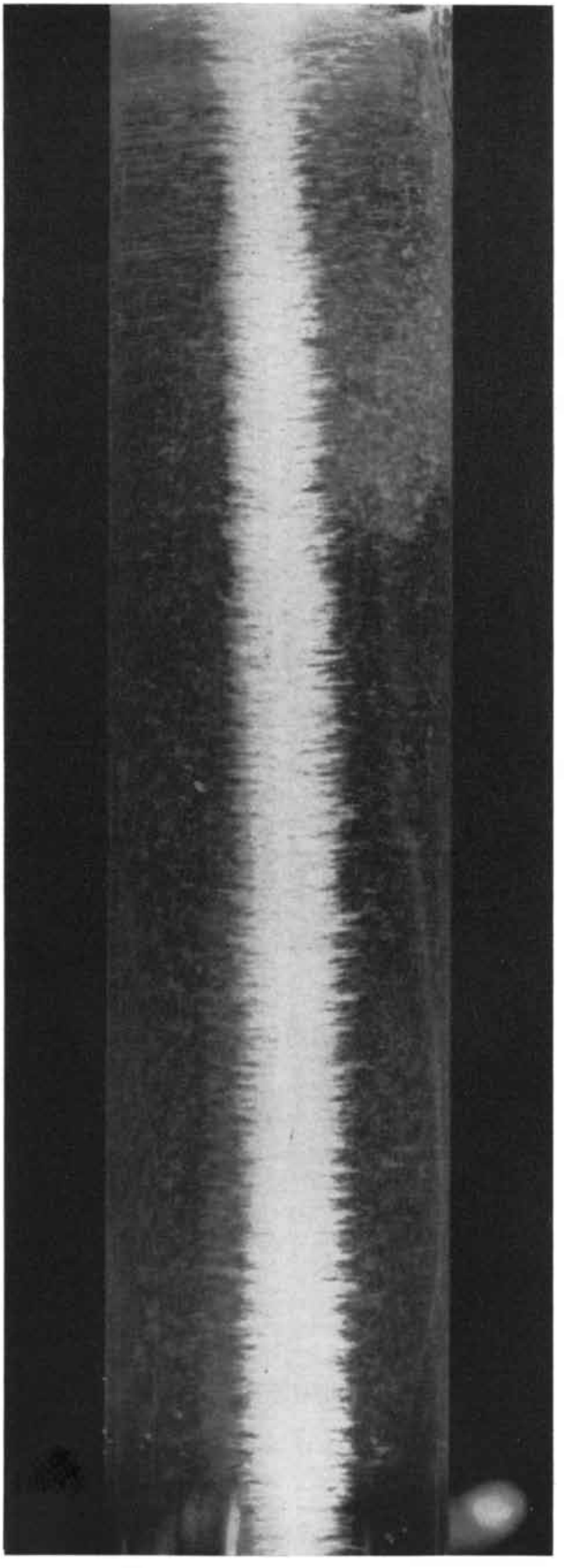

DIELECTROPHORETIC CELL precipitates fine powders from liquid suspension. Cell consists of container and two cylindrical electrodes. The inner electrode is the thin wire in the midde of the container. When field is turned off, particles of ammonium chloride are evenly distributed in nonconducting liquid (*left*); when the field is turned on, particles migrate to wire (*right*).

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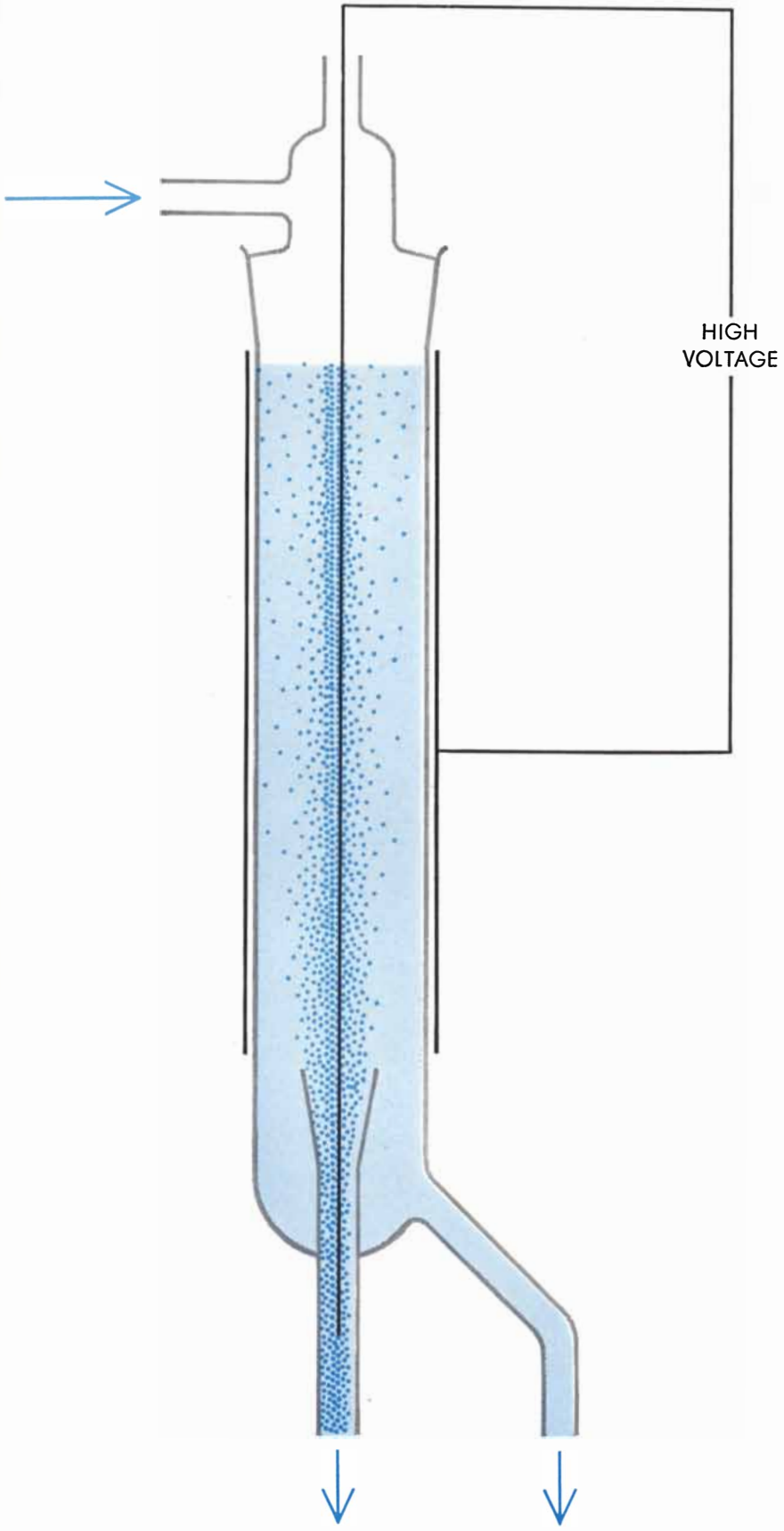

PRECIPITATOR is a dielectrophoretic cell that operates continuously. It consists of a vertical cylinder and wire with two exit ports at bottom. Suspension of powder in liquid enters at top; when 60-cycle voltage is turned on, powder shimmies down wire and out exit port.

ly great enough to pull particles through a syrupy material only at low speed. Benzene, toluene, kerosene, gasoline and certain chlorinated hydrocarbons make quite satisfactory media. They are not very viscous, and have lower dielectric constants than most powders.

Capitalizing on the fact that alternating voltage is just as effective as direct, we have designed a precipitator that operates continuously [*see illustration at left*]. It consists of a vertical cylinder and wire with two exit ports at the bottom, one around the central electrode and the other near the cylinder wall. When 60-cycle voltage is applied to the device, the collected powder shimmies down the wire and out through the central port. The explanation of this downward motion is simple enough: every time the voltage goes to zero (twice in each cycle, or 120 times per second) the coagulated powder slips down a bit under the force of gravity.

Cells of this type have already found commercial application in the purification of certain high polymers. The material emerging from the reaction vessel is contaminated with traces of catalyst particles and other impurities. They are stripped away from the dissolved polymer by dielectrophoresis.

The cylindrical arrangement, however, has a serious drawback. The force it exerts drops off sharply with increasing distance from the central axis. Particles near the axis are pulled much more strongly than those farther away. The difficulty is particularly troublesome when we are trying to separate a mixture of two solid powders rather than merely precipitating one solid material from a liquid suspension. Moreover, the cylindrical shape is not well adapted to handling dry powder.

Recently our laboratory has found a solution to these problems in a device that we call the isomotive cell (because it exerts an equal force on all particles regardless of their position). In a design developed by C. E. Plymale and the writer, a flat-bottomed trough is sandwiched between a pair of charged plates. The lower electrode is also flat, and the upper one curves so that the distance between the two plates increases from one side of the trough to the other [*see bottom illustration on page 116*]. With the proper curvature the field across the width of the trough varies in such a way as to make the dielectrophoretic force the same at every point.

When the trough is tilted about 60 degrees and a powder mixture is shaken

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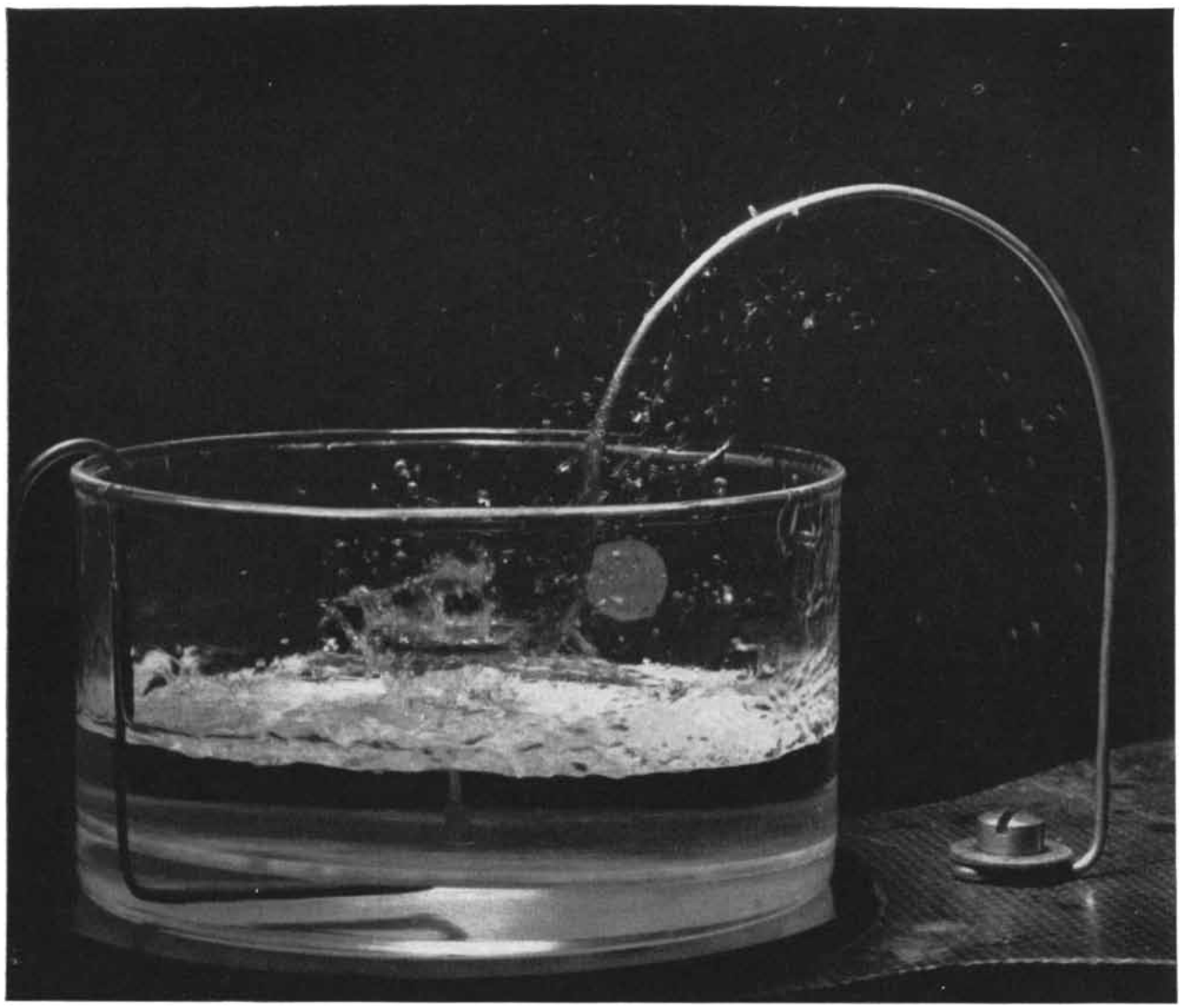

DROPS HANG IN AIR after being pulled from surface of liquid by strong nonuniform electric field. Loop at center is an electrode; the other electrode is visible at far left. Drops of liquid sometimes go into a spiraling orbit around the lead-in wire at right.

into the top end, the particles are subjected to a sideways force as they slide down. Assuming that the materials in the mixture have different dielectric constants, one set of particles is pulled more strongly than the other. To separate them, the apparatus is also tipped sideways a few degrees so that the direction of increasing field strength is slightly uphill. Gravity thus works against the nonuniform field. Now the voltage is adjusted until the electric force is great enough to pull the more polarizable material to the higher side, leaving the other particles to slither down the lower side. At the bottom of the trough the separated powders emerge through different chutes.

Since the arrangement is quite sensitive, it does not require extremely high voltages, which are difficult and dangerous to handle. Usually 300 to 1,500 volts is enough. Even these voltages, however, tend to cause sparking between the electrodes. Sparks are prevented by immersing the apparatus in nonconducting liquid. Here the liquid serves primarily as an insulator, and only incidentally as a medium to carry the particles.

Another problem is the tendency of particles to stack up along the direction of the field, forming minute bridges from the trough to the upper electrode. The stacks contain particles of both kinds, so the process interferes with separation. In some of our earlier designs, where the field ran almost horizontally, "bridging" proved a serious obstacle. With a nearly vertical field, however, the force of gravity is usually sufficient to counteract the effect. In some mixtures bridging does prevent a sharp separation on a single pass through the cell, and one, two or more cycles of retreatment are required.

Using an isomotive cell, we have recovered industrial diamonds that were knocked from a cutting wheel and mixed with the dust of the ceramic material being cut. Among the numerous other mixtures we have been able to separate are: metals and sand, silicon carbide and calcium fluoride (the densities of this pair differ by only one third of 1 per cent), polyvinyl chloride and rutile, zircon and rutile, sodium dichromate and titanium dioxide.

A single isomotive cell is well adapted to analytical work in the laboratory. Only about as big as your middle finger, it accommodates from a tenth of a gram to a gram of material per minute. To process larger amounts a number of cells could be combined in parallel. The ap-

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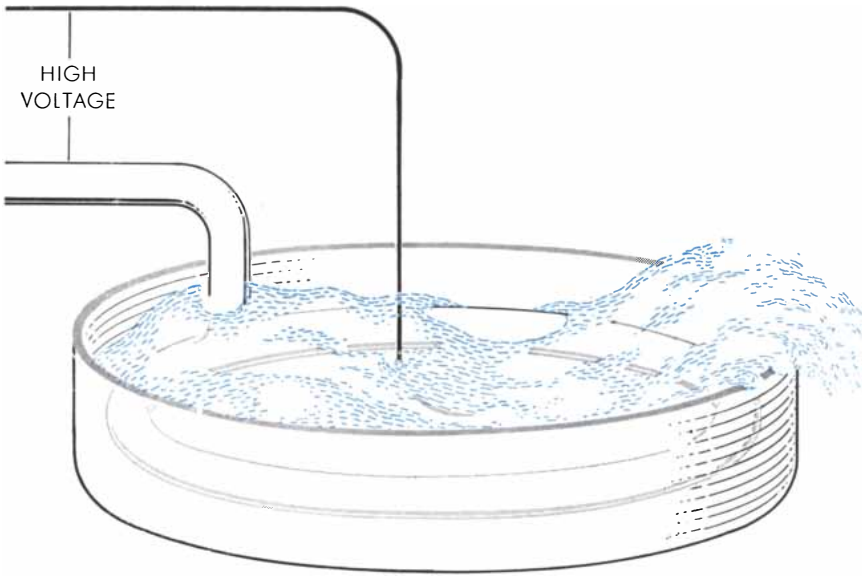
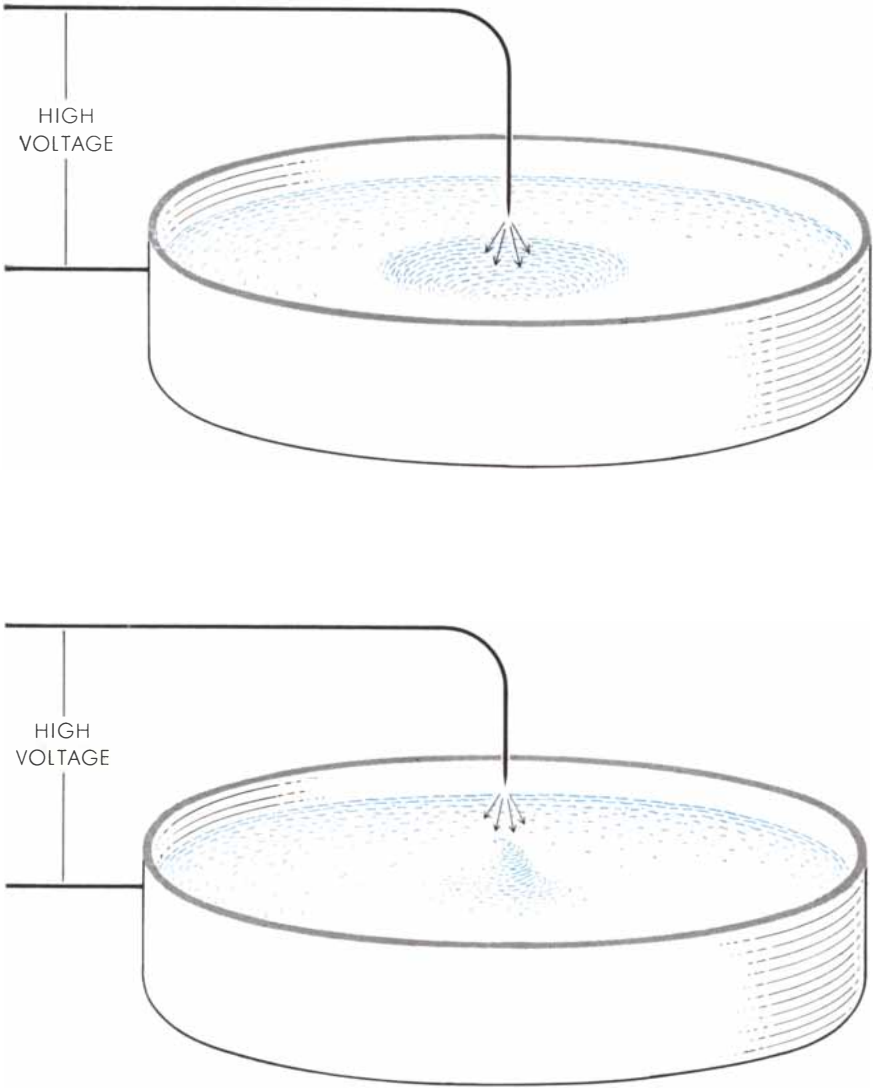


LIQUID IS STIRRED by nonuniform electric field. Field is set up by two cylindrical electrodes: the thin wire at center and the thick, ring-shaped conductor beneath surface of liquid. In addition to stirring liquid, nonuniform field also "pumps" it from dish (*right*).



"ELECTRIC WIND" set up by nonuniform field blows away the liquid beneath the center electrode (*top*). Wind consists of air molecules attracted to the wire. Raising or lowering electrode cancels the effect of the wind, causing the liquid to be attracted to wire (*bottom*).

paratus consumes no more than a millionth of a watt in its electric field, although additional power is required for shaking the powder mixture. Operating at moderate voltages and minute current, the cell is safe to handle. We expect it will soon be used, both as a laboratory and as a production tool, in metallurgy and mineralogy as well as in pharmaceutical and other chemical industries.

Although the separation of mixtures will probably constitute the major application for nonuniform electric fields, such fields also give rise to a number of other phenomena—all spectacular and some potentially useful. Most of these arise out of the same breakdown process that we are careful to avoid in the precipitation and separation techniques.

As was mentioned earlier, when the voltage on a pair of cylindrical electrodes exceeds the critical value, powder is repelled by the central wire. Now the cell stirs the mixture instead of precipitating it. The action takes place through a combination of dielectrophoresis, which pulls the uncharged material into the high-field region, and electrophoresis, which takes over after the particles have acquired a charge.

The effect is accentuated by terminating the small electrode in a sharp point, creating a field of very high intensity. In such a field not only suspended particles but also molecules of liquids (and gases) respond energetically. Some of the tricks we have performed with super-strong fields in our laboratory are illustrated in the drawings and photographs that appear on these pages.

In one arrangement the point of the wire is surrounded by a looped electrode, and both are immersed in a dish of organic liquid. With 10,000 volts or so applied to the electrodes, the liquid springs into violent motion and even leaps out of the dish. A similar stirring arrangement has been used in the analysis of gases.

When the wire is pointed at the surface from above, it sometimes appears to repel the liquid below it. What actually happens is that air molecules, pulled to the wire by the nonuniform field, acquire a charge and are then strongly repelled. This "electric wind" literally blows away the liquid underneath. Raising or lowering the point can cancel the effect of the wind, and the wire then attracts the liquid. By varying the arrangement of the electrodes, the liquid can be made to move quietly or vigorously at the same applied voltage.

Still more striking effects are obtained when the wire passes upward through a liquid or powder. If the loop electrode

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Miniaturization Report No. 2

Micro-Master® 105/35mm as a dynamic in-plant tool

Today, the miniaturization system which does no more than microfilm engineering drawings has won but half the battle. The other half consists of rendering versatile service as a drafting and reproduction tool. Only in this way does the equipment become a money-maker instead of a capital expense. MICRO-MASTER 105/35mm by K&E is the system that saves money, speeds production, greatly expands the capabilities of an engineering reproduction department. True, MICRO-MASTER *does* reduce drawings to miniature negatives and project them back to full or half size. But it goes beyond this to perform a host of other functions – some of which we will outline here.

REDUCED SIZE PRINTS. The growing use of "half-size" working prints is saving industrial reproduction departments a fortune in material costs. This is how the system can work: reduce originals on either 105mm or 35mm negatives. Make blow-backs on transparent material to one-half the linear scale of the original – which actually is one-fourth the area. Diazo or blueprint paper consumption will be reduced by *three-fourths!* Of course, the photo-image must be impeccable, never losing a detail. Projection prints must be pin-point sharp, clearly readable. The burden is on the camera-projector, and only MICRO-MASTER can deliver the quality and range needed by most companies. A 35mm unit alone won't handle larger drawings because of the great reduction necessary to put them on a negative less than two inches square. Only 105/35mm used in conjunction deliver a complete half-size program.

SCISSOR DRAFTING. Drafting departments are often requested to retain elements of a drawing, and add new details. Or they may be asked to combine portions of different originals. Rather than re-trace or start from scratch, modern practice is to scissor out the needed elements, place them on a new title sheet, make additions, and photograph the resulting composite. MICRO-MASTER serves as a vital tool for this time-saving, cost-saving technique. Second-originals are made from 105mm or 35mm negatives. The elements are cut out and pasted down with transparent tape. New details are entered, and the entire drawing filmed and projected for a final, ink-like original – comparable in every way to the most meticulous hand work. Even if the elements abstracted are to different scales, they can be brought to a common scale easily and quickly with the MICRO-MASTER Camera-Projector. A drawing that would take 20-30 hours of a draftsman's time can be produced photographically in less than an hour!

OTHER DRAFTING TECHNIQUES. In printed circuitry, layouts done several times up can be reduced and printed on stable-based materials to microscopic accuracy. Plant layout work can be done with no drafting at all – simply by placing various pre-printed components on a master sheet. Tone-coded prints in which old work is distinguished from new by a light half-tone screen, can be produced in the projection stage.

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WATER	78
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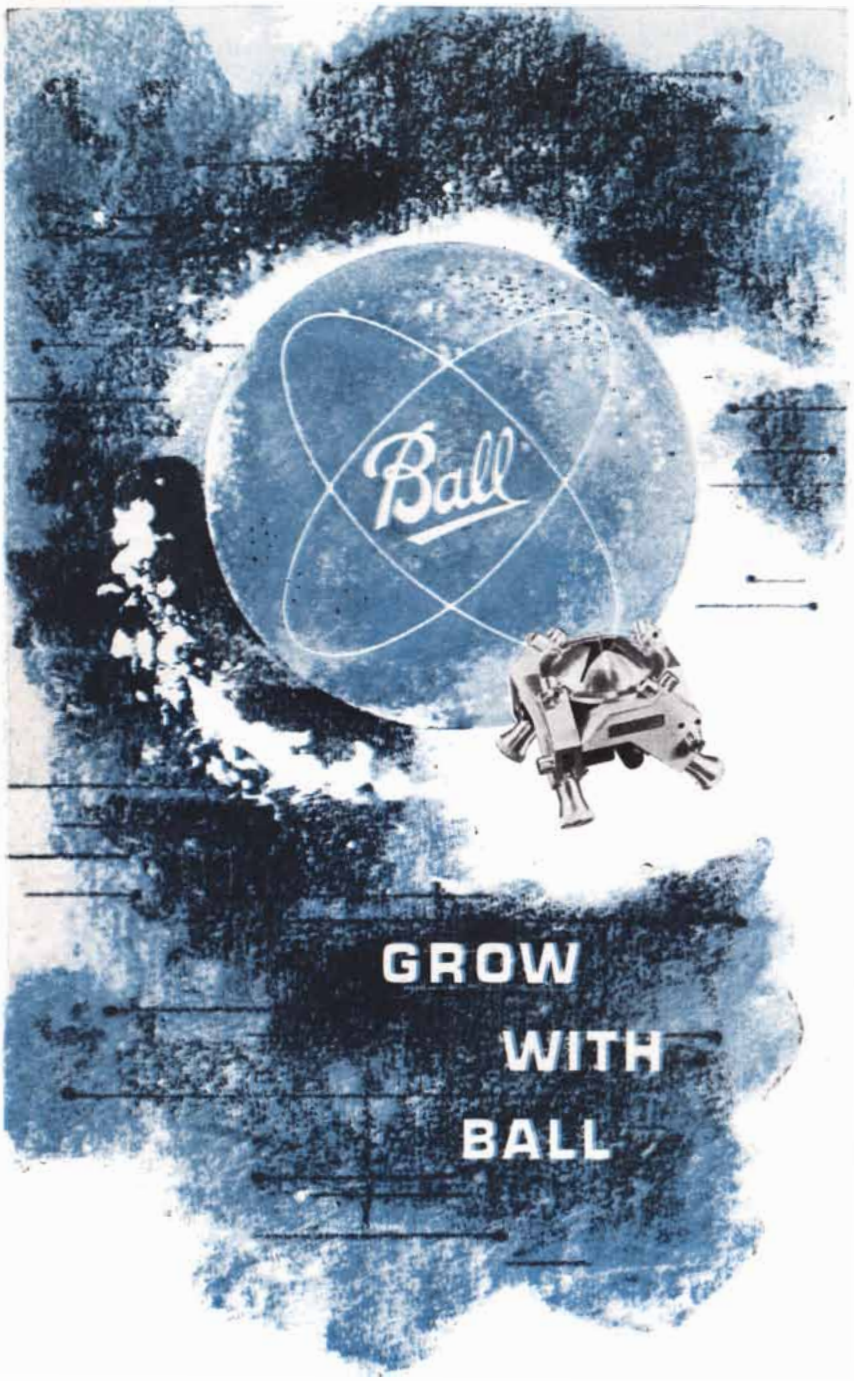

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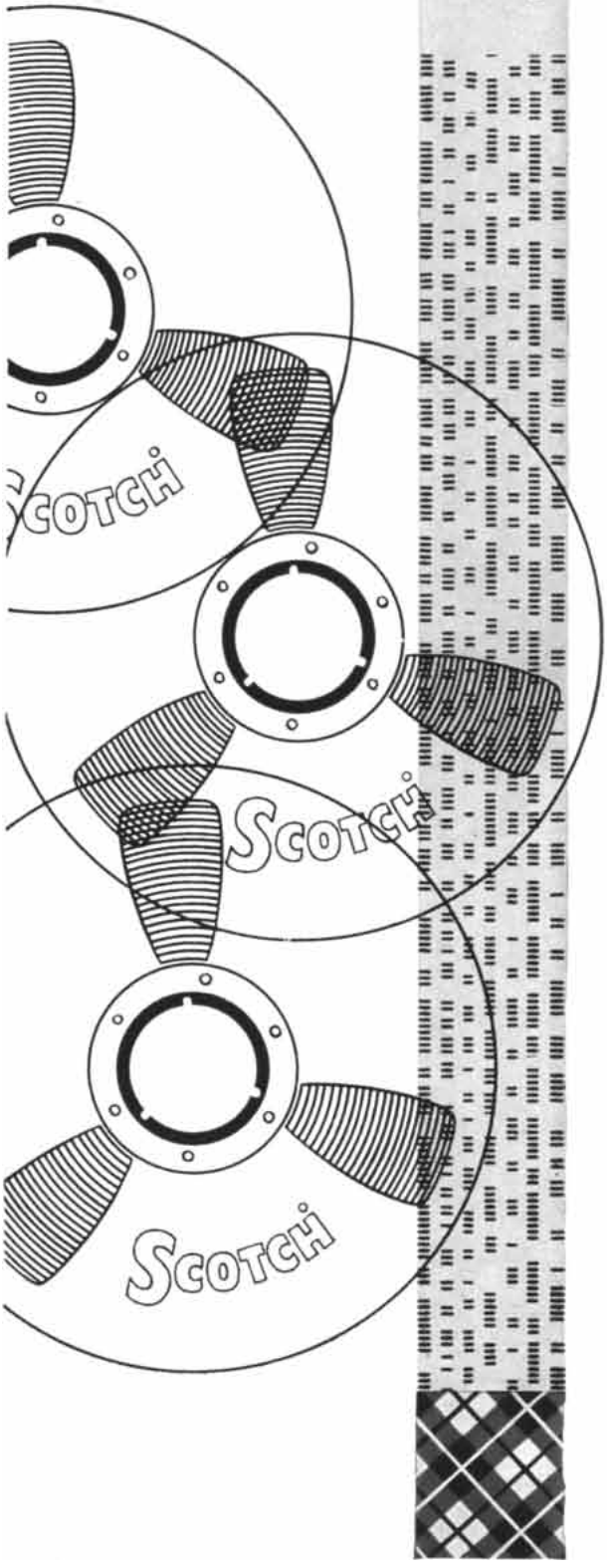
NO DISTORTION OF THE FACTS

"SCOTCH" BRAND Precision Reels stack up well, thread smoothly

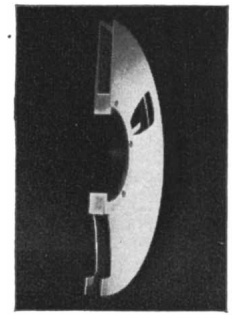


IN INSTRUMENTATION, it nearly goes without saying that your choice of reels is as important as your choice of magnetic tapes. You can't afford any distortion of the facts you deal with—so why not give your "SCOTCH" BRAND Tape the best running mate—a "SCOTCH" BRAND Precision Reel.

While most drop outs come from dust or other contaminants on the tape surface, the next most significant factor is related to improper handling. Dents or creases in the tape backing, damage to tape edges caused by uneven winding, too much tension on the tape at the end of a pass—all of these affect performance. Any stresses which exceed the yield point of the tape can cause a permanent set—a physical distortion which in turn leads to the attenuation or loss of important signals.

Precision is no empty word when applied to the "SCOTCH" BRAND reel. Every detail—design, materials and production techniques – grows out of years of careful research and testing by the same 3M research teams who have continually led in the development of magnetic tapes.

The "SCOTCH" BRAND Precision Reel is machined of aluminum. Its unique design offers maximum protection against tape damage from handling, while greatly lowering the moment of inertia—exerting less stress in stops and starts. Because the flanges are precision machined, they can be held to a fine tolerance—thicker at the hub, thinner toward the rim. These closely spaced, tapered flanges guide the tape into a smooth, even stack. Tape edges are kept perfectly aligned.



Threading up is easy on you and the tape. The "SCOTCH" BRAND reel employs a precision ground neoprene ring instead of a threading slot which can cause distortion of the inner turns of tape. To thread up, you simply start a turn of tape on the take-up reel. The neoprene ring, moreover, acts as a cushion for the innermost tape layers and guards against distortion from winding pressure and expansion-contraction stresses.

Flange apertures are reduced to the minimum compatible with the need for observation and threading—giving further protection to tape and greater rigidity to the reel. Compare—as the moment of reel decision approaches, a look at all the facts should lead you to come out in favor of "SCOTCH" BRAND Precision Reels.

Your 3M Representative is close at hand in all major cities—a convenient source of supply and information. For details on reels and tape constructions, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.

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No. 20 of a series

Eastman 910 Adhesive solves another production bottleneck

Sonotone Corporation, of Elmsford, N.Y., recently introduced its new Model "66" hearing aid. An all-transistor, self-powered unit, the instrument can amplify input sound intensity 10,000 times, is no larger than a lump of sugar, weighs no more than a half-dollar.

More than 150 components are packed into this outstanding example of miniaturization.

In assembling the hearing aid, Sonotone uses fast-setting, high-strength Eastman 910 Adhesive in more than a dozen joints involving a variety of materials: plastics, rubber and metal.

A thin, clear liquid, the adhesive flows into crevices without stringing or balling, sets in seconds with contact pressure. Assembly procedures are simplified. Critical space is conserved.

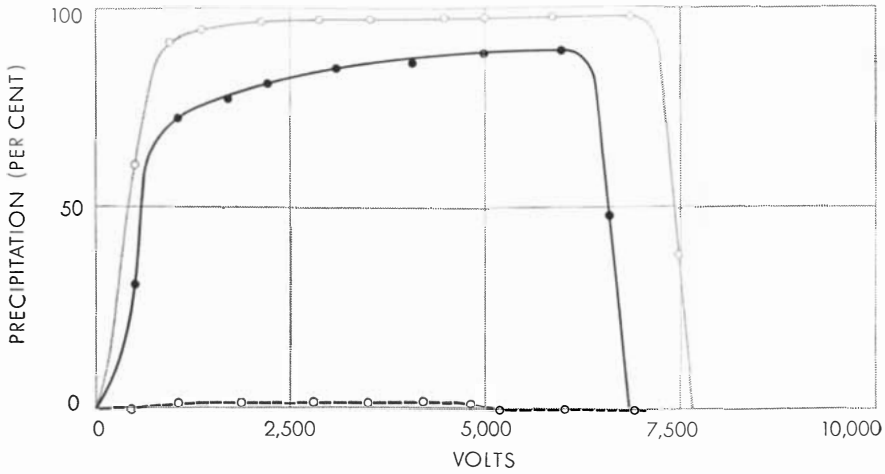
Eastman 910 Adhesive is making possible faster, more economical assembly-line operations and new design approaches. It is ideal where extreme speed of setting is important, or where design requirements involve joining small surfaces, complex mechanical fasteners or heat-sensitive elements.

Eastman 910 Adhesive is used as it comes. No mixing, no heating. Simply spread the adhesive into a thin film between two surfaces. Light manual pressure triggers setting. With most materials strong bonds are made within minutes.

What production or design problems can this unique adhesive solve for you?

Bonds Almost Instantly with Contact Pressure
No Heat...
No Catalyst...

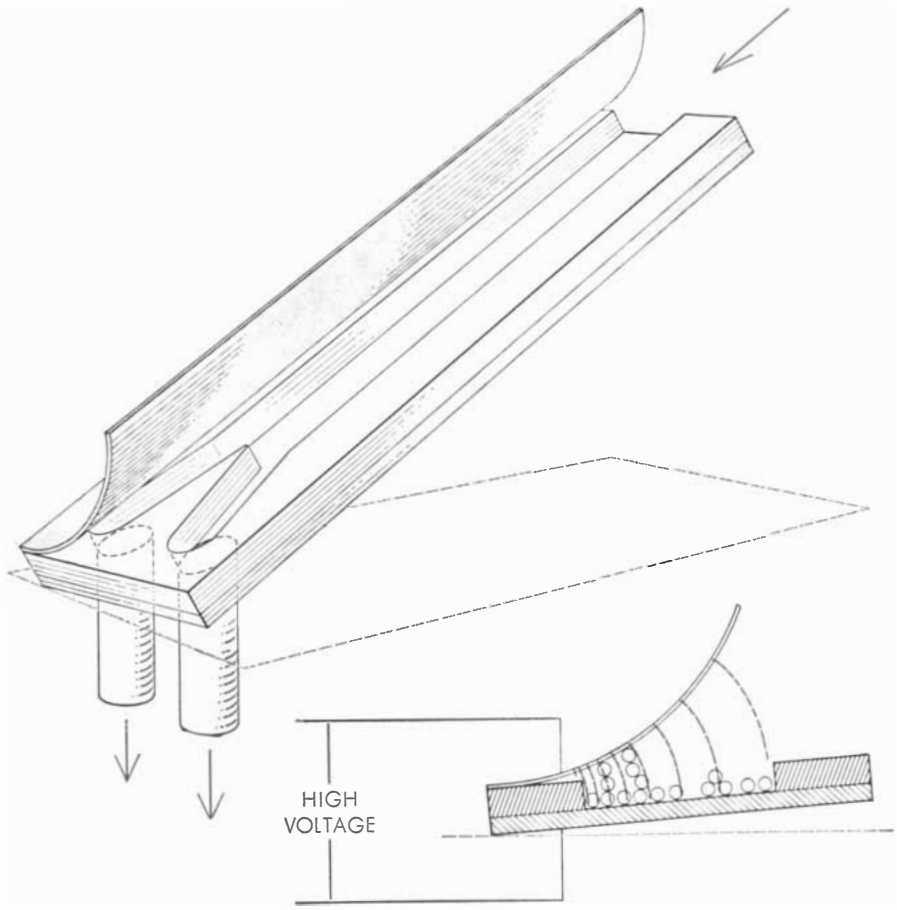
For a trial quantity (⅓-oz.) send five dollars to Armstrong Cork Co., Industrial Adhesives Div., 9112 Inland Road, Lancaster, Pa., or to Eastman Chemical Products, Inc., Chemicals Div., Dept. S-12, Kingsport, Tenn. (Not for drug use)
See Sweet's 1960 Prod. Des. File, 7/E



EFFECT OF POLARIZABILITY on the separation of powdered substances suspended in a liquid medium is illustrated by these three curves. The dielectric constant of the liquid is 2.3; that of sulfur (*broken curve*), 3.7; that of polyvinyl chloride (*black curve*), 4.6; and that of ammonium chloride (*gray curve*), 7. Curves show how much of each substance precipitated at electrode of a dielectrophoretic cell when various voltages were applied to it.

up in the air at the rate of a gallon a minute. The experiment is almost overwhelming. We do not demonstrate it often, because of the problem of cleaning up afterward.

At present these effects are just laboratory curiosities, but some of them may be well worth exploiting. Drawing a current of only 20 millionths of an ampere, the apparatus described above moves fluids with an efficiency of 25 per cent. It makes a simple pump, with no moving parts, that could be used in processing liquids and for handling powders.



ISOMOTIVE CELL separates powdered substances. Cell is shown in perspective drawing (*top*) and in cross section (*bottom*). One of its electrodes is curved; the other, flat. Mixture to be separated is introduced into trough in center of cell. As particles slither down the tilted surface, nonuniform field pushes them toward one or the other of the exit ports at lower end.

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PRECISION ON A PINHEAD

New Hamilton-Zeiss machines will make microminiature cuts and welds in the most difficult materials known to man

Hamilton-Zeiss electron beam cutting and welding machines introduce a new dimension in precision manufacturing. They will drill, weld, or cut such "temperamental" materials as molybdenum, beryllium, tantalum, tungsten, quartz—even diamonds or ceramics. The heart of the machines is an electron gun which focuses up to 10 billion watts-per-square-inch on the "target" —with such pinpoint concentration that areas only thousandths of an inch away remain cool and retain their physical properties.

The machines are already in use by more than a dozen U. S. companies and government agencies. They are performing a wide range of heretofore difficult, if not impossible, tasks . . . machining and cutting precision parts for aircraft and missiles . . . welding dissimilar materials and assembling elements in miniature electronic components. The machines are also potentially valuable in the manufacture of miniature crystals and other electronic elements.

By agreement with the Carl Zeiss Foundation, Hamilton Standard holds complete rights for developing and manufacturing the machines in North America. A separate organization, Hamilton Electrona, Inc., of New York City, has been established to administer all sales. The entire manufacturing/marketing program is another of Hamilton Standard's fast-growing fields of interest which today include missiles and space systems, ground support equipment, aircraft engine controls, starters, air-conditioning systems, and new propellers.

NOTE: Complete information on the Hamilton-Zeiss machines is available from Hamilton Electrona, Inc., New York City.

Hamilton Standard offers exceptional opportunities to individuals with advanced engineering and science degrees. Write: R. J. Harding, Recruitment.

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HEAD OF A COMMON PIN, magnified about 100 times, shows cut 0.003 of an inch wide, made by Hamilton-Zeiss machine.

Sample manufactured on Hamilton-Zeiss machine by L.R. Industries, Inc., Mt. Vernon, N. Y.

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The Evolution of Behavior in Gulls

Gulls communicate with one another by means of calls, postures and movements. Differences in the signaling behavior of various species reflect the influence of environment on gull evolution

by N. Tinbergen

Gulls live in flocks. They forage together the year around and nest together in the breeding season. No external force or agency compels them to this behavior; they assemble and stay together in flocks because they respond to one another. Their gregarious and often co-operative behavior is effected through communication. Each individual exhibits a considerable repertory of distinct calls, postures, movements and displays of color that elicit appropriate responses from other members of its species. Some gulls have a special food call that attracts their fellow gulls, and most have an alarm call that alerts the others. On the breeding grounds the male gull scares other males from its territory by certain calls and postures. Sex partners stimulate each other by a ritual of displays that leads to precisely timed and oriented co-operation in mating. Parent gulls attract their chicks by uttering the "mew call" or "crooning call" and lowering the beak. The chick pecks at the tip of the beak, and this stimulates the parent to regurgitate the food it has brought to the nest.

Even a nodding acquaintance with gulls suggests that their signaling behavior is just as typical of the family as their coloring and other physical conformation. Under the same circumstances the members of a given species invariably strike the same posture or act out the same ritual. Such observations suggest that signaling behavior must be largely unlearned. Investigators have found, in fact, that it is highly "environment-resistant." When a young bird is raised away from its parents or with foster parents, it does not develop a different pattern of signaling behavior but displays the repertory peculiar to its species. Moreover, gulls "understand" the meaning of various signals, apparently without the necessity of learning. The fact that many signaling movements of animals are as typical of the species as are anatomical structures and physiological mechanisms has been repeatedly stressed by Konrad Z. Lorenz of the Max Planck Institute of Comparative Ethology in Germany [see "The Evolution of Behavior," by Konrad Z. Lorenz; SCIENTIFIC AMERICAN, December, 1958].

When our group at the University of Oxford began some years ago to study the signaling behavior of gulls, we were interested primarily in finding out how the system works. We were concerned with such questions as: What is the exact function of each display? What makes a gull give a particular signal? But it was not long before another question claimed our interest. The members of our group (including Esther Cullen, Martin Moynihan and Rita and Uli Weidman) had been working at many sites around the world and observing the habits of 15 or more species of gull. We had found that the signaling systems of these species are very similar; this strengthened the conclusion, drawn from structural similarity, that gulls must have evolved from a common ancestral species. But we also found that the signaling repertories of the various species differ from one another in significant ways. Since the differences among these closely related birds are not induced by the environment, but are truly innate, it was clear that the present differences among the species must have arisen through evolutionary divergence. We decided that a comparative study of the signaling of the gulls might yield fresh insight into the evolution of their behavior.

Much as the anatomist makes comparative studies of structures in order to discover the origins and relationships of species, we have been conducting a comparative study of the signaling systems of gulls. These systems provide excellent instances for the study of behavior; precisely because of the function they serve, the signals are distinct and plain enough to be recognized even by an attentive human being. In our program the comparative method is applied in combination with our earlier methods of study. We continue to investigate the form and motivation of the displays, and this work has been facilitated by recent improvements in technique. We continue also to be concerned with the function of the displays, for this bears upon their survival value and so allows us to trace the selection pressures which must have been at work molding them. Thus the comparative study of the differences among species and the comparison of the present displays and their apparent origins make it possible to approach a description of the evolutionary changes that must have occurred as the ancestral gull family split up into the present 35 or so species of different appearances, habits and distribution.

Since there is no fossil behavior to certify our conclusions, our method of study might better be compared to that by which modern linguistics, through comparative study of languages, has worked out the family tree of the Indo-European languages, and has even reconstructed parts of the original Indo-European language [see "The Indo-European Language," by Paul Thieme; SCIENTIFIC AMERICAN, October, 1958]. The findings of such a study must always be regarded as probabilistic. On the other hand, the data of our investigation are sufficiently clear-cut. The postures and displays of each species are distinct and

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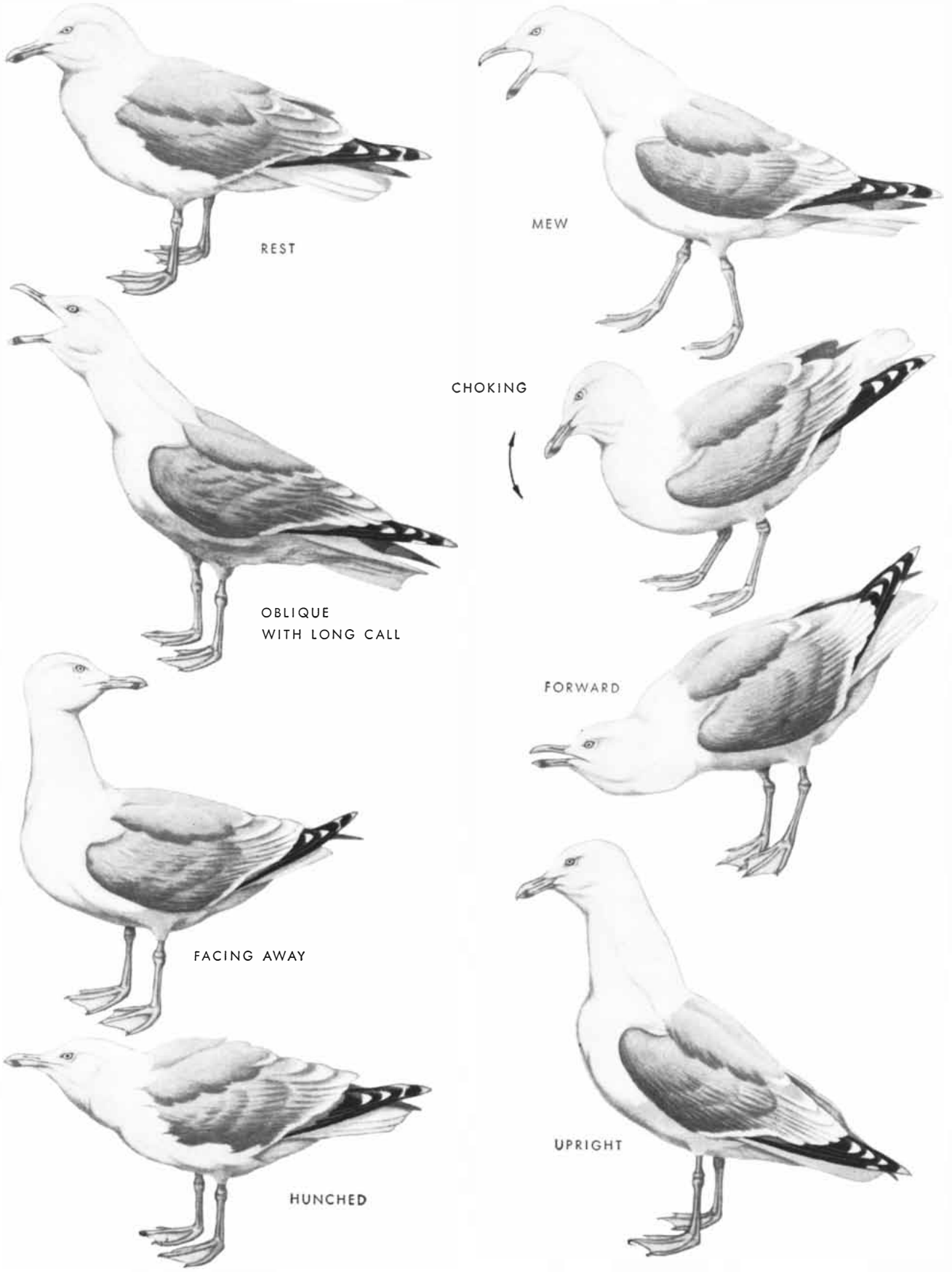

PRINCIPAL DISPLAY POSTURES of herring gull are almost identical to those of other large gulls, and very similar to those of other groups in gull family. The oblique, mew, forward (and sometimes choking) are accompanied by characteristic calls.

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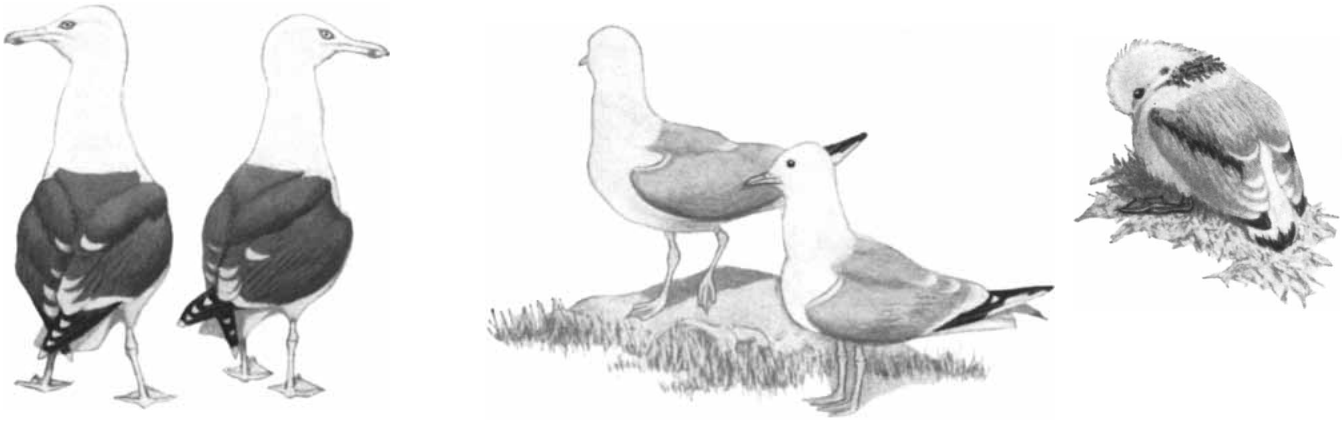


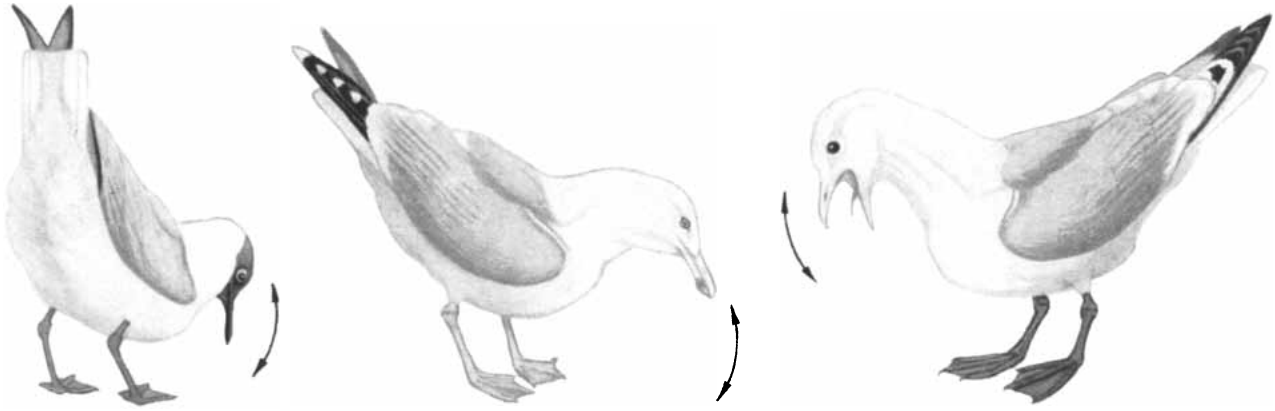
FACING AWAY is an "appeasement" posture in which the gull averts its menacing beak. When a kittiwake alights on a ledge that is already occupied by a pair, he is attacked; he usually responds by facing away (*bottom bird at far right*). Females that alight

constant enough to make them useful in distinguishing and identifying the species.

The illustration on the preceding page shows eight postures and movements that occur in nearly all species of gull in more or less modified form. When they are employed for taxonomic purposes, they greatly increase the number of characteristics by which gulls may be classified. The similarities and differences among the displays of the major subgroups correspond roughly to the classifications of the taxonomist, although studies of some of the less well-known species might force revision of their status. All of the "large gulls," among which the most familiar is the herring gull, have quite similar signaling systems. The "hooded gulls" are rather different from these, yet they are close in their habits to one another. Species that have been placed in separate genera, such as the kittiwake and the ivory gull, have correspondingly distinct displays.

It seems clear that the signaling movements originated in more elementary behavior patterns, such as attacking, escaping, mating and nest-building. The postures and the actions themselves suggest where they came from. "Grass pulling" is a good example. In contests over territorial boundaries herring gulls and

LONG CALL of unmated males attracts females and repels other males. It is uttered in the oblique posture. This display is similar in the great skua (*far left*), the herring gull (*left center*), the kittiwake (*right center*) and the black-headed gull (*far right*).



CHOKING is stimulated by the sight of the nest. It consists of a series of down-and-up movements of the head, and in some species is accompanied by a cry. Shown here are choking displays of black-headed gull (*left*), herring gull (*center*) and kittiwake (*right*).

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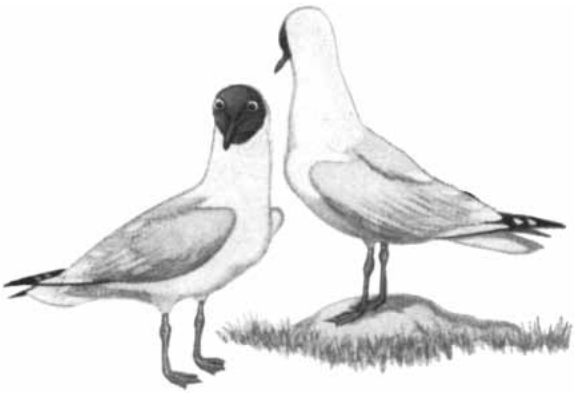
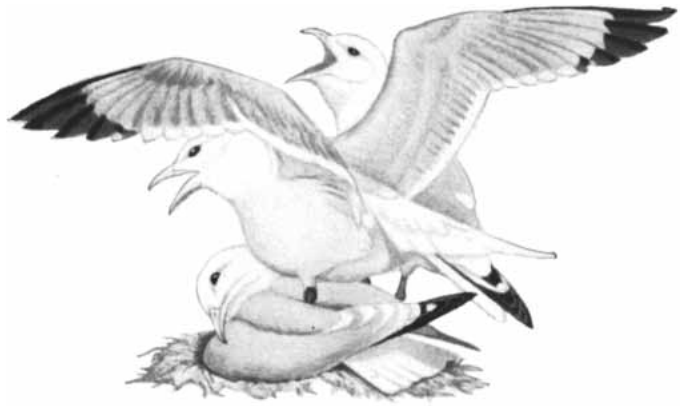
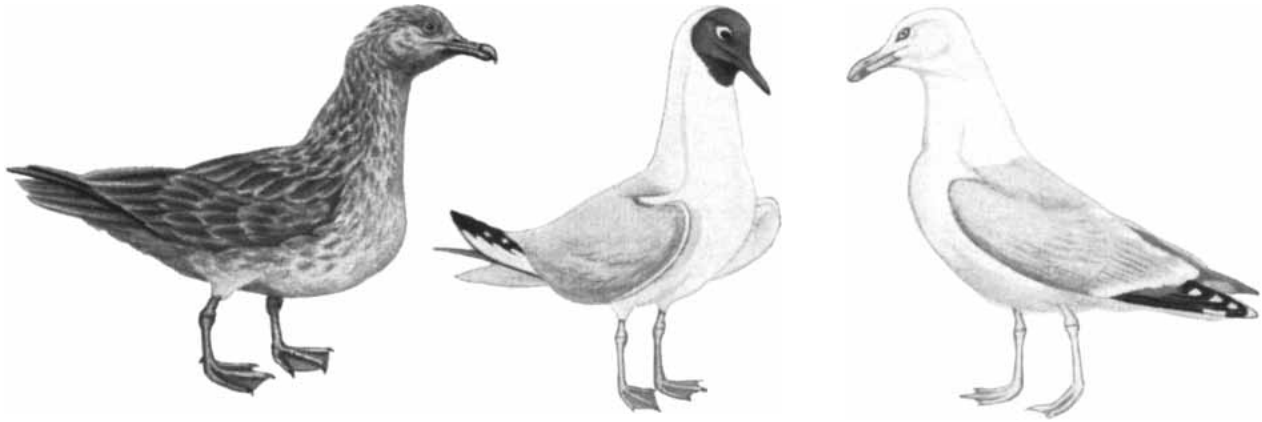




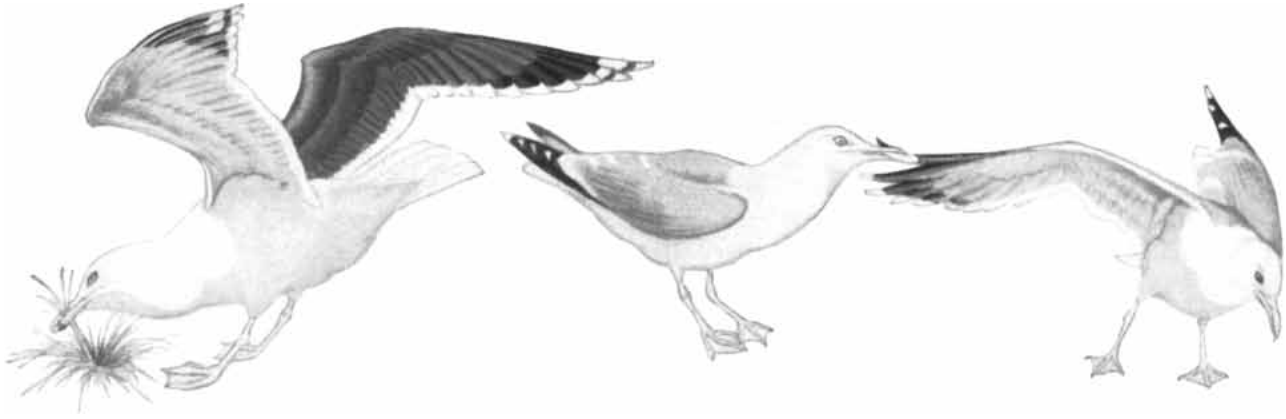
near a strange male also face away. Facing-away postures are similar in all species of gull, including the lesser black-backed gull (*far left*), the common gull (*second from left*), the kittiwake chick (*left center*) and the black-headed gull (*right center*).

other large gulls often peck violently at the ground, uproot plants and toss them sideways with a flick of the head [*see bottom illustration on this page*]. The pecks are indistinguishable from those aimed at rivals in actual attacks, and the pulling movements are identical with those seen when a gull seizes an opponent's wing, bill or tail. But the strange thing is that this activity is directed at the ground, not at the intruder for whose benefit the signal is displayed. The technical term for this is "redirected attack," and it may be compared to the human tendency to bang a table with the fist or kick a chair when angered. More puzzling is the sideways flick of the head that terminates this action. It is familiar to anyone who has observed gulls through more complete cycles of behavior; all gulls (and other birds as well) perform this movement when they build material into the nest. Apparently the sideways flick is stimulated by the "nest material" that the bird finds in its bill following its attack on the ground. Grass pulling may therefore be described as a redirected attack followed by a displaced nest-building movement.

"Choking" seems to have had a rather similar origin. This is the display by which the unmated male kittiwake advertises the nest site to passing females



UPRIGHT is a threat posture. The neck is stretched, bill points down and wings are raised slightly. Gulls adopt this posture when facing an intruder. Shown here are the upright postures of great skua (*left*), black-headed gull (*center*) and herring gull (*right*).



GRASS PULLING (*left*) is another threat display. The gull pecks at the ground and tears out grass in much the same way as it would peck and pull at an opponent during a fight (*right*). Bird at left is lesser black-backed gull; those at right are herring gulls.

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and warns other males off; in other species it appears in boundary conflicts and is exhibited when male and female come close together, particularly at the nest site. It begins with a bending down over the nest (or any depression in the ground similar to a nest, such as a human footprint), followed by a rhythmic up-and-down movement of the head. The initial bending movement looks remarkably like the posture that the gull assumes just before it settles on the eggs, and is apparently derived from it. The rhythmic up-and-down movement appears to be a displaced nest-building, or perhaps a regurgitative movement.

But what makes a gull take up a certain posture? The controlling elements in the immediate situation in which a gull strikes one of these postures can be summed up in a single word: conflict. In a boundary dispute or in the preliminary stages of courtship the bird is in the grip of two mutually opposed impulses: to attack or to escape. The "upright," another hostile (or "agonistic") posture, is more readily recognized as a mosaic of these two behavior patterns. The gull reaches its head upward with its bill pointing down and lifts its still-folded wings from its sides. Stretching the neck and pointing the bill downward are the beginning of one form of attack, and lifting the wings is the first stage in the delivery of a blow with the folded wing. Occasionally the upright posture passes over into actual attack, but the gull usually stops short before he makes contact with his antagonist. If his opponent does not give way before his posturing, the gull will withdraw his neck, turn his bill upward and flatten his plumage; in short, he abandons the aggressive upright posture. Often he turns himself broadside to his antagonist; this maneuver appears in many postures and is a consequence of fear. It is not an uncommon sight in such a contest to see two birds walking parallel to or even around each other. Finally one gull abandons the offensive and adopts a posture of appeasement or runs away. Thus the upright is a posture that may pass over to a retreat as well as to an attack. It may be compared to the clenched-fist posture of a man whose anger is aroused, but whose action is restrained by fear or social convention. In such states of inner conflict the impulse to attack may also be redirected against inanimate objects or displaced by some irrelevant activity such as the nest-building head flick in the gull or the lighting of a cigarette in man.

Elements of conflict appear equally in the appeasement postures. The bird that yields in a contest of agonistic posturing is frequently seen to adopt the "face-away" posture: it turns its head away. The victim of an actual attack will do the same while standing his ground; this often stops the attack and always reduces it. Facing away also appears in the early phases of the mating ritual, when the members of an incipient pair are still strangers to one another. Plainly in all these situations the bird is seized simultaneously with the impulse to flee and the impulse to stay.

Somehow in the course of evolution these "involuntary" expressions of inner conflict between two incompatible behavior tendencies acquired value as signals. Other gulls responded to them, and since they facilitated adaptive social behavior, the postures or displays became incorporated in the signaling system of the species. Just how this happened in any single instance can only be imagined. On the other hand, once a given posture acquired such value, it is apparent that it tended to become quite clearly differentiated from the movement in which it originated. The original movements were primarily adapted to the functions of attack or escape, nest-building or some other activity. In becoming adapted to the signaling function they have been transformed in significant ways. Thus choking still resembles the nest-building action closely enough to be recognizable. But it also differs from that action in being much more prolonged and rhythmic. Similarly, while turning away suggests the motion that initiates fleeing, the action is usually more jerky, and the bird "freezes" in the turned-away posture. All these modifications of movement and of posture are such as to make the signal more distinct and conspicuous and so better suited to the function of providing strong stimuli to other gulls.

The same process of "ritualization" tended to make each of the postures in the repertory of a given species clearly distinguishable from one another. Thus every species has a number of agonistic displays. They are usually strikingly different, as the upright is from the choking posture. Though intermediate postures are not rare, they are much rarer than one would expect if there were a true sliding scale of displays between them. The black-headed gull, for example, has two quite distinct agonistic postures, the "oblique-*cum*-long call" and the "forward." There is good reason to believe, however, that they have a common origin. In the former the bird tilts its body head downward and tail upward (that is, obliquely), lifts it folded wings from its sides and emits the long call. The forward looks like an extremely low oblique and, with the bill shut or half-shut, the call becomes a muffled version of the long call. When a flying stranger approaches and passes within a yard or so, the male black-headed gull exhibits first the oblique-*cum*-long call and then the forward. Though it is a smoothly changing external situation that elicits these responses, the gull does not gradually shift from one posture to the other. On the contrary, he stands in the oblique for several seconds and then abruptly (in about a fifth of a second, as shown by analysis of motion pictures) assumes the forward posture. This must mean that selection has favored distinctness of displays by suppressing intermediates among them. Since each display has a slightly different function, the elimination of ambiguity minimizes misunderstanding.

However, the evolutionary development of signaling movements has not only been controlled by the need of avoiding ambiguity between the different signals of one species, but seems also to have involved differentiation between species. The differences that distinguish the repertories of the various species are numerous. For example, the black-headed gull tilts its body head-down into an almost vertical position while choking. In this and in other postures it also lifts its folded wings in a greatly exaggerated manner compared to other gulls [*see bottom illustration on page 120*]. The great skua, which is not a gull, but belongs to the closely related jaegers, spreads its wings fully in the oblique posture when it gives the long call [*see middle illustration on page 120*]. The kittiwake opens its bill wide in all agonistic displays.

Some of these idiosyncrasies in behavior can be related readily to the characteristics of color and marking by which species are ordinarily identified. The postures have the effect of heightening the displays of these markings. Thus the kittiwake's mouth and tongue are a bright orange, and when the bird opens its bill in a posture of hostility, the color becomes visible. The great skua has bright white patches on its otherwise dark wings, which become visible as it opens its wings in the oblique. When the black-headed gull faces its opponent in the forward posture, it shows off its brown facial mask most conspicuously against the surrounding white of its body. This undoubtedly has something

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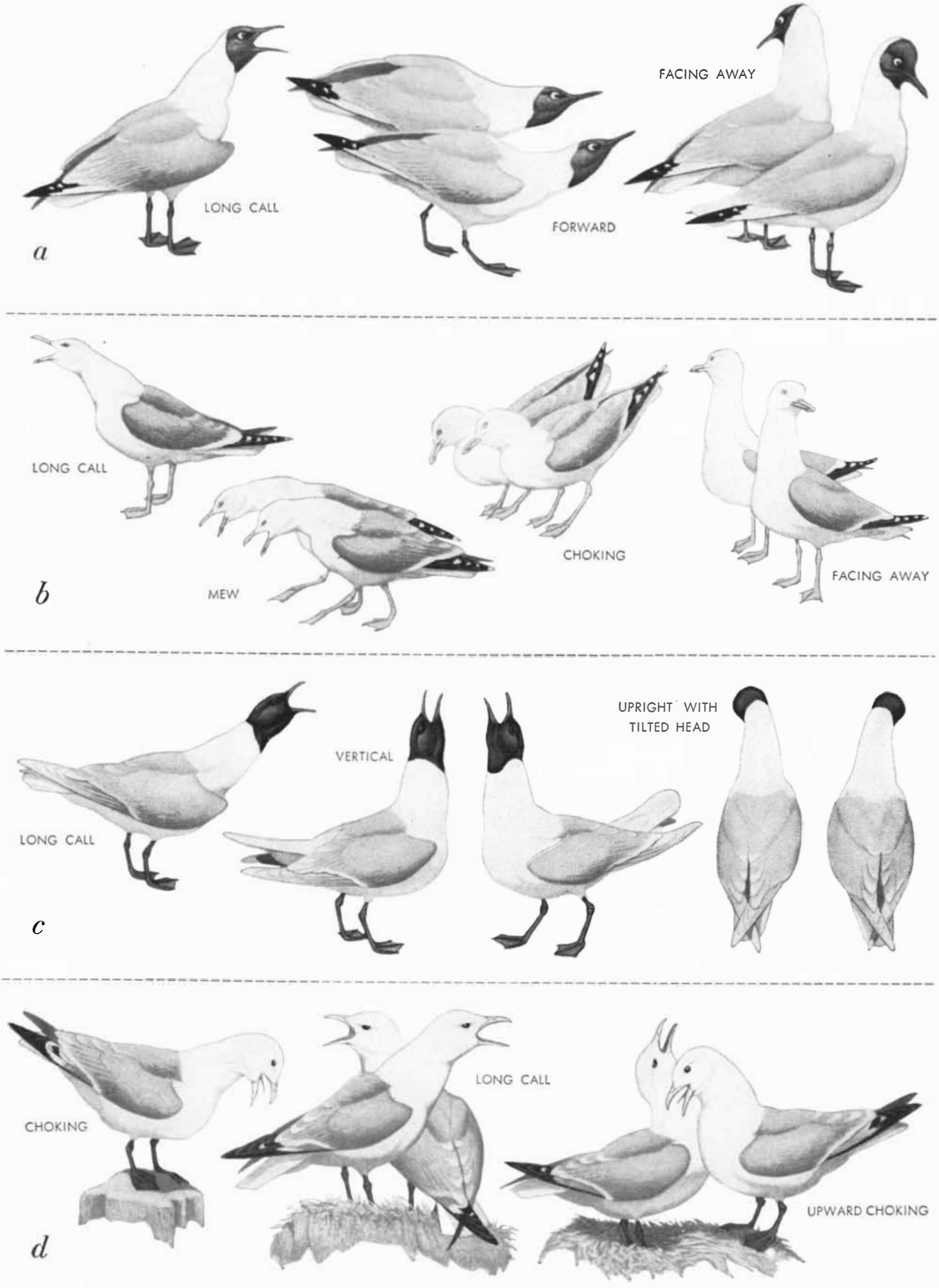

PAIR-FORMATION involves a different series of displays in each of the four species of gulls shown here. In the black-headed gull (*a*), the herring gull (*b*) and the little gull (*c*), pair-formation begins with the long call; in kittiwake (*d*) it begins with choking.

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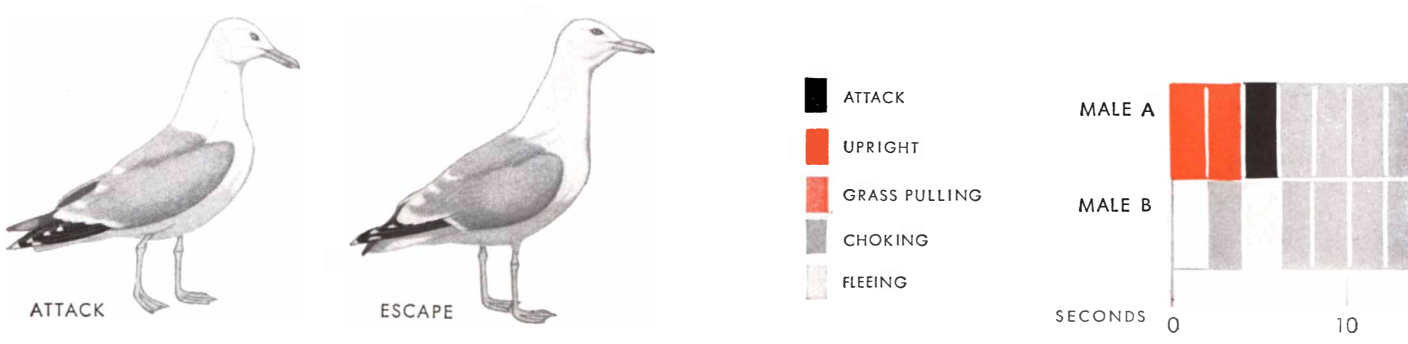
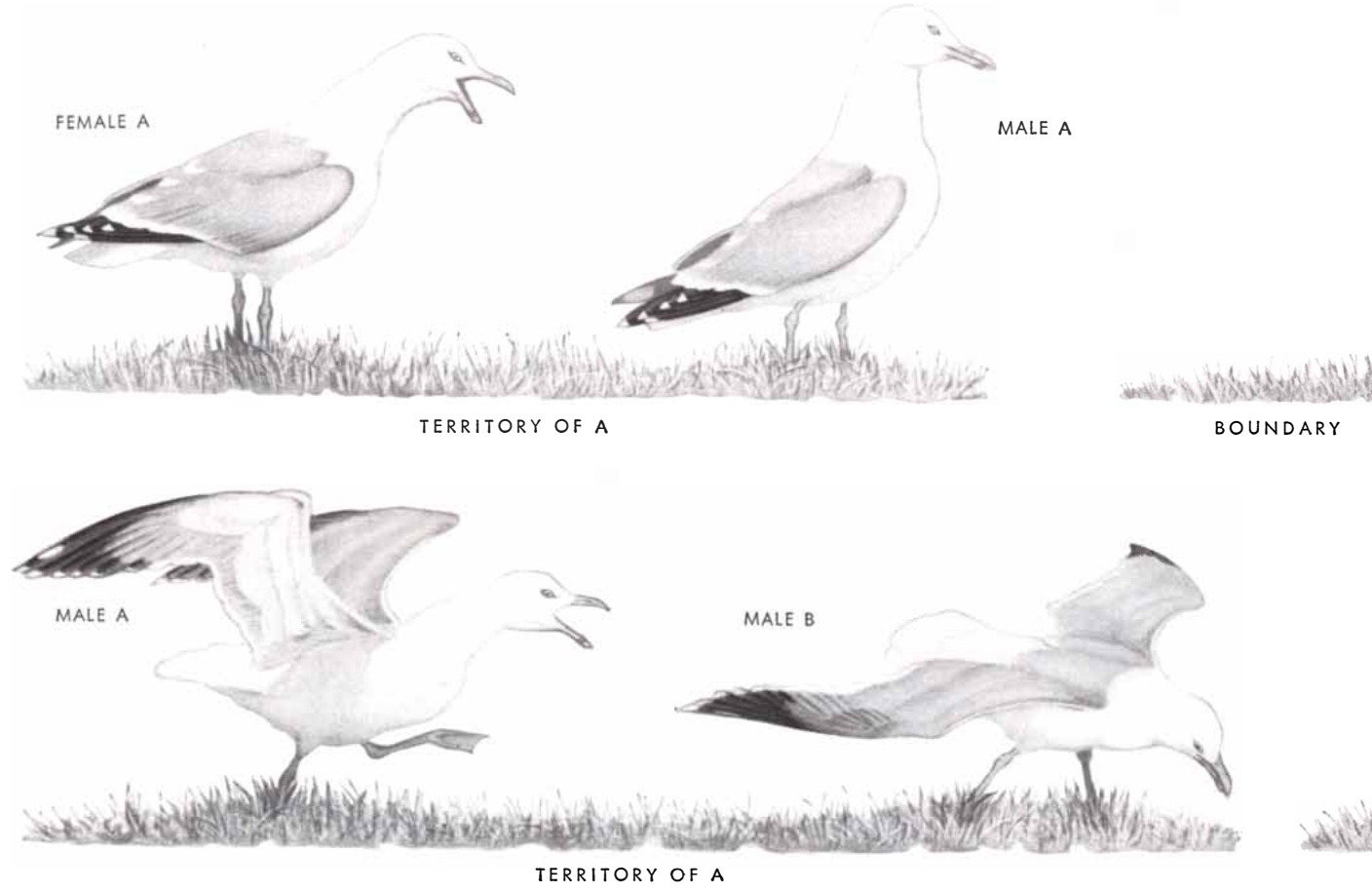


BEHAVIOR SEQUENCES were made from motion-picture films of a boundary clash between two gulls. Threat displays alternated with attack and defense behavior. Each block in the sequence at right represents an interval of two seconds. Legend at left center is key to the type of behavior shown by gulls during each of these intervals. Small drawings at far left show the "attack" components

to do with the fact that it employs the forward posture more frequently than other gulls do. Moreover, when this gull faces away, it turns its head around with a jerk and raises its white neck-feathers, completely concealing the mask. The hostile and the appeasement displays thus present an unmistakable contrast to the bird's antagonist. Generally speaking, however, gulls all look very much alike. Perhaps for this reason the principal interspecies differences in displays are to be found in the sharp definition of movements and postures.

The evolutionary significance of the differences among species becomes clearer when the displays are considered in terms of their functional relationship to the varying ways of life of the gulls. The most disparate of the gulls is the kittiwake. In contrast to most other species, which set up their breeding communities on dunes or grassy flats, the kittiwake is a cliff dweller. Esther Cullen, who has made an intensive study of this species, has shown convincingly that many peculiarities in its behavior are corollaries of its adaptation to this habitat. Secure from attacks by predators, including other gulls, the kittiwake is extremely tame. It does not attack predators, and its alarm call is so rare that to elicit it one has to climb down to the narrow slanting ledges where the nests on their mud platforms cling so precariously. It is not surprising that the contrasts that distinguish the kittiwake's signaling behavior from that of other gulls emerge sharply in the displays concerned with the establishment and defense of the nesting site.

Among the grass-dwellers the agonis-



BOUNDARY CLASH begins with two pairs of gulls facing each other across the boundary between their territories. Display behavior (*top row*) is a result of conflict between "anger" and "fear." Male B is choking in response to upright display of male A;

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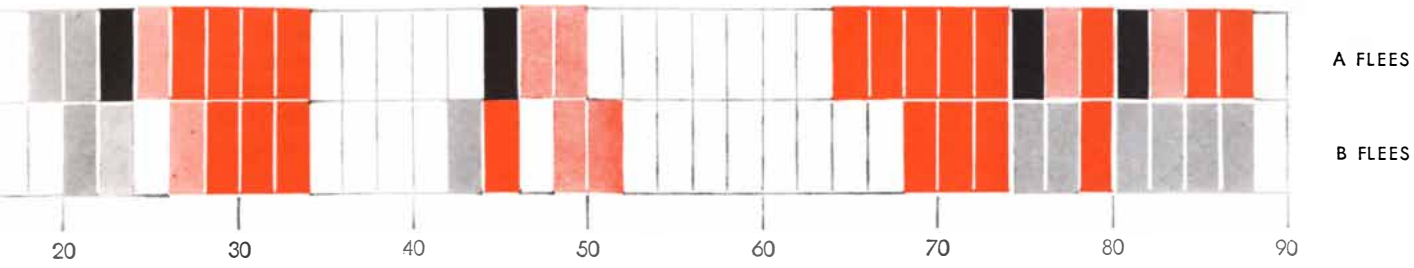

of the upright posture; gull adopts this form of upright as he runs at an intruder. If intruder fails to withdraw, or adopts the upright himself, the attacker usually stops and adopts the "escape" version of the upright (*second from left*): The bill points forward or upward, and the neck is vertical. The illustrations at the bottom of these two pages depict the behavior sequence schematically.

tic displays that maintain the territorial claims of the individual play a vital role in their adaptation to their habitat. Each male bird, having chosen a nesting site, defends an area around it, the size of which depends upon the species, the bird's own enterprise and the population pressure at the breeding ground. The spacing-out of the nests effected by this behavior prevents interference with mating; it keeps other gulls from preying on the broods, and it makes the individual nest a less inviting target for attack by predators of other species. Although the eggs and chicks of most gulls are beautifully camouflaged, this confers no absolute protection. The scattering of the nesting sites is necessary to make the camouflage effective. But the gulls are also gregarious, and this trait promotes survival by providing a warning system and social defense against predators. Thus the density of the colony appears to be a compromise between the advantages of proximity and the advantages of spacing-out.

The behavior of the male black-headed gull in defense of its territory is typical. His first response to another bird's approach in the air or on the ground is the oblique-*cum*-long call. Moving out to meet the intruder at the boundary of his territory, he may assume the upright posture. However, the farther the defender ventures from the center of his territory, the more does his aggression become attenuated. At a certain point he may find himself under counterthreat. He is then likely to adopt the choking posture, which conveys a message roughly like: "Be careful. I may not attack, but if I am attacked, I will fight back!" This

female A utters mew call, while female B adopts the "escape" version of upright posture. When male B invades the territory of male A, A attacks and B flees (*bottom left*). Conversely, when male A invades the territory of B, B attacks and A flees (*bottom right*).

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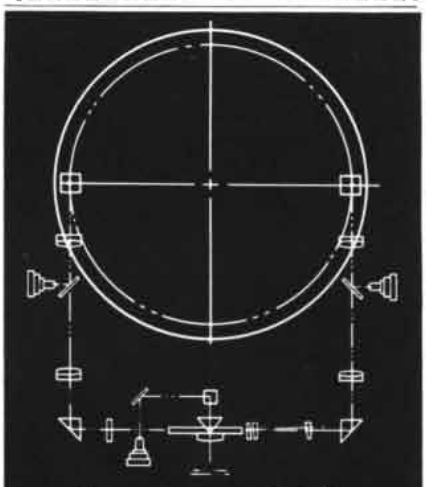

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does not cause his antagonist to withdraw, but it does reduce and often halts an attack.

The kittiwake, on his narrow ledge, acts out a quite different strategy. Most often, his first response to the approach of another kittiwake is choking. The reason for this is apparent. The kittiwake is the only species we have studied so far whose territory is so small that the bird, when it is at home at all, is standing right on the nest or the site of the nest-to-be. Now in all species of gulls choking is a posture readily elicited at the nest, and one that is probably derived from nest-building activity. The kittiwake, standing on his nest, accordingly chokes. The association of this posture with nesting activity is especially plain in the case of the kittiwake. The head-bobbing movement, so reminiscent of the action involved in putting nest material in place, is prolonged and sharply rhythmic, as befits a bird that builds with a sticky material such as mud, and must shake its head repeatedly and violently in order to put the material in place.

Another apparent effect of the nesting site upon the signaling behavior of this species is the early appearance of the face-away posture in the chick. Other gull chicks begin to roam about within a day or two after hatching, and in a couple of days think nothing of walking four feet away from the nest. When a chick is fed, its nest mates mob it in the attempt to share the meal, and the chick's natural response is to flee. But the kittiwake chick, having no place to go, has a strong tendency to stay put in the nest. Accordingly its defense against its nest mates is to face away. The effectiveness of this appeasement posture is perhaps heightened by the conspicuous black band across the back of its neck [*see illustration at top of pages 120 and 121*].

As might be expected, the differences among species show up most numerously and plainly in the displays associated with pair-formation and mating. Here signaling serves the obviously adaptive function of intraspecies recognition and interspecies segregation.

As contrasted with the sequence of territorial-defense postures, which induces spacing-out, the mating ritual brings the birds together. In winter most gulls lead a bachelor existence, uniting in flocks but not in pairs. Pairs form in early spring on or near the breeding site. Once gulls are paired, they know each other individually, and often re-pair without much ado each spring. Young birds mating for the first time, and widowed birds, pair up in more elaborate ways, in each case in a manner typical of their species.

The male and female of all species of gull look very much alike. Although there is evidence suggesting that the male, waiting at the nesting site he has chosen, can distinguish between males and females, he does not show it in his first response to an approaching female. In the case of the black-headed gull, the male greets the female with a display of the agonistic oblique-*cum*-long posture. Strange males avoid a long-calling male. But unmated females respond quite differently: they are attracted by him, and actually alight near him.

When this happens, both birds adopt a posture similar to the forward posture observed in the boundary flights of this species. The only differences are that the bill usually points up a little more than in hostile clashes, and the male and female tend to stand parallel to and not facing each other. After standing in this posture for perhaps a few seconds, first one and then the other gull suddenly jerks into the upright, another agonistic posture. But at the same time each turns its face away from the other; in other words, they moderate the hostility implied by the upright with a posture of appeasement [*see "a" in illustration on page 123*]. As their behavior plainly shows, the partners upon first meeting are in the thrall of three conflicting impulses—to attack, to escape and to remain near one another.

The female is usually the more timid of the two. This shows in her tendency, especially in the beginning, to stay at a safe distance from the male, and also in the extreme flattening of her plumage. Often the female, after having faced away, cautiously turns her face toward the male again, but quickly faces away each time the male moves. As a rule the female stays only a very short time, and then flies off. When the male starts calling again, she may either approach him once more, or alight near another calling male. Females can often be seen to visit a series of males in quick succession.

Sooner or later a female will become attached to one particular male. She alights near him again and again, each time going through the same performance: forward, upright and facing away. But the meeting ceremony slowly changes with repetition. Signs of aggression in the male subside, and so do signs of fear in the female. She no longer flattens her plumage so much, her neck is less stretched and she ventures nearer the male, often facing him. This proc-

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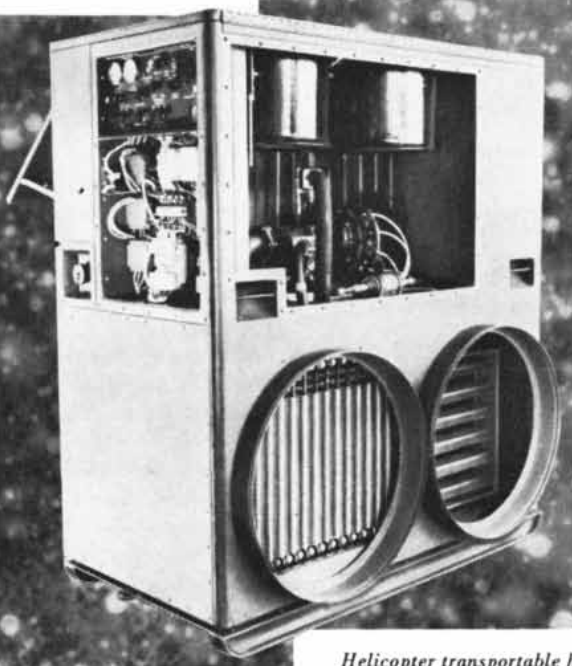

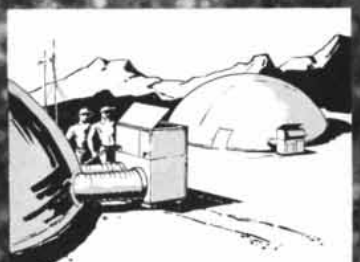

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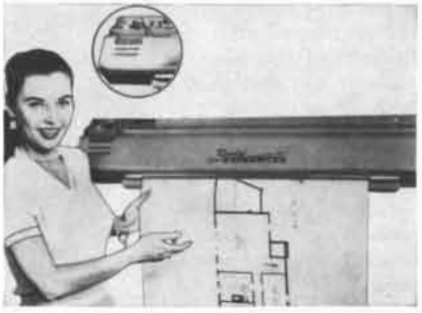

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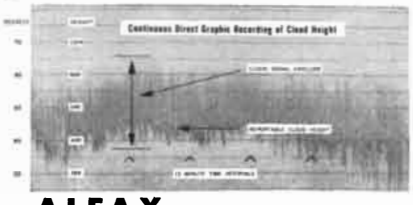

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ess of getting used to each other may take a short time and few visits, or it may take days and many dozens of visits. But ultimately the ceremony becomes desultory, and the birds spend a great deal of time together. The female now also begins to do the "head-tossing" movement, and then the male regurgitates and feeds her. In a short time the birds copulate.

The pair-formation ceremony is different in different species, although similar within the subgroups. All relatives of the black-headed gull follow the same ritual. But all large gulls, so far as is known, show another sequence: the oblique-*cum*-long call, the mew call, choking and facing away [*see "b" in illustration on page 123*]. The latter movement is less abrupt and less well oriented than in the black-headed gull. The little gull starts with the long call, then adopts the vertical posture (corresponding at this stage to the black-headed gull's forward) and changes to the upright, combined not with facing away but with tilting of the head, a movement also known in terns [*see "c" in illustration on page 123*].

All of the species show some evidence, admittedly slight, of distinctness in the character of the long call which serves the function of a mating "song" in the breeding season. The long calls are at least more distinct than the later calls and movements by which partners stimulate one another to copulate. This indicates that selection for distinctness must be much more severe for the song that first attracts the mate than for the precopulation displays that are performed after the mate has been attracted and accepted. The herring gull's long call can be distinguished even from that of its close relatives, the glaucous-winged gull and the western gull; except for this difference the mating displays of these species are practically identical.

The kittiwake follows still another routine, in keeping with the confined quarters of its nesting site. It begins by choking. This is the very display that keeps other males at their distance, but it attracts the female. When the female alights, both birds utter their version of the long call. They then return to choking once more and end by "upward choking" [*see "d" in illustration*]. Significantly the long call does not function as an initial advertisement in the pair-formation ceremony of this species. The kittiwake habitat probably served to give the species sufficient sexual isolation, and as a result there was no selec-

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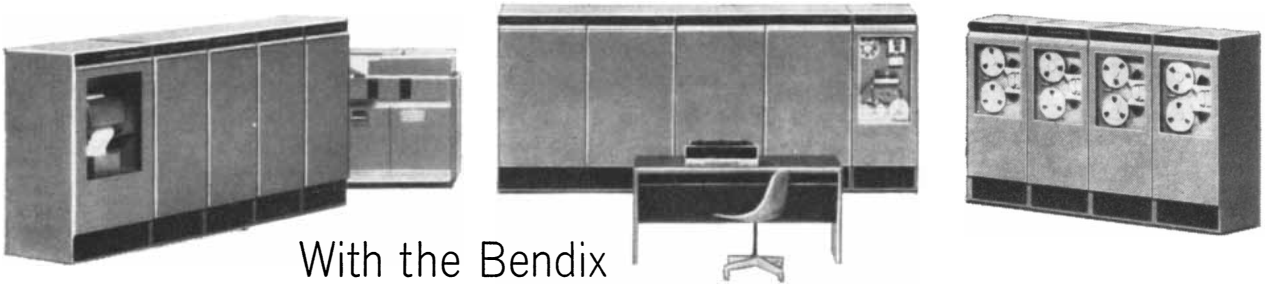

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tion for a mating call with a large range of audibility.

Thus selection pressures arising in various ways from the environment brought about the differentiation in signaling behavior that distinguishes the various species of gull. The comparative method, applied to the study of behavior in much the same way as it has been applied to structure, is a powerful method for reconstructing the evolutionary history of species and for elucidating the relationships among them. Used in conjunction with motivational analysis (which shows origins) and with study of function (which shows the selection pressures), the comparative method reveals how beautifully these behavior characteristics are adapted to promote the survival of the species.

It cannot yet be said when the signaling displays that distinguish gulls from one another and from other birds first made their appearance. Some may well be much older than the gull family itself; others may have arisen later. Comparison of more species of gull and of more distantly related forms may help to solve this. Nonetheless it is clear that signaling displays are just as stable and reliable taxonomic characters as structures. As such they have much to tell about the selection process that brought the existing species of gull into being.

In our studies we have tried to follow Sherlock Holmes, by casting our nets wide to collect as many pieces of evidence as we could and taxing our brains to fit them together into a picture that makes sense. But we must confess at the end that our findings will remain probabilistic. We cannot re-enact the gull's evolutionary history, which was a unique event. But we believe that the methods I have tried to sketch allow us to reconstruct the past with some degree of probability. These methods are essentially the same as those of comparative and functional anatomy. Like its venerable senior sister, comparative ethology can provide a description of what must have happened in the past. In addition, the study of survival value or function allows us to formulate at least likely guesses about the way the evolution of a species has been controlled.

Surely it is necessary to check whether conclusions which are mainly derived from the study of structure are consistent with the facts of behavior. If we are ever to understand the evolutionary history of our own behavior, we will need the sharpest tools we can get, and there is no denying that our present tools are very blunt indeed. My main concern has been to help sharpen them a little.

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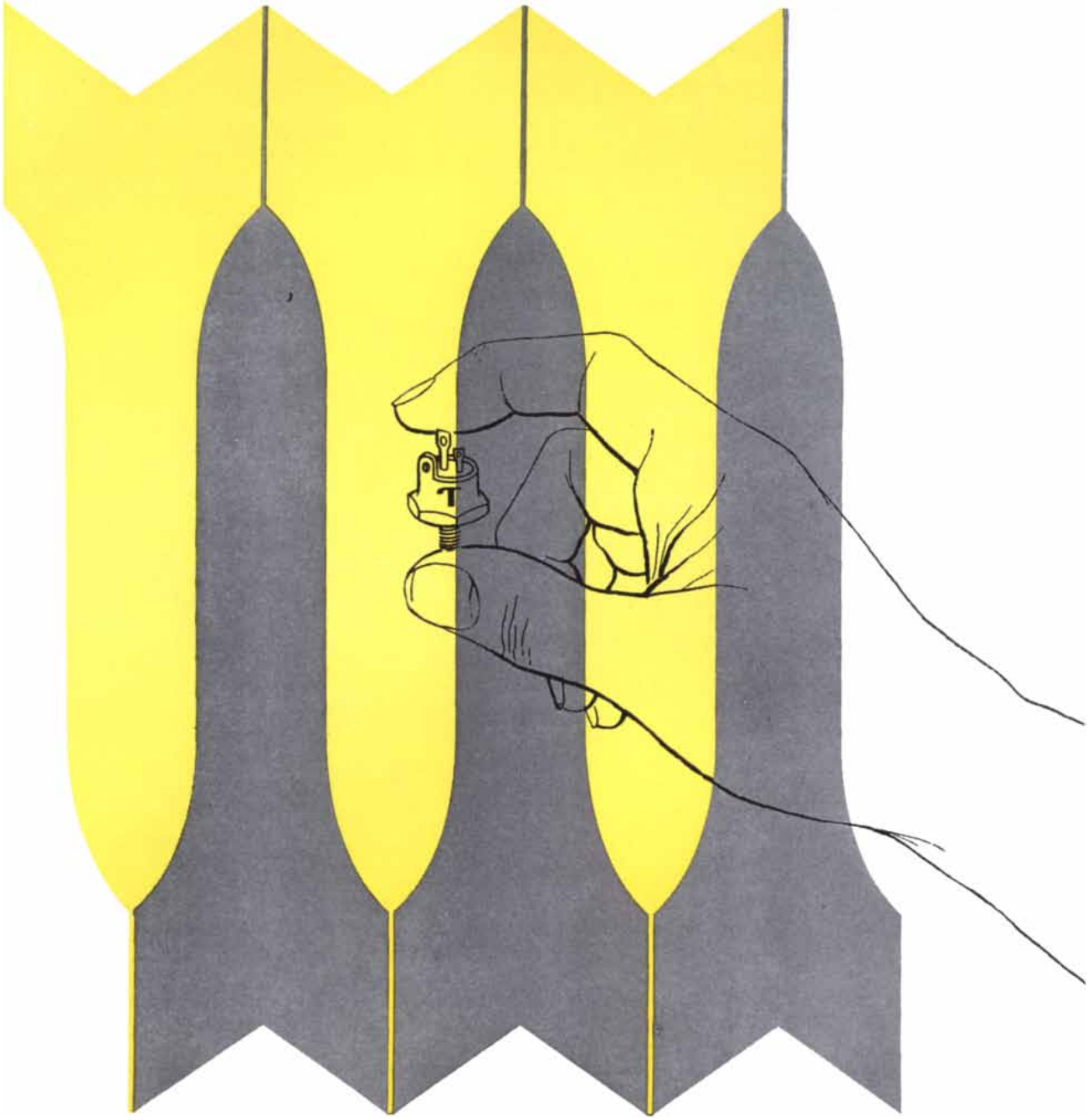

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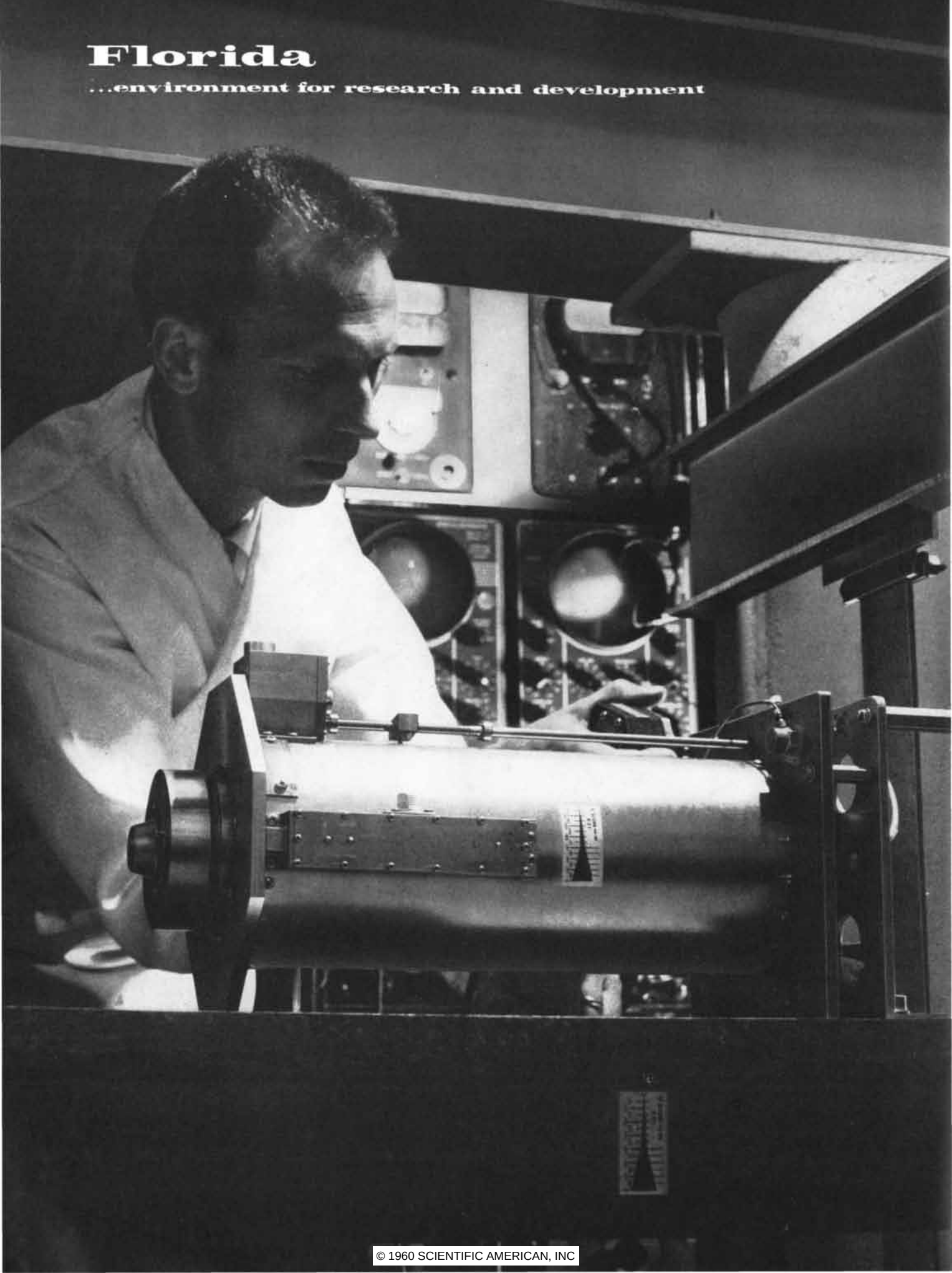

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Florida

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For one of its most vital activities — research — industry is finding that Florida provides an ideal location.

Some companies, such as Piper Aircraft Corporation, chose Florida locations originally for research activities and later decided to open factories as well. Piper, which established a development center at Vero Beach in 1957, is now adding a 400-man aircraft plant.

Others, such as Univis Lens Company, have found it advantageous to combine research and manufacturing with a single move to Florida. Ohio research and production facilities, and the New York plastic division are being brought to Fort Lauderdale. Some 75 key Univis technicians willingly agreed to move with the company.

In 1958, when the USI Technical Center, a division of U.S. Industries, Inc., was established in Pompano Beach, President John I. Snyder, Jr., stated that among the area's greatest attractions are "... many people with the specific kinds of engineering and scientific background which are required in our research and development work."

SKILLED PERSONNEL A KEY FACTOR

Several giant corporations, including Pratt & Whitney Aircraft, have publicly stated that Florida's ability to attract skilled personnel was a major reason for locating in the state. Recently, General Manager Charles T. Roelke commented: "In actual experience, we have had an average of 18 applicants for every job available."

Frequently, a large organization's success with one division's research and development operation in Florida has led to the opening of a second facility. An example is Minneapolis-Honeywell which in 1957 established an inertial guidance center in St. Petersburg. Last summer, the company opened a million dollar center for research and development in semi-conductor products near West Palm Beach.

Prototypes are checked by Electronic Communications, Inc., St. Petersburg, in the Southeast's best equipped environmental laboratory. Shown is vibration holding device with frequency range of 5 to 2000 cycles per second and maximum output of 1250 force pounds.

FROM NYLONS TO NUCLEONICS

Industrial research in Florida covers widely varied fields. Chemstrand Corporation dedicated a nylon development center at Pensacola last winter. International Minerals & Chemical Corporation studies ores from all parts of the world at its experiment station in Bartow. Chris-Craft Corporation operates its engineering and research facilities at Pompano Beach.

GENERAL NUCLEAR ENGINEERING CORPORATION is designing a nuclear power plant for Puerto Rico in its headquarters at Dunedin. In Miami, Dade Reagents, Inc., performs large scale serology research and in the same city National Spectrographic Laboratories, Inc., provides analytical services for industries throughout the United States and overseas.

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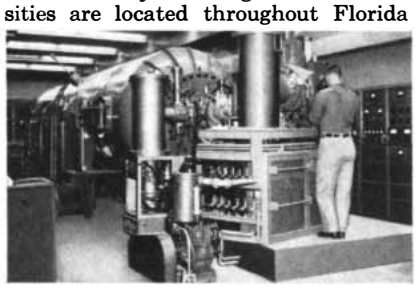

10-million electron volt Van de Graaff accelerator at Florida State University.

including the University of Florida at Gainesville, Florida State University at Tallahassee, the University of Miami at Coral Gables and the new University of South Florida at Tampa.

Work by the University of Florida on the proximity fuse in World War II and the development of prestressed concrete are internationally famous. The Florida Engineering and Industrial Experiment Station is described by Dean Joseph Weil as "research creating industry of tomorrow."

Fundamental research programs in physical, organic, inorganic, analytical chemistry and biochemistry are in progress at Florida State University. Florida is the first state in the nation to sponsor in its university system a program of nuclear science and engineering research with the cost of major facilities at state expense.

State co-operation has been a strong factor in the decision of such firms as Sperry-Rand to locate in Florida. During 1958 and 1959 alone, 27 new plants designed *primarily* for research and engineering were opened and expansions were announced by seven existing plants in the same category.

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In rate of overall industrial growth, Florida ranks first among the major states. Manufacturing employment has more than doubled in the last decade and is now well over 200,000.

Ten years ago, only a few hundred Floridians were employed in the manufacture of electrical machinery. Today the figure is almost 9,000.

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In Florida's "electronics triangle" bounded by Orlando, Cape Canaveral and Melbourne, more than 22,000 persons are employed in manufacturing and research in electronics, aircraft, missiles and scientific instruments.

Miami has become a world center for aircraft service and maintenance with over 200 manufacturers and distributors in the area.

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If you are interested in opening a plant or branch in Florida, a new booklet explains in detail how the Industrial Services Division of the Florida Development Commission can help you choose the most advantageous location.

This booklet describes special studies which can be prepared for potential locations covering markets, manpower, transportation and supplier industries as related to your individual needs.

Meetings with community leaders may be arranged, but unless authorized, your identity will not be revealed.

Write to B. R. Fuller, Jr., Exec. Dir., Florida Development Commission, 4016-4 Carlton Building, Tallahassee.

For more general information about industrial Florida, ask for the nine-part file folder, "Profile of Progress."

See industrial Florida for yourself. Write State of Florida, Dept. B, Carlton Building, Tallahassee, for a 100-page color "Vacation Guide."

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Primitive Architecture and Climate

Despite meager resources, primitive people have designed dwellings that successfully meet the severest climate problems. These simple shelters often outperform the structures of present-day architects

by James Marston Fitch and Daniel P. Branch

In the building of his shelter primitive man faces one supreme and absolute limitation: the impact of the environment in which he finds himself must be met by the building materials which that environment affords. The environment is scarcely ever genial, and the building materials are often appallingly meager in quantity or restricted in kind. The Eskimo has only snow and ice; the Sudanese, mud and reeds; the Siberian herdsman, animal hides and felted hair; the Melanesian, palm leaves and bamboo. Yet primitive architecture reveals a very high level of performance, even when judged in the light of modern technology. It reflects a precise and detailed knowledge of local climate conditions on the one hand, and on the other a remarkable understanding of the performance characteristics of the building materials locally available.

Of course primitive architecture, like primitive medicine or primitive agriculture, often has a magico-religious rationale that is of interest only to anthropologists. But its practice—that is, how things are done, as distinct from the reasons offered for doing them—is apt to be surprisingly sensible. (This illogical situation is characteristic of prescientific technologies: the Roman architect Vitruvius, writing during the reign of Augustus, gives excellent formulas for concrete and stucco, but his explanation of their "chemistry" makes no sense at all.) The primitive architect works in an economy of scarcity—his resources in materials and energy are severely restricted. Yet he has little margin for error in coping with natural forces: gravity, heat, cold, wind, snow, rain and flood. Both his theory and his practice are strictly determined by these conditions.

An understanding of this primitive experience is of more than academic interest today because, with the rapid industrialization and urbanization of the Western world, there is a growing tendency to minimize or ignore the importance and complexity of the natural environment. Not only is the modern architect quite removed from any direct experience with climatic and geographic cause-and-effect; he is also quite persuaded that they "don't matter any more." Yet the poor performance of most modern buildings is impressive evidence to the contrary. Many recent buildings widely admired for their appearance actually function quite poorly. Many glass-walled New York skyscrapers have leaked badly during rainstorms, and have had to be resealed at large cost. The fetish of glass walls has created further problems. The excessive light, heat and glare from poorly oriented glass places insuperable loads on the shading and cooling devices of the building—a problem that is often compounded in the winter when the air-conditioning machinery is turned off [see "The Curtain Wall," by James Marston Fitch; SCIENTIFIC AMERICAN, March, 1955].

Thus Western man, for all his impressive knowledge and technological apparatus, often builds comparably less well than did his primitive predecessor. A central reason for his failure lies in consistent underestimation of the environmental forces that play upon his buildings and cities, and consistent overestimation of his own technological capacities. Still, the worst he faces is a dissatisfied client. When the primitive architect errs, he faces a harsh and unforgiving Nature.

A few definitions are perhaps in order. As used here, the term "primitive" describes the buildings of preliterate societies, whether historical or current, whose general knowledge comes by word of mouth, whose training is by apprenticeship, whose industry is handicraft and whose tools are pre-Iron Age. Although the folk architectures of modern civilization often display the same kind of pragmatic sagacity as the primitive, they are of a qualitatively different order. The iron tools and the measurement systems of civilization immediately introduce factors such as modular building material (*e.g.*, brick, tile, dimensioned lumber) and repetitive structural systems (*e.g.*, Roman arcade, vaulted Gothic bay) which are antithetical to the plasticity of primitive structure. Literacy, on the other hand, introduces the disconcerting concept of a spectrum of building styles—an inconceivable situation to the primitive architect, to whom it has never occurred that there is more than one way to build. It is obvious that even primitive structures must have changed and evolved gradually over millennia, but at any given time the primitive architect was spared this unrecorded and forgotten history of styles. Indeed, knowledge of prehistoric architecture, as expressed in ordinary humble dwellings, is so scanty that this article will deal almost entirely with examples of primitive dwellings still being built in various parts of the world.

As used here, the term "performance" refers to the actual physical behavior of the building in response to environmental stresses, whether they be mechanical (snow load, wind pressure, earthquake) or purely physical (heat, cold, light). Civilization demands other sorts of performance from its architecture, but those faced by the primitive architect are basic and must be satisfied before more sophisticated performance is possible.

For the purposes of this discussion we are not concerned with plan, that is, the shape, size, scale or compartmentation given to architecture by problems of social exigency or cultural convention. For

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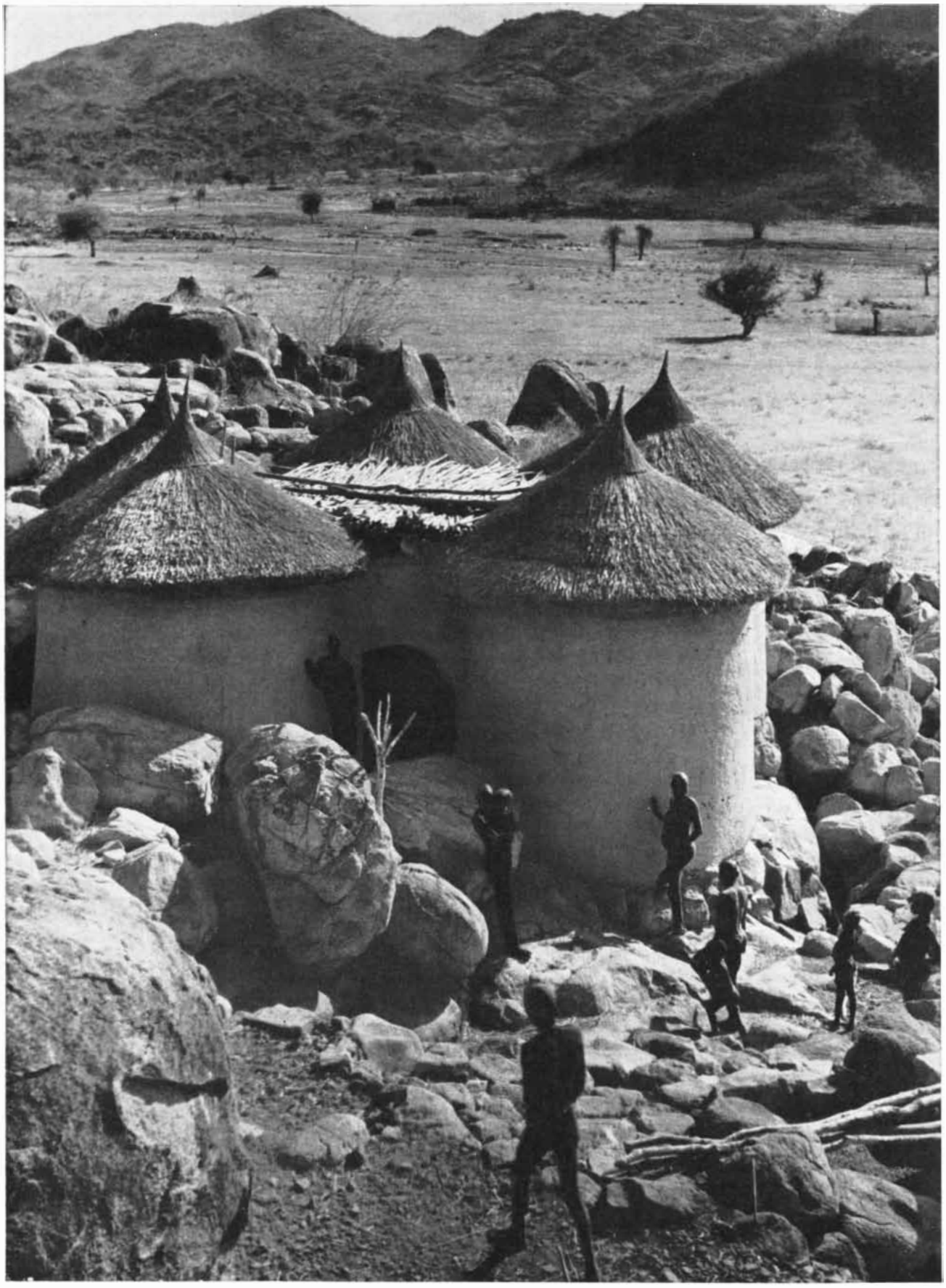

TIDY THATCHED HUTS are built by the natives of Kordofan, located in the Republic of the Sudan. This village lies 11 degrees north of the Equator in open savanna country. The climate requires a massive structure to absorb the intense solar heat. The huts are of adobe built on a solid rock foundation, which protects them from the water that pours down the hillsides when it rains.

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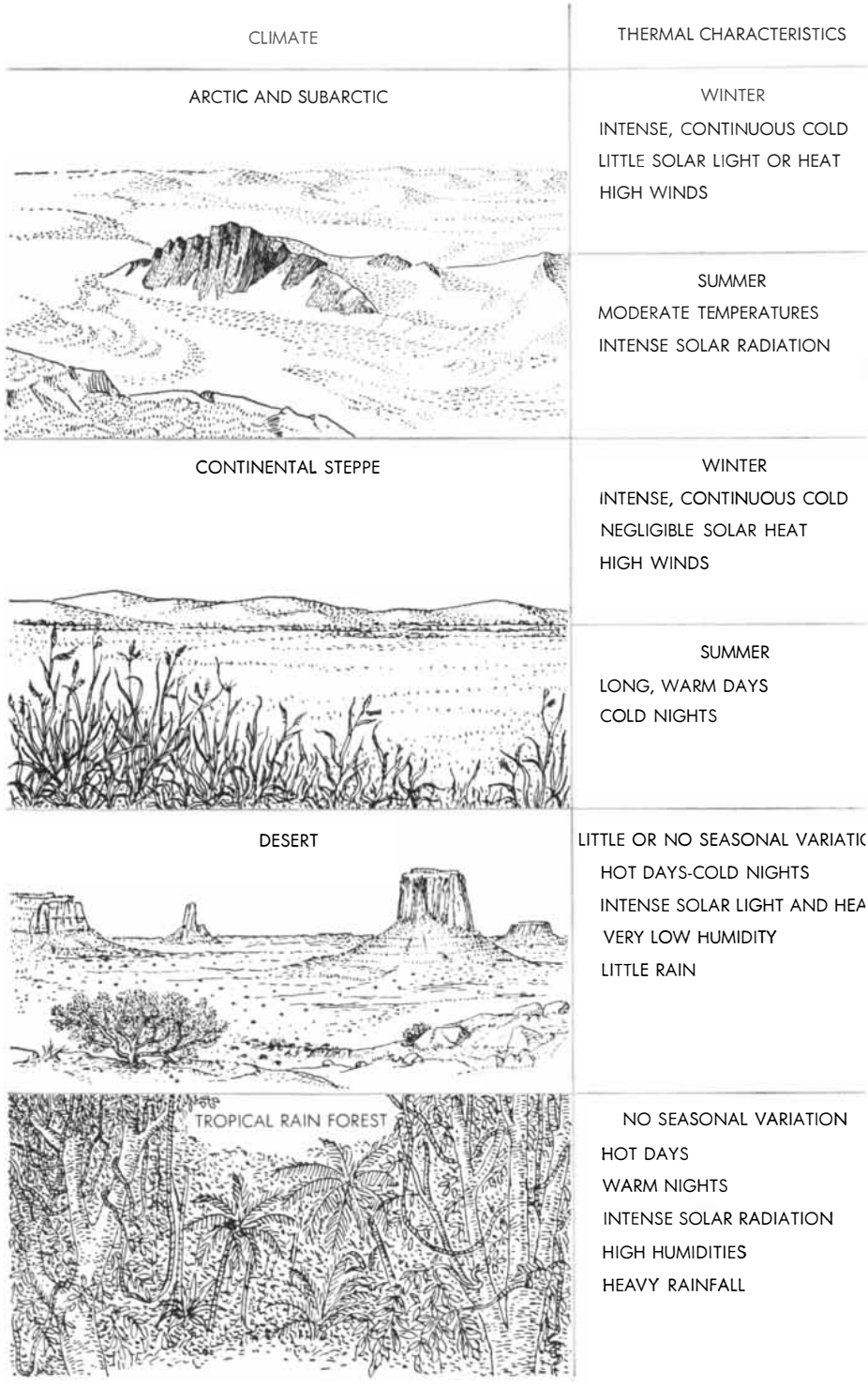
example, the exigency of organized warfare would add a moat and a wall to one plan, and the convention of polygamy would introduce a harem into another. Neither will have any significance except in relation to the culture that gave it birth. The significance of architectural structure, on the other hand, is absolute: a roof either supports a load of snow or it collapses; a wall either stands up to the wind or it falls. Even the simplest hut will have a plan, just as the most primitive society will have its taboos and conventions. But the simpler the plan requirements of a building, the clearer will be its aspect of environmental response.

When we contemplate the world's enormous range of temperature and precipitation, whose summation largely describes climate [*see illustrations at right and at top of pages 138 and 139*], we must be impressed by man's ingenuity. Of these two chief components of climate, it is heat and cold that present the primitive architect with his most difficult problem. In culture after culture the solutions he has found show a surprising delicacy and precision. Since thermal comfort is a function of four separate environmental factors (ambient and radiant temperatures, air movement, humidity), and since all four are in constant flux, any precise architectural manipulation of them demands real analytic ability, even if intuitive, on the part of the designer. In the North American Arctic and in the deserts of America, Africa and the Middle East he has produced two classic mechanisms of thermal control: the snow igloo and the mud-wall hut.

On a purely theoretical basis it would be hard to conceive of a better shelter against the arctic winter than the igloo. Its excellent performance is a function of both form and material. The hemispherical dome offers the maximum resistance and the minimum obstruction to winter gales, and at the same time exposes the least surface to their chilling effect. The dome has the further merits of enclosing the largest volume with the smallest structure; at the same time it yields that volume most effectively heated by the point source of radiant heat afforded by an oil lamp.

The intense and steady cold of the Arctic dictates a wall material of the lowest possible heat capacity; dry snow meets this criterion admirably, though at first glance it seems the least likely structural material imaginable. The Eskimo has evolved a superb method of building quite a strong shell of it, composed of snow blocks (each some 18 inches thick, 36 inches long and six inches high) laid in one continuous, insloping spiral. The insulating value of this shell is further improved by a glaze of ice that the heat of an oil lamp and the bodies of occupants automatically add to the inner surface. This ice film seals the tiny pores in the shell and, like the aluminum foil on the inner face of modern wall insulation, acts as a radiant-heat reflector. When, finally, the Eskimo drapes the interior of his snow shell with skins and furs, thereby preventing the chilling of his body by either radiant or conductive heat loss to the cold floor and walls, he has completed an almost per-



IMPACT OF CLIMATE and available building materials on the design of primitive dwellings is summarized in this chart. It describes the four climatic regions where the greatest variety of primitive architecture is still to be found. In the first three climate zones, control

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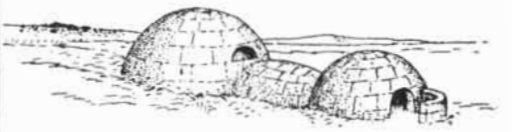
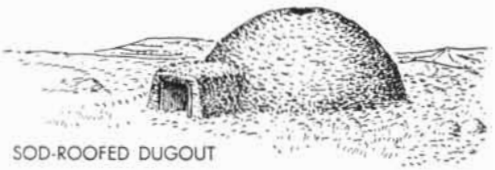
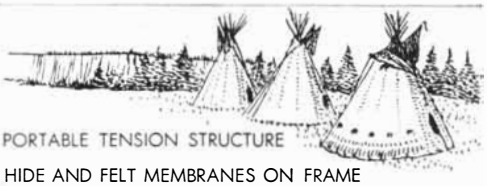
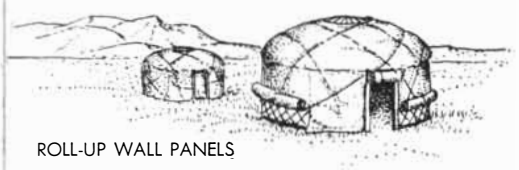
fect instrument of control of his thermal environment [*see illustration at bottom of next page*]. For the civilized Western nostril, the ventilation may leave something to be desired (it usually consists of a small opening somewhere near the top of the igloo). But odor is a subjective matter, and the oxygen supply is adequate for breathing and keeping the oil lamp alight.

Normally the igloo is a temporary structure. Like most primitive architecture, it sacrifices permanence to high performance. The wife of the noted explorer Vilhjalmur Stefansson, Evelyn Stefansson, reports on one that she observed. The inside walls began to drip when the outside temperature rose to 21 degrees Fahrenheit, and the structure collapsed the next day, when the temperature rose to 32½ degrees F. and it began to rain. But the Baffin Land Eskimos build permanent igloos of several units, connected by vaulted tunnels and

REQUIRED ARCHITECTURAL RESPONSE	RAW MATERIALS AVAILABLE	TYPE OF TENANCY	STRUCTURAL SYSTEM EVOLVED
LOW HEAT CAPACITY WALLS AND ROOF MINIMUM SURFACE, MAXIMUM STABILITY	SNOW	SEASONAL (HUNTING)	 SNOWDOME, ICE-AND FUR-LINED
HIGH HEAT CAPACITY ROOF AND WALLS	TURF, EARTH, DRIFTWOOD	SEASONAL (HUNTING-FISHING)	 SOD-ROOFED DUGOUT
LOW HEAT CAPACITY WALLS AND ROOF MINIMUM EXPOSED SURFACE, MAXIMUM STABILITY	ANIMAL SKINS, HAIR SAPLINGS	NOMADIC (HERDING)	 PORTABLE TENSION STRUCTURE HIDE AND FELT MEMBRANES ON FRAME
SHADE, VENTILATION LOW HEAT CAPACITY WALLS AND ROOF			 ROLL-UP WALL PANELS
HIGH HEAT CAPACITY ROOF AND WALLS SHADE MINIMUM VENTILATION NONWATERPROOF	MUD, STONES REEDS, PALMS, SAPLINGS	PERMANENT (AGRICULTURE)	 SOLID, LOAD-BEARING MUD-MASONRY WALLS ROOFS: MUD CEMENT ON WATTLE; POLE OR PALM TRUNK RAFTERS
LOW HEAT CAPACITY WALLS AND ROOF MAXIMUM SHADE MAXIMUM VENTILATION	VINES, REEDS, BAMBOO, PALM-FRONDS, POLES	PERMANENT (AGRICULTURE, FISHING)	 SKELETAL FRAME, THATCHED ROOF, WALLS SLOPING PARASOL ROOF STILTED FLOORS

of temperature is the crucial architectural problem. In the fourth heavy seasonal rains add to the difficulty. To solve his problems the primitive architect shrewdly exploits the limited materials available to him and works them into a structural form that admirably meets both the demands of the climate and the requirements of his particular culture: nomadic, hunting or agricultural.

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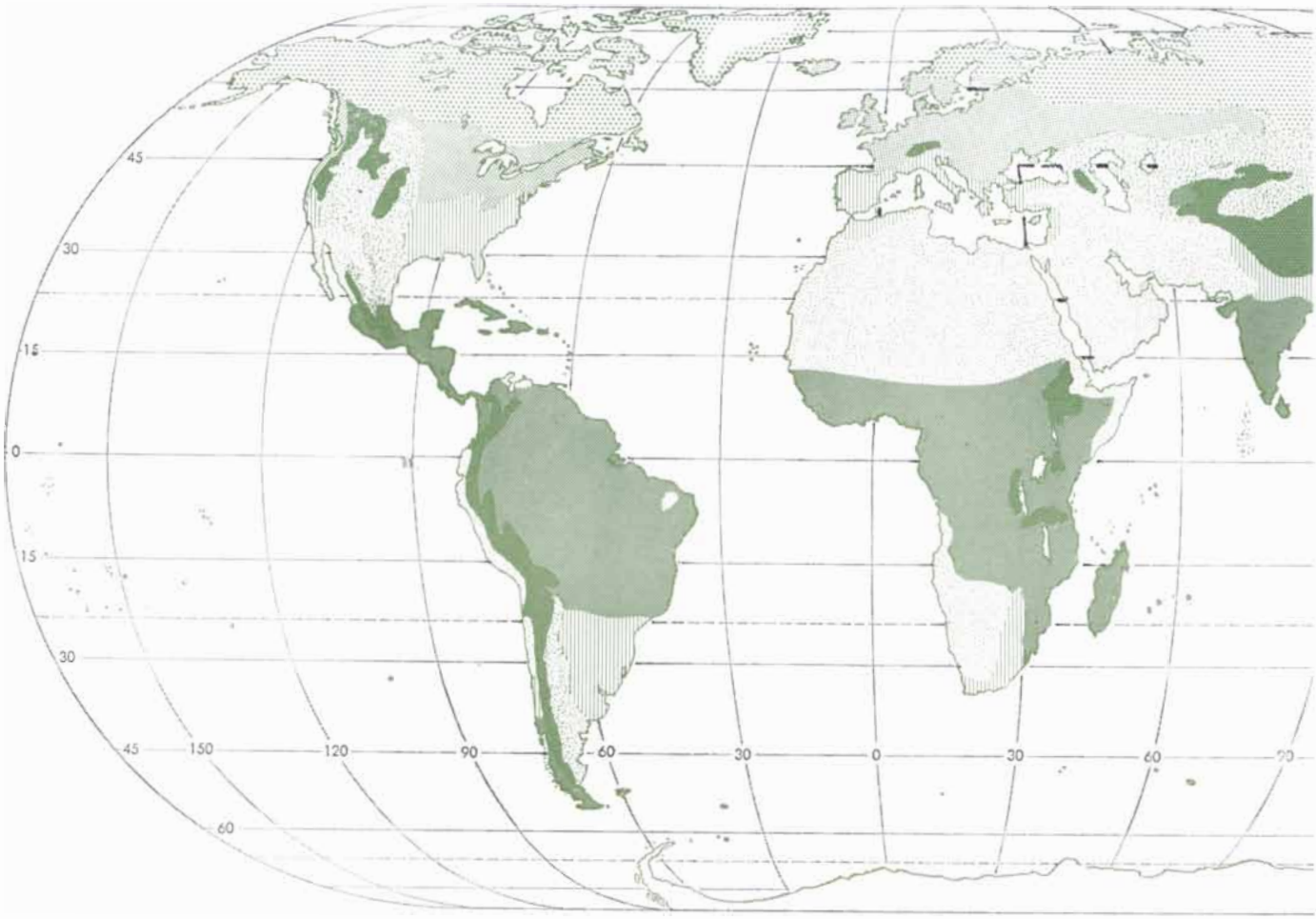
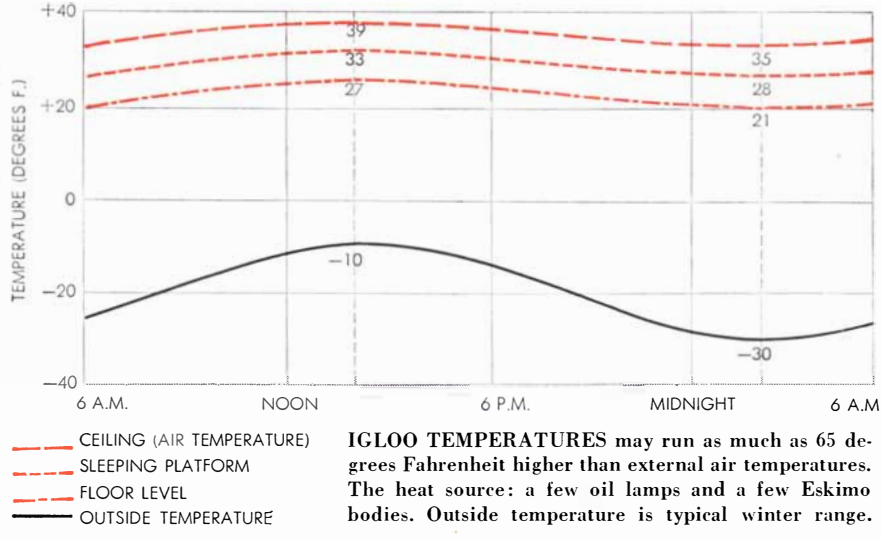


CLIMATE MAP identifies seven principal regions, all once occupied by primitive man. He has now been largely pushed out of the two most genial climate zones: the temperate and subtropical. Thus the primitive architect, where he still exists, has to cope with

airlocks to subsidiary units for food storage, dogs and equipment. In any case, the igloo melts no sooner than the Eskimo is ready to discard it. It didn't take him long to build, and it gives him first-class protection while it lasts.

If we turn to quite another type of thermal regime, that of the great deserts of the lower latitudes, we find an architectural response equally appropriate to radically different conditions. Here the characteristic problem is extremely high daytime temperatures coupled with uncomfortably low temperatures at night. Sometimes, as in the U. S. Southwest, wide seasonal variations are superimposed upon these diurnal ones. Against such fluctuations the desirable insulation material would be one with a high heat-capacity. Such a material would absorb solar radiation during the daylight hours and slowly reradiate it during the night. Thus the diurnal temperature curve inside the building would be flattened out into a much more comfortable profile: cooler in daytime, warmer at night [*see illustration at bottom of opposite page*]. Clay and stone are high heat-capacity materials; they are plentiful in the desert, and it is precisely out of them that primitive folk around the world make their buildings. Adobe brick and *terra pise* (molded earth) as well as mud and rubble masonry, appear in the Southwest; massive walls of sun-baked brick in Mesopotamia; clay mortar on reed or twig mesh in Africa from the Nile Delta to the Gold Coast. And the native architect evolves sophisticated variations for subtle changes in environ-



IGLOO TEMPERATURES may run as much as 65 degrees Fahrenheit higher than external air temperatures. The heat source: a few oil lamps and a few Eskimo bodies. Outside temperature is typical winter range.

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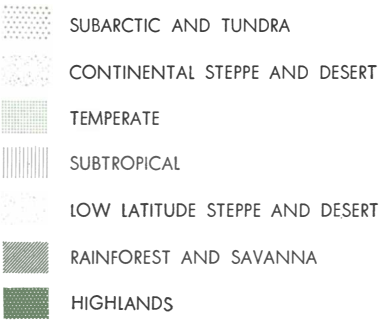
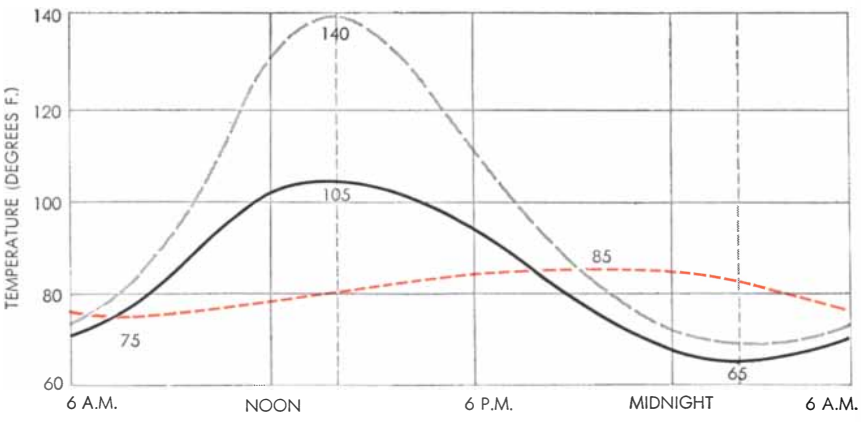


more difficult climate problems than those confronting the average modern architect.

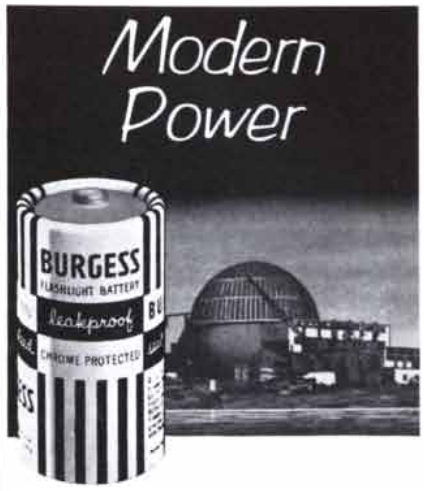
ment. Here, to avoid a sharp winter wind, the entrance door will be moved around to the lee; there, to get early morning solar heat, it will face the east. Where afternoons are cool, dooryard benches face the west; where hot, the shaded east.

Limited to what for us would be a pitifully meager choice of materials, the primitive architect often employs them so skillfully as to make them seem ideal. Africa, for example, has developed dozens of variations of the structural use of vegetable fibers (grasses, reeds, twigs, saplings, palm trunks) both independently and as reinforcement for mud masonry. In Egypt, where it seldom rains, flat roofs are practicable; hence mud walls carry palm-trunk roof beams which in turn support a mud slab reinforced with palm fronds. Other regions, although arid, will have seasonal rains; here sloping forms and water-shedding surfaces are necessary. The beautiful beehive hut appears. Built like a conical basket on an elegant frame of bent saplings and withes, the beehive hut is sometimes sheathed with water-repellent thatch; sometimes mud plaster is worked into the wattle; sometimes the two are combined, as in the huts of the Bauchi Plateau of Nigeria.

The Nigerians construct a double-shelled dome for the two seasons. The inner one is of mud with built-in projecting wooden pegs to receive the outer shell of thatch. An air space separates



ADOBE HOUSE TEMPERATURES compare favorably with those obtainable in modern air-conditioned homes. Moreover, the solar heat trapped by the roof slab in the daytime keeps the interior warm through the chill night.



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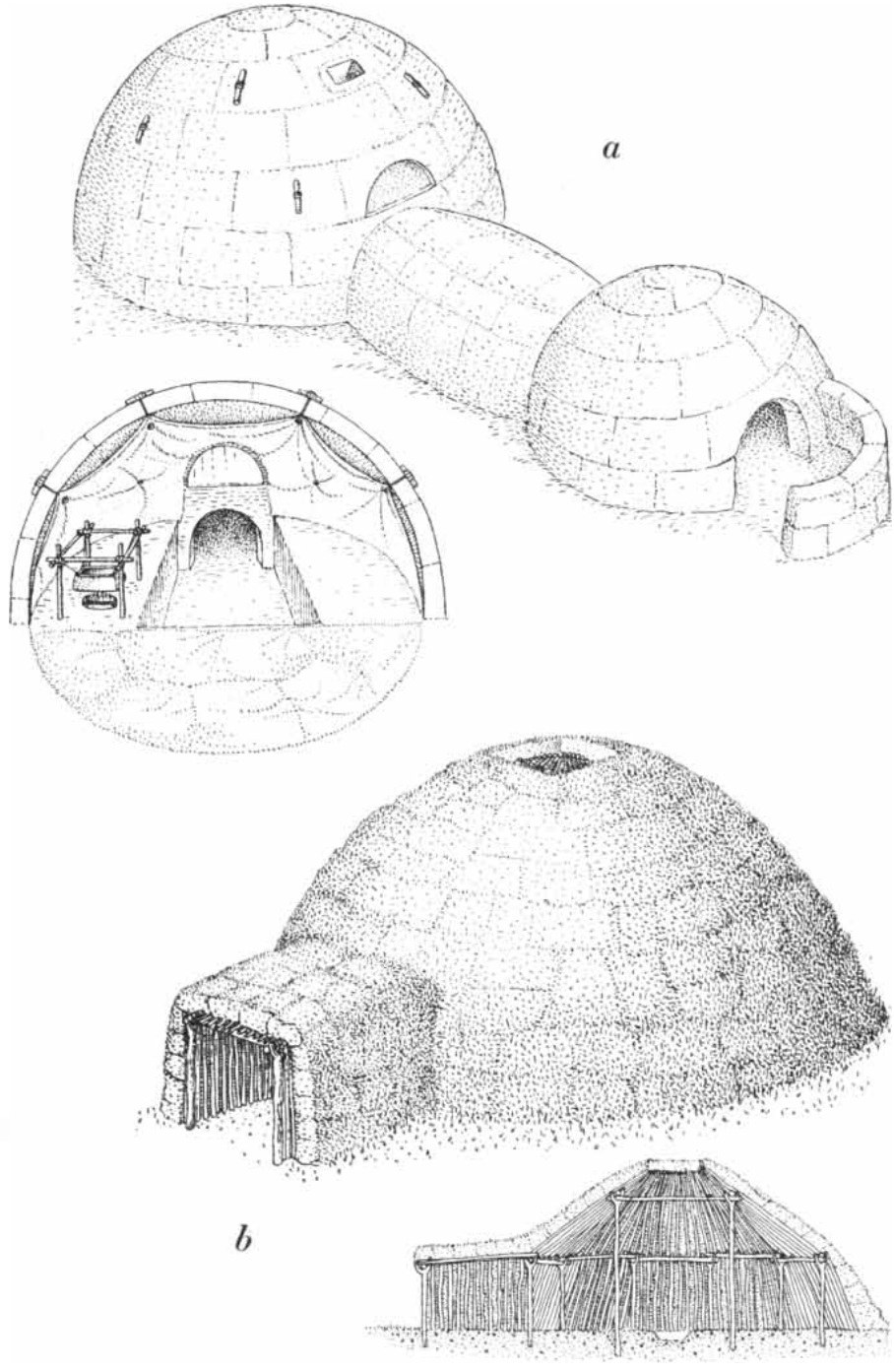
the two. This construction accomplishes three things: the thatch sheds water and protects the clay dome during the rainy season; the air space acts as additional insulation during hot days and the mud dome conserves heat for the cool nights.

The principle of reinforcing is well understood. The Ashantis of West Africa build truly monolithic structures of mud beaten into a reinforcing web of woven twigs. Moreover, we find that the mass of the wall is adjusted to meet varying temperature regimes. In the colder desert areas the walls will be very thick to increase their heat-holding capacity. Often, in fact, to benefit from the more stable earth temperatures, the houses will be built into a southern cliff face (U. S. Southwest, southern Tunisia, Shensi province in China). In warmer desert regions, where diurnal or seasonal variations are smaller, the wall mass can be greatly reduced by the reinforcing techniques described above. In these regions, too, intense radiation and glare are the source of discomfort. Here again we find the primitive architect alertly responsive. Door and window openings are reduced in size to hold down interior light levels, and walls are painted or stuccoed white to reflect a maximum amount of radiant heat.

The inner tropical zones of the earth confront the primitive architect with quite another set of comfort problems. Here heavy rainfall and high humidity are combined with moderate air temperatures and intense solar radiation. There is no seasonal, and very little diurnal, variation in temperature. Thus shade and maximum ventilation are the critical components of comfort. To reduce the heat-holding capacity of the walls and to maximize the air flow across the interior, the primitive architect reduces the wall to a minimum, or gives it up altogether. The roof becomes the dominant structural element: a huge parasol, steeply sloping to shed torrential rains, opaque to solar radiation and of minimum mass to avoid heat build-up and subsequent reradiation into the living space. This parasol roof usually extends far beyond the living space to protect the inhabitants against slanting sun and blowing rain. And the floors of these airy pavilions are sometimes raised on stilts for better exposure to prevailing breezes as well as for protection from snakes, rats and crawling insects. This is the basic architectural formula of the Seminoles of Florida, of the tribes of the Caribbean littoral and of the Melanesians. The materials employed are predominantly vegetable fibers of all sorts: saplings and bamboo, vines for lashing them together, shredded fronds and grasses. In the absence of iron tools the cutting and fitting of carpentry is totally missing; instead the techniques of assembly are the tying and weaving of basketry or textiles. Here again, from the point of view of environmental response, the primitive designer shows an acute understanding of the local problem and a precise understanding of the properties of local materials.

In the outer tropical zones other refinements appear. Here the climate is characterized by two distinct seasons:



PRIMITIVE DWELLINGS, viewed as engineering structures, extract remarkably high performance from commonplace materials. Eskimo igloo (*a*) is built from snow blocks 18 inches thick that have insulating value equivalent to two inches of glass fibers. When lined with skins (*detail drawing*) the temperature of the interior can be raised to 40 degrees F. without melting the dome. Summer house of Nunamiut Eskimos (*b*) follows igloo plan,

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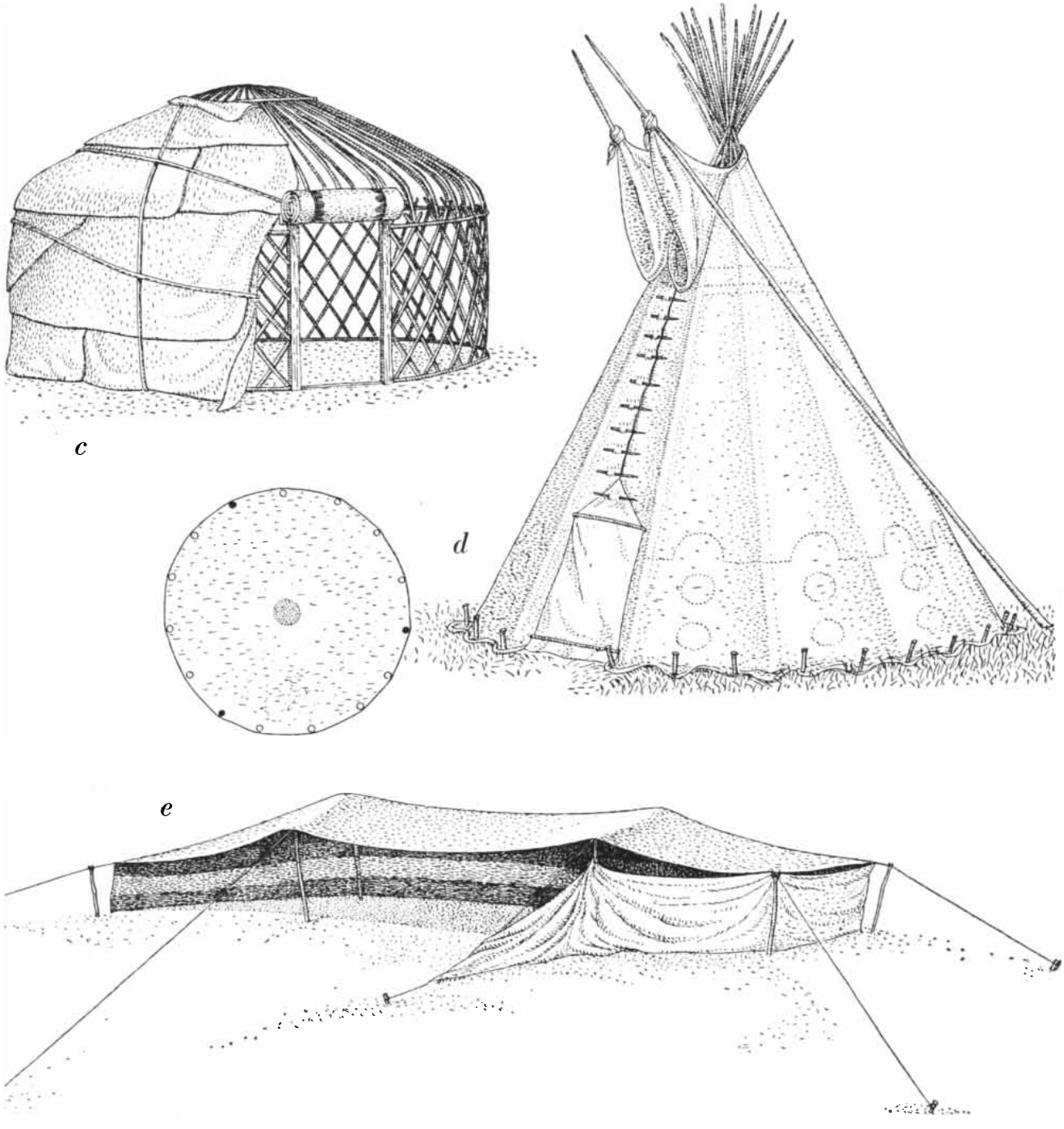
one very wet and one very dry. (Both are hot.) Vegetable fibers are still employed, but in varying techniques, to achieve a wide range of permeability to heat and air. Thus certain tribes of Natal in South Africa build a hut whose light wooden frame is sheathed in woven fiber mats. The weave of these mats contracts in dry weather, permitting the movement of air through its interstices; but the fibers expand in wet weather, converting them into nearly waterproof membranes. In the huts of the Khosian tribe of South Africa these mats are detachable and can be moved from wall to wall according to wind direction.

Naturally many other forces beyond the purely climatic are at work in shaping primitive architecture. The culture and means of subsistence will determine whether the shelter be permanent, mobile, seasonal or purely temporary. If the culture is a hunting one, like that of the Indians who once inhabited the



but is made of sticks covered with slabs of turf. The yurt, or Kazak tent (*c*), is among the most ingenious and weatherproof of the many types of demountable dwelling conceived by nomadic tribes. Its lightweight willow walls fold up like a child's safety gate. The covering is felt, sometimes two-layered with an air space between. The familiar Indian tepee (*d*) has a hide covering that can be closed weathertight or opened variably. Floor plan of tepee shows the three poles (*solid circles*) that are erected first. Bedouin tent (*e*), usually of woven goat hair, is primarily a sunshade, but, when required, must serve as a protective shield against sandstorms.

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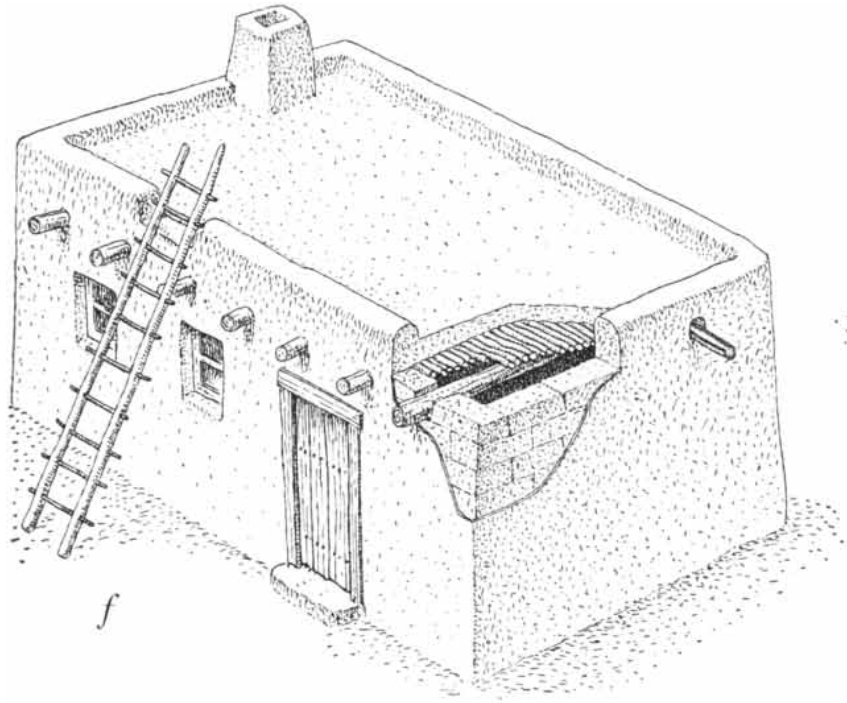
Great Plains of North America; or a herding one, like that of the peoples of the Asiatic steppes, the architecture will tend to be demountable and mobile. But it will not be expendable, because suitable building materials are not readily available on the open steppe or prairie. (The sod dugout would make sense only in a permanent settlement.) Hence the structurally brilliant invention of the tent —light in weight, composed of small members and easily erected, dismantled and packed. At the same time, if we judge it by the modern structural criterion of "the most work from the least material," the tent (like all tension structures) ranks as a very advanced form of construction. The basic type has been modified to meet a wide variety of climates: The American Indians covered the skeleton with skins; the Australian aborigines, with bark; the nomads of northern Asia, with felted hair; the nomads of the Middle East, with woven



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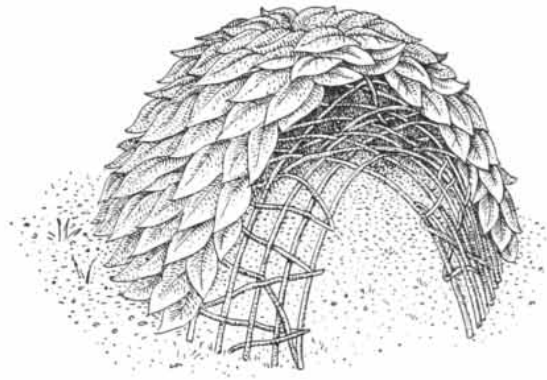

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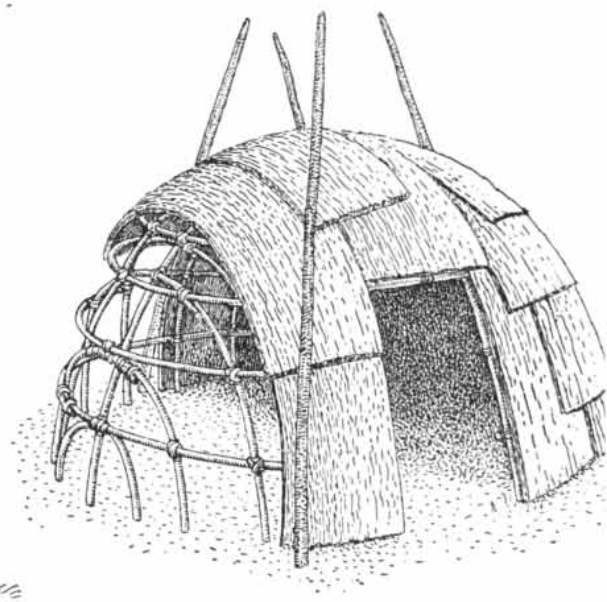

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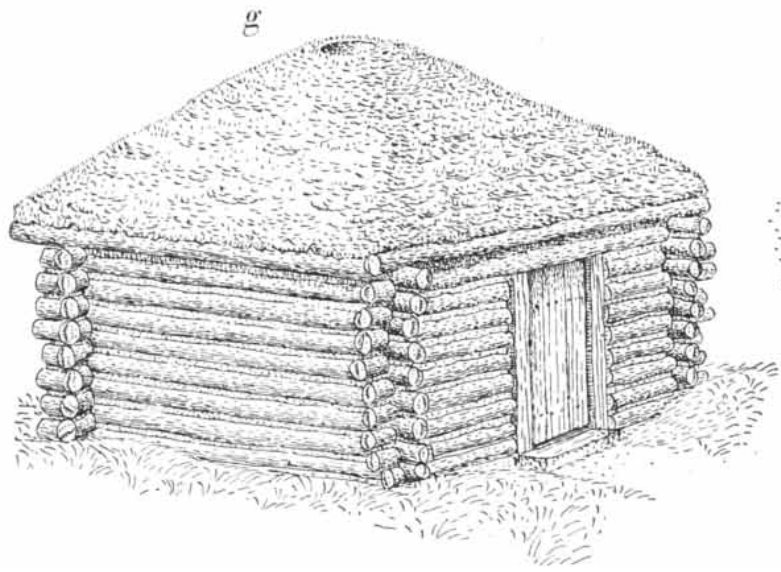

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TROPICAL DWELLINGS, including one for temperate climate, reflect a great disparity in sophistication, but all are effective shelters. The adobe house (*f*) of Indians of the Southwest is built of baked mud bricks with a smooth mud-plaster exterior. The massive roof is ideally designed to absorb the midday heat. The Navajo hogan (*g*) is usually much cruder, consisting of mud daubed on a rough wooden frame. (The one illustrated is neater than most.) The simple hut (*h*) of the Banbuti Pygmies (northeastern Congo) is a woven frame of twigs covered with large leaves. Since it is protected by the deep shade of the forest it does not need massive

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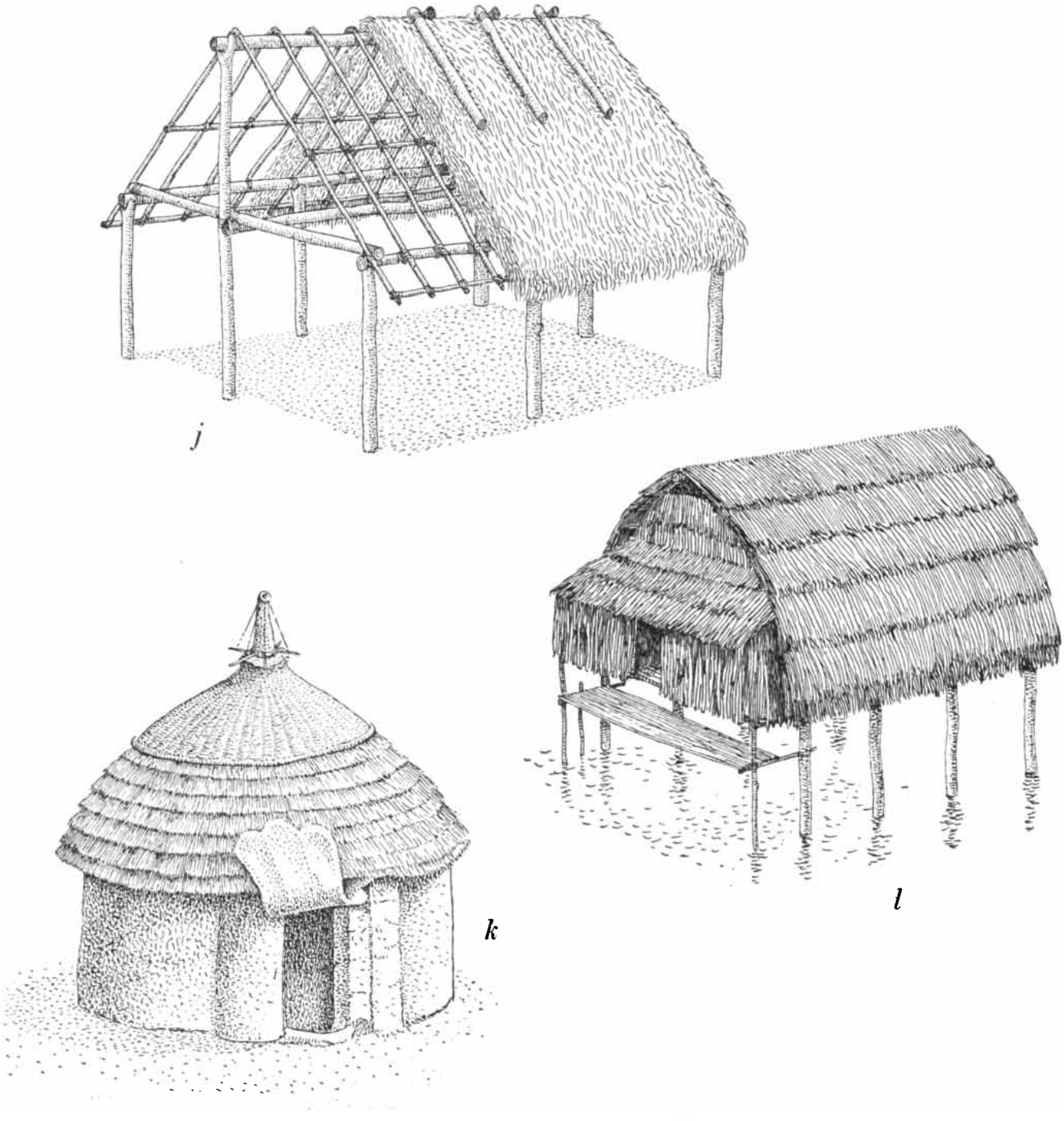
cloth. Perhaps the most advanced form, in the bitter cold of Siberia, was that developed by the Mongol herdsmen. Here the demand for effective thermal insulation is met by two layers of felt stretched over the inside and outside of a collapsible wooden trellis. The elliptical dome, staked to the earth, furnishes excellent protection against the high winds and bitter cold of Siberia.

One could extend this catalogue of human ingenuity indefinitely. But the examples cited are surely adequate to establish the basic point: that primitive man, for all his scanty resources, often builds more wisely than we do, and that in his architecture he establishes principles of design that we ignore at great cost. It would be a mistake to romanticize his accomplishments. With respect to civilized standards of scale, amenity, safety and permanence, the actual forms of his architecture are



heat-absorbing walls and roof. The Chippewa hut (*i*) closely resembles the Pygmy hut except that it is covered with birch bark. It affords a snug shelter against the weather characteristic of the U. S. Great Lakes region. The Seminole Indian house (*j*) anticipates the open, airy structures so admired by today's civilized Florida dwellers. In the Lake Chad region of Africa the local tribes build a cylindrical adobe hut (*k*) with a conical thatched roof. This roof, like that of the stilt house (*l*) of the Admiralty Islands off New Guinea, is most effective in shedding rain. In World War II the Pacific troops found such roofs much drier than a tent.

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totally unsuitable. Neither is there any profit in the literal imitation of his handicraft techniques or in the artificial restriction of building materials to those locally available. Primitive architecture merits our study for its principles, not its forms; but these have deep relevance for our populous and ill-housed world. If we are to provide adequate housing for billions of people, it cannot be on the extravagant model of our Western urbs, suburbs and exurbs. The cost in building materials and in fuels (for both heating and cooling) would be altogether prohibitive for the foreseeable future.

Western science may be able to measure with great accuracy the environmental forces with which architecture deals. But Western technology—especially modern American technology—too often responds with the mass production of a handful of quite clumsy stereotypes. This is obvious, for example, in the thermal-control features of our architecture. In the house or the skyscraper, generally speaking, we employ one type of wall and one type of roof. The thermal characteristics of these membranes will be roughly suitable to a thermal regime such as that of Detroit. Yet we duplicate them indiscriminately across the country, in climates that mimic those of Scotland, the Sahara, the Russian steppes and the subtropics of Central America. The basic inefficiency of this process is masked by the relative cheapness of fuels and the relative efficiency of the equipment used to heat, cool and ventilate our buildings. But the social waste of energy and material remains.

Contemporary U. S. architecture would be greatly enriched, esthetically as well as operationally, by a sober analysis of its primitive traditions. Nor would it be stretching things to include in these traditions the simple but excellent architecture of the early white settlers who, in many respects, were culturally closer to primitive man than to 20th-century man. The preindustrial architects of Colonial and early 19th-century America produced designs of wonderful fitness: the snug, well-oriented houses of New England, the cool and breezy plantation houses of the deep south, the thick-walled, patio-centered haciendas of the Spanish Southwest. All these designs should be studied for the usefulness of their concepts, and not merely be copied for antiquarian reasons.

PUEBLO in Taos, N.M., is one of two multistoried structures that were in existence at the time of the Spanish conquest in 1540.

INDO-CHINESE VILLAGE illustrates how primitive architects turn traditionally to adobe when climate calls for heat absorption.

ZULU KRAAL in Union of South Africa answers climate problem with thatched huts built on woven framework of light branches.

SOUTH SEA VILLAGE on Alor Island near Borneo shows light parasol construction so admirable for regions of heavy rainfall.

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PORES IN THE CELL MEMBRANE

Molecules and ions pass in and out of the cell through tiny openings in the cell wall. Although the holes are too small to be seen with an electron microscope, their size has been measured experimentally

by Arthur K. Solomon

The living cell carries on a constant traffic with its surroundings. Like every other device, animate or inanimate, that does work, it must take in fuel and excrete waste products. Many cellular activities, such as the contraction of muscle and the transmission of nerve impulses, are accompanied by a shift of ions in one direction or the other. Tracing this pattern of flow is one of the major tasks of cellular biophysics, engaging investigators all over the world.

It is quite clear that the cell's outer membrane is not merely a passive barrier. Under the electron microscope it is revealed as a complex structure about 100 angstrom units thick. (An angstrom unit is a hundred millionth of a centimeter.) Some materials pass directly through the fabric of the membrane, either by dissolving in the membrane or by interacting chemically with its substance. But it seems equally certain that a large part of the traffic travels via holes in the wall. These are not necessarily fixed canals; as the living membrane responds to changing conditions inside or outside the cell, some pores may open and others may seal up. Nevertheless there is good reason to conceive of the membrane as containing, on the average, a uniform number of holes. Thus an understanding of the transport system turns on the question: How big are the holes? Our laboratory at the Harvard Medical School has devoted a good part of the past six years to this problem in molecular biology.

At the outset we had certain clues to the range in which the pore diameter must lie. These came primarily from observations of the behavior of sodium. Blood plasma and other extracellular fluids are chiefly solutions of sodium chloride—ordinary salt. On the other hand, the dominant salt within the cell is potassium chloride. Sodium, which leaks into the cell from the outside, is removed by a mechanism called the sodium pump. The principles of operation of this mechanism are still unkown. Clearly the work that the pump has to do is related to the size of the sodium leak. And if the work load is not to be very heavy, the pore diameter should not be much greater than the diameter of the sodium ion in water.

Both sodium and potassium ions in water solutions travel surrounded by a shell of water molecules. The diameter of the hydrated sodium ion is roughly five angstrom units. Thus the concept of a pore with a diameter of five to 10 angstrom units seemed an attractive working hypothesis.

There are three ways to measure the size of a hole: (1) directly, by placing a graduated scale across the entrance; (2) indirectly, by probing the hole with particles just large enough to be excluded by it; (3) inferentially, from the friction the hole exerts on particles small enough to pass through it. A hole 10 angstroms across cannot yet be resolved, even by the electron microscope. Therefore there was no hope of measuring the pores in the cell membrane directly.

The second method would have been quite simple if the probing particles (that is, individual molecules) were available in an infinitely fine gradation of sizes. But molecular size jumps discontinuously as more atoms are added, and so we could not be sure that the smallest excluded particles would be only minutely larger than the holes.

Accordingly we chose the third approach. It is also difficult; in retrospect it presents substantially greater problems than we had bargained for when we first embarked on the enterprise.

We first set out to measure the speed at which water diffuses across the cell membrane. In itself this measurement could not determine the average size of the individual pores, but it would tell us something about the total cross-sectional area of all of them. Specifically, the rate of diffusion is a measure of the total area of the pores divided by their average length: A/L.

For our experiments we chose human red blood cells. They are easy to isolate, since they float freely in their natural environment and are not attached to other structures in the body. Our plan was to immerse red cells in a solution containing water molecules labeled with atoms of radioactive hydrogen (tritium), and to determine the rate at which the labeled water entered the cells. This was not easy to do, because the reaction is very fast. The exchange of ordinary water inside the cell with radioactive water outside is essentially complete in only 20 milliseconds (thousandths of a second).

To follow the progress of the rapid diffusion, we adopted a method for studying fast reactions that was devised some 20 years ago by Hamilton Hartridge and F. J. W. Roughton of the University of Cambridge. The reacting substances are stored in separate containers and are discharged through fine jets into a chamber where they are mixed thoroughly and instantaneously. From the chamber the liquid passes into a long observation tube, through which it flows under pressure at a controlled and constant rate. The reaction begins as soon as the two streams make contact, and continues as the mixture moves down the tube. Thus at every point along the tube the reaction will have been proceeding for a definite, known length of

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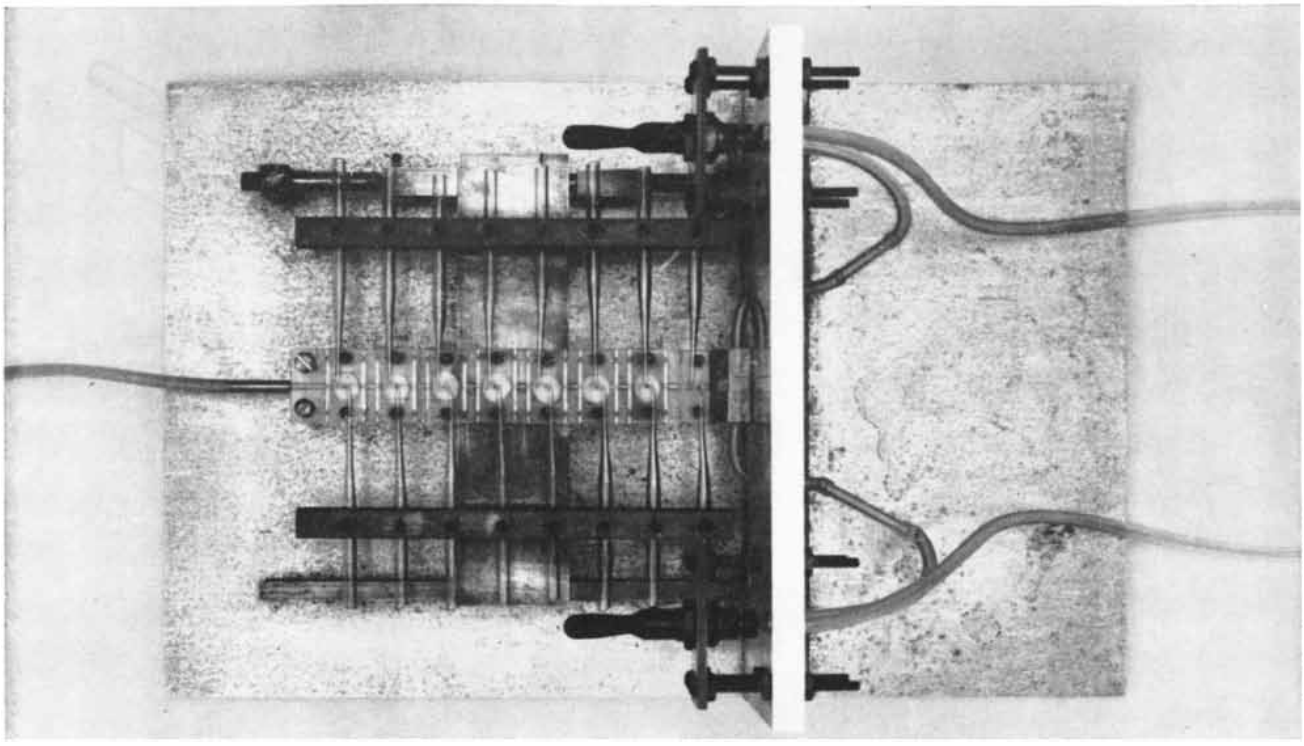
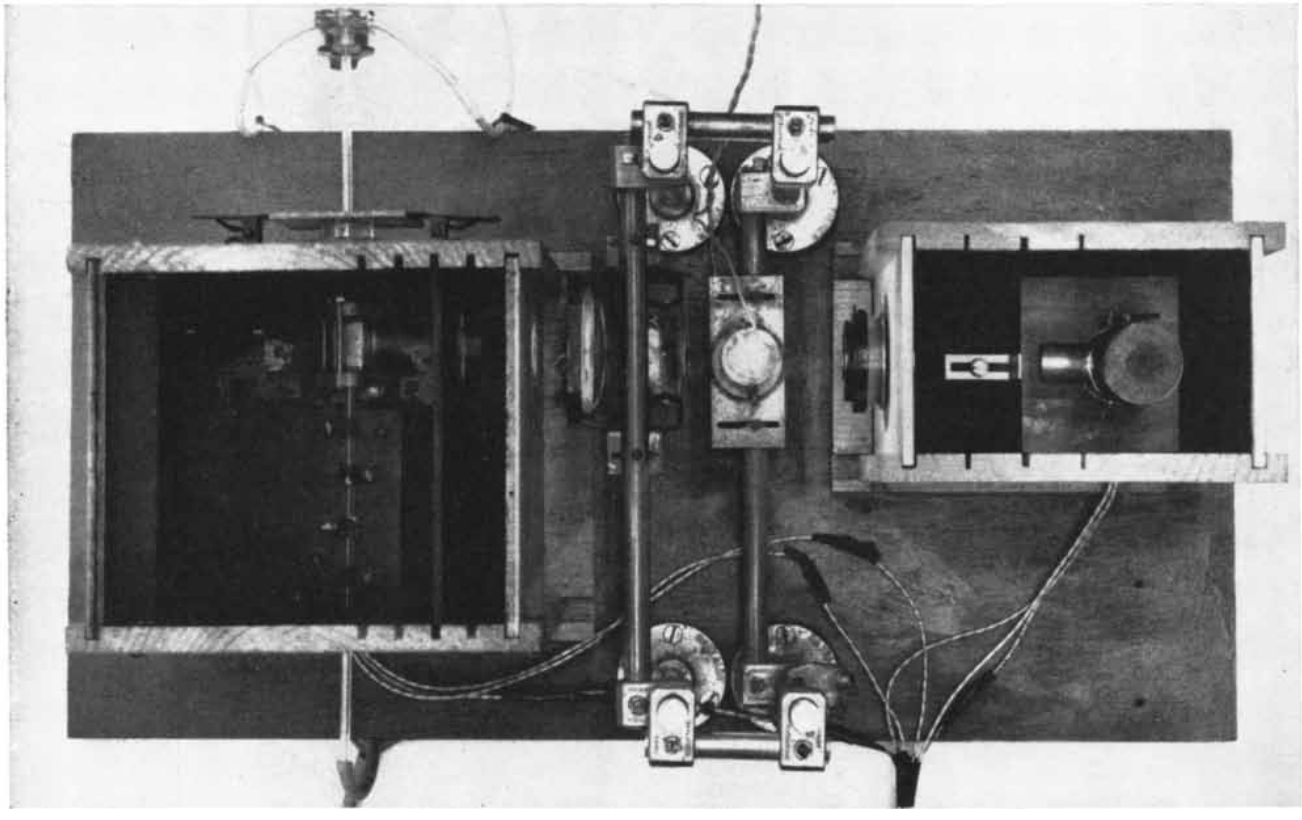


RAPID-FLOW APPARATUS was devised to study diffusion of water through membrane of human red blood cell. Tube extends through lucite block (*center*) from right to left. Suspension of red cells entered through one of the plastic tubes at right, and a solution of radioactive water entered through the other. Solutions mixed and traveled down observation tube. Samples were drawn off through the rows of glass tubes on both sides of observation tube. Diminished radioactivity of samples indicated diffusion rate.



LIGHT-SCATTERING APPARATUS is used to measure the volume of the red cells. Rate of change of volume of cells is a measure of rate at which substances move in or out through cell membrane. Volume of cells is determined by measuring the amount of light they scatter. Here a suspension of cells flows through the glass tube at left. Light from source at center strikes the suspension of cells and is scattered at right angles by a prism. Intensity of scattered light is measured by a photocell (*not visible*) and is compared to intensity of source (measured by photocell at right). Diagrams of the apparatus in these photographs appear on next page.

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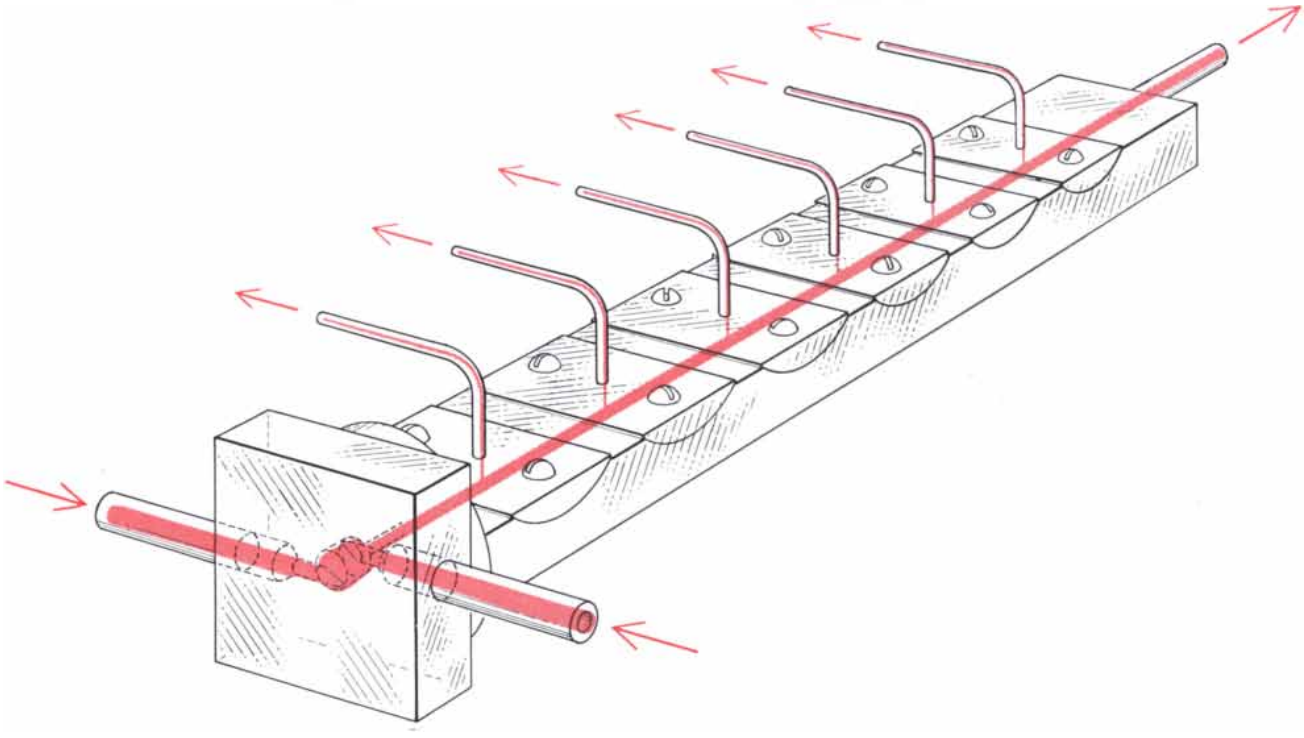

DIAGRAM OF DIFFUSION APPARATUS shown in photograph at top of preceding page indicates how suspension of red cells is mixed with radioactive water. Here the two liquids (*color*) enter at left and flow through observation tube and sampling tubes.

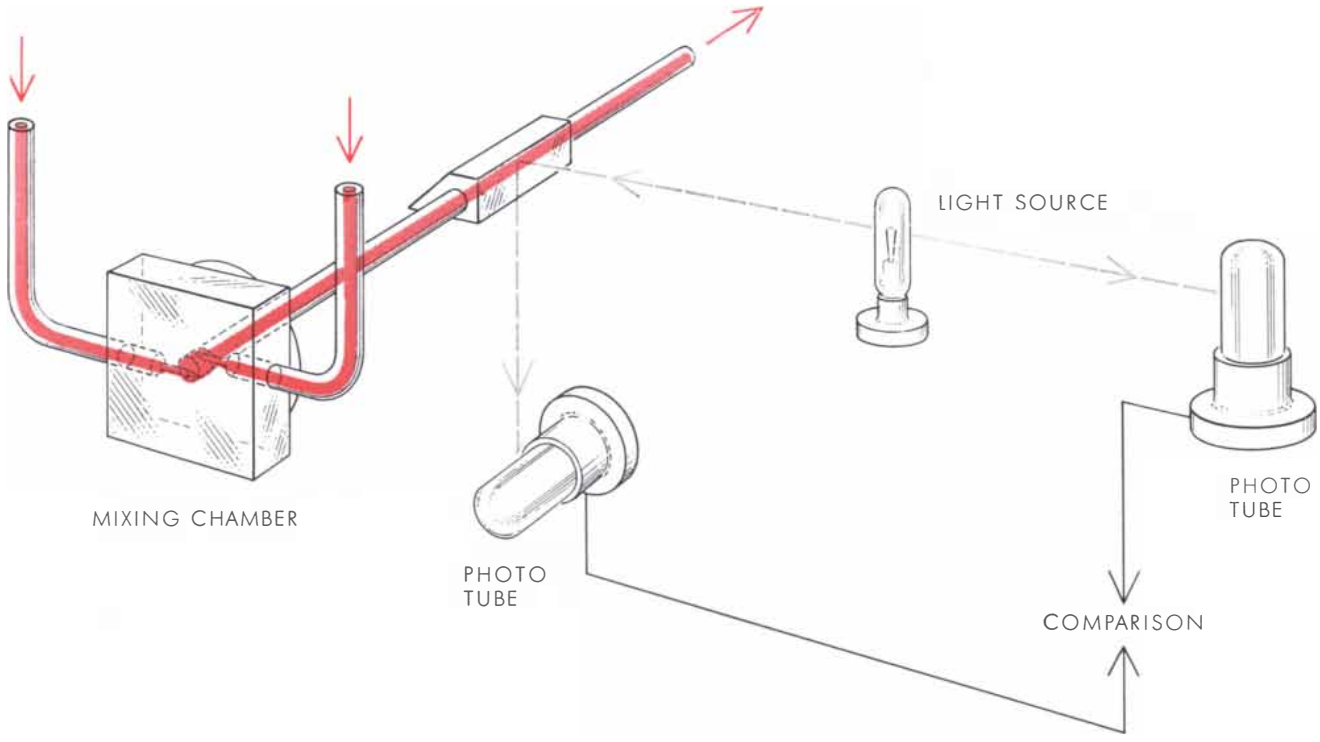

DIAGRAM OF LIGHT-SCATTERING APPARATUS shown in photograph at bottom of preceding page indicates how light scattered by suspension of red cells reaches the phototube (*bottom*). The output of this phototube is compared electronically to the brightness of the source, as measured by the phototube at far right. The observation time can be varied by moving the mixing chamber.

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time. Observing the solution at various distances from the mixing chamber provides, in effect, a time exposure of successive stages of the very fast reaction.

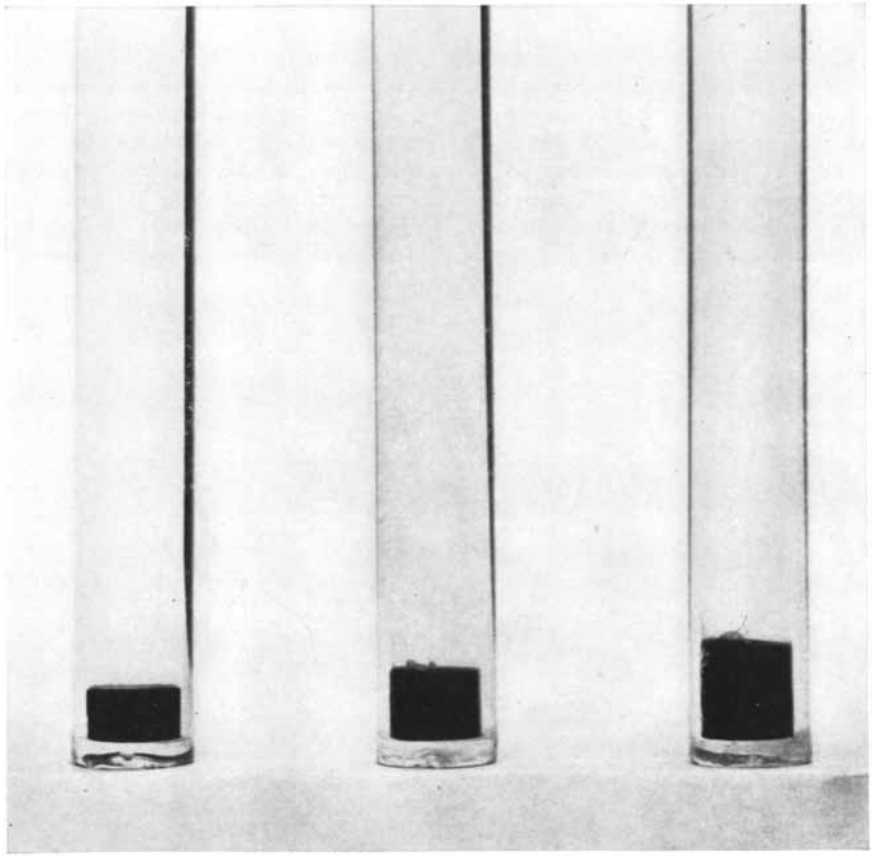
In the arrangement that Charles Paganelli and I devised [*see illustrations at left and at top of preceding page*] radioactive water and a solution of red cells were injected into a small, cylindrical chamber. After mixing, the fluid traveled down the observation tube at a rate of 10 meters per second (about the speed of a slow freight-train), so that a distance of one centimeter corresponded to a time interval of one millisecond. Of course red cells do not change appearance when they take up radioactive water, so we could not follow the reaction visually. Instead we collected samples of the tritium solution at intervals of about 1.5 centimeters. The pressure of two atmospheres that propelled the fluid through the system was enough to force water through ports sealed with Millipore filter paper (a special paper fine enough to hold back red blood cells). Small samples of fluid from each port were carefully diluted, and their radioactivity was determined by a very accurate procedure developed by Charles V. Robinson in our laboratory. From the activity of the liquid emerging from each port we could tell how much tritium had left the solution at that point and had therefore entered the cells. Observations covering the first nine milliseconds established that the half-time of the reaction—the time in which the cells take up half the equilibrium amount of radioactive water—was 3.6 milliseconds under our experimental conditions.

As has already been mentioned, this half-time enabled us to calculate the ratio of the total cross-sectional area of the pores to the average pore length (A/L). To derive the diameter of the individual pores from this ratio, we would have had to know the number of pores and their average length. We had no way of estimating the number of pores. As to the length, there was no guarantee that the path of the pores through the membrane was direct. In cellophane, for example, the pores have been found to be long and tortuous. Consequently we had to turn to another type of experiment for additional data.

The resistance offered by a pipe to the one-way flow of liquids under pressure is different from that opposing the two-way process of diffusion. It too is related to the diameter, but by another law, known as Poiseuille's law after the French physician who first placed the study of fluid flow on a quantitative basis. Applied to a membrane containing small pores, Poiseuille's law shows that the rate at which liquid crosses the membrane under pressure depends on the square of the pore diameter, as well as on total area and length ($d^2 \times A/L$). Thus by measuring the flow rate under pressure the value of $d^2 \times A/L$ can be determined. Substituting the value of A/L obtained in the diffusion experiment then leads to the diameter.

When we began our work, the possibility of finding pore diameters by combining two experiments had already been pointed out by John R. Pappenheimer of the Harvard Medical School and H. H. Ussing of Denmark. Pappenheimer had used the method to determine the size of the pores in the capillary bed in the leg of a cat. This membrane consists of many cells, held together by a connective material. We now proceeded to apply the same technique to determining the pore diameter in a single cellular membrane—that of the red cell. Since human red cells are small (some .0008 centimeter in diameter), it is not possible to apply hydrostatic pressure to one side of the membrane to force water to move across it in bulk. Instead we used the force of osmosis to push water through the membrane. The reader will recall that osmotic pressure results from the tendency of solutions separated by a porous membrane to equalize their concentrations. In classical demonstrations of the effect a solution of large molecules, such as polymer molecules, in one chamber is connected through a membrane to a chamber containing pure water. The membrane is semipermeable: its pores are small enough to admit water molecules but not polymer molecules. Water now passes into the polymer solution, raising the pressure in that chamber to a value that exactly balances the tendency of the water to move in. When the system reaches such an equilibrium, the flow stops.

Although the experiment is usually performed in the way just described, the liquid in the second chamber need not be pure water, but can also con-



RED BLOOD CELLS (*dark masses in tubes*) shrink or swell if immersed in a solution with an osmotic pressure different from their own. Each tube contains same number of cells. Cells in center are normal size. Cells in tube at left shrank after being placed in concentrated salt solution; cells in tube at right swelled after being placed in dilute salt solution.

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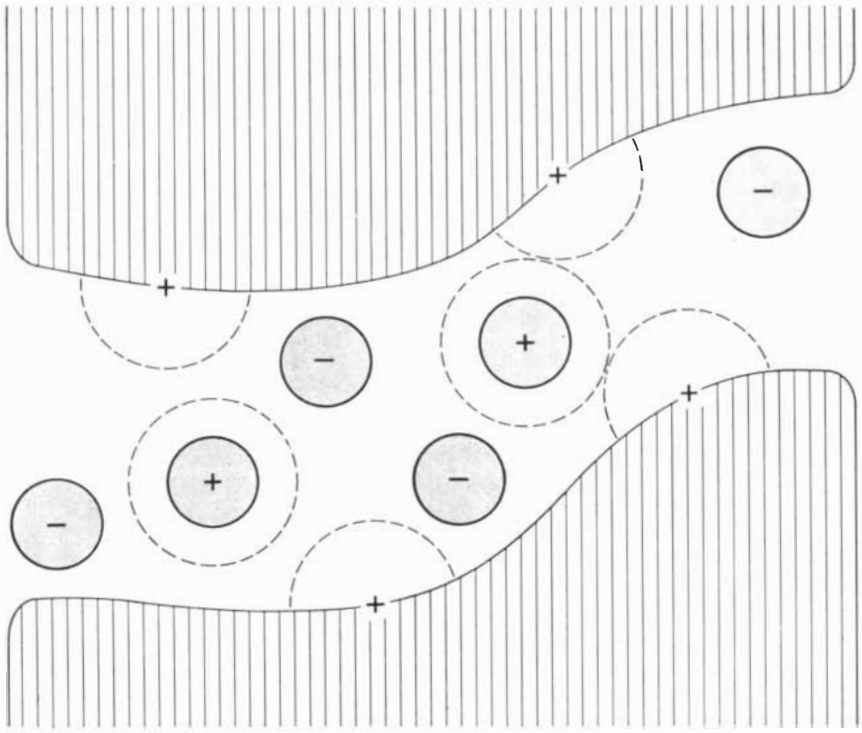
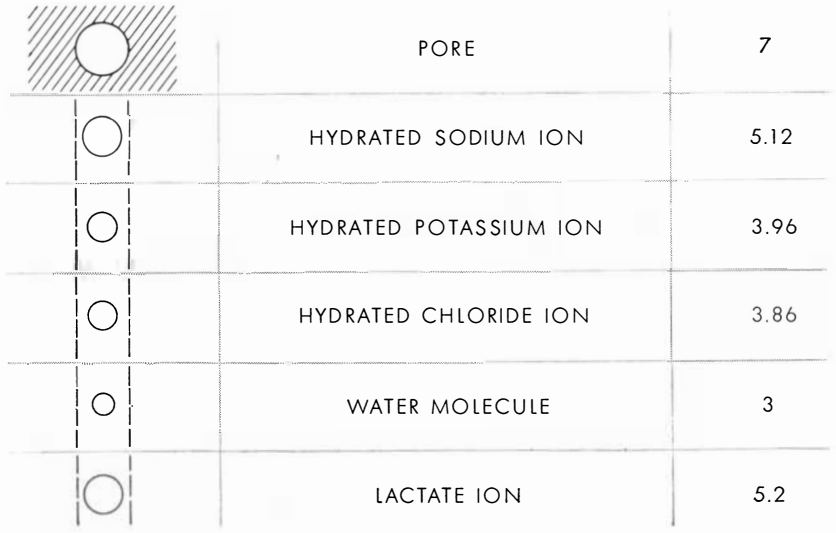


PORE in cell membrane is depicted in this schematic diagram. Pore is lined with molecules bearing a positive charge. "Sphere of influence" of these positive charges (*broken circles*) hinders the passage of positively charged ions, but does not retard negatively charged ones.

tain polymer. As long as there is a difference between the initial concentrations on the two sides of the membrane, osmotic pressure will develop, the amount of pressure depending on the relative concentrations. Thus a red cell in its normal plasma bath is in osmotic equilibrium. But if the cell is removed from the plasma and placed in distilled water, osmotic pressure forces enough water into the cell to burst it in less than a second. Since the potassium salts inside cross the cell membrane only at a negligible rate, they act as if the membrane were impermeable to them. By adding salt to the distilled water the osmotic pressure can be reduced or even reversed.



DIAMETER OF PORE is compared to the diameters of substances involved in cell metabolism (*left*). Sizes are given in angstrom units (10^{-8} centimeter) in column at right. Diameters of hydrated ions are derived from electrical conductivities measured in water solution.

That is what Victor W. Sidel and I did in our experiment. We placed red cells in sodium chloride solutions of almost the same concentration as that of the intracellular fluid, thus limiting the pressure to moderate values in one direction or the other. When the concentration was lower outside, a little water flowed into the cells, leaving them slightly swollen upon reaching equilibrium. When the conditions were reversed, water flowed out and the cells shrank. Thus we could set the pressure by adjusting the salt concentration, and determine the speed at which water crossed the membrane from the rate of swelling or shrinking.

Since the rate is very high, we turned again to the rapid-flow apparatus. This time we had a visible indication of the reaction rate in the changing volume of the cells. They move down the observation tube too fast to be observed under a microscope. Nevertheless we could use a simple optical measurement. When a beam of light is sent through the flow tube, some of it is reflected from the surface of the tumbling red cells. The amount of light reflected at an angle of 90 degrees from the incident beam turns out to be directly proportional to the volume of the cells. We measured the scattered light intensity at 50, 100, 150 and 200 milliseconds after mixing. The intensities were translated first into cell volume and then into the rate of water movement.

From these data we could establish a value for the resistance offered by the cellular membrane to the passage of water under pressure. As previously stated, the resistance depends on the quantity $d^2 \times A/L$. When the results of this computation were combined with the value of A/L determined in the diffusion experiment, we were able to calculate that the "equivalent diameter" of the red cell pores is seven angstrom units. The reason for the term "equivalent" will appear in a moment.

Now a pore seven angstroms wide would easily pass both sodium and potassium ions. Not only that, but it would fail completely to discriminate between the positively charged potassium ions and negatively charged chloride ions, which have almost identical hydrated diameters. Yet in fact chloride ions travel through the cell membrane almost a million times faster than potassium ions. We therefore supposed that the pores are lined with positive charges, which repel the positively charged ions and block their passage. The picture also fits well with other experimental facts. A seven-angstrom pore would exclude molecules

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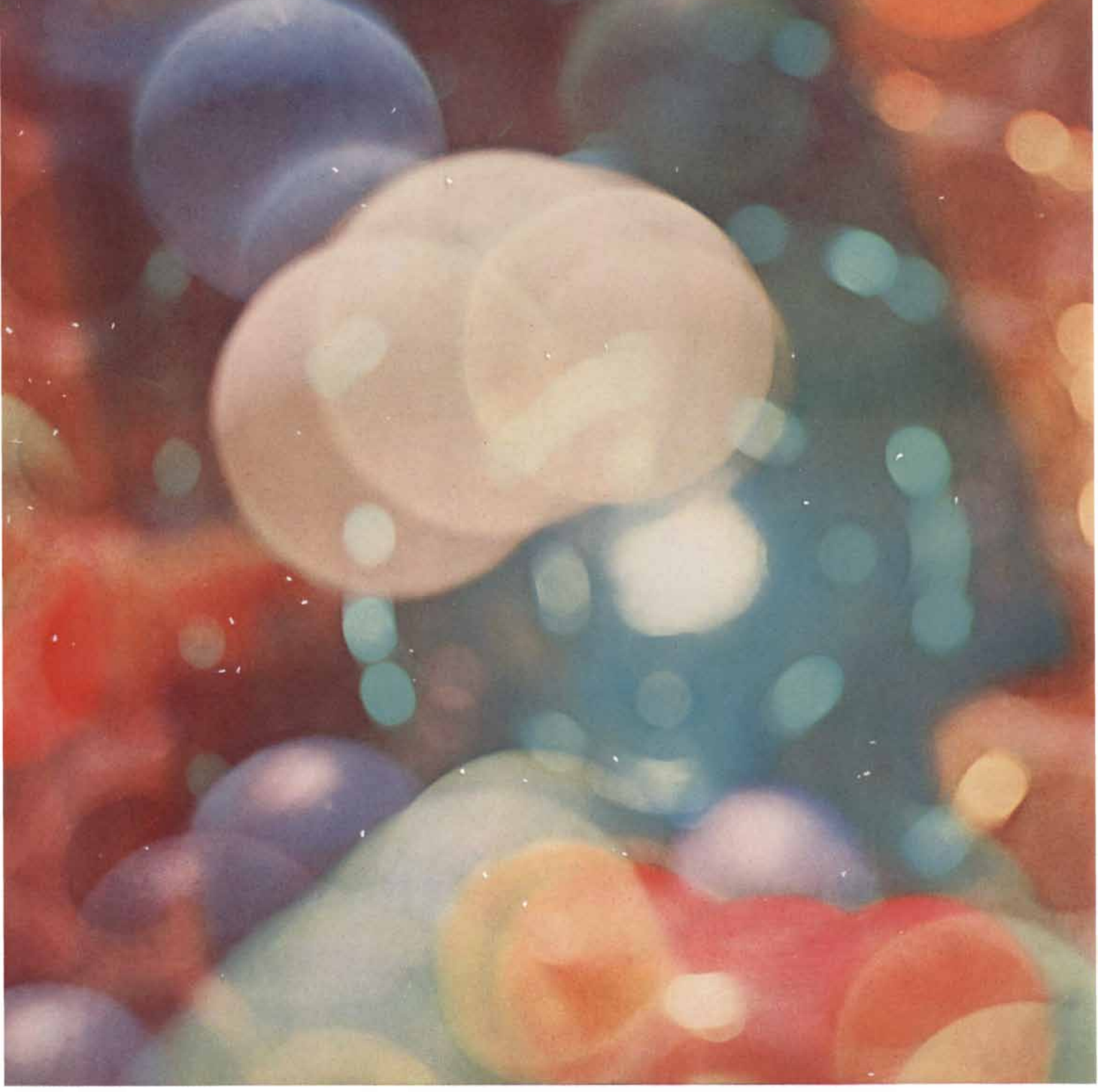

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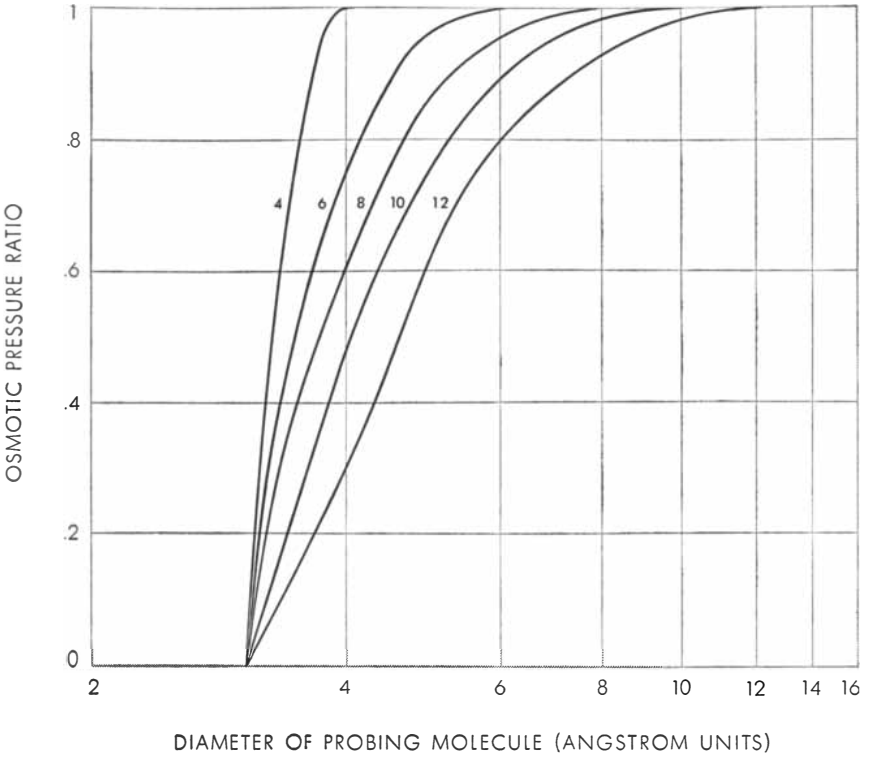
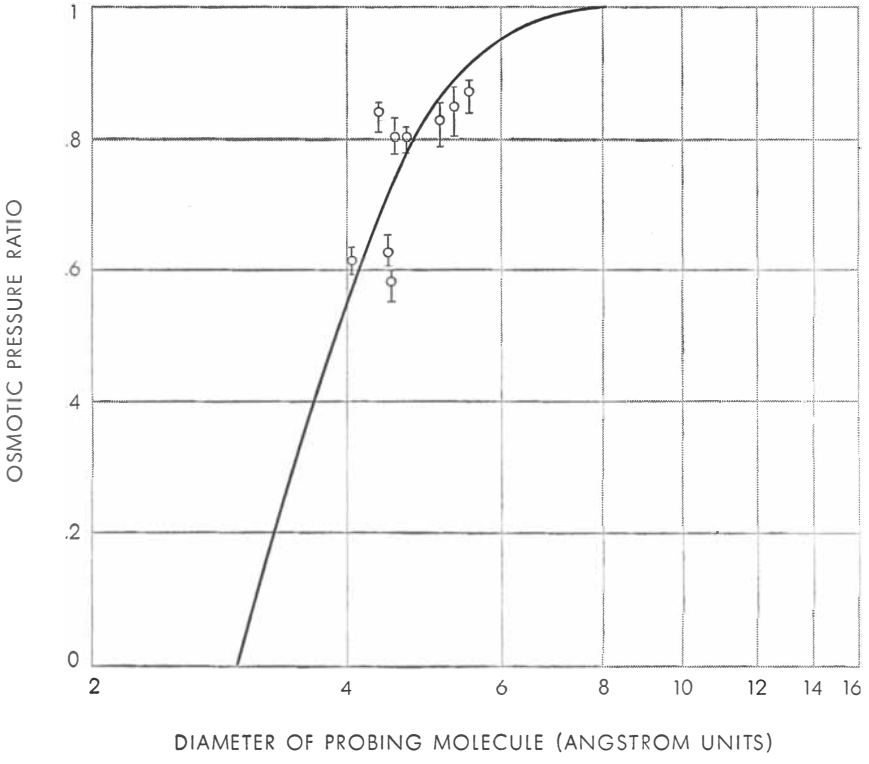
of glucose, the chief fuel of the cell. And in fact the red cell has developed a specific chemical transport system to take in glucose across the fabric of the membrane. The end product of glucose metabolism is the negatively charged lactate ion, which has only three carbon atoms as against six in glucose. This ion is small enough to escape through the pores. Thus no special excretory mechanism is required, and none has been found.

Having an idea of the size of the pores, we next tried to estimate how densely they are distributed over the surface of the membrane. If the length of the pores (L) were known, then their total area (A) could be found. On the assumption that the pores are 300 angstroms long, allowing a factor of three for their presumably tortuous path through the membrane, the total pore openings occupy only .06 per cent of the surface. If the holes were evenly spaced, each seven-angstrom pore would be surrounded by an unbroken square 200 angstroms on a side. Thus the red cell, whose membrane is the most permeable known, devotes only a minute fraction of its surface area to ionic communication with its environment.

The measurements so far described depend upon the validity of the laws governing flow by diffusion and under pressure. These laws were derived for macroscopic systems, where the diameter of a pipe is very much larger than that of the molecules flowing through it; the application of the laws to pores whose dimensions are measured in a small number of angstroms involves a considerable extrapolation. If one probes a seven-angstrom pore with a water molecule three angstroms in diameter, does Poiseuille's law apply? There is a good deal of experimental evidence that it is adequate to describe the flow of water through pores down to 40 angstroms in diameter, but almost none, save the self-consistency of our own results, showing that this law holds in a situation where the pore diameter is only two or three times as large as the water molecule. Similar objections can be made to the use of the ordinary laws of diffusion in this domain. In view of these theoretical difficulties we use the term "equivalent diameter" to show that the value we have calculated is the diameter an ideal pore would have if the macroscopic laws were adequate to describe the processes taking place in our experiments. The equivalent pore, like the ideal gas, is a concept applicable only in the limit. However, it does provide a physical



THEORETICAL CURVES show osmotic pressure ratio for molecules and pores of various sizes. Numbers on curves indicate diameter of pore in angstrom units. Ratio represents pressure across "leaky" membrane compared to that across an ideal semipermeable one.



EXPERIMENTAL CURVE of osmotic pressure ratio versus diameter of probing molecule can be compared to one of the curves at top of page to determine actual diameter of pore.

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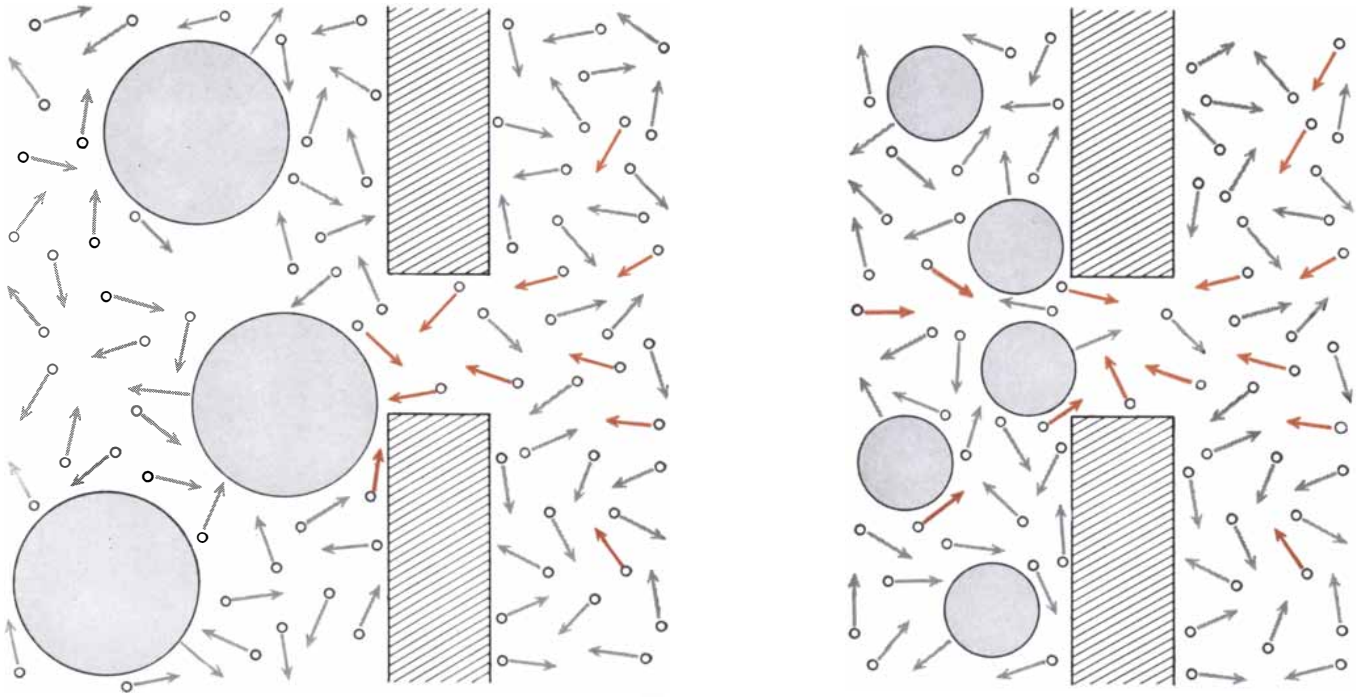
model by which we can visualize the membrane structure and predict the rates of passage of many molecules across it.

About a year ago we were delighted to find a way to check our estimates through an independent method of measuring pore diameter. It came from a careful examination of the very nature of osmotic pressure. The preceding discussion of osmosis dealt with water solutions in which the dissolved molecules are completely, or almost completely, unable to pass through the pores of the membrane separating them. But if these molecules are made smaller (or the pores larger), then they too can pass through the membrane, although not so easily as water molecules. The membrane is now leaky. If the chambers of our earlier example are separated by a membrane that is leaky to polymer molecules, osmosis will at first cause water to flow across the membrane into the polymer solution. As time goes on, however, the polymer molecules will gradually diffuse out of their chamber, and water will follow, so that the pressure will gradually diminish. Finally the polymer concentration will come to the same value on both sides of the membrane. At that point no osmotic pressure remains. Thus with leaky membranes the initial osmotic pressure is a transient phenomenon, dissipating at a rate that depends on the ease with which polymer molecules cross the membrane.

The Dutch chemist A. J. Staverman, who has studied osmosis in leaky membranes, pointed out that the osmotic pressure never reaches the value it would if the membrane were ideally semipermeable. Even at the first instant, before any polymer molecules diffuse across the membrane, the osmotic pressure is less than that across a perfect membrane. This is because the tendency of a polymer molecule to diffuse through the pore will partially counterbalance the force causing water to enter from the other side. Staverman's analysis demonstrated that the ratio of the initial osmotic pressure of a leaky membrane to the classical pressure developed by an ideal membrane would be a measure of the ability of the pores to discriminate between the polymer and water. This becomes clear if we imagine a polymer solution, containing molecules whose size can be altered at will, separated from a bath of pure water by a membrane. When the polymer molecules are larger than the membrane pores, the osmotic pressure has the maximum classical value. Now let the molecules begin to shrink. As soon as the polymer is small enough to just pass through the pores, the pressure will start to drop. As the polymer becomes smaller and smaller, and can pass more and more easily through the pore, it is obvious that the osmotic pressure will continue to diminish. Eventually, if the polymer molecule is the same size as the water molecule, there will be no osmotic pressure, because the membrane will be unable to discriminate between the two molecules. The argument shows that the initial osmotic pressure across a leaky membrane is a measure of the size of the polymer molecule if the diameter of the pores is known, or of the pore diameter if the molecular size is given.

How could these theoretical considerations be applied to the problem of the pore size of the human red cell, where osmotic pressure cannot be measured directly, but only the rate at which molecules of known size cross the membrane? Two further links in the theory were required. The first was supplied in 1955, when Richard P. Durbin, Heddy Frank and I put forward an equation relating the osmotic pressure across a leaky membrane to the relative rate of filtration of water and the molecule ("polymer") that caused the osmotic pressure. The relationship has since



CELL MEMBRANE (*cross-hatched area*) is not permeable to giant molecules like proteins (*largest circles*). Arrows indicate random motion of smaller molecules; colored arrows show paths that will carry molecules through pore in cell membrane. In diagram at left, proteins inhibit movement of small molecules from left to right, setting up large difference in osmotic pressure between inside and outside of cell. In diagram at center, molecules whose diameter is slightly smaller than diameter of pore "leak"

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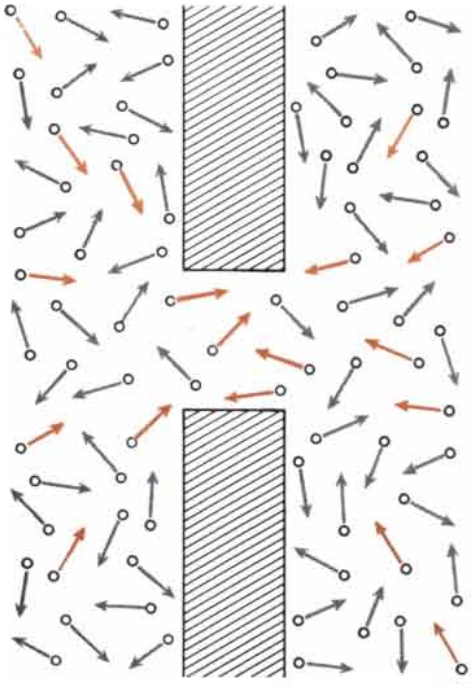
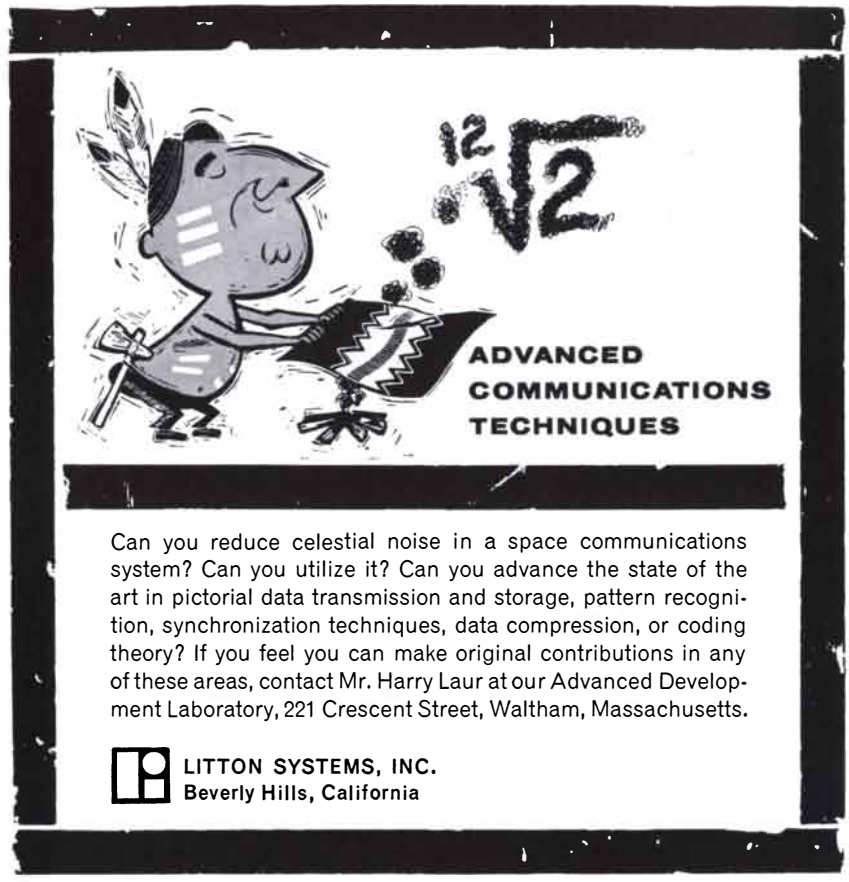
been studied extensively by Durbin, who has confirmed it down to pore diameters of about 40 angstroms.

We next needed to know how the rate of filtration depends upon the relative diameters of "polymer" and water. This problem had been tackled by Eugene M. Renkin, a student of Pappenheimer's. Renkin derived a set of theoretical curves that described the hindrance offered by the filter to molecules passing through it as the size of the molecule approached the size of the pore in the filter. Filtration turns out to be an extremely selective process: Very small differences in molecular size can be detected by quite gross filters. Durbin has shown, for example, that a filter with pores 160 angstroms in diameter will hold back heavy water more than ordinary water. The diameter of the heavy-water molecule is 3.4 angstroms, as compared with three angstroms for ordinary water! Thus it is clear that filtration experiments provide a method of extraordinary sensitivity for determining the equivalent pore diameter.

During the past four years David Goldstein and I have developed a new method for determining the equivalent pore diameter of the human red cell, based on the equations of Staverman, of



through membrane, resulting in small difference in osmotic pressure. Small molecules in diagram at right pass freely through pore, resulting in no difference in osmotic pressure.



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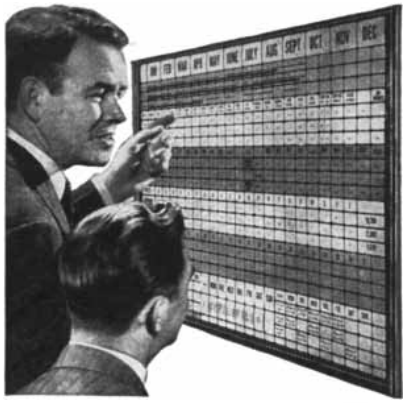

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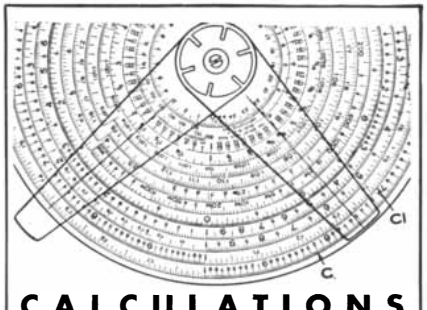

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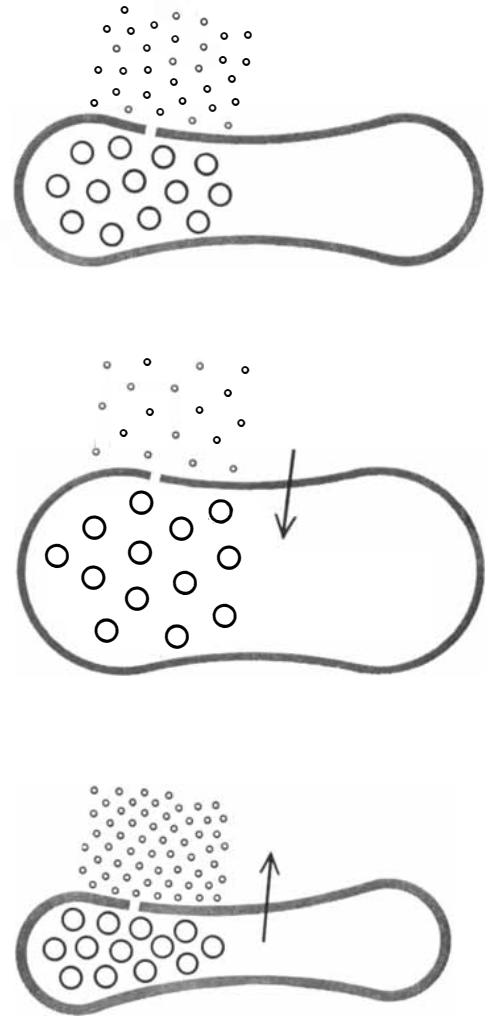
Renkin, and of Durbin, Frank and myself. (Although the relationships I have just outlined make it clear that a measurement of the osmotic pressure developed across a leaky membrane is equivalent to a measurement of pore diameter, this was not apparent to us when we embarked on the problem.) We immersed red cells in solutions of various molecules such as glycerol and urea, which are larger than water but small enough to pass through the pores. Before they diffuse into the cells, these molecules tend to offset the osmotic pressure due to the salts and proteins inside. Using the rapid-flow apparatus and the light-scattering technique that Sidel and I had developed, we measured the initial rate of swelling or shrinking in solutions of various concentrations. For each test molecule we adjusted the concentration to make the rate of flow across the membrane smaller and smaller. Extrapolating from these results, we were able to determine the concentration that initially would just balance the interior osmotic pressure. The smaller the probing molecule, the greater the concentration that was required, as compared with the concentration of a particle that could not cross the membrane at all. Thus the smallest molecule (urea) required a concentration 60 per cent higher than the classical value to produce transient equilibrium; the largest molecule (glycerol) needed only an excess of 14 per cent over the classical value.

Having determined these figures, we had in effect measured the osmotic pressure at zero time. At zero time none of the test molecules has entered the cell, so that the make-up of both the internal and external solutions is precisely known. Moreover, the technique has the advantage of not requiring absolute measurement of the true rate of swelling or shrinking. As a null method it depends only on the external concentration at which the initial rate of water flow across the membrane is zero.

Referring our results to the theoretical equations, we arrived at an equivalent pore diameter of 8.4 angstrom units—a result that agreed remarkably well with our earlier figure of seven angstrom units. The agreement is most heartening. It gives us increased confidence in the concept of the equivalent pore as a valid measure for single cellular membranes, and suggests that macroscopic laws do indeed continue to hold for very small dimensions. Recently the zero-time method has been applied to other tissues, leading to calculated equivalent pore diameters close to that of the red cell. It may very well be that pores of this approximate size are characteristic of membrane architecture. The broad applicability of our new zero-time method and the ease with which measurements can be made on a variety of cells lead us to believe that the way is now open for a general description of passive permeability in simple physical terms.



ZERO-TIME osmotic pressure was measured by immersing red blood cells (*shown here in schematic cross-sectional view*) in solution containing smaller molecules such as urea (*small circles*). Initial osmotic pressure caused by presence of molecules (*large circles*) that could not pass through membrane was balanced by greater concentration of smaller molecules outside (*top*). If concentration of smaller molecules was lowered, an excess of water (*arrow*) flowed into the cell, causing it to swell (*center*); if concentration was raised sharply, water flowed out, causing cell to shrink (*bottom*).

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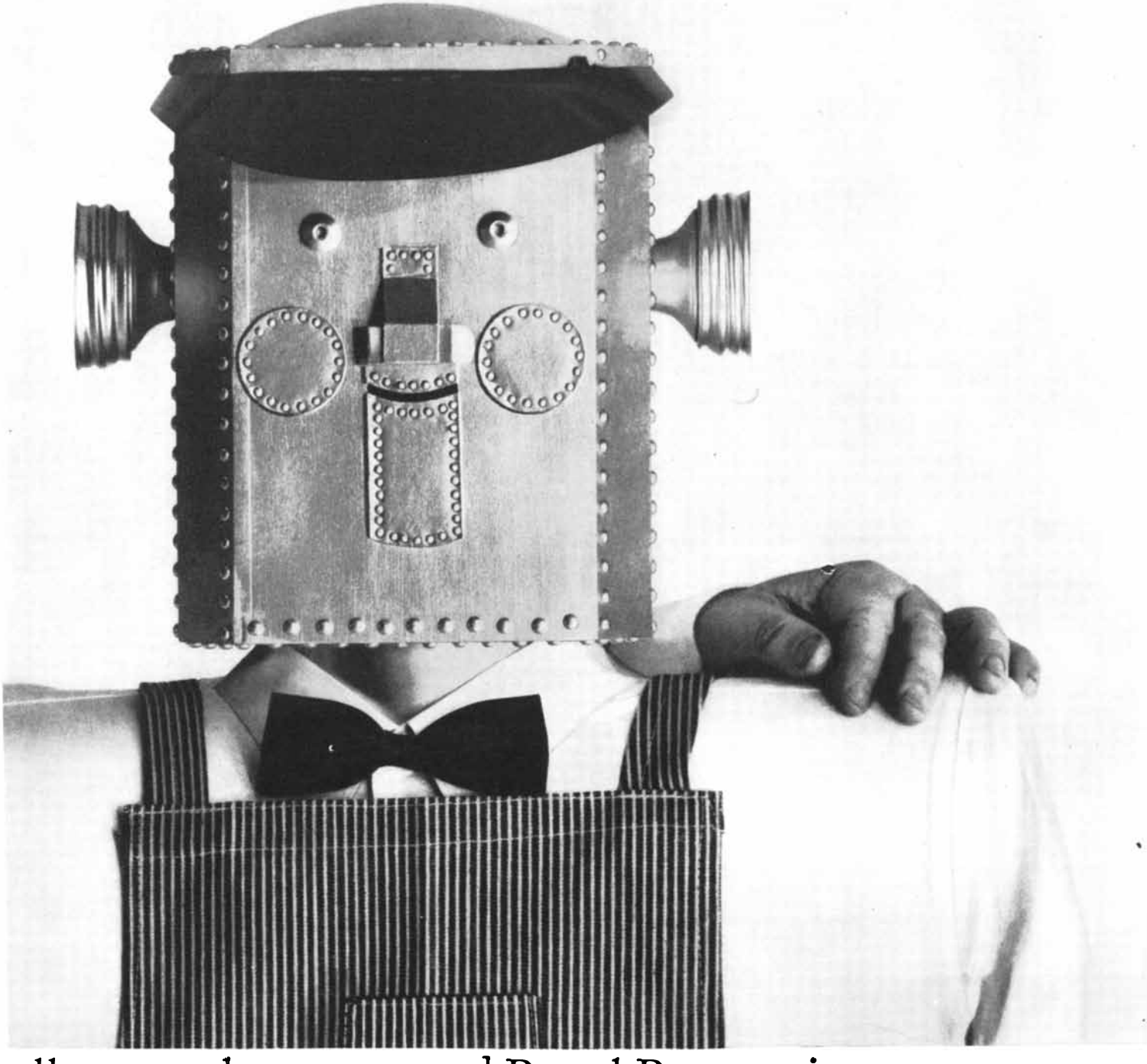

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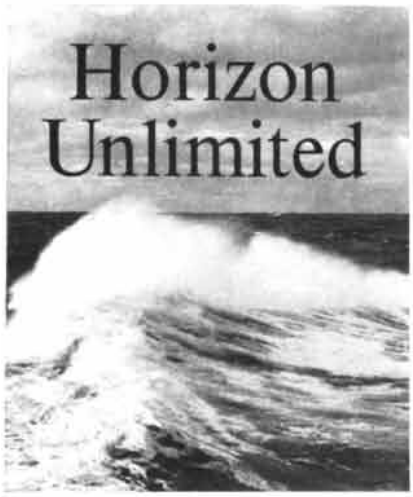

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MATHEMATICAL GAMES

Some recreations involving the binary number system

by Martin Gardner

The number system now in use throughout the civilized world is a decimal system based on successive powers of 10. The digit at the extreme right of any number stands for a multiple of 10^0, or 1. The second digit from the right indicates a multiple of 10^1; the third digit, a multiple of 10^2, and so on. Thus 777 expresses the sum of $(7 \times 10^0) + (7 \times 10^1) + (7 \times 10^2)$. The widespread use of 10 as a number base is almost certainly due to the fact that we have 10 fingers; the very word "digit" reflects this. If Mars is inhabited by humanoids with 12 fingers, it is a good bet that Martian arithmetic uses a notation based on 12.

The simplest of all number systems that make use of the positions of digits is the binary system, based on the powers of 2. Some primitive tribes count in binary fashion, and ancient Chinese mathematicians knew about the system, but it was the great German mathematician Gottfried Wilhelm von Leibniz who seems to have been the first to develop the system in any detail. For Leibniz, it symbolized a deep metaphysical truth. He regarded 0 as an emblem of non-being or nothing; 1 as an emblem of being or substance. Both are necessary to the Creator, because a cosmos containing only pure substance would be indistinguishable from the empty cosmos, devoid of sound and fury and signified by 0. Just as in the binary system any integer can be expressed by a suitable placing of 0's and 1's, so the mathematical structure of the entire created world becomes possible, Leibniz believed, as a consequence of the primordial binary split between being and nothingness.

From Leibniz's day until very recently the binary system was little more than a curiosity, of no practical value. Then came the computers! Wires either do or do not carry a current, a switch is on or off, a magnet is north-south or south-north, a flip-flop memory circuit is flipped or flopped. For such reasons enormous speed and accuracy are obtained by constructing computers that can process data coded in binary form. "Alas!", writes Tobias Dantzig in his book *Number, the Language of Science*, "what was once hailed as a monument to monotheism ended in the bowels of a robot."

Many mathematical recreations involve the binary system: the game of nim, mechanical puzzles such as the Tower of Hanoi and the Rings of Cardan, and countless card tricks and "brain-teasers." Here we shall restrict our attention to a familiar set of "mind-reading" cards, and a closely related set of punch-cards with which several remarkable binary feats can be performed.

The construction of the mind-reading cards is made clear in the illustration on page 162. On the left are the binary numbers from 0 through 31. Each digit in a binary number stands for a power of 2, beginning with 2^0 (or 1) at the extreme right, then proceeding leftward to 2^1 (or 2), 2^2, 2^3 and so on. These powers of 2 are shown at the top of the columns. To translate a binary number into its decimal equivalent, simply sum the powers of 2 that are expressed by the positions of the 1's. Thus 10101 represents 16 + 4 + 1, or 21. To change 21 back to the binary form, a reverse procedure is followed. Divide 21 by 2. The result is 10 with a remainder of 1. This remainder is the first digit on the right of the binary number. Next divide 10 by 2. There is no remainder, so the next binary digit is 0. Then 5 is divided by 2, and so on until the binary number 10101 is completed.

The table of binary numbers is converted to a set of mind-reading cards simply by replacing each 1 with the decimal number that corresponds to the binary number in which the 1 occurs. The result is shown at the right side of the illustration. Each column of numbers is copied on a separate card. Hand the five cards to someone, ask him to think of any number from 0 to 31 inclusive, and then to hand you all the cards on which his number appears.

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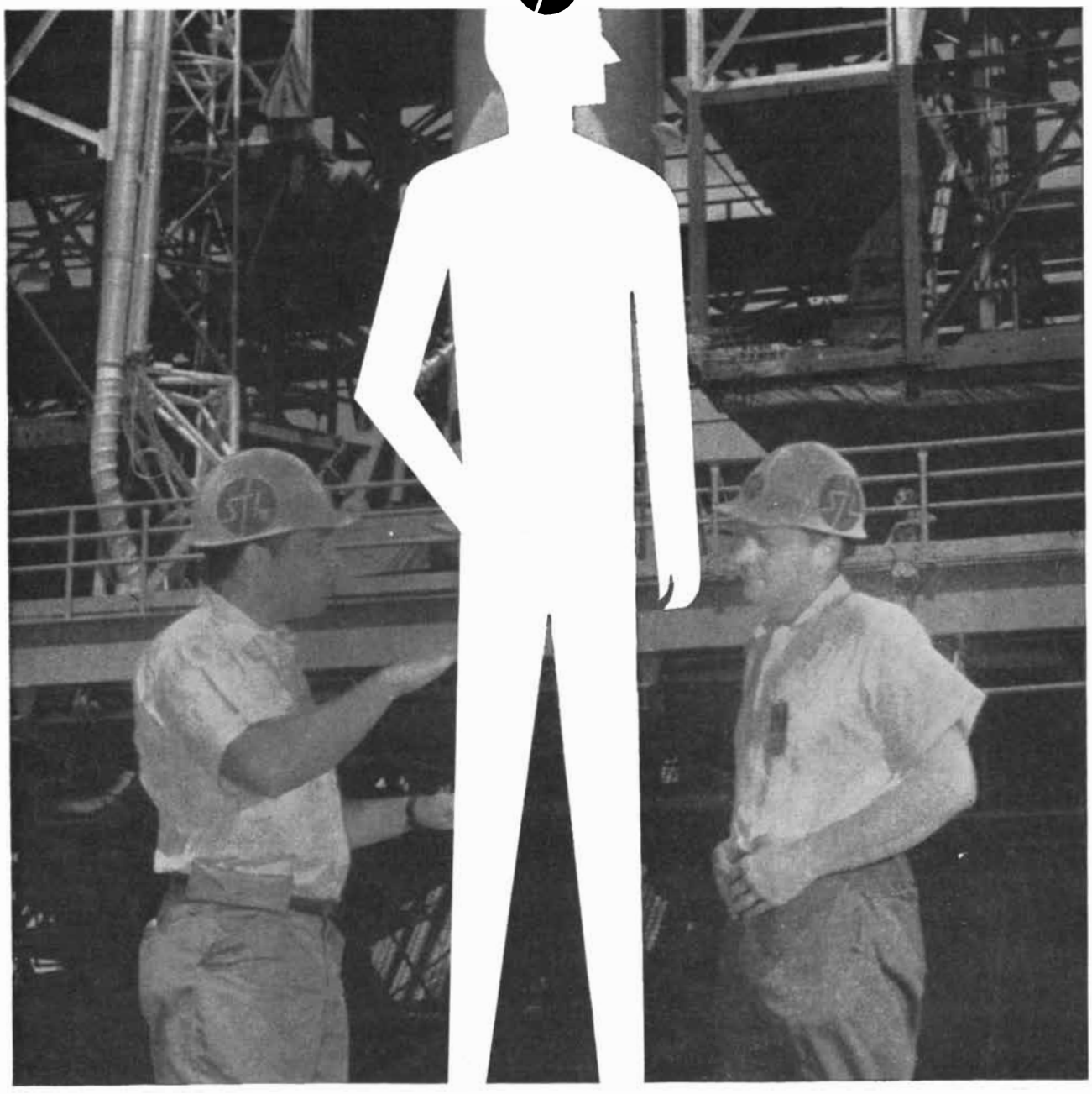

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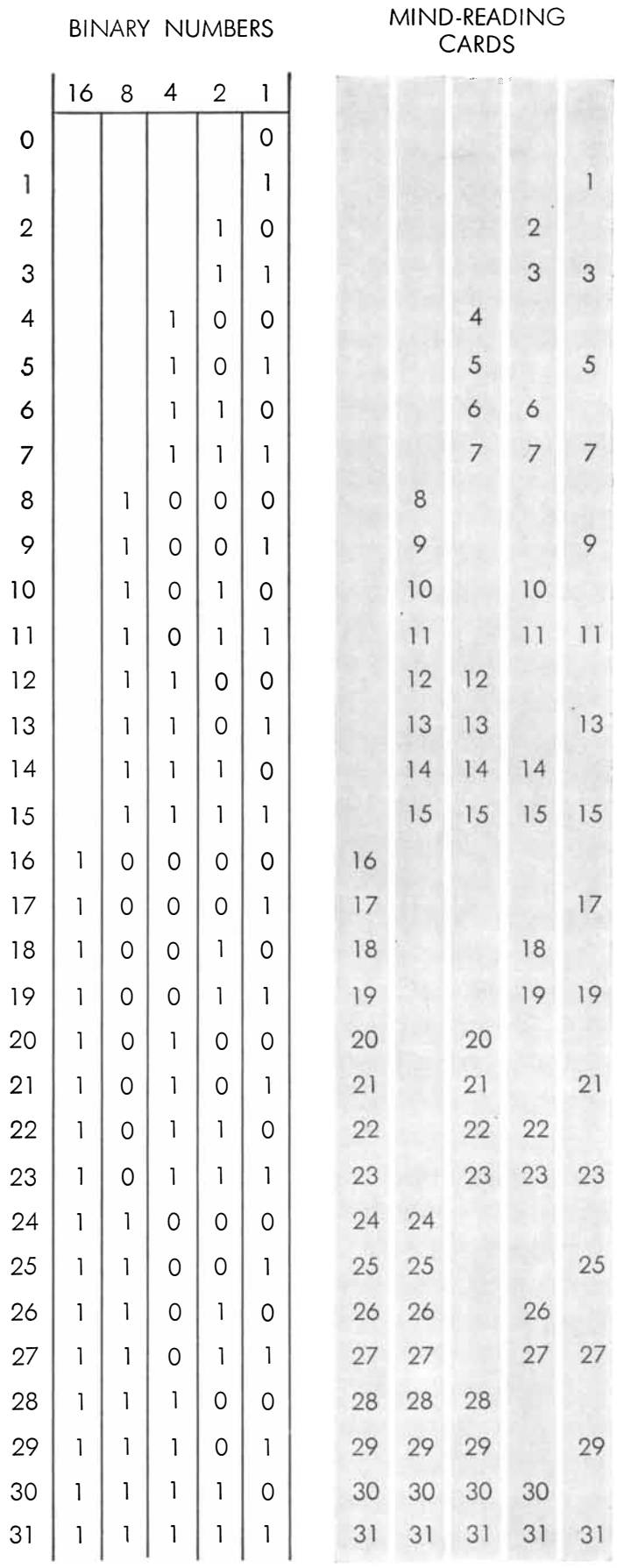

Numbers on a set of mind-reading cards (right) *are based on the binary numbers* (left)

You can immediately name the number. To learn it, you have only to add the top numbers of the cards given to you. How does it work? Each number appears on a unique combination of cards, and this combination is equivalent to the binary notation for that number. When you total the top numbers on the cards, you are simply adding the powers of 2 that are indicated by the 1's in the binary version of the chosen number. The working of the trick can be further disguised by using cards of five different colors. You can then stand across the room and tell your subject to put all the cards bearing his number into a certain pocket and all remaining cards into another pocket. You, of course, must observe this, remembering which power of 2 goes with which color.

The binary basis of punch-card sorting is amusingly dramatized by the set of cards depicted in the illustration on page 164. They can be made easily from a set of 32 file cards. The holes should be a trifle larger than the diameter of a pencil. It is a good plan to cut five holes in one card, then use this card as a stencil for outlining holes on the other cards. If no punching device is available, the cutting of the holes with scissors can be speeded by holding three cards as one and cutting them simultaneously. The cut-off corners make it easy to keep the cards properly oriented. After five holes have been made along the top of each card, the margin is trimmed away above certain holes as shown in the illustration. These notched holes correspond to the digit 1; the remaining holes correspond to 0. Each card carries in this way the equivalent of a binary number. The numbers run from 0 through 31, but in the illustration the cards are randomly arranged. Three unusual stunts can be performed with these cards. They may be troublesome to make, but everyone in the family will enjoy playing with them.

The first stunt consists of quickly sorting the cards so that their numbers are in serial order. Mix the cards any way you please, then square them like a deck of playing cards. Insert a pencil through hole E and lift up an inch or so. Half the cards will cling to the pencil, and half will be left behind. Give the pencil some vigorous shakes to make sure all cards drop that are supposed to drop, then raise the pencil higher until the cards are separated into two halves. Slide the packet off the pencil and put it in *front* of the other cards. Repeat this procedure with each of the other holes, taking them right to left. After the fifth sorting, it may surprise you to find that the binary numbers are now in serial order, beginning

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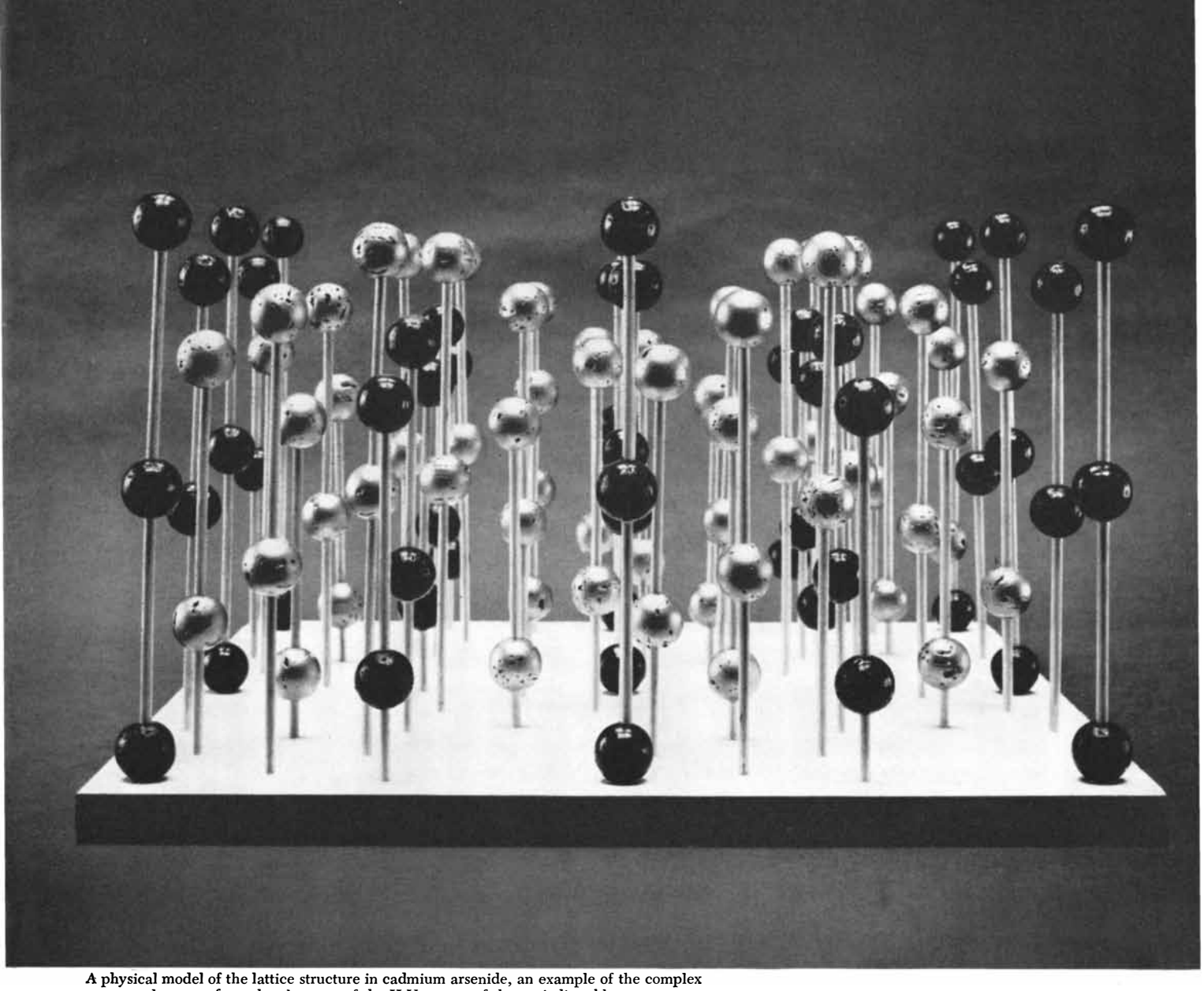

A physical model of the lattice structure in cadmium arsenide, an example of the complex compounds grown from the elements of the II-V groups of the periodic table.

Electron motion within a crystal lattice

Determination of the energy band structures of semiconductor crystals is necessary for complete understanding of the electron conduction processes in these crystals.

The energy band structure is the relationship between electron energy and momentum. While this relationship has been determined for some semiconductors, IBM scientists are now formulating energy band structures for an entirely new class of compounds consisting of elements from the II-V groups of the periodic table.

One of the experimental techniques they employ is based on a phenomenon known as *cyclotron resonance*. It occurs when electrons come under the influence of both a DC magnetic field and a radio-frequency electric field. The magnetic field causes the electrons to rotate in a helical path while the electric field induces oscillations. When the frequency of the electric field oscillation matches the frequency of the electron motion, the electrons absorb energy from the radio-frequency electric field. By measuring the strength of the magnetic field and the frequency of the electric field, the details of the energy band structure can be calculated.

Cyclotron resonance was first noticed by astrophysicists concerned with the propagation of radio waves through the ionosphere in the presence of the earth's magnetic field. In the laboratory, it can be observed in single crystals placed in a microwave cavity and immersed in a helium bath. The low-temperature environment reduces vibrations of the lattice, which tend to scatter the electrons and obscure the phenomenon.

By determining energy band structures for new compounds, these experiments are helping to broaden understanding of the basic properties of semiconductors. In addition, cyclotron resonance has proved valuable in the study of scattering mechanisms and the analysis of high-purity compounds.

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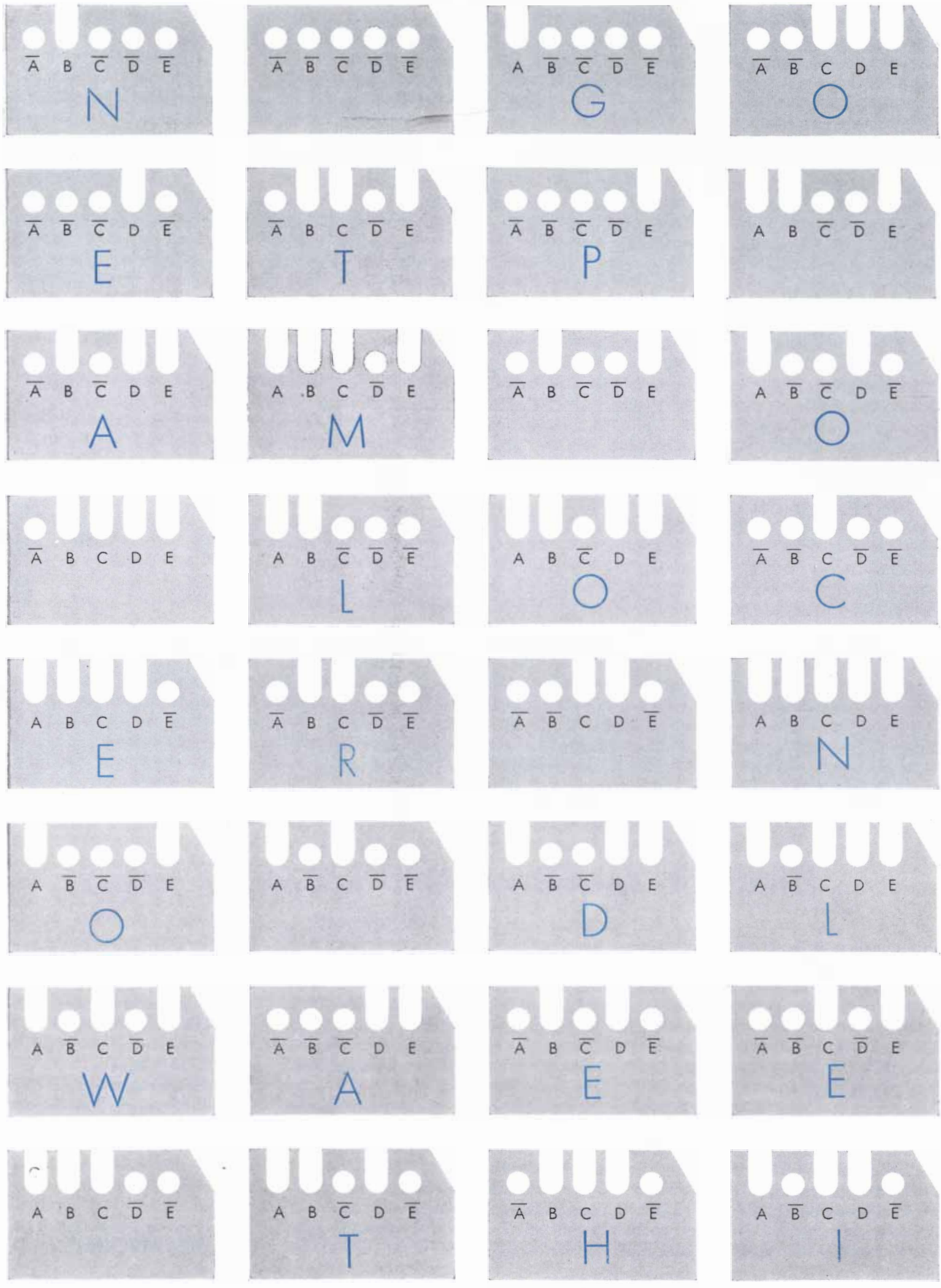

A set of punch-cards that will unscramble a message, guess a selected number and solve logic problems

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with 0 on the card facing you. Flip through the cards and read the Christmas message printed on them!

The second stunt uses the cards as a computer for determining the selected number on the set of mind-reading cards. Begin with the punch-cards in any order. Insert the pencil in hole E and ask if the chosen number appears on the card with a top number of 1. If the reply is yes, lift up on the pencil and discard all cards that cling to it. If no, discard all cards left behind. You now have a packet of 16 cards. Ask if the number is on the card with a top number of 2, then repeat the procedure with the pencil in hole D. Continue in this manner with the remaining cards and holes. You will end with a single punch-card, and its binary number will be the chosen number. If you like, print decimal numbers on all the cards so that you will not have to translate the binary numbers.

The third stunt employs the cards as a logic computer in a manner first proposed by William Stanley Jevons, the English economist and logician. Jevon's "logical abacus," as he called it, used flat pieces of wood with steel pins at the back so that they could be lifted from a ledge, but the punch-cards operate in exactly the same way and are much simpler to make. Jevons also invented a complex mechanical device, called the "logic piano," which operated on the same principles, but the punch-cards will do all that his piano could do. In fact, they will do more, because the piano took care of only four terms, and the cards take care of five.

The five terms A, B, C, D and E are represented by the five holes, which in turn represent binary digits. Each 1 (or notched hole) corresponds to a true term; each 0, to a false term. A line over the top of a letter indicates that the term is false; otherwise it is true. Each card is a unique combination of true and false terms, and since the 32 cards exhaust all possible combinations, they are the equivalent of what is called a "truth table" for the five terms. The operation of the cards is best explained by showing how they can be used for solving a problem in two-valued logic.

The following puzzle appears in *More Problematical Recreations,* a booklet issued recently by Litton Industries of Beverly Hills, Calif. "If Sara shouldn't, then Wanda would. It is impossible that the statements: 'Sara should,' and 'Camille couldn't,' can both be true at the same time. If Wanda would, then Sara should and Camille could. Therefore Camille could. Is the conclusion valid?"

To solve this problem, start with the punch-cards in any order. Only three terms are involved, so we shall be concerned with only the A, B and C holes.

A = Sara should
$\overline{A}$ = Sara shouldn't

B = Wanda would
$\overline{B}$ = Wanda wouldn't

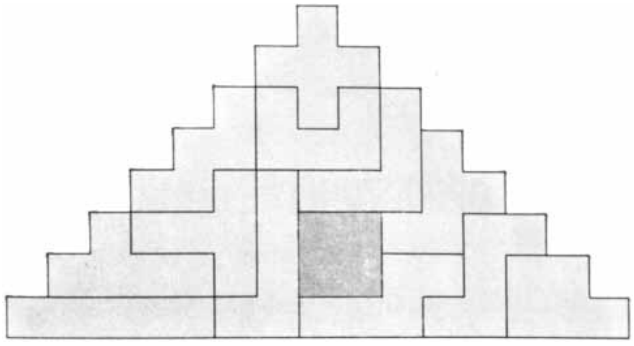
C = Camille could
$\overline{C}$ = Camille couldn't

The problem has three premises. The first—"If Sara shouldn't, then Wanda would"—tells us that the combination of $\overline{A}$ and $\overline{B}$ is not permitted, so we must eliminate all cards bearing this combination. It is done as follows. Insert the pencil in A and lift. All cards on the pencil bear $\overline{A}$. Hold them as a group, remove the pencil, put it in B and lift again. The pencil will raise all cards bearing both $\overline{A}$ and $\overline{B}$, the invalid combination, so these cards are discarded. All remaining cards are assembled into a pack once more (the order does not matter), and we are ready for the second premise.

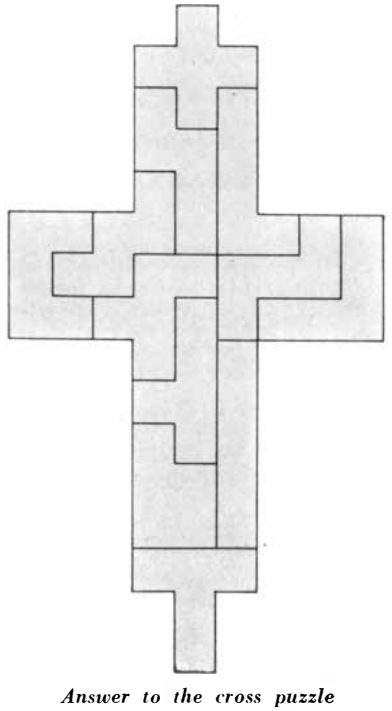
Premise two is that "Sara should" and "Camille couldn't" cannot both be true. In other words, we cannot permit the combination $A\overline{C}$. Insert the pencil in A and lift up all cards bearing $\overline{A}$. These are *not* the cards we want, so we place them temporarily aside and continue with the A group that remains. Insert the pencil in C and raise the $\overline{C}$ cards. These bear the invalid combination $A\overline{C}$, so they are permanently discarded. Assemble the remaining cards once more.

The last premise tells us that if Wanda would, then Sara should and Camille could. A bit of reflection will show that this eliminates two combinations: $\overline{A}B$ and $B\overline{C}$. Put the pencil in hole A, lift, and continue working with the lifted cards. Insert pencil in B; lift. No cards cling to the pencil. This means that the two previous premises have already eliminated the combination $\overline{A}\overline{B}$. Since the cards all bear $\overline{A}B$ (an invalid combination), this entire packet is permanently discarded. The only remaining task is to eliminate $B\overline{C}$ from the remaining cards. The pencil in B will lift out the $\overline{B}$ cards, which are placed temporarily aside. When the pencil is put in C of the cards that remain, no cards can be lifted, indicating that the invalid combination of $B\overline{C}$ has already been ruled out by previous steps.

We are thus left with eight cards, each bearing a combination of truth values for A, B and C that is consistent with all three premises. These combinations are the valid lines of a truth table for the combined premises. Inspection of the cards reveals that C is true on all eight, so it is correct to conclude that Camille could. Other conclusions can also be deduced from the premises. We can, for example, assert that Sara should. But the interesting question of whether Wanda



The answer to the pyramid puzzle in last month's department



Answer to the cross puzzle

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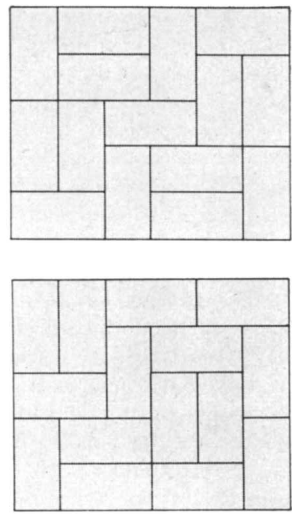


Answer to the fault-free rectangle puzzle

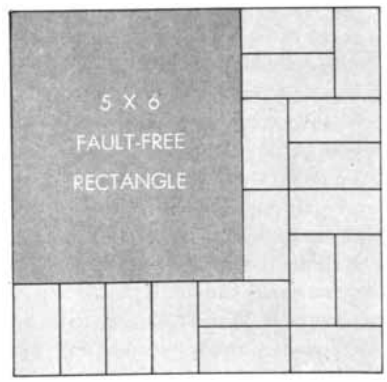
would or wouldn't remains, at least in the light of available knowledge, an inscrutable binary mystery.

For those who would like another problem to feed the cards, here is an easy one that will not be answered until next month. In a suburban home live Abner, his wife Beryl and their three children, Cleo, Dale and Ellsworth. The time is 8 p.m. on a winter evening.

1. If Abner is watching television, so is his wife.
2. Either Dale or Ellsworth, or both of them, are watching television.
3. Either Beryl or Cleo, but not both, is watching television.
4. Dale and Cleo are either both watching or both not watching television.
5. If Ellsworth is watching television, then Abner and Dale are also watching.

Who is watching television and who is not?

Answers to the pyramid and cross puzzles in last month's department are depicted in the illustrations on the preceding page. Readers were asked to de-



A fault-free rectangle on an 8 × 8 board

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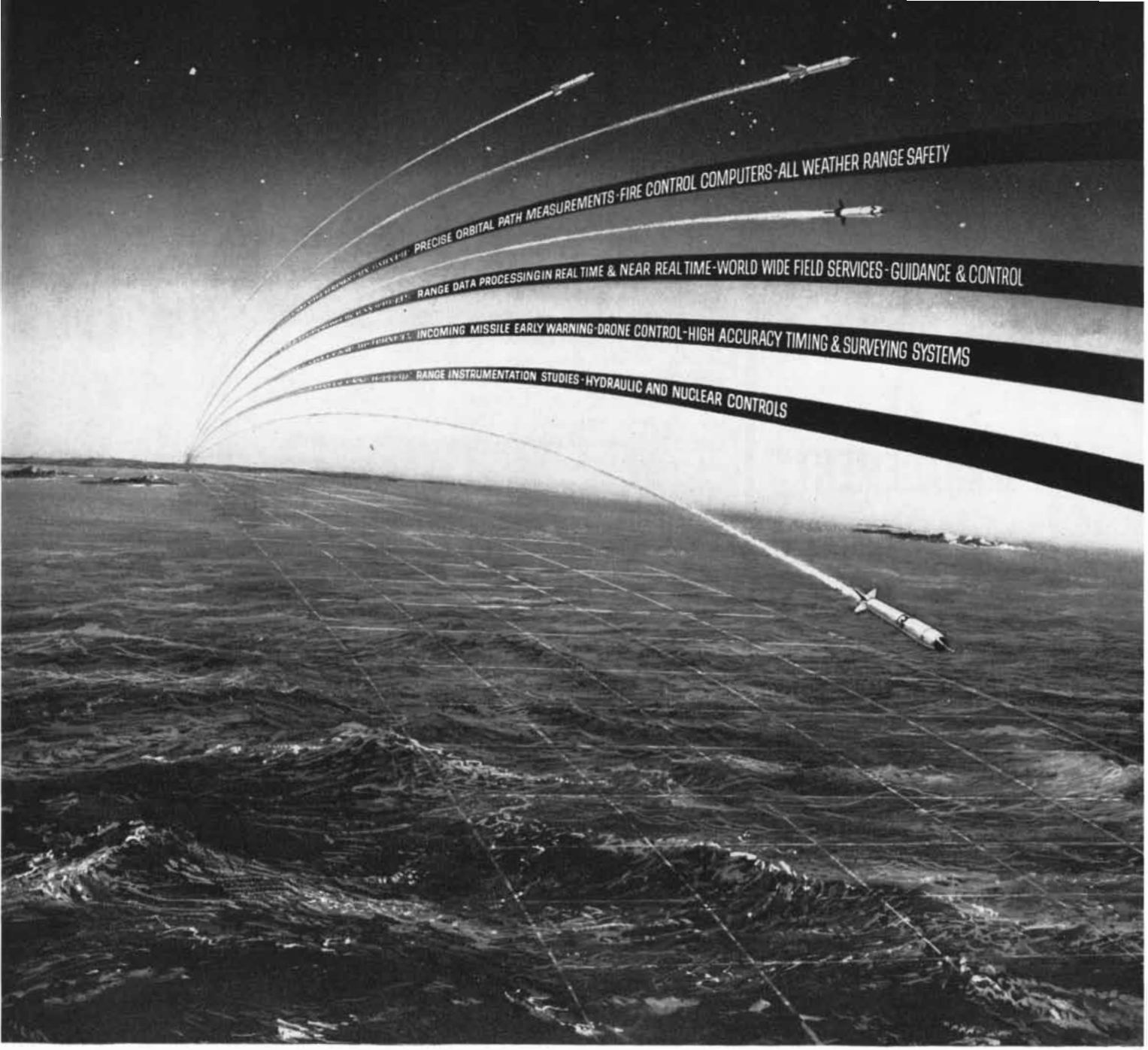

THE MISSILE RANGE: Measure of Capability

The missile range today is a vast proving ground for advanced technologies. It symbolizes the "state of the art" in computation, physics, chemistry, metallurgy, propulsion, hydraulics, electronics, inertial guidance, communications and every other scientific field.

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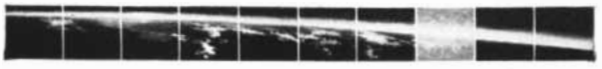
To this problem Sperry Rand has a logical answer: *compatible instrumentation*. The scope of Sperry Rand capability, illustrated above, embraces the whole panorama of the space age. Compatible Instrumentation is the principle of precision in missile range measurement, and a plan of action for applying this principle to projects now developing.

For the necessary team approach to missile range technology Sperry capabilities are joined with those of all other corporate divisions which have contributions to make—among them Ford Instrument Company, Remington Rand Univac, Vickers Incorporated and several component divisions specializing in microwaves, electronic tubes and solid state devices. General Offices: Great Neck, N. Y.



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termine which individual pentominoes can be combined with the five tetrominoes to form a 5 × 5 square. This is possible with all pentominoes except the I, T, X and V.

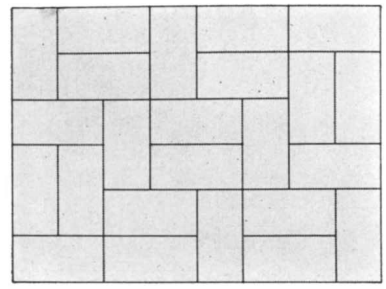
The smallest fault-free rectangle (a rectangle with no straight line joining opposite sides) that can be formed with dominoes is a 5 × 6. The two basically different solutions are shown in the top illustration on page 166.

"It is not difficult to show," writes Solomon W. Golomb, who wrote last month's article, "that the minimum width for fault-free rectangles must exceed 4. (Cases of width 2, 3 and 4 are best treated separately.) Therefore, since 5 × 5 is an odd number of squares, and dominoes always cover an even number of squares, the 5 × 6 rectangle is the smallest solution.

"A 5 × 6 rectangle can be extended to an 8 × 8 checkerboard and still satisfy the fault-free condition. An example is shown in the accompanying illustration [*bottom of page 166*]. Surprisingly, there are no fault-free 6 × 6 rectangles. For this there is a truly remarkable proof:

"Imagine any 6 × 6 rectangle covered entirely with dominoes. Such a figure contains 18 dominoes (half the area) and 10 grid lines (five horizontal and five vertical). It is fault-free if each grid line intersects at least one domino.

"The first step in our proof is to show that in any fault-free rectangle each grid line must cut an *even* number of dominoes. Consider any vertical grid line. The area to the left of it (expressed in number of unit squares) is even (6, 12, 18, 24 or 30). Dominoes *entirely* to the left of this grid line must cover an even area because each domino covers two squares. Dominoes *cut* by the grid line must also occupy an even area to the left of it, because this area is the difference between two even numbers (the total area to the left, and the area of the uncut dominoes to the left). Since each cut domino occupies *one* square to the left of the grid line, there must be an *even* number of dominoes cut by the grid line.



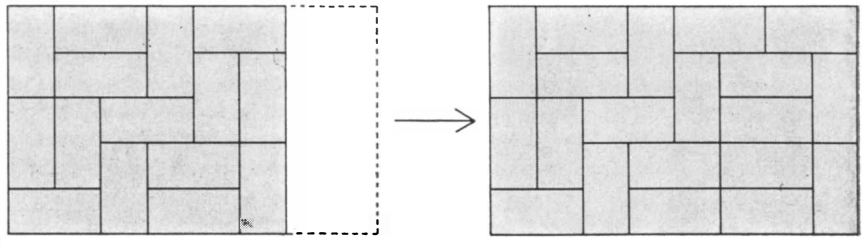
A fault-free 6 × 8 rectangle

"The 6 × 6 square has 10 grid lines. To be fault-free, each line must intersect at least two dominoes. No domino can be cut by more than one grid line, therefore at least 20 dominoes must be cut by grid lines. But there are only 18 dominoes in a 6 × 6 square!

"Similar reasoning shows that for a fault-free 6 × 8 rectangle to exist, every grid line must intersect *exactly* two dominoes. Such a rectangle is shown in the next illustration [*above*].

"The most general result is the following: If a rectangle has even area, and both its length and width exceed 4, it is possible to find a fault-free covering of the rectangle with dominoes, *except* in the case of the 6 × 6 square. Actually coverings for all larger rectangles can be obtained from the 5 × 6 rectangle and the 6 × 8, using a method of enlarging either the length or width by 2. This method is easiest to explain by the last illustration [*below*]. To extend it horizontally by 2, a horizontal domino is placed next to each horizontal domino at the old boundary, while vertical dominoes are shifted from the old boundary to the new, with the intervening space filled by two horizontal dominoes.

"The reader may find it interesting to study trominoes as bricks. In particular, what is the smallest rectangle that can be covered by two or more 'straight trominoes' (1 × 3 rectangles) without any fault lines?"



A general solution to the fault-free rectangle puzzle

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Portrait of a Mach number

Air blasting across an aerodynamic shape at Mach 2 (above, left) records its image on film. In private industry's most extensive complex of wind tunnel installations, Boeing engineers and scientists are defining the shape of the future in supersonic and hypersonic flight. A new hypersonic tunnel, the nation's largest privately owned facility of its kind, tests up to Mach 27.

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Illustrated is a laboratory model of a thermally regenerative liquid metal fuel cell for the conversion of heat to electricity, jointly developed by Allison and Delco-Remy Divisions.

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THE AMATEUR SCIENTIST

Two amateurs calculate the exposure needed to photograph a lunar eclipse

Conducted by C. L. Stong

At 5:30 (Universal Time) last March 13 the slender cone of shadow cast by the earth extended 855,000 miles into space. The full moon then rounding the dark side of the earth was approaching the shadow on an intercepting path at a rate exceeding 2,200 miles per hour. A total eclipse of the moon was about to occur. At North Plainfield, N.J., the clock indicated approximately 12:30 a.m. (Eastern Standard Time). There, on a wooden platform atop a three-story frame house, a pair of amateur astronomers switched on a small red lamp and spent several minutes loading film into a battery of cameras that was kept trained on the stars by an automatic telescope drive. After checking the lens settings, they switched on a short-wave radio that fed precision time signals into a magnetic-tape recorder. Finally they manned the cameras in readiness for the instant when the edge of the earth's shadow made contact with the limb of the moon. Aside from gusts of cold wind that jiggled the equipment from time to time, conditions for observing were good. The amateurs, J. F. Ossanna, Jr., and L. C. Thomas, who are engineers at Bell Telephone Laboratories, were ready after months of preparation to photograph the lunar eclipse in full color.

The observers did not seek to make unique pictures. Lunar eclipses have been photographed in color many times. Instead, Ossanna and Thomas were out to validate a reliable technique for determining the optimum camera-exposure for lunar photography. In the past most pictures of the moon have been made by the traditional technique of cut-and-try. One simply makes a series of increasing exposures and hopes that one pair will bracket the optimum exposure. In contrast, Ossanna and Thomas had computed the absolute brightness of the full moon and had taken account of the many optical and photographic variables associated with the eclipse of March 13. With these data they hoped to hit every exposure dead on the nose. A match between the color of their developed film and that of the eclipsed moon would confirm their value for the brightness of the full moon, an astrophysical quantity that had not been well established.

"We did not set out to establish anything," they write. "In the fall of 1959 we decided to photograph the eclipse in color, partly because the next one of long duration would not be visible from the East Coast until 1964, but mostly because the project presented a stimulating challenge. Would it be possible to calculate camera exposures in advance?

"The method of determining shutter speeds and lens openings that camera enthusiasts use when making casual snapshots does not work in the case of the moon. The shutterbug simply holds an exposure meter up to the scene, reads the brightness indicated by the pointer and inserts this figure, along with one representing film speed, into the little slide rule on the side of the instrument. The slide rule automatically solves a built-in equation that gives the optimum lens setting and shutter speed for the scene in question. But you can't hold an exposure meter up to the moon!

"It seemed reasonable to suppose, however, that the moon's relative brightness during an eclipse could be calculated rather easily from the size and structure of the shadow. The shadow is composed of two principal regions. The largest, called the penumbra, takes the form of a truncated cone with the earth at the apex. When in the penumbra, an observer on the moon would see a partial eclipse of the sun. The second region, called the umbra, lies wholly within the penumbra and is coaxial with it. The umbra is characterized by two conical regions: (1) a short inner cone of total solar eclipse that on March 13 extended into space approximately 159,000 miles from the center of the earth, and (2) the longer surrounding cone within which an observer on the moon would see the earth encircled by a bright ring of reddish light. The boundary between the two umbral regions is formed by rays of light from the sun's limb which are refracted by the atmosphere toward the earth's surface, then skim the surface at zero elevation and are further refracted as they traverse the atmosphere above the dark side of the earth. The shorter wavelengths (*i.e.*, those at the blue end of the spectrum) of these rays tend to be scattered as they pass through the atmosphere; as a consequence the rays that divide the two regions of the umbra are deep red. The shorter wavelengths of the rays that traverse the higher levels of the atmosphere are not so strongly scattered; thus a cross section through the outer part of the umbra would appear deep red toward the center and gradually fade into orange, yellow and finally into the white of clear sunlight at the boundary between the umbra and penumbra. When totally immersed in the umbra, the moon accordingly acquires the colors of sunset on the earth. The three major features of the shadow are depicted in the accompanying drawing [*page 175*].

"Illumination within the shadow decreases progressively from full sunlight at the outer boundary of the penumbra to the deep red of the shadow's axis. To determine camera exposure, the first problem is to determine the size of the umbra and penumbra and the extent to which the moon will be immersed in them. Information for computing these quantities is listed in *American Ephemeris and Nautical Almanac*, an indispensable reference for anyone interested in astronomy. (The ephemeris is published each year by the Government Printing Office, and is available from the Superintendent of Documents in Washington for $4.25.) Three quantities are involved in the computation. The first, *P*, is called the 'equatorial horizontal parallax of the sun,' and is the angle subtended at the sun's edge by lines drawn from the limb

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Stages in the lunar eclipse of March 13, as photographed by J. F. Ossanna, Jr., and L. C. Thomas

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A ski is less innocent than it looks. A rascal, an enigma—an uncommon complex of shape, camber, flexibility, torsion, weight, tip, running surface, groove, edge—expressed in materials of more or less beauty and durability. A great ski is a rare achievement.

On great skis

A DISSERTATION

Proper size for a ski is not mysterious. And every ski designer knows the bottom must arch—he has a word for it, camber. Obviously, a ski must also have side camber, narrowing from shovel to waist, widening again toward the tail—how else can you get it to turn? A ski must bend—more if you're a tyro who likes his comfort, less if you have your eye on winning the downhill.

Merely finding the gross measurements is simple—just take a micrometer to any good ski (that's why a certain black ski can be found in ski factories all over the world) —but make sure you follow it to tolerances as close as .010 inch.

Now you have a ski—but do you love it?

The brutal fact is, a ski can have good dimensions at foot, shovel, and tail, the right amounts of camber, side camber, and flexibility, yet fail to enthrall—flexibility wrongly distributed, camber somehow the wrong *shape*—a sorry companion, dragging or floating, overturning or stubbornly refusing to turn at all, grabbing now or letting go just when you need its bite—the rascal still undisciplined, the enigma still unsolved.

So you cajole, coax, refine, test, again and again, patiently, persistently, until . . . finally . . . *mirabile dictu*, despair changes to delight, trauma turns into treasure . . . "THIS IS IT!"—a great ski, a thing of beauty, flexibility flowing softly at the tip, running smoothly into firmness under the foot, ebbing to a steady but gentle tail—flaunting breathtakingly subtle curves, arcs of circles with centers somewhere off in the next block . . . "THIS IS IT!"—a ski that turns with a breath or equally follows without question your bidding to track—a great ski.

What makes a great ski is creative skill and meticulous attention to detail—years of research to find precisely the right form for each component, precisely the right fusion of all—then fulfilling the intention of great design, accepting nothing less than craftsmanship so fine and materials so durable the ski will last as long as your devotion.

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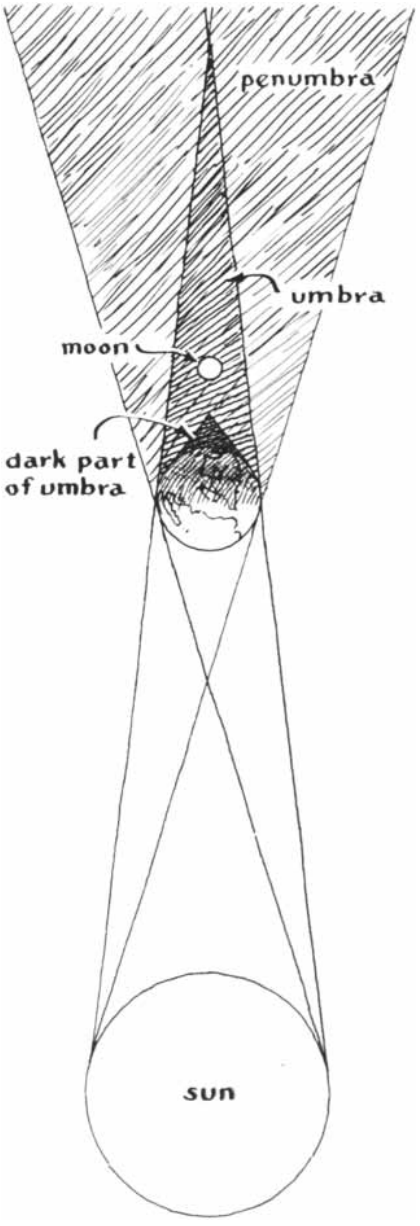
of the earth and from its center. The second quantity is similar, but applies to the moon. The equatorial horizontal parallax of the moon is used for calculating the radius of the earth's shadow at the distance of the moon. It is designated P', and is subtended at the edge of the shadow as shown in the accompanying diagram [*next page*]. The third quantity, designated r, is also an angle. It comprises a measure of the sun's angular semidiameter (or radius).

"An inspection of the diagram will disclose that the angle P' is equal to the sum of two other angles: the umbral radius, designated s, plus half of the angle formed by the umbral cone, v. Also note that the angle representing the solar semidiameter, r, is equal to P plus v. By eliminating the angle v it is seen that the umbral radius is equal to P' plus P minus r. Similar reasoning demonstrates that the penumbral angular radius, s', is equal to the sum of P', P and r.

"For the lunar eclipse of March 13 the values of these angles were: P, 8.85 seconds of arc; P', 57 minutes 29.62 seconds of arc; and r, 16 minutes 5.3 seconds of arc. The umbral radius at the point of intersection with the moon's path ($P' + P - r$) was therefore 41.553 seconds of arc, and the penumbral angular radius ($P' + P + r$) was 73.730 seconds. The angular radius of the moon on the date of the eclipse was 15.653 seconds of arc, slightly more than a third of the umbral radius. The umbral and penumbral radii have here been calculated on the assumption that the earth has no atmosphere. It is customary to increase these values by 2 per cent to take account of the optical effects of the atmosphere. With this correction s and s' become 42.384 seconds and 75.204 seconds respectively. The length of the umbral shadow is equal to the radius of the earth divided by the trigonometric sine of the angle v. That computation yields a shadow length of 855,000 miles for this eclipse. The length of the dark portion of the umbra depends on the size of the angle, θ, between the outer and inner cones. This angle is equal to approximately 70 minutes of arc. To compute the length of the dark portion divide the trigonometric cosine of θ by the trigonometric sine of the sum of θ plus v and divide the quotient by the radius of the earth in miles. With these data plus the time schedule of the eclipse and related facts listed in the ephemeris we plotted the details shown on the accompanying diagram [*page 178*].

"Having thus established the size and location of the scene to be photographed, our next consideration turned to the theory of camera exposure. In simplest terms exposure is equal to the product of the illumination (in meter-candles) multiplied by the shutter speed (in seconds). The equation becomes impressively more complex when one comes to grips with an actual camera loaded with real film. It turns out that many additional factors are built into the little slide rule on the exposure meter, all of them assumptions. The illumination falling on the film *increases* as the product of the scene brightness in candles per square foot, the transparency of the lens system,



Major components of the earth's shadow

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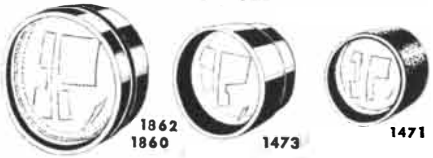

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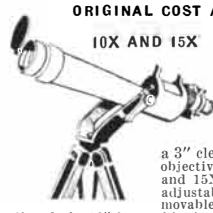

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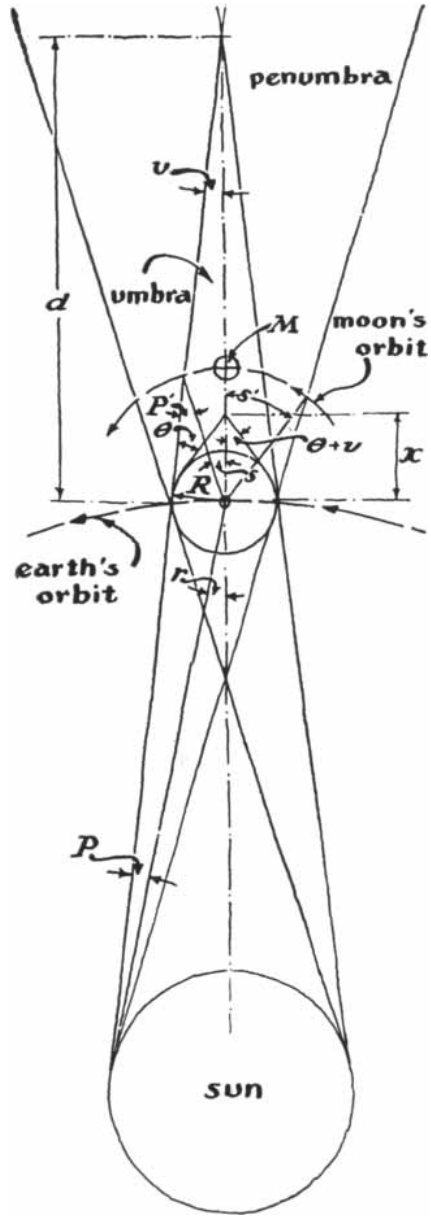
the vignetting factor introduced by the opaque parts of the lens housing, scene distance minus the focal ratio squared, and the fourth power of the cosine of the angle through which a desired portion of the image departs from the axis of the lens system. The illumination *decreases* as the product of the square of the focal ratio (f number) multipled by the square of the scene distance. If all of these factors except scene brightness and the f number are combined in a quantity q, then for a given situation the illumination in meter-candles is equal to q multiplied by the scene brightness and divided by the square of the f number. The numerical value of q of course depends on the values assumed for its component factors. The transparency of the lens system, called the transmission factor, varies with the number of lens elements and whether they are coated or not. For a typical camera with coated lenses the transmission factor usually falls between .80 and .95. In other words, 80 to 95 per cent of the light that enters the lenses gets through to the film. The rest is dissipated by the glass. The vignetting factor depends on the design of the lens barrel, relative aperture and the angular distance of the off-axis image. It can vary from .1 to 1, but typical values fall between .7 and .8. For lunar photography scene distance minus the focal ratio squared can be taken as unity. The off-axis image factor depends on the geometry of the scene. In the case of moon photography a value of 1 can be assumed, because for practical considerations the object of interest is largely confined to the axis. Considerable disagreement is found among the values listed for these factors in the photographic literature. The value of q for ordinary terrestrial scenes ranges from about 4.5 to 7.5, according to which authority you consult. We found that if a lens of 95 per cent transmission is used in lunar photography, where the image is nearly on axis, a value of 8 can be taken for q. The illumination falling on the film then becomes equal to eight times the brightness of the scene (in candles per square foot) divided by the square of the focal ratio, or f number. The exposure E is equal to this value of illumination multiplied by the time that the shutter is open.

"This formula assumes that all areas of the moon are uniformly bright. In reality the moon's brightness varies from some minimum to maximum value. The brightness of ordinary scenes (for which color films are designed) is assumed to range from 100 to 160. This means that



Angular dimensions of the earth's shadow

if the dimmest part of the scene reflects light equal to the intensity of a single candle at a specified distance, the brightest part reflects light equivalent to 100 to 160 candles of the same size at the same distance. The range of brightness that falls on the film is much narrower, however. Reflections occur within the camera, with the result that an appreciable amount of scattered light reaches the film. This light increases the illumination of the dimmer portions of the image, an effect called the flare factor. The scattered light reduces the difference between the dimmest and brightest parts of the image by a factor of three or four. The effective brightness there-

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fore ranges between 25 and 50; the value of 32 has frequently been assumed.

"The film must receive a certain minimum amount of light from the dimmest portion of the scene or no image will be registered. At the opposite extreme, a certain maximum exposure (in the case of color-reversal film) results in transparency. Overexposure beyond this value is not recorded by the film.

"The exposure index (S_e) that is supplied by the manufacturers of color films is based on the geometric mean of these two extremes. The geometric mean exposure, designated E_{mid}, is equal to the square root of the product of the maximum exposure multiplied by the minimum exposure. The exposure index for color film is defined as 8 divided by the exposure in meter-candle-seconds corresponding to E_{mid}. For each scene there is an effective geometric mean in the range of scene brightness, the value of B_{mid}, that corresponds to E_{mid}. We combined these relations in an equation that gives the camera exposure we used to photograph the lunar eclipse:

$$\frac{t}{A^2} = \frac{1}{B_{mid}S_e}$$

Here A is the relative aperture, or f number, and B_{mid} is expressed in candles per square foot. The exposure time, t, is in seconds.

"The latitude of color films currently available does not appear to extend much beyond that required by scenes of average effective brightness range. When the range of scene brightness exceeds the latitude of the film, the photographer must compromise and select a portion of the scene that falls within the latitude of the film by adjusting camera exposure to the midpoint B_{mid} of the range desired.

"From the foregoing it is evident that the exposure recommendations of film manufacturers, the exposure index specified for a given type of film and the characteristics of exposure meters rest on many assumptions about the average camera and average scene. These assumptions should be taken into account when unusual scenes are photographed.

"To determine the optimum exposure for photographing the eclipsed moon we predicted both the range of the moon's brightness during its transit through the shadow and the absolute brightness (in foot-candles) of the full moon. The brightness of a diffuse reflecting surface depends on the illumination that falls on it, the angle of incidence at which the rays strike the object and the reflectivity

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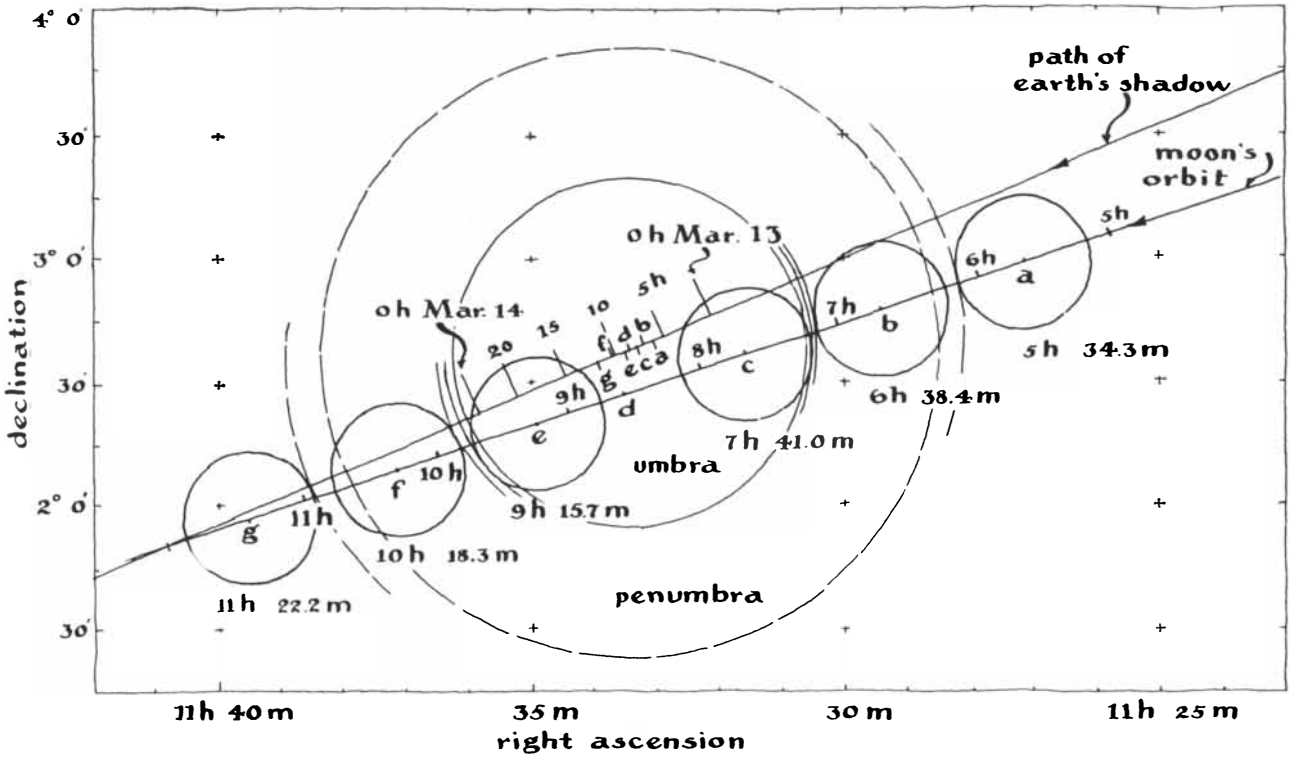

Details of the lunar eclipse of March 13

of the surface (the percentage of light reflected). Experiments and theory demonstrate that brightness is equal to the product of the reflectivity, the illumination and the cosine of the angle of incidence divided by 3.1416. When the illumination is measured in lumens per square foot, the equation gives brightness in terms of candles per square foot. For example, a diffuse sphere viewed from the direction of the light source appears brightest at the center, and because of the increasing angle of incidence, appears progressively dimmer toward the edge. This effect is not observed in the case of the full moon. Although the moon might be expected to be a diffuse sphere, it looks like a disk of uniform brightness. The explanation appears to be that surface irregularities on the moon, such as mountains and the walls of craters, catch sunlight at much smaller angles of incidence than would a smooth surface. This effect upsets the theoretical formula, but greatly simplifies the determination of lunar brightness during an eclipse. Normal incidence can be assumed everywhere on the moon's disk, and attention can be confined to illumination within the shadow.

"The illumination in the penumbra varies according to the proportion of the sun's disk that is covered by the earth, and on the darkening of the sun's limbs. It has been computed and measured by many observers. The relative illumination in the umbra has been similarly measured. A small area on the moon is selected for observation, and the light reflected by it is measured as the area proceeds through the shadow. Such measurements also show that the relative brightness falls slowly as the moon enters the penumbra, and rapidly at the inner edge of the penumbra. There it reaches a value of —6.2 magnitudes (a ratio of 1:302) with respect to the brightness of the full moon, to which we arbitrarily assigned a value of zero magnitude. The brightness continues to drop sharply as the small area under measurement enters the umbra, after which the rate gradually decreases.

"Sunset hues predominate in the umbra. Thus the rate of diminution that is indicated by a photometer is influenced by the color selected for measurement. We analyzed a large number of measurements made during various previous eclipses and plotted a composite curve of relative illumination for the penumbra and two of the umbra's colors: orange (wavelength 6,100 angstrom units) and green (5,400 angstroms). As shown by the accompanying graph [*page 180*] the brightness ratios of the orange curve vary from —6.2 magnitudes at the edge of the umbra to —10.3 magnitudes (a ratio of 1:13,200) at the center of the umbra.

"It is obvious from the graph that the range of brightness characteristic of the lunar eclipse greatly exceeds that of color film. However, more information is required for computing camera exposure, because the graph expresses brightness with respect to that of the full moon. To compute camera exposure we also need to know the *absolute* brightness of the full moon.

"Acquiring this information proved to be rather more difficult than we had anticipated. The published data are in wide disagreement. The crux of the difficulty resides in the failure of observers to state fully the conditions and times of their measurements and calculations. Absolute lunar brightness depends on a number of variables. A major one is the intensity of sunlight. Illumination from the sun varies about 7.5 per cent, because of the approximately 3.7-per-cent variation in the moon-to-sun distance that arises from the eccentricity of the earth's orbit and that of the moon. Moreover, we cannot measure the moon's absolute brightness on earth because of the earth's atmosphere. The apparent brightness that we can measure is less than the true brightness because of absorption by the atmosphere. The absorption varies with the elevation of the moon above

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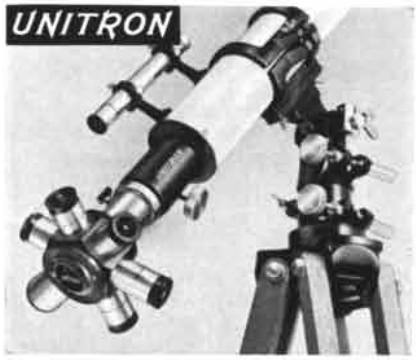

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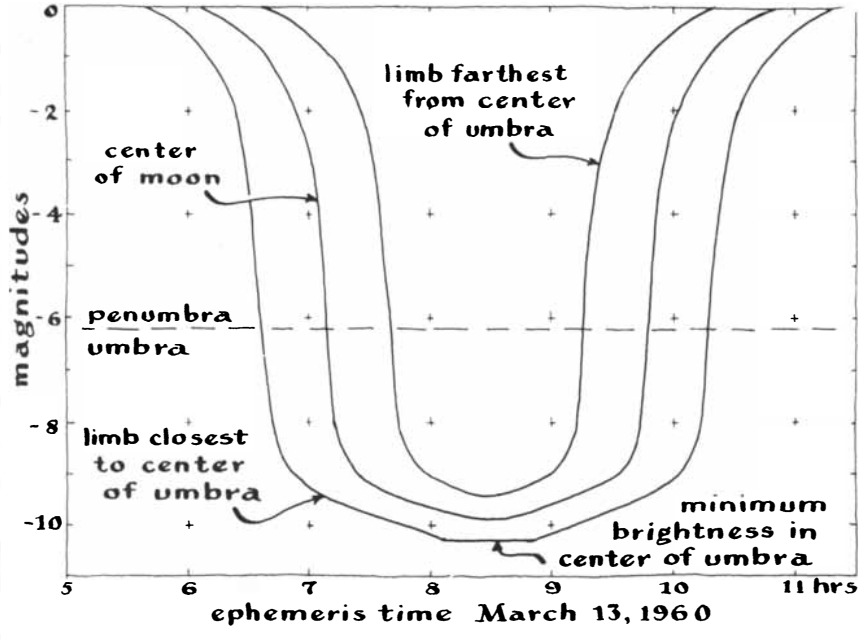
the horizon. Measurements of apparent brightness are meaningless, therefore, unless the observer specifies the moon's elevation at the time of observation. In addition, the intensity of moonlight falling on the earth varies some 23 per cent because of the 11-per-cent variation in earth-to-moon distance.

"Considerably less spread is found in published values for solar illumination and the moon's apparent magnitude. We decided to compute the absolute lunar brightness from these quantities by taking the reflectivity of the moon's surface into account.

"The disparity of the published values in the case of the sun is in the ratio of 1.5 to 1. We selected a value of 14.14 lumens per square centimeter for the solar light-flux outside the earth's atmosphere at the mean earth-sun distance. The surface reflectivity of the moon was taken to be .106. The full-moon brightness is equal to the product of the reflectivity and the illumination divided by 3.1416. With the quantities assumed, it comes out to 433 candles per square foot. During the March 13 eclipse the moon-sun distance was about .9967 times the mean moon-sun distance. The solar illumination was therefore .66 per cent higher, or 446 candles per square foot.

"For the alternative method of arriving at a value for lunar brightness we took the moon's visual magnitude as −12.70 (at mean earth-sun and earth-moon distances). Assuming the illumination of a zero-magnitude star to be .243 billionths of a lumen per square centimeter, the illumination of the full moon equates to .0292 thousandths of a lumen per square centimeter. The brightness of the full moon is equal to the illumination divided by 3.1416 times the square of the trigonometric sine of the angle expressing the moon's semidiameter. During the March 13 eclipse this angle was 15 minutes 39.2 seconds of arc. When the moon-sun distance of .9942 multiplied by its mean value, and the earth-moon distance of 1.0079 multiplied by its mean value, are taken into account, the equation gives 418 candles per square foot as the moon's brightness—slightly lower than the value of 446 candles per square foot based on the sun's illumination. We used the average of the two: 432 candles for the brightness of the full moon.

"To find the absolute brightness of a small area on the eclipsed moon at a specified time, first determine the distance of the area from the edge of the umbra in minutes of arc, and then from the graph of brightness range calculate the relative brightness in magnitudes compared with the full moon. Convert the brightness ratio in magnitudes to a numerical ratio and multiply by the brightness of the full moon. To facilitate this procedure, the distances of the brightest part of the moon's disk (the edge of the moon farthest from the center of the umbra), the dimmest part (the edge closest to the center of the umbra,



Graph of relative lunar brightness during eclipse

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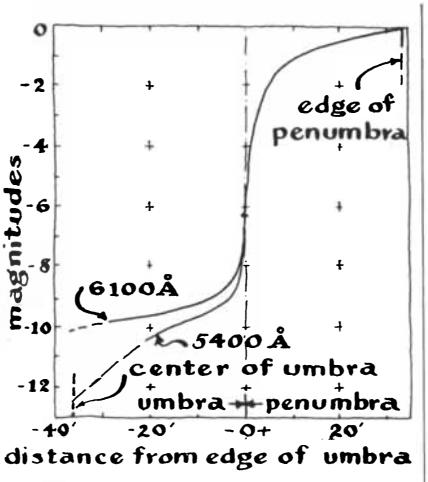

Brightness range of moon during eclipse

except when the moon's disk includes the umbra center) and the center of the umbra were calculated as a function of ephemeris time. This information, together with that from the graph of brightness range, enabled us to plot against time the brightness ratio in magnitudes for these three parts of the moon [*above*]. The chart gives the total brightness range across the disk of the moon at all times during the eclipse.

"This information does not take into account the loss of brightness due to atmospheric absorption. We therefore charted the moon's predicted elevation above the horizon against ephemeris time for the night of March 13 at the latitude and longitude of North Plainfield, N.J. [*see opposite page*]. A final graph was then made to display the visual atmospheric absorption in magnitudes with respect to the apparent angle of elevation above the horizon for a clear atmosphere [*see page 184*].

"As a demonstration of the method used to compute exposure from these data, consider a moment during the March 13 eclipse when the moon had just slipped completely into the umbra (about 7:41 ephemeris time). The graph of brightness range [*page 180*] indicates that the brightness ratio varies from −6.2 magnitudes to −9.9 magnitudes, a range of 3.7 magnitudes. This is well within the range of color transparency film (about 5 magnitudes). It would be logical to expose for the middle (B_{mid}) of this range: −8 magnitudes. The moon at this time is at 38.3 degrees elevation [*see graph on opposite page*], which corresponds to an atmospheric absorption of about .4 magnitude [*see graph on page 184*]. Taking the apparent brightness ratio as −8.4 magnitudes, the corresponding absolute brightness

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(in candles per square foot) for calculating exposure is:

$$B_{mid} = 432 \text{ antilog}_{10}\left(\frac{-8.4}{2.5}\right)$$

$$= 432/2290 = .189$$

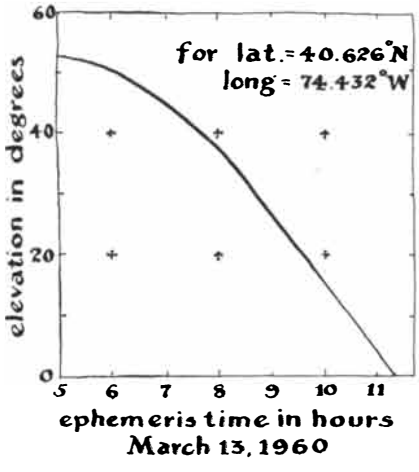
"To determine the exposure we need to know the film exposure-index. For Daylight Ektachrome (sheet film, process E-3) the exposure index S_e is 50. For a relative aperture of $f/6$, the expression for the time in seconds (t) would be as follows (A designates the f number):

$$t = \frac{A^2}{B_{mid} S_e} = \frac{36}{B_{mid} 50} = \frac{.72}{B_{mid}}$$

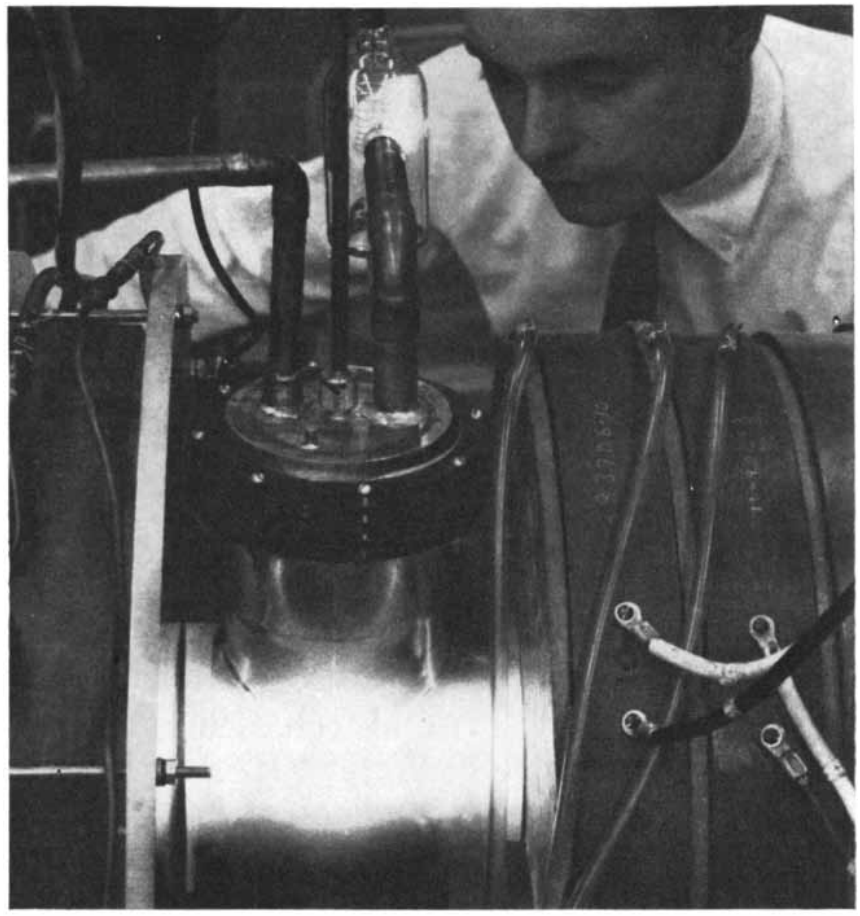
"For $B_{mid} = .189$ candle per square foot, the time is .72/.189, or 3.8 seconds. Because the brightness range in this case is less than the range of the film (3.7 magnitudes compared to 5 magnitudes), it would be logical to expose longer to attempt to capture more detail in the lunar 'seas,' or maria.

"So long as the moon is not partly out of the umbra, the brightness range across its disk is roughly within the range of color film. When the edge of the umbra does cut across the disk, the brightness range can be much greater than color film can record; for example, at 7:00 ephemeris time the total range is 8.7 magnitudes. In these cases one must decide what part of the range to try to cover. If the exposure is made for the portion of the disk in the umbra, the portion outside will be overexposed.

"It should be noted that the accuracy of these calculations should not be expected to be too great. The most serious contributions to error are the assumption that the reflectivity of the moon's disk is uniform, the use of a brightness curve



Graph of the moon's apparent elevation



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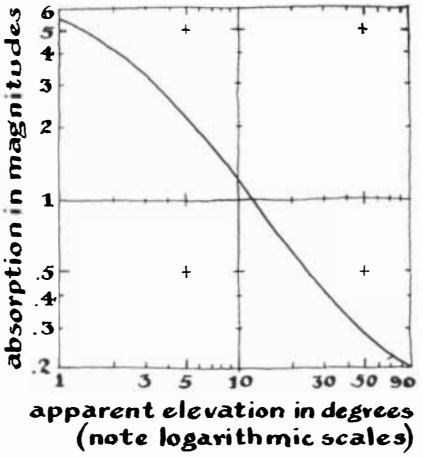

Atmospheric absorption v. *elevation*

within the umbra that corresponds to only one color, and variations in published physical data. We are reasonably confident that the accuracy of the calculators for the absolute brightness of an area of the moon is accurate within one magnitude.

"Four samples of the results of our predictions are herewith reproduced [*see page 173*]. The first photograph [*top left*] was made at 6:58 Universal Time and was exposed 1/2 second to show the irregularity of the shadow along the umbral edge. The second photograph [*top right*] was made at 7:23 Universal Time and was exposed for eight seconds to show the color of the umbra. The region of the moon still immersed in the penumbra is necessarily overexposed. The third photograph [*bottom left*] was made at 7:35 Universal Time shortly before totality. Exposure time was 10 seconds. It shows the difference in color and light intensity within the umbra. The upper right side of the lunar disk is nearest to the umbra center and therefore is generally darkest. Local variations in color outline the maria regions of the moon. The fourth photograph [*bottom right*] was made at 9:26 Universal Time and shows the moon emerging from the umbra. This exposure of 10 seconds again shows the lunar maria as well as the umbra coloring. The center of the earth's shadow zone is now beyond the upper right of the lunar disk.

"We believe that the results displayed indicate the validity of the calculated exposures. By presenting the reasoning that led to the exposure figures, we have tried to demonstrate how simple camera-exposure theory can be adapted to the special problems of eclipse photography."

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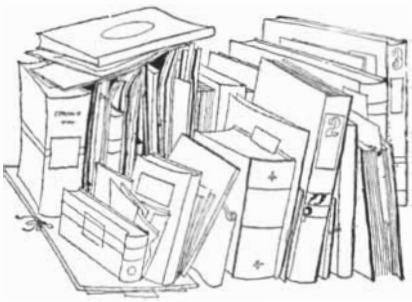

BOOKS

A Christmas survey of new books about science for younger readers

by James R. Newman

"What!," said the Duke of Gloucester to the author on being presented a copy of Volume III of *The Decline and Fall of the Roman Empire.* "Another of those damned, fat, square, thick books! Always scribble, scribble, scribble, eh, Mr. Gibbon?" It is an attitude with which this department is not entirely out of sympathy, especially as it comes time again to prepare the Christmas roundup of children's books about science, a task we have discharged for the last 11 years. Fortunately not many of the books are fat and thick, and while none is so good as Mr. Gibbon's, quite a few are better than scribble.

Three or four hundred of the class, perhaps more, come to our attention every year. The current roundup treats nearly 100. A few points are worth noting. The reviews cover most of the year's good books about science for children, but not all. There isn't enough room. Moreover, some publication dates don't catch our closing time. We also think it useful to review some books of negligible merit so as to let the reader know what not to read.

It wasn't a bad year. Average, say. Half a dozen or so books are first-rate, and there is plenty of bread and butter. May the new books, and the New Year, give you joy.

Physical Sciences

ON THE VARIOUS FORCES OF NATURE, by Michael Faraday. The Viking Press, Inc. (95 cents). A paper-back reissue of the second series of Faraday's famous Christmas Lectures at the Royal Institution, delivered in 1859. The lectures deal with gravitation, chemical affinity, heat, magnetism, electricity. They are personal, informal, simple and lucid. They can be understood by teenagers. The publishers have had the good taste to reproduce the original illustrations. A charming book and a companion to Faraday's even better-known *Chemical History of a Candle,* also available in this edition.

THE GIANT GOLDEN BOOK OF MATHEMATICS, by Irving Adler. Golden Press, Inc. ($3.95). This book is as gaily colored and as stuffed as a Christmas stocking. It is a collection of mathematical knickknacks, some historical, some practical, some conceptual. There are short essays on how numbers were written in ancient times, on standards and measurements, on prime, triangular, square and cubic numbers. Adler discusses the right angle, measuring the distance to the moon, polygons, Buffon's needle problem, square root extraction, Fibonacci series, the golden section, the Pythagorean theorem, the five regular solids, number systems, complex numbers, the rudiments of algebra. Other brief essays deal with mathematics and nature, coordinate systems, conic sections, sine waves, latitude and longitude, the speed of a falling body, infinite series, measuring area and volume, Pascal's triangle, calculating machines, mathematics and music, mathematics and art. Almost any reader of 12 or older will find sustenance and pleasure in these bright pages.

PHYSICS IS FUN, by Gerhard Niese. Astro-Computing Books ($2.95). Experiments which illustrate the laws of mechanics, heat, sound and light, and which require no special equipment. The directions are simple and the explanations clear. Suitable for a 12-year-old.

THE WONDER OF LIGHT, by Hy Ruchlis. Harper & Brothers ($2.95). How light behaves, how and why we see things, the principle of lenses, the different kinds of light. Photographs, diagrams. An acceptable book for readers of 11 and over.

ELECTROMAGNETIC WAVES, by Robert Irving. Alfred A. Knopf, Inc. ($3). About one family of seven rays: light, infrared, ultraviolet, radio, X-rays, gamma rays, microwaves. Reasonable exposition of the properties of the waves, how they are produced, what they can be used for, and how the group fits into the design of modern physics. The illustrations are no better than average. For teenagers.

RAYS AND RADIATION, by Robert Scharff. G. P. Putnam's Sons ($2.75). For ages 8 to 10, a primer on the radiations of the electromagnetic spectrum. Routine job.

ELECTRICITY: HOW IT WORKS, by Percy Dunsheath. Thomas Y. Crowell Company ($3.95). There are many primers on electricity, but very few are really any good. Somehow the explainers seem to forget the troubles they must have had learning the subject, and are unable to put themselves in the position of the beginner to whom the concepts are stubbornly incomprehensible and unreasonable. This honest and sturdy book by a leading British engineer never quite attains the felicity of a true breakdown of the hard items. Dunsheath covers static electricity, magnetism, electric currents, electromagnetic effects, mechanical generation of electricity, alternating current and the transformer, light and heat, telecommunications. He makes a valiant effort to impart the details, to describe experiments, to examine the workings of various machines. He furnishes many illustrations, and he tries conscientiously not to leave loose ends, but when you have finished the book, you are apt to have the uneasy feeling that, while you might pass an examination in elementary electricity, the essence of the wretched stuff is still an enigma.

ADVENTURES IN ELECTROCHEMISTRY, by Alfred Morgan. Charles Scribner's

EDITOR'S NOTE

The illustrations that accompany this article are not from the books reviewed here. They were made by Bernarda Bryson.

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Sons ($3.50). Revised edition of one of Morgan's sound, no-nonsense science books, which provides much accurate information about its subject and explicit directions for a large number of illuminating experiments that cannot all be done with one of dad's cigar boxes, a pie plate and an empty soup can. For the serious youngster there is enough material here to keep him busy for months on experiments involving displacement of one metal by another, electrolytes and nonelectrolytes, making a voltaic pile and other kinds of cells, electroplating and electrotyping, photoelectricity, producing ozone, building a rectifier and so on. Morgan's approach may have gone a little out of fashion, because he assumes there are children who are willing to work to learn science, but a book like this is a bargain and worth six dozen painless primers if your youngster cares enough. Recommended.

THUNDERSTORM, by Thelma Harrington Bell. The Viking Press ($3). Myths and truths about thunderstorms, the build-up of the thunderclouds, their internal mechanism, a brief historical account of the growth of electrical science, with specific reference to lightning. Mrs. Bell once wrote an admirable book on snow; this book is not as good. The explanations of electricity and thunderbolts are a little fuzzy and often absurdly animistic (positive and negative charged particles "want to rush at each other"), and the drawings are meager both in number and clarity. For readers of 11 or 12 and up.

THE STORY OF GEOLOGY, by Jerome Wyckoff. Golden Press, Inc. ($4.95). An excellent popularization which explains, among other things, how science learned to read the rocks, the anatomy of volcanoes, the shaping of the land by erosion and pressure, the phenomenon of ground water, the genesis of lakes and swamps, the history of rivers, the formation of sedimentary rock, the rise and fall of lands, the making of mountains, the earth's magnetism, the continental shelves and deep-sea trenches, how the past is dated. Clearly written and lavishly illustrated in color. Highly recommended.

ICE AGE COMING?, by Leverett G. Richards. The John Day Company, Inc. ($3.25). The answer is maybe, and maybe not—it all depends on many things, not all of which are known, and none of which is fully understood, not even their effect on the weather. Anyway, the story of glaciers, icebergs and icecaps is easy to follow, full of oddities, paradoxes, enigmas and excitement. Richards tells it plainly, and there are good photographs. Young teenagers will enjoy it.

ROCKS AND THE WORLD AROUND YOU, by Elizabeth Clemons. Coward-McCann, Inc. ($3.50). For 10 to 14's a manual on rock-collecting: where to find them, the different kinds and their properties, how to test them, how to classify them, and so on. Many illustrations. Average.

THE EARTH FOR SAM, by W. Maxwell Reed. ($4.95). THE SEA FOR SAM, by W. Maxwell Reed and Wilfrid S. Bronson ($4.95). THE STARS FOR SAM, by W. Maxwell Reed ($4.50). Harcourt, Brace and Company. The Sam books first appeared in the 1930's and were widely and justly appreciated as model science-primers for youngsters of 12 and older. Here and there the books are a little chummy, but this is a small fault when set against their simplicity and accuracy and the authors' obvious interest in their subjects, which flows easily to the reader. The books have now been revised by Paul F. Brandwein, redesigned and illustrated with new photographs. This has been so skillfully done that Sam is better served than ever. You can't do better in this field—which is not to say that there are not many other good books on the subjects. But these old friends wear well.

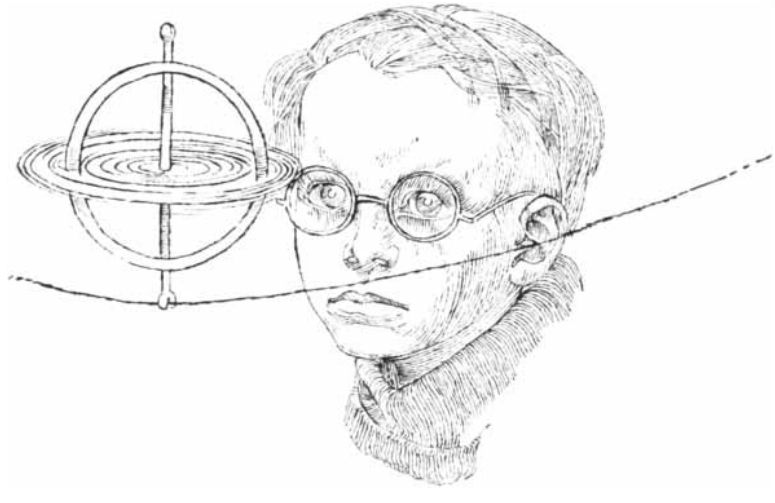
THE MOON, by Franklyn M. Branley. Thomas Y. Crowell Company ($3.50). A nice account of the earth's natural satellite, covering such topics as the moon's motions; why it stays in orbit; eclipses; the surface, temperature, atmosphere, mass and density of the moon; tides; moon mythology and superstitions. Illustrations. For ages 12 to 16.

ATOMS, by Jerry Korn. PLANETS, by Otto Binder. Golden Press, Inc. (50 cents each). Colorfully illustrated, simply written, reasonably accurate 56-page board-bound primers for 12's and older. These are agreeable and inexpensive invitations to further study; they may open a new world for a number of young readers.

FUN WITH SCIENCE EXPERIMENTS, by Mae and Ira Freeman. Random House ($1.50). Children of 10 and up can learn in this new book by the Freemans how to do simple experiments that illustrate important physical principles. The experiments deal with center of gravity, inertia, action and reaction, centrifugal force, the curve of a spinning baseball, mixing molecules, heat convection and conduction, making a cloud chamber, elasticity, capillarity and surface tension, reflecting waves, magnetic drag.

EDISON EXPERIMENTS YOU CAN DO, by Marjorie Van de Water. Harper & Brothers ($2.50). Illustrated with helpful photographs, this book consists of experiments based on Thomas Edison's own work and derived from his original notebooks. The experiments have to do with electrical insulation, electric light, fuses, wireless, the Edison effect, the phonograph and related matters. For youngsters of 11 and over.

THINGS THAT SPIN, by Irving and Ruth Adler. The John Day Company, Inc. ($2). A primer for 9- or 10-year-olds about the why and how of spinning tops, gyroscopes, centrifugal force, sta-



"Things that Spin"

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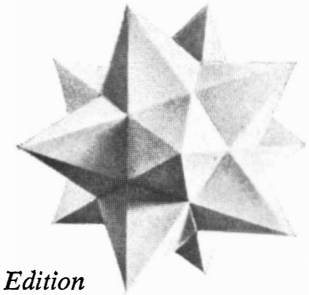
mathematical snapshots

by h. steinhaus



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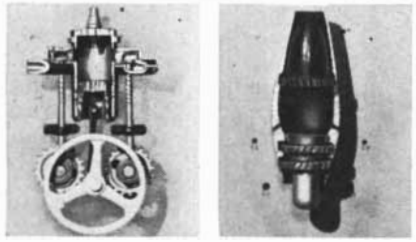

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Biological Sciences

FROM CELL TO TEST TUBE, by Robert Warner Chambers and Alma Smith Payne. Charles Scribner's Sons ($3.50). An informative, well-written introduction to the science of biochemistry. There are not many entries into this fascinating subject, and this fortunately is a good one. It gives the scientific background and the state of contemporary knowledge of enzymes, proteins, metabolism, the amino acids, hormones, vitamins, nucleic acids. The authors convey the excitement of the researches and make plain what has been learned and what is still unknown about the chemistry of the biological processes. For older teenagers.

SCIENCE ON THE SHORES AND BANKS, by Elizabeth K. Cooper. Harcourt, Brace and Company ($3.25). A first-rate field book for youngsters (of 10 to 14) on the smaller plants and animals to be found in or near fresh or salt water or in swamps. Miss Cooper tells you what to look for, the equipment and methods needed to observe and to collect specimens, how to make and maintain an aquarium or underwater garden, how to explore a tide pool, how to experiment with water insects, how to identify and collect shells. She describes the different kinds of mollusk; starfish and their relatives such as sea urchins, sand dollars and sea cucumbers; water worms (ribbon-, clam-, lug-, hair-worms, leeches, planarians); sundry crustaceans from sand bugs and crabs to lobsters, shrimps, crayfish, water sow-bugs and acorn barnacles; frogs and other amphibians; lizards, snakes, turtles and crocodiles (not to be collected by the kiddies); assorted fish; seaweeds and fresh-water plants. A relaxed style, a quiet competence in handling the material and cleanly drawn and helpful illustrations (by the author) make this a fine job.

IN THEIR ELEMENT, THE STORY OF WATER MAMMALS, by Maurice Burton. Abelard-Schuman ($3). Information about whales, dolphins, seals, porpoises, otters, river horses (*i.e.*, hippopotamuses), sea lions, sea cows, manatees, beavers, water shrews, water voles, platypuses, presented by an old naturalist and journalist hand. A good professional job, which is to say readable, accurate and seasoned with diverting out-of-the-way facts. Drawings and photographs. For readers of 12 and older.

A BIRD IS BORN, by E. Bosiger and J. M. Guilcher. A BUTTERFLY IS BORN, by J. P. Vanden Eeckhoudt. Sterling Publishing Co., Inc. ($2.50 each). A pair of very appealing little books addressed to young readers (6 to 12) *and* to their parents, for while the text is elementary, the photographs will fascinate persons of any age. The bird book has 111 step-by-step photos by E. Hosking and R. H. Noailles, which begin the moment the egg is laid and follow up, by X-ray pictures and superb close-ups, until the baby chick gnaws and wriggles its way out of the shell. Other photographs show the growth of curlews, tomtits, owls, gulls, bitterns, herons, swallows, blackbirds, nuthatches, nightingales. The butterfly book has 120 equally fine photographs by the author, showing the gradual transformation of egg into caterpillar into butterfly or moth.

MEN, ANTS & ELEPHANTS, by Peter K. Weyl. The Viking Press ($3). This book for young teenagers is about size in the animal world. The author describes the range of size of living organisms and then considers how size affects our ability to do things, our hearing and sight, the strength of our bodies and our body temperature. While the idea is sound, the text gets to be pretty special and repetitious in the length, area and volume problems, and one grows a little weary of the frequent contrasts between Gulliver, the Lilliputians and the Brobdingnagians. All the same, the book is above the common.

STRANGE TRAVELERS, by Sigmund A. Lavine. Little, Brown & Company ($2.95). For youngsters of 10 and older, a collection of interesting facts about the migrations of various animals: lemmings, caribou, buffaloes, sundry birds, eels, sea snakes, penguins.

THE TALL GRASS ZOO, by Winifred and Cecil Lubell. Rand McNally & Company ($2.75). Palatable sketches of the appearance and habits of tall-grass inhabitants: daddy longlegs, butterflies, fireflies, ants, toads, salamanders, caterpillars, spiders, click beetles, earthworms, ladybugs, praying mantises, spittle insects, snails, cicadas, grasshoppers. For ages five to eight.

DRAGONFLIES AND DAMSELFLIES, by Mary Geisler Phillips. Thomas Y. Crow-

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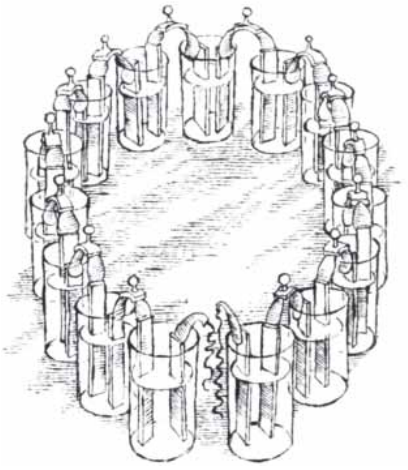

"Adventures in Electrochemistry"

ell Company ($2.50). An ably written little book on the structure, life cycle and habits of the dragon- and damsel-fly, two of the largest and fastest flying insects, which have four wings, are capable of flying backward and upside down and can perform other spectacular aerial acrobatics. For readers of 10 or 11.

HERE COME THE BEES!, by Alice E. Goudey. Charles Scribner's Sons ($2.50). If you feel your child (6-10) should be exposed to the style of a story whose principal character is a bee named Downy (which has such a hard life that no one would ever want to be a bee), this is not a bad account of what happens in a hive, what workers do, how drones and the queen live, how bees forage, dance, communicate and generally keep busy.

PLANTS TODAY AND TOMORROW, by Margaret O. Hyde. McGraw-Hill Book Company, Inc. ($3). A somewhat nondescript, chitchatty book about plant life, with snippets of information on the uses of plants in research, plant enemies and the chemical warfare against them, effects of radiation on plants, growth chemicals and so on. Thin. For ages 12 and up.

WILDLIFE IN DANGER, by Ivah Green. Coward-McCann, Inc. ($3.50). Photographs and a straightforward text plead the case for, among others, the great white heron, wood duck, kit fox, condor, heath hen, bighorn, woodcock, coyote, flamingo, ivory-billed woodpecker, manatee, wolf, sandhill crane, great auk, key deer, trumpeter swan, musk ox, Eskimo curlew, wolverine, roseate spoonbill, Carolina paroquet, walrus, Labrador duck, passenger pigeon, grizzly—all

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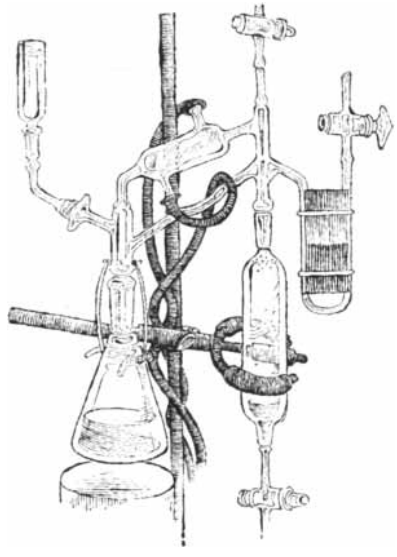
of which rapacious men with red caps, and others of their kind, have exterminated, or would if they could. For age 10 and up.

NATURE AND MAN, by John Hillaby. Roy Publishers ($2.95). A pleasing little book about the balance of nature: how plants and animals move, natural communities, food chains, animal and plant invasions, conservation, extinct species, the concept of ecology. The author manages to cram a good measure of interesting and illuminating information into 60 pages of text. For teenagers.

THE WONDERFUL STORY OF YOU, by Benjamin C. Gruenberg and Sidonie M. Gruenberg. Garden City Books ($2.95). A simple account of genetics and birth, bodily structure and function, the growth and maturation process. The illustrations are pretty drab, but this is a sound book by an experienced husband-and-wife team that deserves thanks for their sustained and sturdy contributions to child education. For adolescents.

THE STORY OF YOUR BLOOD, by Edith Lucie Weart. Coward-McCann, Inc. ($3). About the sovereign juice: its circulation, its constituents, its properties. Average. For ages 9 to 13.

THE WORLD OF FEELING, by J. D. Carthy. Roy Publishers ($2.50). In the Progress of Science Series a primer for young adolescents on how we see, hear, taste and smell, feel. Other chapters explain the sense of balance and consider whether there are senses other than those usually recognized; the answer being that certain animals may have receptors that humans do not. An intelligent book. Illustrations.



"From Cell to Test Tube"

Social Sciences

THE SCIENCES OF MANKIND, by Jane Werner Watson. Golden Press, Inc. ($4.95). A sampler of the social sciences. Miss Watson's well-illustrated book presents sections on the historian's tools, the methods of the archeologist, the researches of anthropologists, how economists, sociologists, geographers, demographers keep busy, the statisticians' problems, the activities of social workers, the interests of experimental psychologists. It is doubtful that this crowded, hurried and somewhat formless volume will give anyone a clear idea of the social sciences as a whole, but a few of the close-ups are mildly informative and interesting. At least the book does show that there is a bewildering variety of attempts to understand man's behavior and human relationships. For older teenagers.

GOOD DIGGING, THE STORY OF ARCHAEOLOGY, by Dorothy and Joseph Samachson. Rand McNally & Company ($3.50). This book sketches the history of archeology, explains its principles, tools and methods, shows what it borrows from other sciences to help locate remains and interpret them and describes the training of an archeologist and the preparations for an expedition. The writing is a little gummy, but the material is interesting enough to hold the attention of adolescent readers. Photographs, maps, glossary

THE WORLD OF THE PHARAOHS, by Hans Baumann. Pantheon Books, Inc. ($4). The story of a modern Egyptian boy, the son of an archeologist, who decides to dig for himself and make his own discoveries, and who then finds a knowledgeable guide who introduces him to the landmarks of the Old Kingdom, the pyramids, Thebes and Karnak, Tutankhamen's tomb, the Golden Pharaoh and other ancient wonders. The guide recounts the history of Egyptology and shows his young pupil how to be an archeologist. The fictional setting is implausible and the conversations are absurd, but much of the factual material is quite interesting, and the book is admirably illustrated with drawings and colored photographs. A suitable, if somewhat over-priced, gift for young teen-age diggers.

THE FIRST COMERS, by Alice Marriott. Longmans, Green & Co. ($4.50). Miss

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Marriott's book describes what archeology has learned about the early American Indians: their artifacts dug up in the frozen North, their mounds in Ohio, their pyramids in the Southeast, their culture and way of life. She also explains how one can pursue archeology as a hobby. Her book is for teenagers.

THE MOUND BUILDERS, by William E. Scheele. World Publishing Company ($2.50). The director of the Cleveland Museum of Natural History has written a fine simple account for young people (10 to 14) of the prehistoric people, the Hopewells and their Adena ancestors, who flourished in the Ohio Valley for 1,500 years (from about 850 B.C. to A.D. 400) and built the high, cone-shaped mounds that archeologists have only recently begun to understand. Many illustrations.

AMERICAN INDIANS, YESTERDAY AND TODAY, by Bruce Grant. E. P. Dutton & Co., Inc. ($4.95). For ages 12 and up, a revised edition of an illustrated encyclopedia of the American Indian. In it they can learn about adobe huts and Zuñis; sign language and pemmican; the Miamis (who used to be called Twightwees—a name that comes from the cry of the crane), Micmacs, Crows, Arapahoes, Assiniboins and Sioux; Custer's Last Stand and powwow; maple sugar, maize, masks and Minnehaha; how, hunting, Powhatan, tepee, thunderbird (early model with wings instead of tires), throwing sticks, trail blazing, Yuki, wooden Indians (used as a cigar-store shill because the Indian originated the use of tobacco), Sacajawea (a Shoshone woman who guided Lewis and Clark), sand painting, Conestoga wagons, Daniel Boone, Biloxis, birch bark, medicine men, Leatherlips (Huron chief of the Sandusky tribe sentenced to death by Tecumseh), kinnikinnick (smoking mixture of bearberry leaves and tobacco), the Eliot Bible, cockarouse (a Virginia Indian word for a person of importance), burying the hatchet, scalping and other essential television-watching terms.

PEOPLE OF THE WORLD: VOL. II, by Geoffrey Whittam and others. Henry Z. Walck, Inc. ($2.75). Agreeable, pleasantly illustrated chapters on lumbering in Canada, cattle raising in Australia, tea growing in Ceylon, fur hunting and fur farming in Canada. For ages 8 to 12.

THE LAND AND PEOPLE OF ARGENTINA, by Elvajean Hall. J. B. Lippincott Company ($2.95). Another book in the Portraits of the Nation Series: geography,

An announcement from Simon and Schuster about

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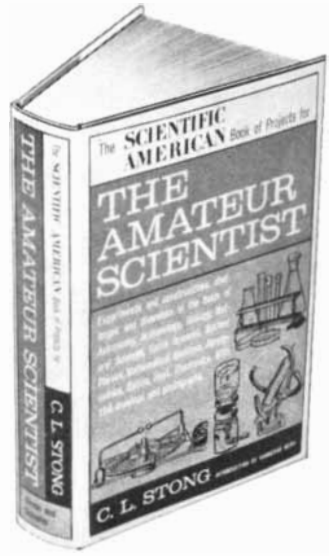

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GETTING TO KNOW NIGERIA, by Sam Olden. Coward-McCann, Inc. ($2.50). About one of the new independent nations of Africa: its geography, cities, resources, ways of life, people. Routine. For readers of 10 and up.

MY VILLAGE IN GREECE, by Sonia and Tim Gidal. Pantheon Books, Inc. ($3.50). For 9- to 13-year-olds a new volume in the My Village Books Series, which in text and photographs describes a boy's daily life on Mykonos, a beautiful Greek island in the Aegean. The story tells of the youngster's chores in the little fishing village, his friends and sports and games, what he eats, how he dresses, his visit to the famous island of Delos and his exploration with his classmates of its temple remains and other archeological sites. Pleasant.

THIS IS NEW YORK, by M. Sasek ($3). THIS IS PARIS, by M. Sasek ($3.50). THIS IS ROME, by M. Sasek ($3). THIS IS LONDON, by M. Sasek ($3.75). The Macmillan Company. A quartet of attractive picture books giving impressions of four of the great cities of the world. The many illustrations are imaginative and colorful; the text is brief. Especially effective is the impressionistic method of catching the spirit of a city by showing its policemen, kiosks, lampposts, cats, flower markets, subway tickets, taxis, cafés, as well as its famous streets, houses, buildings, monuments, shops and the like. The volume on New York is delightful.

THE GOLDEN BOOK PICTURE ATLAS OF THE WORLD. Golden Press, Inc. ($10). The assets of this three-volume work deserve recognition. They consist of an easy-reading text which encompasses the geography and resources, industry and agriculture, people and places of all the countries of the world; of skillfully assembled facts and figures that both enlighten and stimulate further studies; of more than 1,000 color photographs and maps which, if not the finest examples extant of reproduction and cartography, are still thoroughly pleasing and give a better over-all picture of the globe than can be found in any geography textbook that was ever made. A youngster whose parents buy him this set is lucky.

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"The Tall Grass Zoo"

FIRST GEOGRAPHY OF THE SUEZ CANAL, by Arensa Sondergaard. Little, Brown and Company ($3.50 each). Illustrated primers for 7- to 10-year-olds, giving the history and geography of these man-made waterways. Easy to digest.

MAP MAKING, by Lloyd A. Brown. Little, Brown and Company ($4.75). Some years ago Brown published an excellent book, *The Story of Maps,* which gave a comprehensive account of the evolution of cartography from an art to a science. He has now very skillfully compressed the earlier material into this shorter version addressed to teenagers. He explains why maps were first made, how the ancients envisaged the shapes of the land masses, how the study of the heavens helped to an understanding of geography, the achievements of Strabo, Ptolemy's rules for map makers (many of which are still followed), the influence of travel on map making. Other chapters consider the beautiful maps and atlases of the 16th and 17th centuries, the beginnings of the determination of latitude and longitude, John Harrison's clock, the advent of systematic national maps, world map-making in our century. The story is told with admirable clarity both as to the scientific details of cartography and to the historical elements of its development. A distinguished children's book. Fine illustrations.

Technology

HARVESTS AND HARVESTING THROUGH THE AGES, by Norman E. Lee. Cambridge University Press ($2.95). A well-planned, effectively illustrated, clearly and interestingly written brief history of food and farming through the ages, including the harvesting and processing

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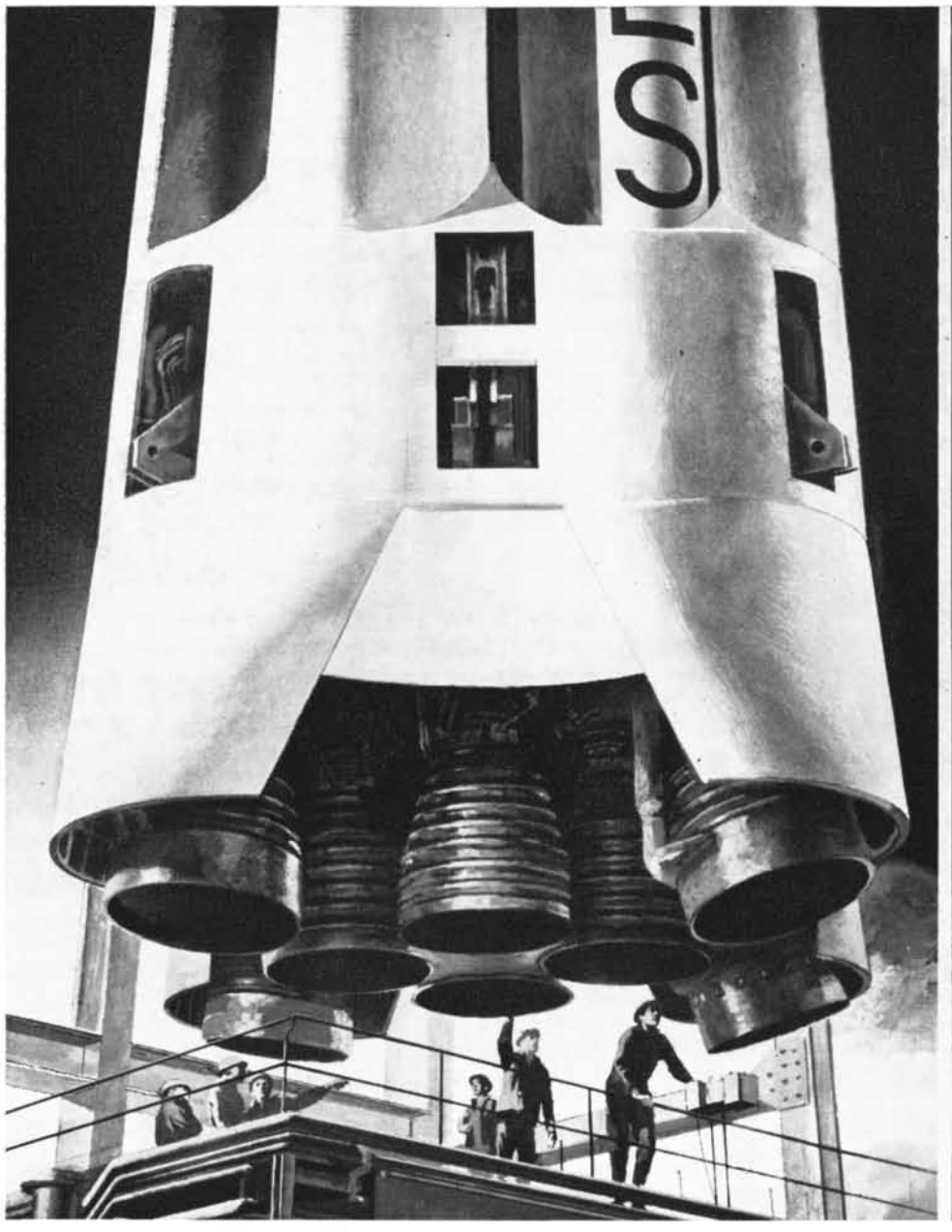

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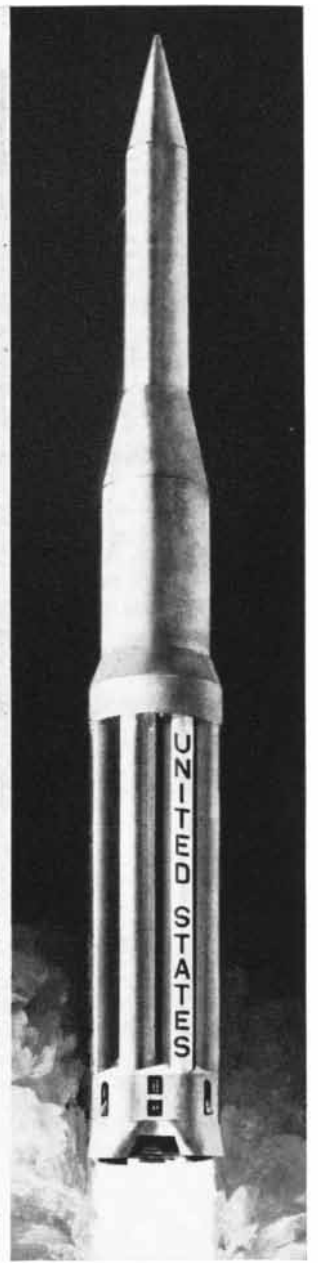

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of crops. In addition to covering his main topic succinctly and accurately Lee touches upon a variety of items in the history of technology and in social and political history that are related to food-raising. For example, he tells about the discovery of fire and the fire drill, the hunting of mammoths, the gathering of wild honey, the domestication of animals, dating methods, irrigation, the ingenious scientific detective work of Sergei Vavilov in solving the problem of the origins of wheat, the invention of farm machinery, the 14th-century Peasants' Revolt in England, the role of barbed wire and windmills in the settlement of the American West, the relation of slavery to agriculture, the raising of great new crops in Australia, Canada and Africa. A first-rate primer, suitable for teenagers or grownups.

PAPER, by Jerome S. Meyer. World Publishing Company ($3). A short illustrated primer on the history of paper and modern paper-making. The text is understandable, and some of the photographs are helpful. For readers of 10 and up.

WATER OVER THE DAM, by Dorothy Childs Hogner. J. B. Lippincott Co. ($3.95). About the new high dams, old milldams, ancient and medieval dams, mills of the ancient world, earth dams: how they were built, the problems they solved and the problems they raise, famous dam collapses, and so on. Mrs. Hogner packs in a great wad of information and tells her story straightforwardly, but the book is peculiarly organized, running back and forth chronologically and topically. The illustrations by Nils Hogner are more decorative than educational. For teenagers.

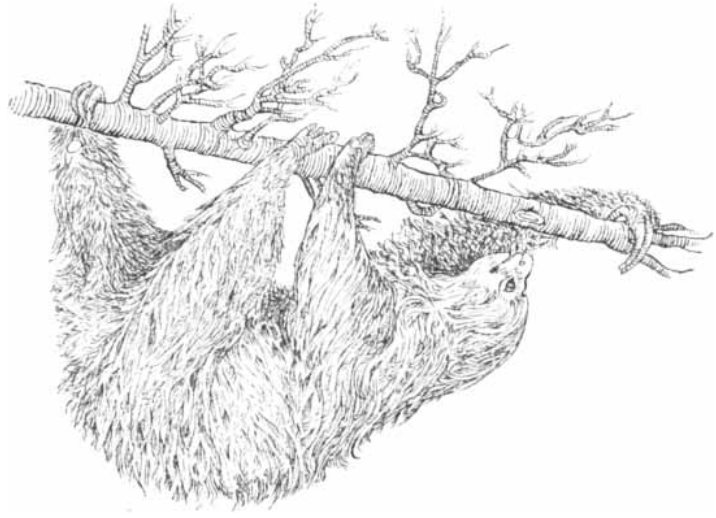
ALUMINUM FROM WATER, by Sabra Holbrook. Coward-McCann Inc. ($2.75). A lively story of the building of Canadian dams, hydroelectric stations and aluminum plants. For readers of 11 or 12 and up.

TEAR DOWN TO BUILD UP, by Jean Poindexter Colby. Hastings House ($2.95). The story of building wrecking: the tools and machinery that are used, the different kinds of workmen, demolition methods. An unlikely subject, but Mrs. Colby does pretty well with it. For sidewalk superintendents of 10 to 13.

History

EVERYDAY LIFE IN ROMAN AND ANGLO-SAXON TIMES, by Marjorie and C. H. B. Quennell. G. P. Putnam's Sons ($3.50). The Everyday Life books of the Quennells are very good: well written, admirably illustrated. Here they have combined into one volume (and revised) two earlier books, *Everyday Life in Roman Britain* and *Everyday Life in Anglo-Saxon, Norman and Viking Times*, first published in the 1920's and often reprinted since. The result is a literate and attractive package that conveys a clear, living impression of the people, places and periods described. Recommended. For 12's and up.

DOWN THE COLORADO WITH MAJOR POWELL, by James Ramsey Ullman. Houghton Mifflin Company ($1.95).



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BECAUSE *each day* nearly 140,000 more people are added to the world's population, and *each year* 50,000,000 more people;

BECAUSE unless a favorable balance of population and resources is achieved with a minimum of delay, there is in prospect a Dark Age of human misery, famine and unrest;

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THEREFORE WE SUPPORT with conviction the efforts, within individual nations, to control the birthrate.

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"Harvests and Harvesting through the Ages"

A highly readable retelling, as one would expect from Ullman, of the great story of John Wesley Powell's hair-raising boat journey through the Grand Canyon of the Colorado in 1869. It is hard to imagine any youngster (11 and up), in fact anyone, who would not enjoy this gripping book; and he can then go on to Powell's own account, *The Exploration of the Colorado River*, and to Wallace Stegner's excellent *Beyond the Hundredth Meridian*, which deals with the whole of Powell's career.

THE IMPOSSIBLE JOURNEY OF SIR ERNEST SHACKLETON, by William Bixby. Little, Brown and Company ($3). A most readable retelling of one of the greatest stories of heroism, skill, leadership and endurance in the annals of polar exploration: the journey of Shackleton and his crew by ice floes and tiny boats from the Antarctic continent to South Georgia Island. The book could have used a decent map and at least a few illustrations, but the story stands up by itself. For ages 12 and up.

FROM STONES TO SKYSCRAPERS, by Thea and Richard Bergere. Dodd, Mead & Company ($3.50). A short tour through the history of architecture: prehistoric times, the buildings of the Egyptians, Babylonians, Greeks and Romans; Byzantine, Romanesque, Gothic and Renaissance structures; the Baroque period; Saracenic monuments; contemporary architecture. The text is straightforward and gives a good many details about elements, styles and techniques; there are many drawings by Mr. Bergere and a glossary. For teenagers.

ROADS TO DISCOVERY, by Ralph E. Lapp. Harper & Brothers ($3.75). A survey of the march of modern physics, from Röntgen's discovery of X-rays and the work of Becquerel, the Curies and Rutherford to recent studies of nuclear structure. Lapp is at home in his subject and very much at ease in explaining it to the lay reader. This is an excellent entry for the teenage and older group.

THE QUEST OF ISAAC NEWTON, by Barbara and Myrick Land. Garden City Books ($2.50). This book has one of the most hideous covers to have appeared in many years, but the contents are acceptable. They consist of an illustrated account for young teenagers of Isaac Newton's researches in optics, mechanics and mathematics.

BREAKTHROUGHS IN SCIENCE, by Isaac Asimov. Houghton Mifflin Company ($4). Essays, which first appeared in a magazine for high-school students, on the work of certain scientific discoverers: Archimedes, Copernicus, Harvey, Galileo, Leeuwenhoek, Newton, Watt, Lavoisier, Faraday, Henry, Bessemer, Jenner, Pasteur, Mendel, Röntgen, Darwin, Einstein, Rutherford and others. For readers of 10 and older.

TIME FOR YOU, by Duane Bradley. J. B. Lippincott Company ($2.75). A brief history of time measurement, from shadow sticks to modern clocks. Illustrations. For children of 9 to 11.

Biography

ALEXANDER VON HUMBOLDT, by M. Z. Thomas. Pantheon Books, Inc. ($3.50). A translation from the German of a youngsters' (12 to 14) biography of the famous naturalist and geographer who spent five years adventuring in South America, wrote *Cosmos*, one of the prodigious scientific works of the 19th century, made a journey through Central Asia and explored the Ural and Altai mountains. In remembrance of his achievements his name has been given to the Humboldt Glacier of northern Greenland, to the vast current that sweeps around the coast of South America, to Humboldt Bay in California, to rivers, mountains, cities and national parks. This is what has been called an "inspirational biography," replete with imaginary dialogue, but, allowing for that, it is lively and interesting.

ELIZABETH GARRETT, M. D., by Jo Manton. Abelard-Schuman ($3). A biography of Elizabeth Blackwell's opposite number in Britain, the first English woman medical student, who by sheer determination, and by desire to elevate her sex and to help sick people, rather than by any special aptitude for her profession, opened the career of medicine to women and contributed to the advancement of public health. For teenagers.

THE WALLS OF WINDY TROY, by Marjorie Braymer. Harcourt, Brace and Company ($3.50). A young people's (12 and up) biography of the great digger Heinrich Schliemann. His life and work were so exciting that it is next to impossible to make a complete hash of the story. Miss Braymer's account is full of imaginary and stiltedly implausible conversations, but the facts are straight. An upper teenager would have more fun reading Robert Payne's biography or even Emil Ludwig's.

KETTERING: MASTER INVENTOR, by Sigmund A. Lavine. Dodd, Mead & Company ($3). Excruciatingly adulatory biography of a very ingenious and prolific inventor who contributed to automobile development and made a huge fortune out of, and for, General Motors. Lavine thinks it best to quote frequently from Kettering's aphorisms and salty *aperçus*, which are neither quotable nor aphoristic nor especially aperçuish; but he did once say something amusing about how easy it is to pilot a plane in bad weather: "All you have to do is throw out a monkey wrench. If it goes up, you

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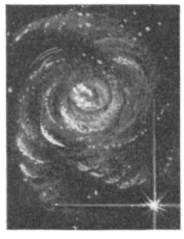

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are flying upside down. If it goes down, you're flying right side up." For readers 12 and over, until the critical faculty awakens.

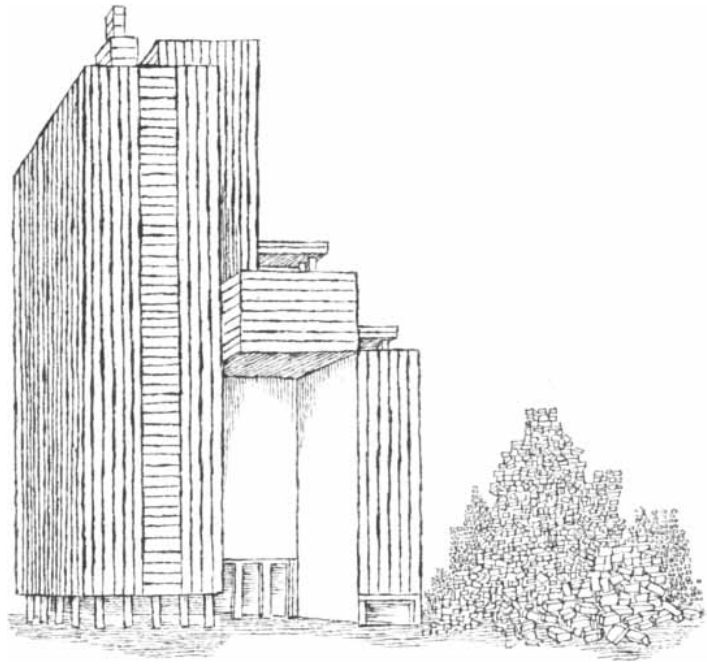
CONGO EXPLORER, by Jeanne Carbonnier. Charles Scribner's Sons ($3). A short biography for young persons of Pierre Savorgnan de Brazza, who opened up the French Congo (its capital, Brazzaville, is named after him). He was a farsighted, humane and liberal man whose actions were guided by "kindness to others, sternness toward myself," and who dreamed of a "free Africa civilized by the combined efforts of all nations." Imaginary conversations.

Miscellaneous

RACING CARS THAT MADE HISTORY, by David C. Cooke. G. P. Putnam's Sons ($2.50). An interesting photographic album, with brief accompanying text, of the feats of high-speed automobiles from the two-cylinder, four-horsepower Panhard (which in 1895 won the 732-mile Paris to Bordeaux race with an average speed of 15 miles per hour) to the Leader Card Special (which in 1958 won the 500-mile grind at Monza, Italy, at 166.788 m.p.h.). In between are details about the Winton Bullet, the Locomobile, the Mercedes 12.8, the Marmon Wasp, the Stutz 6.3, the Ballot, the Duesenberg, the Bugatti, the Auto-Union, the Alfa Romeo P.3, the Ferrari 4.5, the Maserati 250F, the Cooper Climax, the Ford 999, the Fiat two-liter and other entrancing models. For children of all ages.

THE BOYS' BOOK OF VETERAN CARS, by Ernest F. Carter. Roy Publishers ($3). An informative and entertaining book about vintage cars and vintage motoring: the first London to Brighton run, the White steamer, the Prince of Wales's Coventry-Daimler, the hazards of early motor races, the first Rolls-Royce, the development of tires, horns and lights, the famous Pekin to Paris race, the first magnetic clutch, the beginnings of famous firms (Austin, Ford, Morris, Humber). The last chapter describes the rejuvenation by the author and his son of a lovely seven-horsepower 1908 Renault, which they drove 1,000 miles to Wales and back. For 12's and over. Many excellent photographs.

INDIANS OF THE PLAINS, by the editors of American Heritage. RAILROADS IN THE DAYS OF STEAM, by the editors of American Heritage. Golden Press, Inc. ($3.50 each). Two appealing volumes in the American Heritage Junior Library. The first book, "narrated by" Eugene Rachlis, is a history of the Plains Indians: their relations with white men, their customs, tribal laws, weapons, tools, methods of hunting, warfare, religious ceremonies, myths. The railroad volume, written by Albert L. McCready, is even more attractive and less usual. It begins with the tale of the *Best Friend of Charleston*, the



"From Stones to Skyscrapers"

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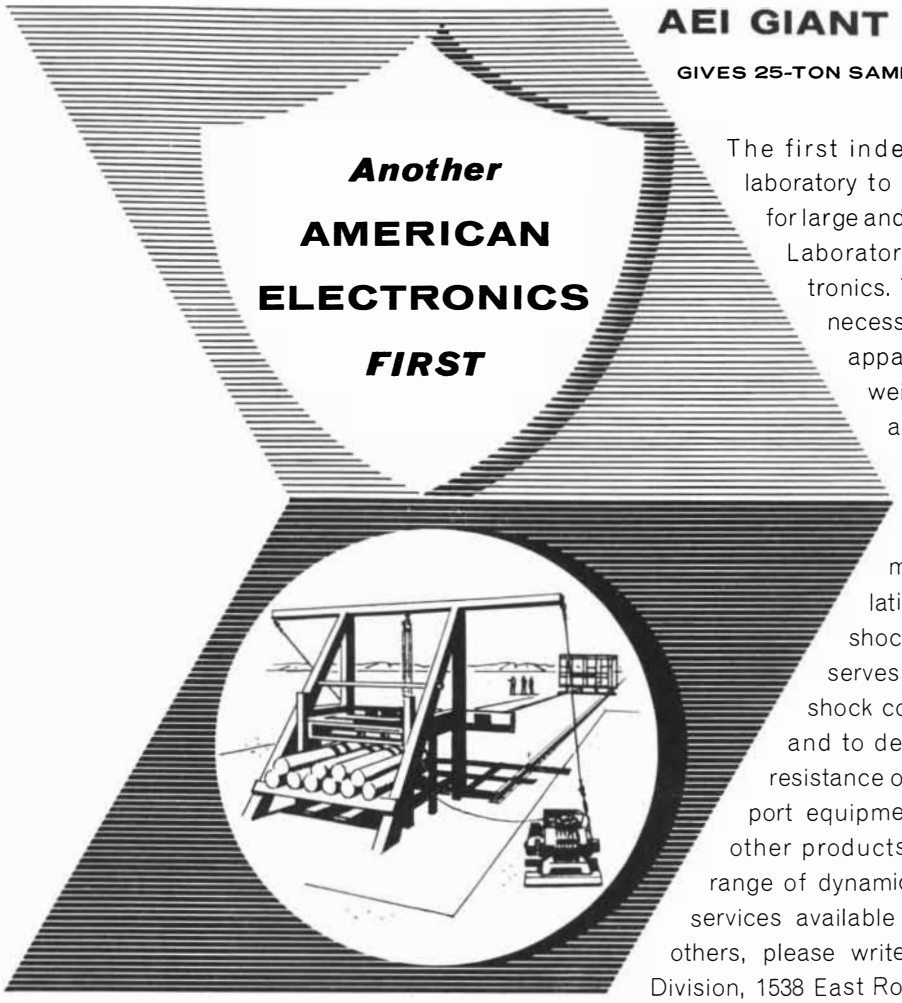

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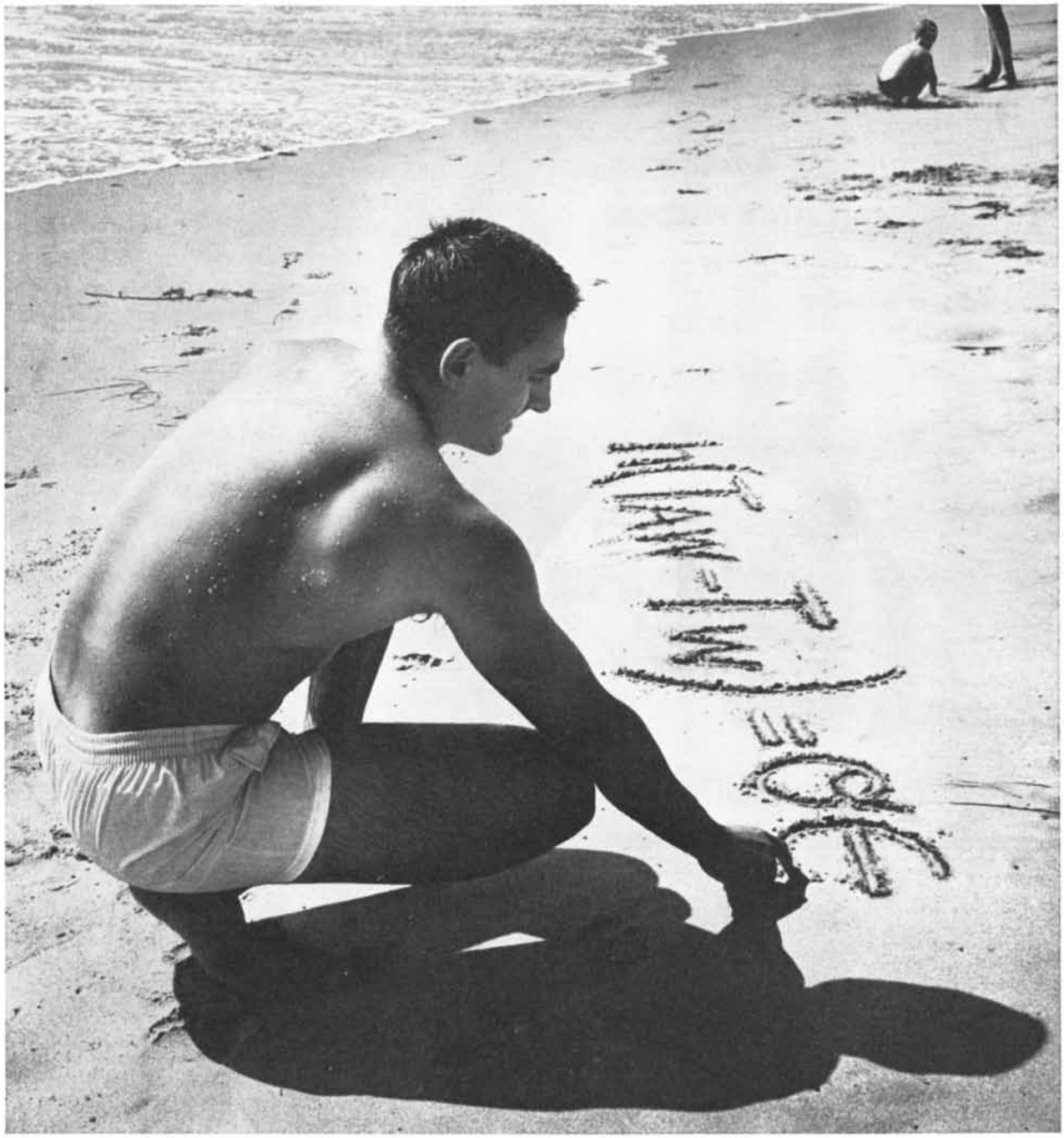

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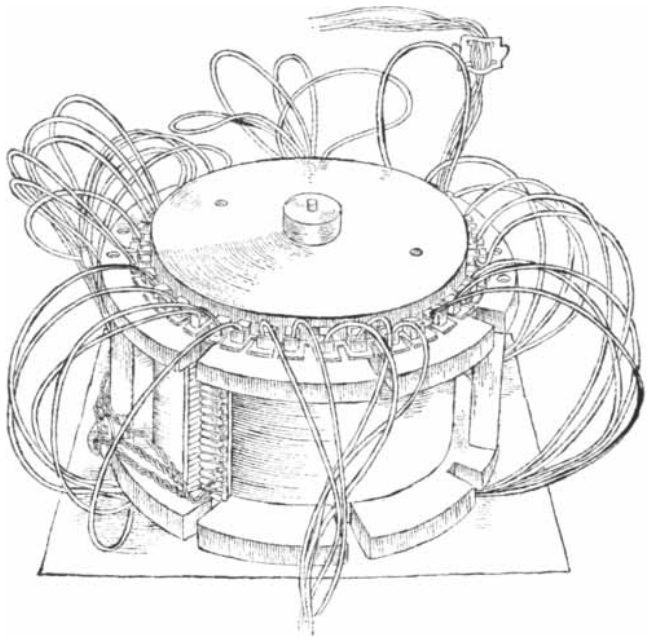

"The Wonderful World of Communication"

first American-built steam locomotive (made at the West Point Foundry in New York) to haul a train of passenger cars on a public railroad, and goes on to describe the evolution of the iron horse, railroading in the Civil War, the spanning of the Continent, the fabulous capers of various railroad financiers, the making of the Wild West, the railroads and the farmers, famous wrecks, inventions, the beginnings of the railroad brotherhoods, railroad travel in the 19th century. The outstanding feature of both volumes is the illustrative material: contemporary paintings, prints, drawings and photographs. First-rate books for anyone over eight or nine.

THE FIRST BOOK OF MEASUREMENT, by Sam and Beryl Epstein. Franklin Watts, Inc. ($1.95). A short history of measurement that tells how the units of length, weight, volume, time, evolved from the age of Rome to the present.

REALM OF MEASURE, by Isaac Asimov. Houghton Mifflin Company ($2.75). About the historical origin and meaning of such measures as feet and yards, inches and miles, centimeters and kilometers, acres and gallons, ounces and grams, seconds, dynes and Newtons, ergs and watts, poises and quanta. For readers of 12 and up.

KEEPING TIME, by Walter Buehr. G. P. Putnam's Sons ($3). Chapters on the calendar, time measurement, mechanical timekeepers, time at sea, the clockmakers and their guild, the evolution of watches. Illustrated by the author. A book of modest claims and modest merit. For sub-teenagers.

THE WORLD ALOFT, by Guy Murchie. Houghton Mifflin Company ($3.75). An abridged version for adolescents of Murchie's well-received book (*The Song of the Sky*), dealing with the airman's world: wind and storms, cloud formations, navigation, aerodynamics, exciting experiences aloft. Good reading.

ONE HUNDRED AND ONE SCIENCE EXPERIMENTS, by Illa Podendorf. Grosset & Dunlap ($3.95). Illustrated directions for simple experiments with air, magnets, electricity, water, heat, sound, light, machines, plants. The experiments are designed to answer such questions as: Can a magnet be used as a compass? Will sound vibrations travel through wood? Why do we wear light-colored clothing in the summertime? What happens when things rust? What is the principle of the pulley? What happens if the roots of a plant get started growing up instead of down? Miss Podendorf has a natural inability to write simple English, but the experiments are sensible.

ELEPHANT BILL, by J. H. Williams. The Viking Press ($1.45). It is very good to have back in print in an inexpensive edition this delightful book by Colonel Williams, who for 25 years was an elephant manager in the teak forests of Burma, who loved and knew the animal as few other men have and whose fascinating stories about it are

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free of any taint of nature-fakery. For any age from 11 or 12 up. Photographs.

THE WONDERFUL WORLD OF COMMUNICATION, by Lancelot Hogben. Garden City Books ($2.95). From cave art to alphabet, penman to printer, magic lantern to movie, telegraph to television—the lesson being that communication makes the world one. Colorful illustrations (as in all the volumes of this series) and a readable, humane, cocksure text (as in all of Hogben's books). For 12's and up.

HIGH TIMBER, by Charles I. Coombs. World Publishing Company ($4.95). The story of American forestry: the nature of trees, the difference between hard and soft woods, conservation, lumber manufacture, paper-making, forest fires. Plain text and some very good pictures. For ages 12 and up.

SHOTS WITHOUT GUNS, THE STORY OF VACCINATION, by Sarah R. Riedman. Rand McNally & Company ($3.50). Stories of the work of Edward Jenner, Louis Pasteur, Robert Koch, Paul Ehrlich, Béla Schick, Jonas Salk. Competent. Photographs. For teenagers.

JUNIOR SCIENCE BOOK OF BEAVERS, by Alexander L. Crosby. JUNIOR SCIENCE BOOK OF ELECTRICITY, by Rocco V. Feravolo. JUNIOR SCIENCE BOOK OF FLYING, by Rocco V. Feravolo. JUNIOR SCIENCE BOOK OF TREES, by Robert S. Lemmon. Garrard Press ($2.25 each). These unpretentious books, for second- to fifth-grade readers, give a few highlights of their subjects and either give directions for easy experiments or tell the youngster what to look for in his outdoor wanderings. The writing is plain, the illustrations are helpful, the facts are straight. A sound lot.

AMERICAN WORDS, by Mitford H. Mathews. World Publishing Company ($3.95). The editor of the *Dictionary of Americanisms* tells stories about the origins of American words and terms: coed, paper wasp, passenger pigeon, Johnny Appleseed, hickory (a liquor made of the nuts from the hickory tree was called pawcohiccora by Virginia Indians), potlatch, Kiwanis, coronary thrombosis, cosmic ray (R. A. Millikan), Santa Claus, O.K. (Old Kinderhook, the Hudson River district where Martin Van Buren was born), air brake, appendicitis, boss (*baas:* Dutch for "master"), Yankee (origin unknown), taxi, pinochle, and so on. For readers of 12 and up.

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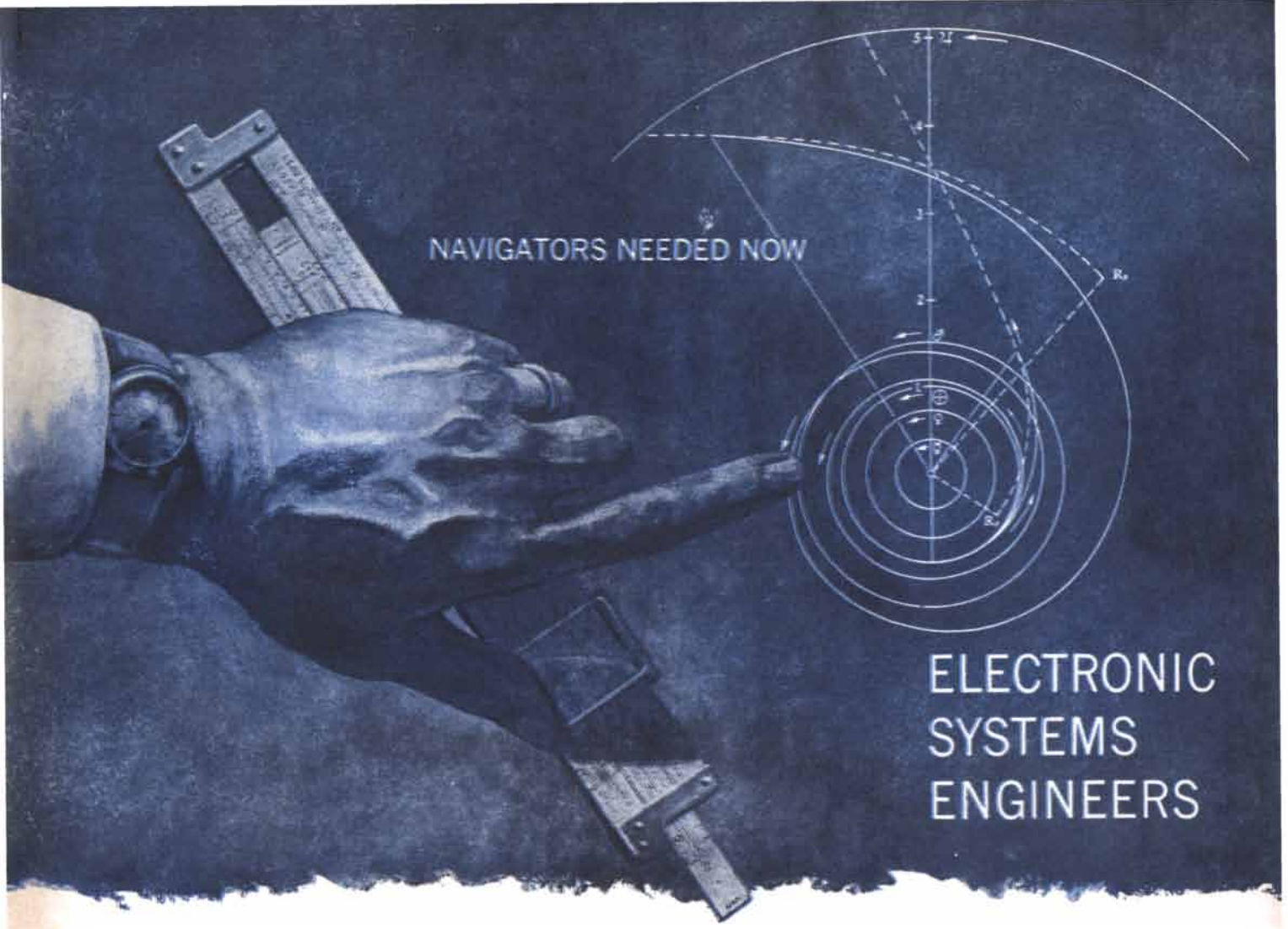

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SATIN

... An Experimental System for High-Altitude Air Traffic Control

Under a contract with the Federal Aviation Agency and jointly supported by the Department of the Air Force, MITRE is designing and implementing an experimental en route Air Traffic Control system. The system, called SATIN (for SAGE Air Traffic Control Integration), utilizes area control techniques to provide positive separation of all high-altitude en route traffic regardless of the route chosen or navigation used.

Through application of a SAGE digital computer and its associated radar, beacon, and radio network, SATIN permits inclusion of both the Boston and New York centers into a single high-altitude control area. The system automatically correlates radar and beacon data with flight plan information to establish a current position for each aircraft under control. Conflict prediction takes place automatically as does the transfer of information for intra-and inter-center coordination.

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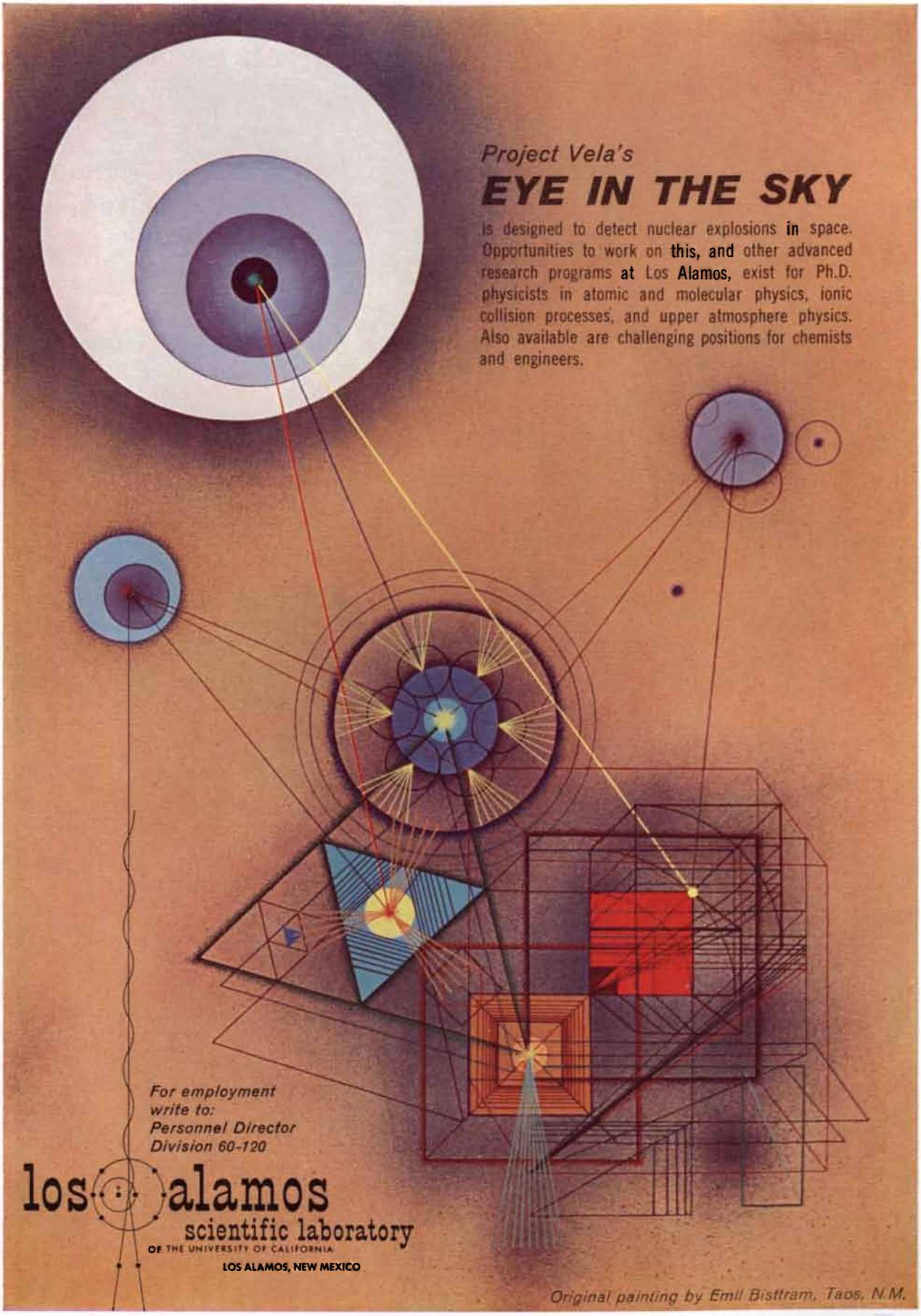

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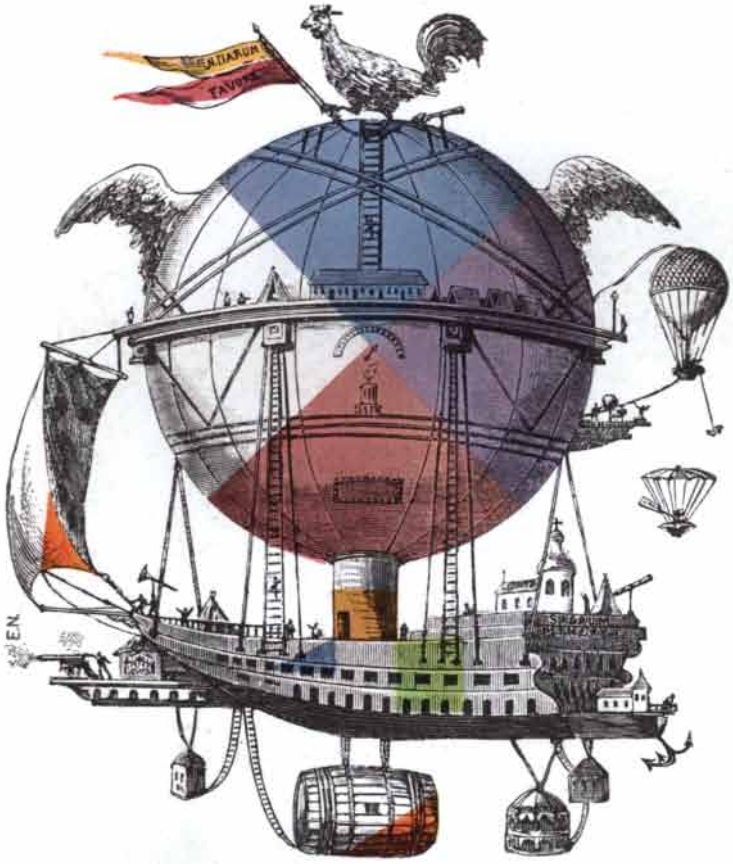

"Voyages to the moon and neighboring planets haunted the imagination of more than weak minds."

Wild schemes proliferated after the Montgolfier brothers sent their first balloon aloft in 1783. The most gloriously fantastic was *La Minerve*, proposed in 1804 by Etienne Gaspard Robertson, a Paris aeronaut. This aerial gingerbread specified a hydrogen balloon 150 feet in diameter, accommodations for 60 people and lavish appointments—promenades, theatre, observatory, clinic and gymnasium. Robertson suggested that a group of scientific gentlemen spend several months aboard to explore the possibilities of flight. *La Minerve* never got beyond the pamphlet stage.

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