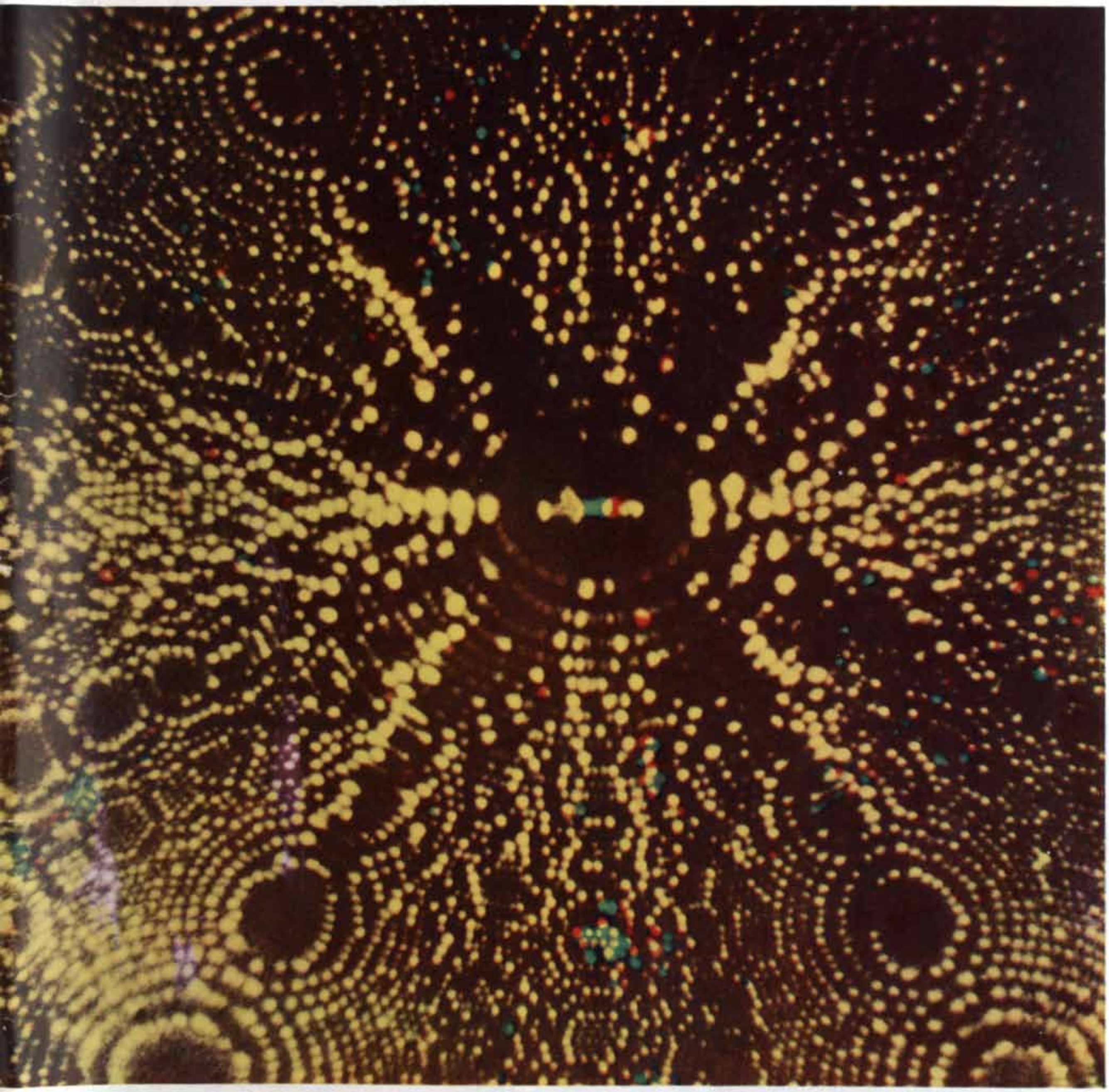
SCIENTIFIC AMERICAN



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June 1957

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The positive TO control lets the radiographer stand well away (up to 50 feet) from the casting as he drives the "pill" into radiographic position.

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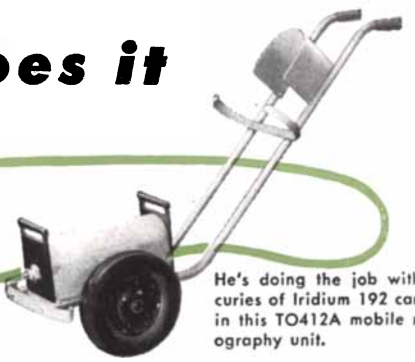

He's doing the job with 50 curies of Iridium 192 carried in this TO412A mobile radiography unit.

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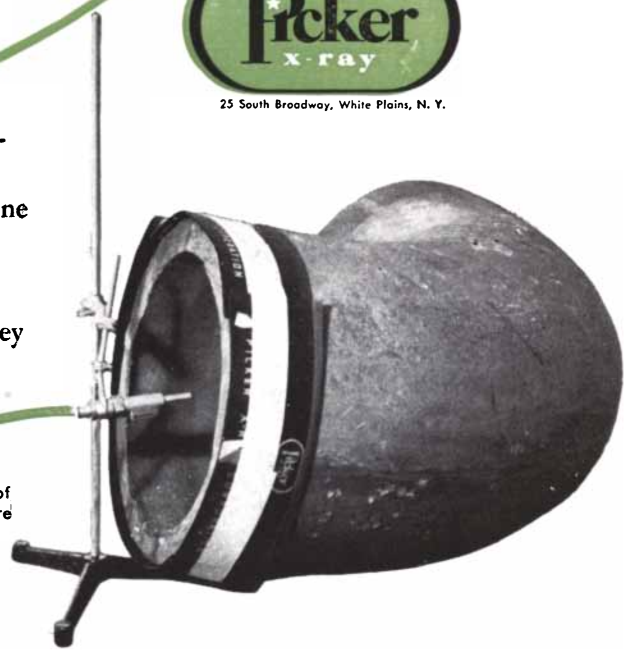

One "shot" radiographs the entire girth of the casting. Picker Flexible Film Holders are quickly taped on, quickly removed.

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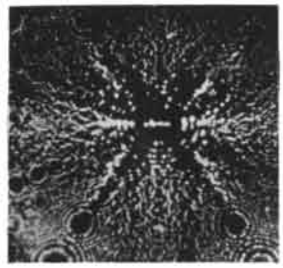
Established 1845 **SCIENTIFIC AMERICAN** June, 1957 Volume 196 Number 6

ARTICLES

DEPARTMENTS

PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK 17, N. Y. ENTERED AT THE NEW YORK, N. Y., POST OFFICE AS SECOND-CLASS MATTER JUNE 28, 1879, UNDER THE ACT OF MARCH 3, 1879. ADDITIONAL ENTRY AT GREENWICH, CONN. SUBSCRIPTION RATE IN THE U. S. $5 PER YEAR.



THE COVER

The photograph on the cover was made at Pennsylvania State University with a new device called the field ion microscope (*see page 113*). The spots in the photograph are individual atoms in a crystal of tungsten. Some of the spots are yellow; others are red or green. The meaning of these colors is described in the text of the article.

THE ILLUSTRATIONS

Cover photograph
by Erwin W. Müller

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How fast tomorrow?

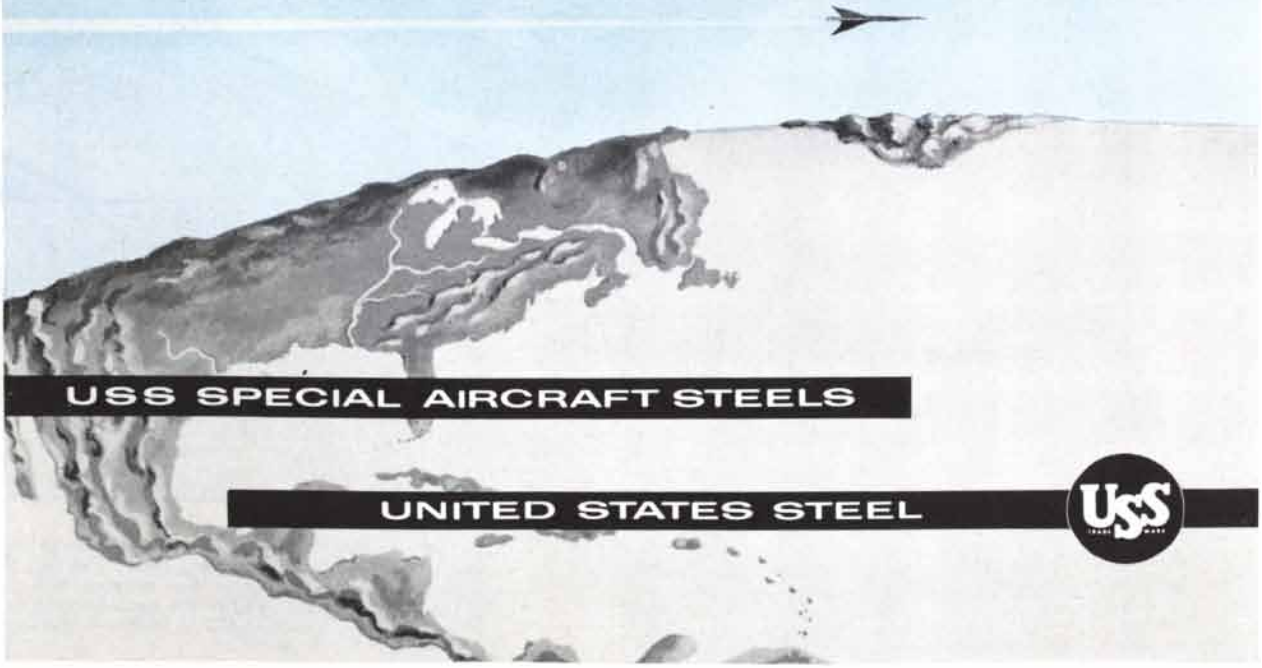
MAN has flown over 2,000 mph. Already there is talk about 4,000 mph. Tomorrow it may be 10,000 mph. Is there a limit to the speed of tomorrow's aircraft?

Actually there are many factors that will define this limit. One is the basic need for an airframe skin material that at temperatures of 800° to 1,000° F. combines a tensile strength of over 200,000 psi with good oxidation resistance. This in itself presents a problem, but in addition, the material must be capable of fabrication into finished assemblies on existing manufacturing facilities and, furthermore, should require a minimum of scarce alloying elements, so that it can be produced in quantity even in an emergency.

As a possible solution to this complex problem, United States Steel has presently developed "USS 12 MoV"—a modified type 422 martensitic stainless steel—that shows definite promise of meeting all the exacting requirements of high speed flight.

With a nominal composition of C 0.20, Mn 0.50, Si 0.50, Ni 0.65, Cr 12.0, Mo 1.0, V 0.30, "USS 12 MoV" Stainless Steel is relatively "lean" or free of scarce alloying elements. Yet it retains strength above 225,000 psi in tension, *throughout* the range of room temperature to 800° F. In this regard it appears to be superior to those materials which, until now, have been considered the most promising for aerodynamic applications.

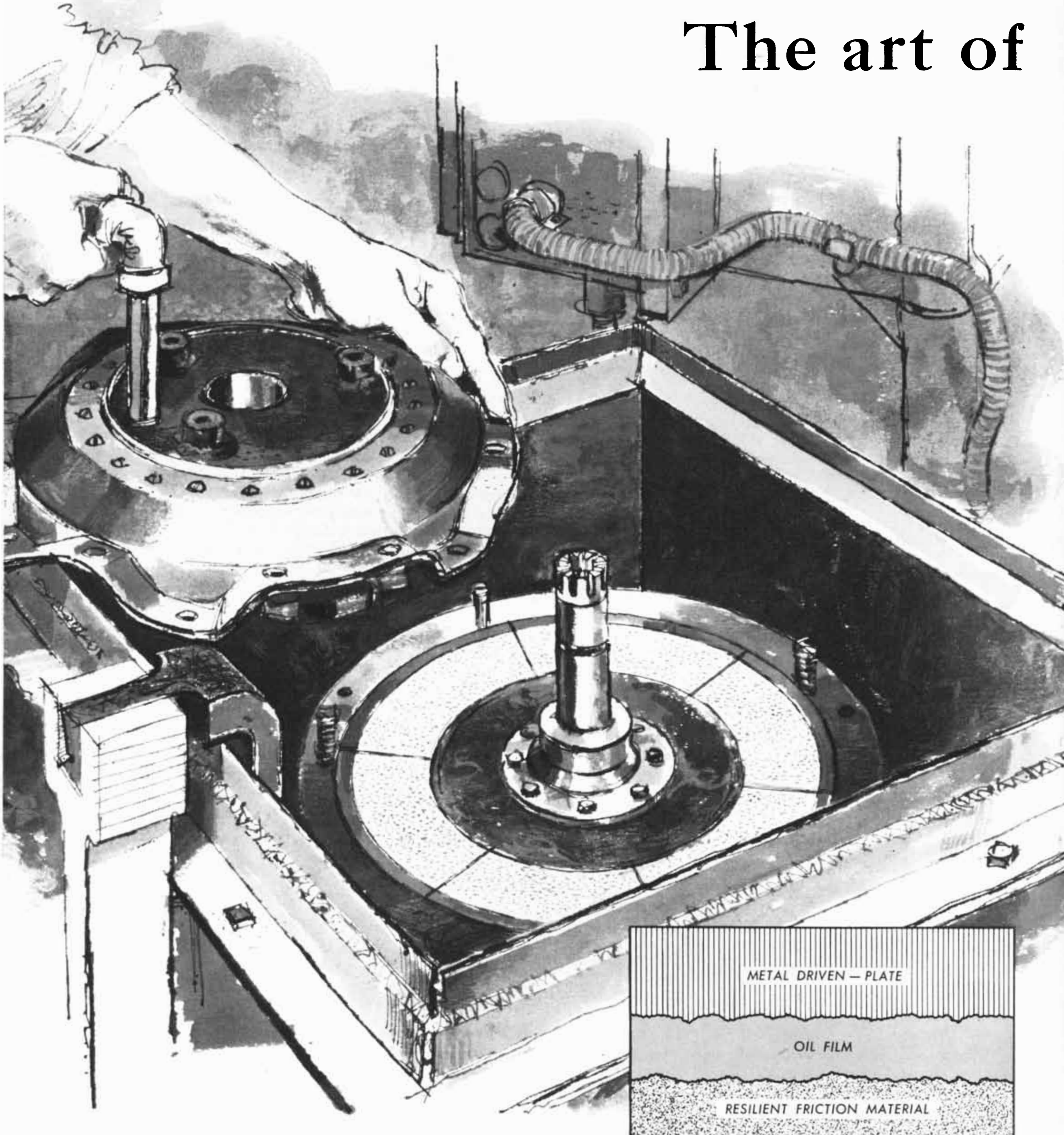
Important, too, both to the steel and aircraft industries is the fact that the heat treatment essential in developing the required tensile strength of "USS 12 MoV" can be carried out by methods already widely used by manufacturers and fabricators. United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pa.



USS SPECIAL AIRCRAFT STEELS

UNITED STATES STEEL

The art of



Experimental friction materials get a work-out in this test clutch at the Armstrong Research and Development Center. All conditions—temperature, pressure, and speed—are precisely controlled. Automatic recorders chart the operating characteristics of facings during each engagement cycle.

In wet clutches, the driving and driven surfaces are separated by an oil film when disengaged. The film thins as engagement pressure forces the surfaces into contact. After a brief period of slip, the surfaces grip and the clutch becomes fully engaged as relative movement ends.

making friction behave

How research men control the grip of friction materials to help cars, appliances run smoother

Shifting gears automatically in an automobile . . . changing from "rinse" to "spin-dry" in a washer . . . rapid-fire starting and stopping of an industrial sewing machine — all depend on how well a thin sheet of friction material in a clutch does its work.

Although the job of the clutch — to engage and disengage the driving force — is nearly always the same, the way it engages may vary considerably.

With an industrial sewing machine, for example, the operator runs a seam at high speed, stops on a stroke of the needle, turns the fabric, and races down another seam. Here, research men found that a cork clutch facing material, operated "dry," will take hold fast enough to take the machine from a dead stop to full speed in a fraction of a second.

But the same kind of fast-acting dry clutch in an automobile would produce too much shock for both car and rider. And if to avoid this shock the clutch plates were allowed to slip during engagement, the heat generated might burn up the facing material.

Smooth, gradual engagements are commonplace, however, in the clutches of automatic transmissions. Here cork facings are operated "wet," that is, immersed in oil. Surprisingly, cork keeps much of its high friction even when flooded with the same oil that lubricates the transmission. In fact, oil makes gradual engagements practical by carrying off much of the heat that's generated.

Changing the shape of the plates in a wet clutch produces different kinds of engagement, too. A flat plate with radial slots, for example, engages faster than a plain flat plate. On the other hand, a "waved" plate engages more slowly.

Although there are many such mechanical techniques, the art of making friction behave also depends a great deal on the compounding of the friction material itself. The research worker faces almost limitless possible combinations of cork, rubber, resins, and fibers. Even small changes in these ingredients or their proportions may make significant differences in clutch performance.

As a result, developing a new material with specific frictional properties is a job that takes a large measure of resourcefulness and imagination. The only criterion for success, however, is found in the very practical question, "Does it work?"

If you make or design clutches for automobiles, appliances, machine tools, business machines, or the like, you may be able to lower costs or improve performance with Armstrong resilient friction materials. We will be glad to submit suggestions to you if you will send us details of your application. Address Armstrong Cork Company, Industrial Division, 8206 Inland Road, Lancaster, Pennsylvania.

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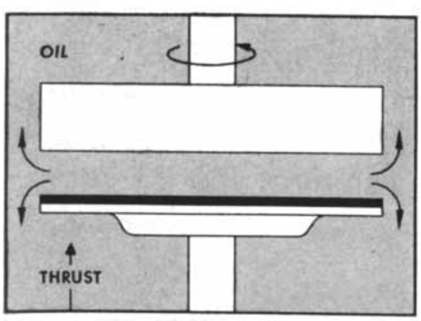
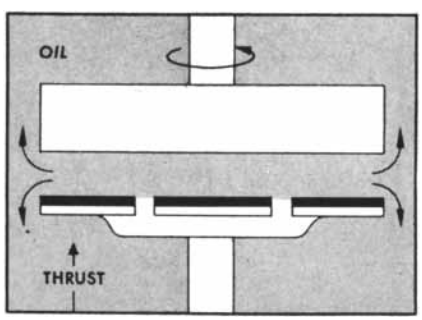
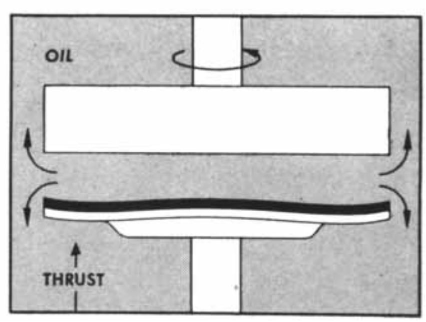


Changes in clutch plate design permit designers to manipulate the oil film and control the engagement period. It takes a flat plate, for example, a relatively long time to squeeze away the oil film and become fully engaged.



Radial slots in a flat clutch plate tend to create short engagement periods, even with low engagement pressures. The slots apparently set up a "squeegee" action that wipes away the film of oil, hastening full contact.



A "waved" plate maintains the oil film much longer during engaging period when the pressure is being applied. When full pressure is finally developed, the plate flattens to make full contact, and engagement is completed.

Bill Waddell discusses ANALOG/DIGITAL CONVERSION

For the past few years one of the most serious concerns in systems design has been the development of equipment eminently suited to "link" the analog input to the digitized output assemblies of the system. Examples of such links are to be found in radar recording problems in the missile test field, in the control of machine tool operations and, most recently, in data logging in the petrochemical and chemical processing industries. In these and similar instances, there has been a conscious striving to produce highly specialized pieces of conversion equipment in an attempt to adapt the system to the particular control problem at hand.

This striving has also led to increasingly frequent discussions of analog to digital conversion in engineering circles. Such discussions have stimulated interest in, and have actually succeeded in clarifying, basic problems faced by the engineer in producing units suitable for the digitization of specific function variables.

However, contending for attention along with the requirement for restricted-purpose conversion equipment, are the types of analog functions requiring to be digitized. These have continuously increased in numbers, in complexity, and in the imposition of increasingly severe criteria for reliability. To illustrate, systems today are successfully coping with shaft rotations, linear displacements and the complete gamut of electrical signals. A few systems have been built where pressure, temperature, and flow variables have been directly converted.

In the past the tendency has been to design the analog to digital converter and then assemble systems around the converter block. Examples of this approach are to be found in the handling of high-speed serial binary digits from input voltages, and in shaft converters containing cyclic codes requiring complicated translations before the outputs are readily adaptable for further processing. In order to achieve suitable solutions in such cases, it became necessary to introduce auxiliary equipment which frequently turned out to be much less reliable than the digitizer. This led, therefore, to more highly complicated and costly systems rather than significantly simplifying the basic analog to digital converter.

The current approach is to engineer a "link" integrating the components directly into the system. Only in this manner can they be properly weighted to assume their true and economical function. This has resulted in consciously avoiding marrying, for instance, a 5,000 sample per second analog input to a converter capable of spewing out 50,000 samples per second. Or by the same token, feeding 50,000 samples per second into subsequent processing components not adequately provided with control equipment and/or direct methods for recording such rapid outputs.

Bill Waddell, systems input-output specialist, discusses analog to digital conversion.

The present awareness of the problem, however, makes for a most encouraging outlook in the foreseeable future. Design break-throughs are bound to integrate the analog to digital conversion step into its proper and logical relationship to the total system. Systems will then become less complex and significantly more reliable, which undoubtedly will rapidly result in unfolding important new fields suitable for control applications.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write to Dept. 11:

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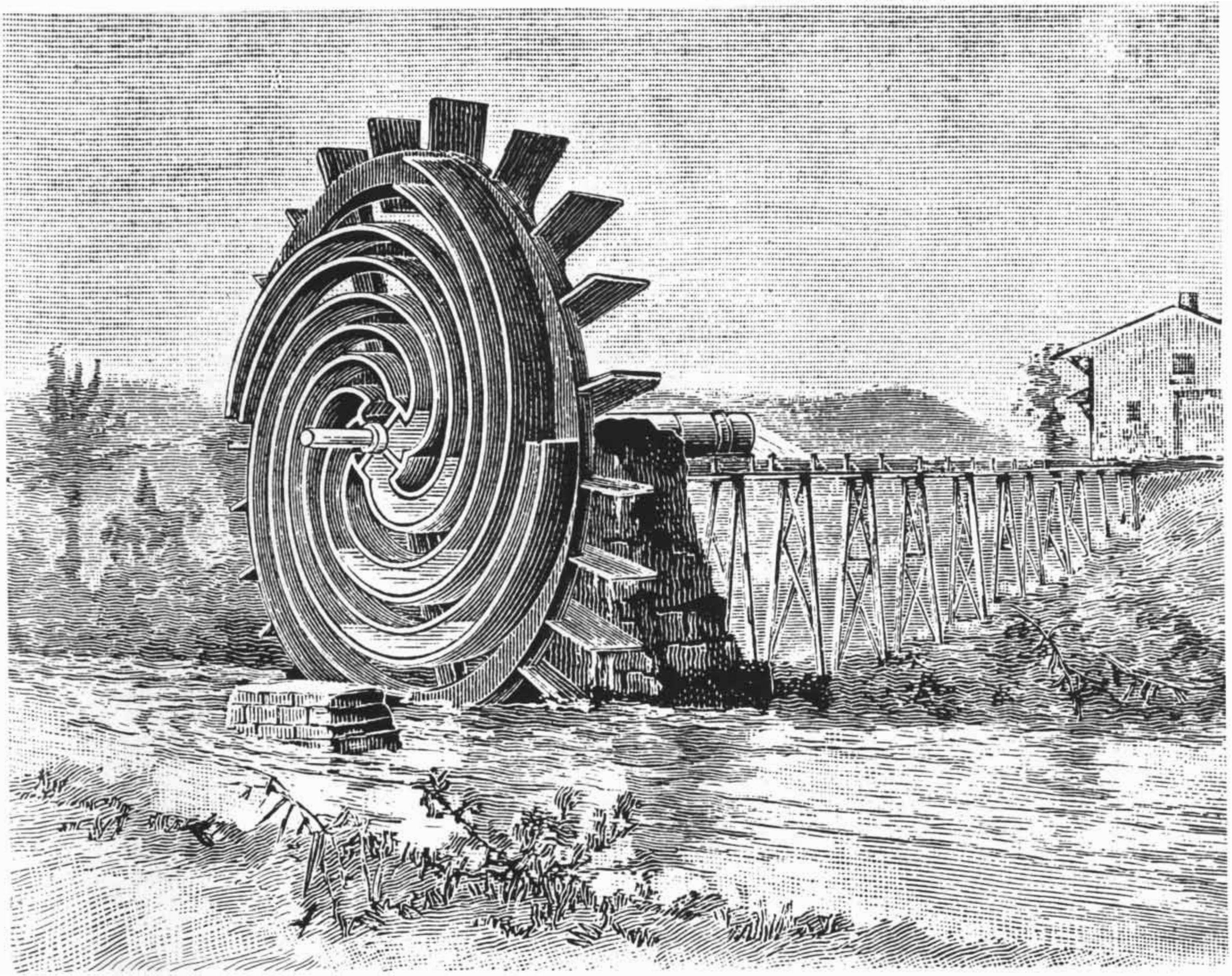

The Tympanum (side and bearing removed to show the construction). Woodcut, 1891.

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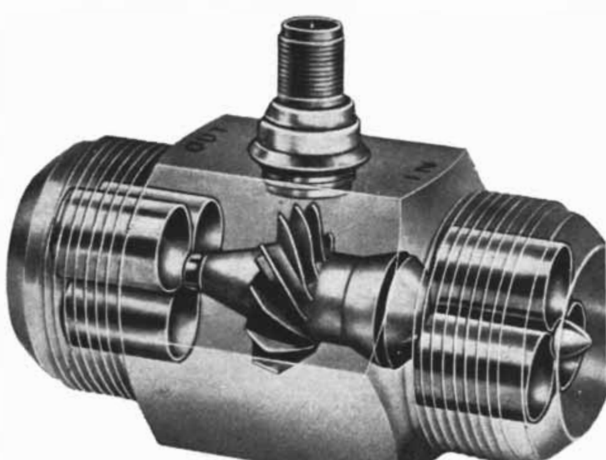

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LETTERS

Sirs:

This letter is to assure that your attention and that of the author is drawn to a particularly charming example of written English.

I refer to the paragraph beginning in the first column of page 63 in your April issue. In discussing skin transplants, P. B. Medawar paraphrases a portion of a lecture delivered by an unidentified geneticist. (Is it to him or to Medawar that we are indebted for the usage?) He says that parthenogenesis occurred in guppies and might not *inconceivably* (italics mine) occur in man. It is indeed a pregnant thought (sociologists of knowledge would probably call it a seminal thought, but it doesn't make a vas deferens) that man might conceive without conception.

There is no need to labor the point. In fact, I shall give it a wide berth.

MITCHELL M. BERKUN

Human Resources Research Office
The George Washington University
Fort Ord, Calif.

Sirs:

Having to some extent been associated with the events that led to "The Overthrow of Parity," I feel embarrassed to offer a few comments on Philip Morrison's lucid article in your April issue. In view of the importance of the subject, I think I may be forgiven for pointing out the following:

1. The hypothesis that neutrinos are left-handed and anti-neutrinos right-handed is not an "explanation" of the failure of minor invariance in beta-decay (or in any other process involving neutrinos for that matter). Unless parity conservation were violated, no decay process could produce particles of unique handedness, but only 50-50 mixtures of both "screw directions."

2. The preference for a unique screw direction has indeed been tested both in the Columbia and the "later" experiments elsewhere not specifically described by Dr. Morrison. But to date nobody has established the "specific" screw direction (whether right or left) of the mu mesons used. This in fact has remained one of the challenges to experimenters.

3. All the experiments referred to by Dr. Morrison were specifically suggested in the original paper of C. N. Yang and T. D. Lee. The Columbia experiments on asymmetrical muon decay were, however, highly unconventional in their design, and the names of the people who conceived them, Richard L. Garwin and Leon M. Lederman, might well have been recorded, should the reader not have gleaned them from the brief discussion in your March issue.

4. The parity-violation effects in muon decay were corroborated in our laboratory by an exceedingly simple experiment performed in nuclear emulsion, in which the correlation between the muon and electron directions was measured directly on the tracks of these particles. (A photomicrograph of these emulsions would yield a picture very similar to the first figure of Dr. Morrison's article.) This experiment, owing to the inherent slowness of the technique, could not be done "within a few weeks." I do not know Dr. Morrison's sources of information. I first heard about the Bureau of Standards and Columbia results on January 11, 1957. A phone call to Columbia on January 13 established that the two muon experiments agreed.

V. L. TELEGDI

Enrico Fermi Institute
for Nuclear Studies
University of Chicago
Chicago, Ill.

Sirs:

Professor Telegdi has in his interesting letter shown us (in points 3 and 4) a

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view of the early history of the experiments on muon decay asymmetry which only a participant could have. It is good to know that Chicago was not behindhand in such experiments. Indeed, the papers of the Columbia and the Chicago groups were received by the editors of *The Physical Review* on the same day, reporting the two pieces of independent and mutually confirming work! The prior suggestion of C. N. Yang and T. D. Lee was the source, of course, of all the experimental work; and the experiments by C. S. Wu and Ernest Ambler were in fact the first unambiguously to demonstrate the overthrow of parity.

As to Professor Telegdi's first point, I cannot agree. It appears to me that the very existence of distinct particles, each with a unique "spirality," itself violates the principle of mirror invariance and explains all experimental results so far, though not without minor discrepancies which may in the end prove real and decisive.

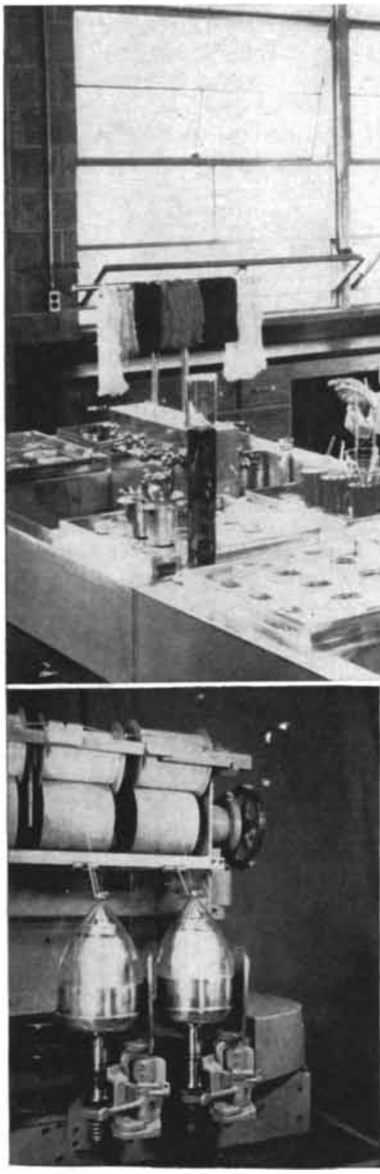
PHILIP MORRISON

Cornell University
Ithaca, N. Y.

Sirs:

David S. Jenkins' article on sea-water desalination [SCIENTIFIC AMERICAN, March] was a fine review of the many water-conversion schemes that have been proposed recently, and of these processes the freezing technique has both a naturally attractive energy requirement and an inherent simplicity in the system of freezing and separating the pure ice crystals from the salty water. It is important to note that there is no scale build-up in the equipment, and another feature of a plant of this type is its tremendous flexibility in regard to the varieties of power sources that can be utilized. Nuclear power could be used to generate electricity, or other forms of electrical generation might be employed to meet the energy requirements of the plant. Also, gas engines, or steam or gas turbines, could be used to drive the refrigeration compressors.

I was engaged in an experimental project to investigate the desalination of sea water by freezing techniques at Wayne State University in 1952, and just recently, in 1956, another chemical engineer and I at the University of Michigan prepared a report on the technical and economic feasibility of sea-water desalination by freezing. For this predesign economic analysis, a desalina-



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tion plant with a capacity of 100 million gallons per day was selected. This would supply enough water to meet the needs of about one third the population of Los Angeles, or the entire population of most cities likely to be affected by such a project. On this basis the process equipment was sized and the economics calculated.

Before discussing the economics of this proposed plant, one must appreciate the immense size of such an undertaking. The design capacity is 36 billion gallons per year or about 70,000 gallons per minute. This can be best visualized by considering a stream 11 feet wide and five feet deep flowing at the rate of two miles per hour. This capacity requires extremely large physical facilities, such as do the great dams built in recent years. A scale of thinking such as this must be continually employed in order to keep the proper perspective.

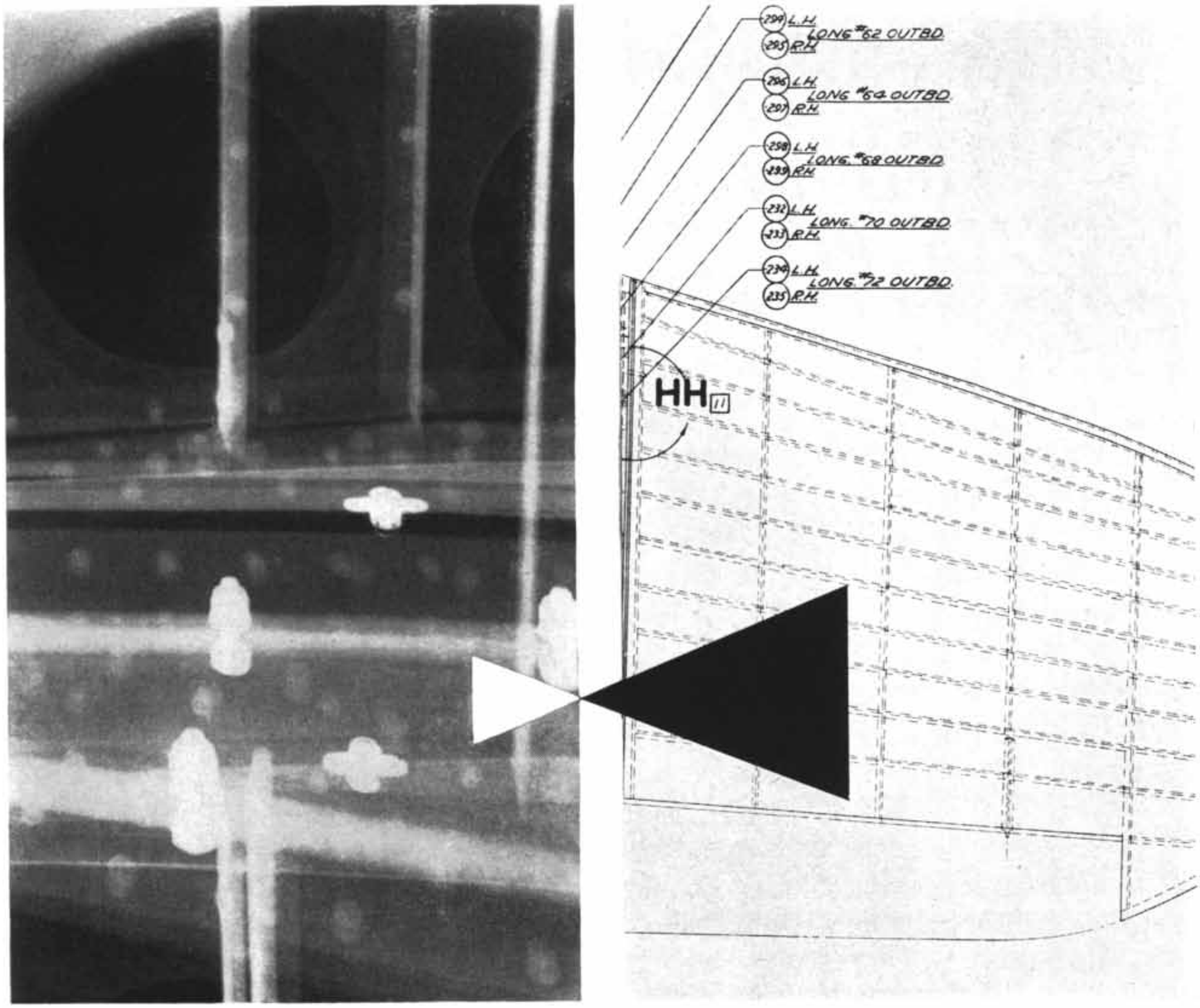
Briefly, our analysis showed that a plant using equipment presently available and natural gas as a fuel for gas-combustion turbines coupled directly to centrifugal compressors for the refrigeration could produce fresh water from sea water at a cost of between 70 and 75 cents per 1,000 gallons. Although not incorporated in our evaluation, it was envisioned that if intensive research were directed toward the freezing method of desalination certain improvements could be made which would lower this figure substantially. Our capital-cost estimates indicate that an investment of $160 million would be required for a plant of the stated capacity; annual operating costs would amount to $27 million, assuming a 20-year depreciation factor. The energy required for this plant was calculated to be 139 megawatts.

The technical and economic analysis of the desalination of sea water by freezing, as concluded by our report, indicates that such a process is both technically and economically feasible, but development is required to acquire certain basic process knowledge and to attempt to lower the over-all operation costs of a large plant.

I hope that this brief summary will stimulate more positive action toward the development of the freeze desalination technique. Too little attention has been directed toward this simple process, but careful analysis of the method's outstanding merits discloses its great potential.

RICHARD J. BIGDA

Baytown, Tex.



Radiograph: courtesy Industrial X-ray Corporation, New Hyde Park, N. Y. *Drawing:* Douglas Aircraft Company, Santa Monica, Calif.

Two ways to look at a wing

Here are two photographs made on Du Pont film.

The film to the right is Du Pont "Cronaflex." It is used to make highly accurate reproductions of engineering drawings. The Cronar® polyester photographic film base is tough. It resists change in size . . . takes rough handling without tearing.

The radiograph at the left is on Du Pont industrial x-ray film. It ferrets out flaws that may lie deep within the structure of the wing.

Both photographs have this in common. This is photography with a purpose. Photography that is not an end in itself, but a means to an end. This is Functional Photography. And, it is this field that the Du Pont Photo Products Department very specially serves.

Among our products are paper and films used in oscillographic testing . . . specialized films used in printing by letterpress, lithography and gravure . . . professional motion picture films used for photographic analysis.

If you use Functional Photography in your business —and you should—you should get to know our products and the many ways in which they can serve you. E. I. du Pont de Nemours & Co. (Inc.), Photo Products Department, Wilmington 98, Delaware.

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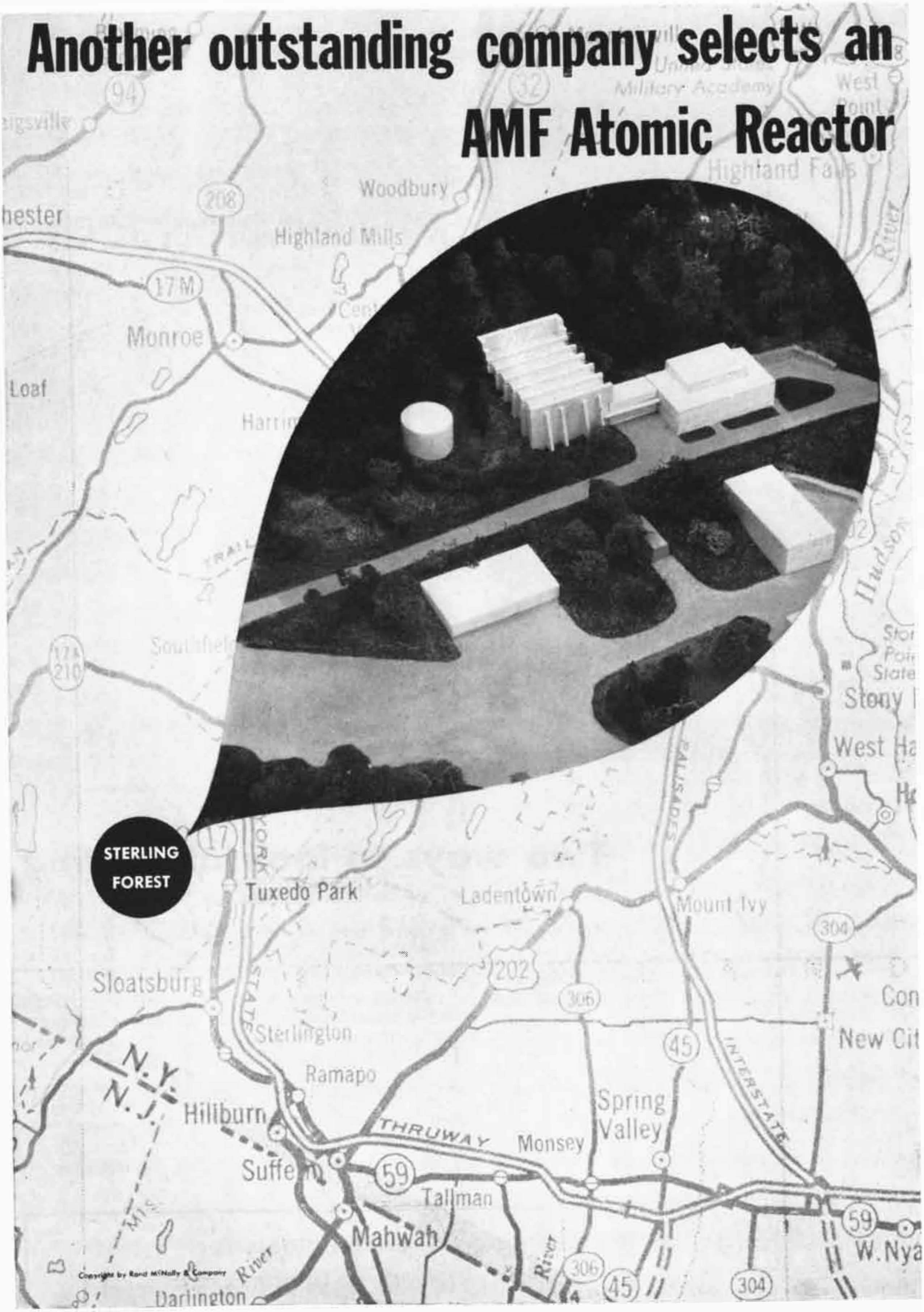


Guidance system check-out equipment program for the Army Redstone Missile was carried out by DFI. Actual equipment illustrated below.

How to pitch a perfect "strike"

. . . 200 MILES AWAY

It's tough enough to pitch a baseball 60 feet, 6 inches, and get a strike. Imagine pitching a multi-ton rocket 200 miles . . . and guaranteeing a strike every time.

It's no accident . . . Such pin-point accuracy comes from a precision-built, self-contained guidance system, developed by U.S. Army scientists and integrated into Redstone Missiles by Chrysler Corporation Missile Operation.

A very small error in guidance, though, means a very large error in target accuracy. So a precise, highly reliable test system for "guidance check-out" had to be developed.

And it's no accident that Designers for Industry was given the responsibility of producing this vital check-out system. During our 22 years, we've built a reputation for performance on many projects critical to national defense. The unusually tight schedule set by the Army for this program was met by closely coordinated teamwork between Chrysler and *DFI.*

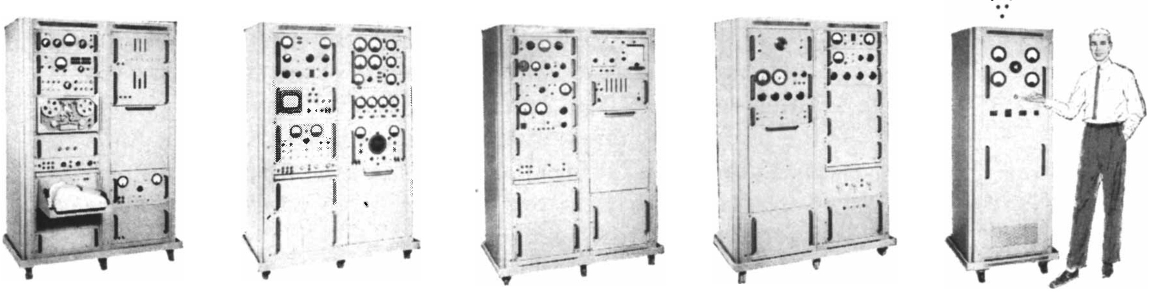
Unusual results were achieved beyond the immediate program requirements. For example, as part of a complete A.C.-D.C. Power Supply, a special control for a standard rotary inverter was needed. This new control gives *regulation of 30 parts per million* at 400 cycles under steady load — and feed or absolute regulation of 0.05 cycles in 400 under varying load and feed.

Production of such equipment has again demonstrated our ability in this and allied fields. We can offer power supplies or inverters for other applications, *including inverters for airborne uses.*

POWER SUPPLY

Input: 220 Volt, A.C., 3 Phase.

Output: 26-32 Volt, D.C. variable; regulation 1%, ripple factor less than 1%, 0.56 KW.
115 Volt, A.C., 3 Phase, 400 cycle, regulation 0.05 cycles for varying load, 30 parts per million for "steady state", 750 VA.



Representative samples of test equipment produced by DFI

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MAGNETIC TAPE APPLICATIONS BY AMPEX

4

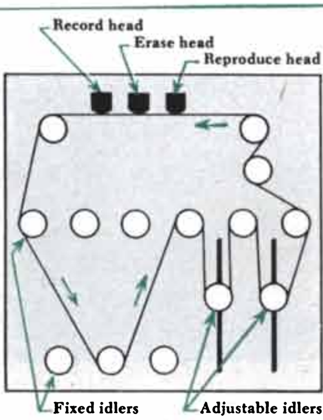
ONE OF A SERIES

How to use the recorder that chases its tail

The continuous loop solves a variety of tricky problems

At first glance the tape-loop recorder is rather like a puppydog chasing its tail. But don't be fooled – electronically, it is as interesting as a re-invention of the wheel. And you can share the challenge of its practical uses.

Are you waiting for lightning to strike? Let a tape-loop recorder stand the watch. It has infinite patience and a perfect sense of anticipation. The tape loop continuously records and erases until an important event takes place. At that moment everything is on the loop – even the important instants before. The tape loop either stops at the end of a cycle or it starts up a reel-to-reel recorder to copy the data. This scheme is used to study natural phenomena, to handle intermittent communications, and to collect data on abrupt mechanical or electrical failures.



The tape loop cycles in a period equal to loop length divided by tape speed. Movable idlers plus use of varying numbers of fixed idlers accommodate any loop length from minimum to maximum. Data can be repeated indefinitely or can be continuously erased.

For time-delay applications, the tape loop is like a conveyor belt for information. The tape continually receives data at the record head. Data rides the tape around the loop to the reproduce head and is withdrawn at a predetermined time delay. The interval is determined by length of tape loop and tape speed. Uses are machine and process control, communications memory, and handling of computer data.

The tape-loop recorder also has a talent for repetition. A short loop synchronized with the sweep rate of an oscilloscope provides a repeating signal that makes transient data stand still. For wave analysis, the tape loop reproduces a sample

The new Ampex FL-100 Tape-Loop Recorder being used with an Ampex FR-100 Reel-to-Reel Recorder. Interchangeable plug-in units make the two compatible with any combination of track characteristics.

of data repeatedly until it has been scanned for all significant frequencies by a succession of filters. Even a short transient can be analyzed.

For processing or simulation devices, the tape loop provides a program-control cycle of great sensitivity. Tape-controlled repetitions are as identical in pattern as the successive cycles of a mechanical cam – but have advantages of electrical control and infinite variations possible with tape.

Newest of Ampex's tape-loop recorders is the FL-100. It shares the styling and features of Ampex's FR-100 and FR-1100 recorders. The FL-100 uses their same interchangeable plug-in amplifiers, hence each track can be used with any of three recording characteristics. Frequencies from DC to 100,000 cycles can be recorded.

Loop length on the Ampex FL-100 is continually variable from a minimum of 3½ feet up to one of three optional maximums – 25, 50 or 75 feet. Tape widths are quarter, half and one inch. Up to eight tape speeds are available on the same machine. Overall speed ratios can be as high as 128 to 1.

If you would like further information on Ampex's new FL-100 Tape-Loop Recorder – or if you have a special problem to which it is applicable, Ampex's application engineers will be pleased to provide added details. Also, would you like to have this informative ad series mailed to you direct? Write Dept. S-6

Series FR-100

Series 800 Mobile and Airborne

Model FR-200 Digital

Series FL-100 Loop Recorders

Series FR-1100

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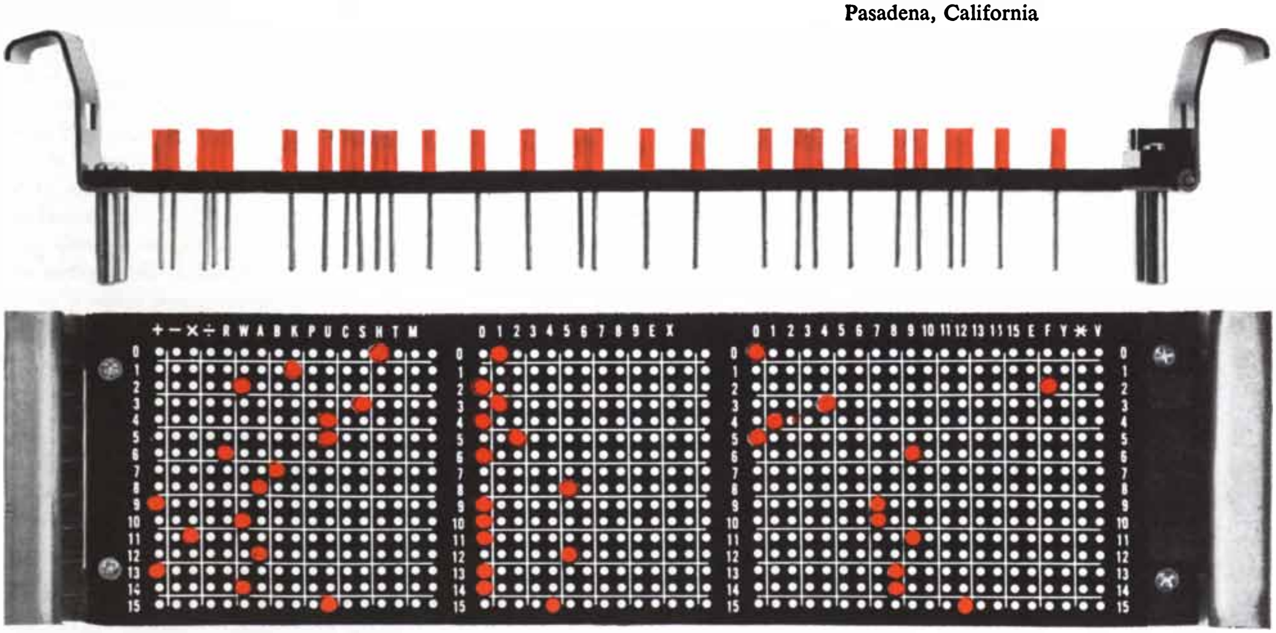


50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JUNE, 1907: "Last February a lamb without indication of limbs appeared in a flock of sheep on the Tar River Stock Farm, near Wilson, N.C. This lamb is perfect in every other respect, having a well-formed head and body and tail. During the latter part of April a second lamb was born on the same farm which was identical with the first, except that it was white instead of black. This one had the same father as the former legless freak but a different mother, both of its parents being white, while the first lamb had a black mother. Monsters or deformed young are usually weak and rarely live, while these lambs are healthy and vigorous. To the scientist and experimental breeder these lambs without legs are remarkably interesting. The newest and in many ways the most popular idea of today regarding the evolution of animals is based on such cases as this. Prof. William Bateson in England and Prof. Hugo De Vries in Holland are the chief champions of this 'mutation theory' of evolution, as it is termed. These prominent scientists believe that the various species in the world today have arisen from other existing or pre-existing species by sudden changes in form, or that is to say by 'sports' or 'mutants,' such as the legless lambs. These 'mutants,' when they once appear, breed perfectly true, and so establish new varieties or species of animals and plants. Prof. De Vries in his gardens in Amsterdam has succeeded in getting a number of entirely new plants which establish themselves and continue to breed true from a single original kind, the evening primrose, which was introduced into Europe from America."

"That the introduction of vanadium in the making of special alloy steels for automobile construction has created a mild sensation in metallurgical circles was evidenced recently by the presence of an even dozen of the most famous steel experts in this country at the plant of the United Steel Company at Canton,

Bell Laboratories researchers Henry S. McDonald, Dr. Eng. from Johns Hopkins, and Max V. Mathews, Sc.D. from M.I.T., examine magnetic tape used in new research technique. Voice waves are converted into sequences of numbers by periodic sampling of amplitudes, 8000 samples per second. General purpose electronic computers act on these numbers as a proposed transmitting device might.

They send real voices on imaginary journeys

In their quest for better telephone service, Bell Laboratories researchers must explore many new devices proposed for the transmission of speech signals. For example, apparatus can be made to transmit speech in the form of pulses. But researchers must always answer the crucial question: how would a voice sent through a proposed device sound to the listener?

In the past it often has been necessary to construct costly apparatus to find out. Now the researchers have devised a way to make a high-speed electronic computer perfectly imitate the behavior of the device, no matter how complicated it may be. The answer is obtained without building any apparatus at all.

The researchers set up a "program" to be followed by the computer. Actual voice waves are converted into a sequence of numbers by sampling the waves 8000 times per second. Numbers and program are then fed into the computer which performs the calculations and "writes out" a new sequence of numbers. This new sequence is converted back into real speech. Listeners hear exactly how well the non-existent device could transmit a real voice.

With this novel technique, new transmission ideas are screened in only a fraction of the time formerly required. Thus valuable time and scientific manpower are saved in Bell Laboratories' constant search to provide still better service for telephone customers.

BELL TELEPHONE LABORATORIES

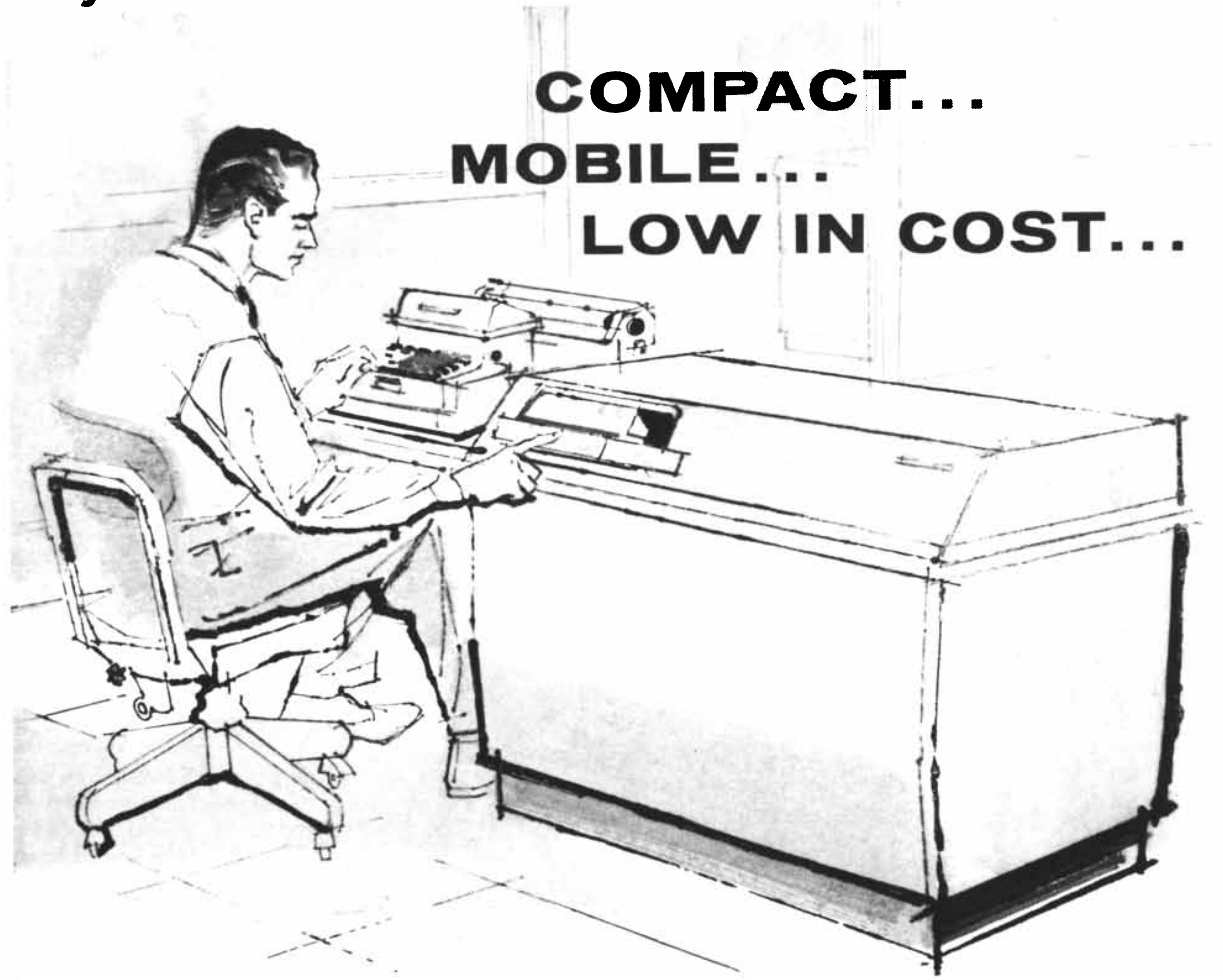
World center of communications research and development

Ohio, when the second heat of vanadium chrome steel was poured. This second heat was a world's record, inasmuch as it exceeded by five tons the former heat of 40 tons, both of which were for the Ford Motor Company. The experts watched the entire course of making the steel from the ore through its forging into automobile axles. They were particularly pleased at the splendid manner in which the steel acted. Some of them had feared that, when it came to forging, difficulties would develop similar to those which arise in forging nickel steel. This fear proved to be entirely without foundation. Not only could the steel be forged in one heat, where nickel steel requires 15 to 20, but the dies stood up as well under the work as in forging ordinary low-carbon steel. The finished products showed remarkably fine and uniform texture. A final analysis of the steel proved that the result was a success from that standpoint also, and that this 45-ton heat made in open-hearth furnaces is equal to the best that has ever been produced in the small experimental furnaces or crucibles."

"By far the boldest and longest transcontinental automobile race thus far attempted is the 9,300-mile endurance trip from Peking, China, to Paris, France, which was started on June 10 from the former city. Five touring cars and a tri-car are the contestants. These consist of two De Dion-Bouton touring cars and a Contal tri-car representing France, a Spiker touring car representing Holland, and an Itala touring car, driven by Prince Borghese, representing Italy. The contestants were given a splendid send-off by the foreign minister and residents of Peking. They expect to average something less than 100 miles a day."

"On June 21, on the side of one of the mountains to be intersected by the aqueduct, Mayor McClellan cut the first sod of what is probably the greatest municipal engineering work ever undertaken in the history of the world—the Catskill water supply for New York City. At the invitation of the New York Board of Water Supply some 300 guests, including, besides the Mayor, the Comptroller, the Corporation Counsel, the State and Civil Service Commissions and representatives of various prominent institutions in this city, were taken by steamer to Cold Spring, on the east bank of the Hudson River, and were then driven some three miles back into the mountains to the valley of what is known as Indian Creek. Here, after appropriate

Royal Precision LGP-30 Electronic Computer



high-speed computation right at your desk

The result of 20 years' experience in the design of electronic computers, LGP-30 puts you in complete control of your own engineering problems. Used right at your desk, LGP-30 allows you to program your own material without planning in detail. You modify equations on the spot, follow your work to completion. Thus, you eliminate much detailed calculation . . . uncover added time for creative engineering.

Ease of operation. LGP-30's simple command structure offers the same complete internal programming found in computers many times its size and cost. Internally binary, serial, single address . . . LGP-30 enters and reports alpha-numeric information by punched paper tape or keyboard.

Greatest capacity in price range. The most powerful stored program computer of its size yet developed, LGP-30 has a magnetic drum "memory" of 4096 words. Fully automatic, it performs sub-routines . . . executes self-modifying programs.

Exceptional flexibility. LGP-30's wide range of applications includes double precision abstractions; compiling and diagnostic routines; 3-address interpretive routine with floating point abstractions; matrix operations including inverting and Eigen value problems; basic trigonometry and log functions; square root and roots of polynomials.

Nation-wide sales and service. Detailed analysis of your requirements is available through Royal McBee's nation-wide staff of trained applications engineers.

Outstanding features of LGP-30

- Operates from regular wall outlet (110 volts AC).
- No expensive installation . . . no external air conditioning.
- Unusually large "memory"— 4096 words.
- Word length: 32 bits, including sign and spacer bit.
- Average access time: 8.5 ms.
- Optimum access time: 2 ms.
- Lowest cost ever for a "complete" computer.
- Nation-wide sales and service.

For further information, write Royal McBee Corporation, Data Processing Equipment Division, Port Chester, N. Y.

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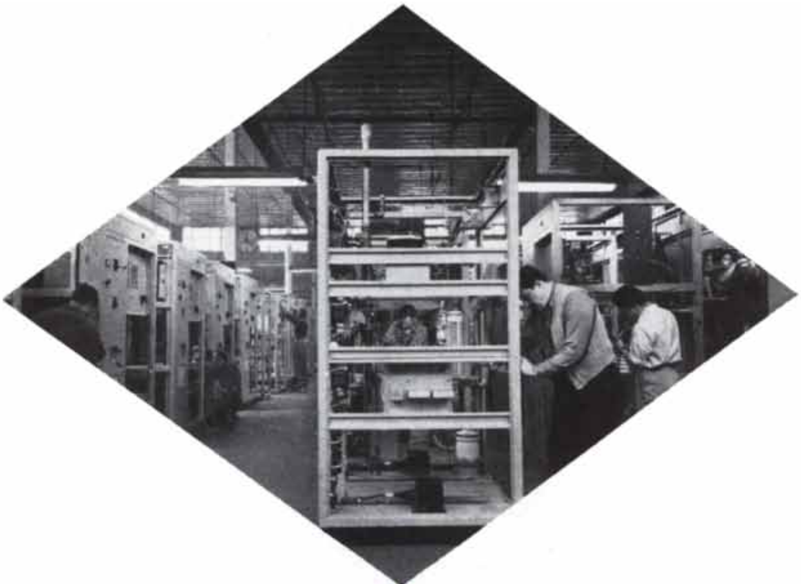
ceremonies, a silver spade was presented by Commissioner Charles M. Chadwick to the Mayor, who, after turning the sod, announced, 'Now I, the Mayor, in the name of the people of New York, declare this work begun.' "

JUNE, 1857: "A machine of liberal proportions has been constructed in New York for the purpose of being worked by a steam engine to generate a magneto-electric current by the revolution of permanent magnets in proximity to insulated coils. It has been suggested that this would be the best method of operating the Atlantic Telegraph, instead of using immense batteries to generate sufficient galvanism. Since electric apparatus of all kinds is attracting much public attention at present, we hope that this, as well as every other new electric machine, will receive a fair test of its qualities. This is the only true way to progress and improve."

"The American *Nautilus*, or submarine diving machine, invented by Major Sears, is now at work in London, and a company has been formed to operate with this apparatus. A short time since, a number of scientific gentlemen and engineers were invited to see the *Nautilus* in operation at the Victoria docks. After the experiments were completed, a repast was given to those present, on which occasion Robert Stephenson, C.E., M.P., made a brief speech, which is not a little flattering to the inventive genius of our countrymen. He stated that, by a careful examination, it appeared to him to possess so many qualifications as a diving bell (a machine hitherto very confined in its practical operations) that it might truly be called *a universal diving bell*."

"The camels which were imported by our Government from Arabia are reported to be doing well in Texas, and as likely to become acclimated as horses. Several native American camels have been born, and others are expected. The only question relates to the quality of the young animals. It is said that the Turks look with suspicion on our efforts to contract for building railroads in their country, while we are at the same time buying their camels. They say we want to get rid of our railroads and adopt their 'improvement.' "



Across this floor

Within the short space of forty months, this portion of REL's production facilities has manufactured more kilowatt miles of tropo scatter radio equipment than that of all other companies combined.

During this same period, REL has also designed and produced more than 75,000 circuit miles of special radio gear for the telephone toll services, in addition to many other types of apparatus.

By autumn, REL will occupy three times its present floor space. These hugely increased manufacturing facilities will further implement REL's ability to solve your specialized radio problems and to be of increased service to the communications industry.

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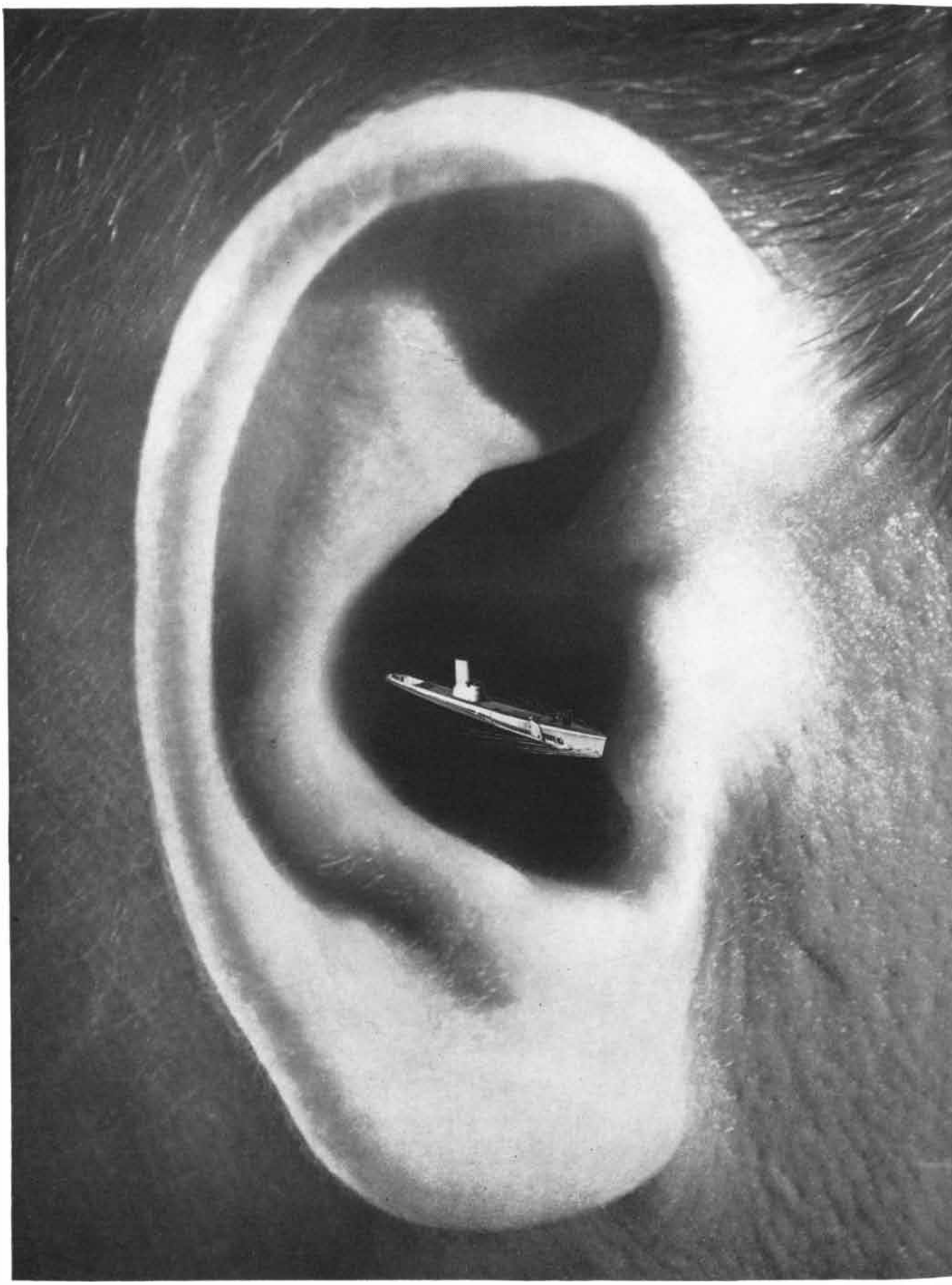

SUB TRAP

A trained ear can trap a submarine. A skilled sonar operator can separate the sound of a sub's propellers from those of destroyers on the hunt, count the prop blades, tell a sub's echo from a whale or school of fish, get its bearing and speed. But he can't learn this at sea. The cost would be prohibitive. To teach him on land, the U. S. Naval Training Device Center went to the Waldorf Instrument Division of Huyck (pronounced Hike) for a Sonar Simulator.

Waldorf designed, engineered, and now produces a simulator in which an electronic task force of aircraft and ships hunt a sub submerged in an electronic sea. The instructor can set up any sub-hunting problem and the computer will automatically create the conditions of actual anti-submarine warfare for a trainee using the very latest techniques and equipment.

Waldorf engineers and manufactures complete systems and instruments in the fields of hydraulics, electronics, and electro-mechanics. These products include instruments, computers, precision controls, test devices, simulators, servo-mechanisms, valves and actuators for industry and the Armed Forces.

Waldorf will undertake creative solutions for your problems, military or commercial, in the development and production of precision instrumentation and controls. For brochure and further information write to Waldorf Instrument Co., Huntington Station, Long Island, New York.

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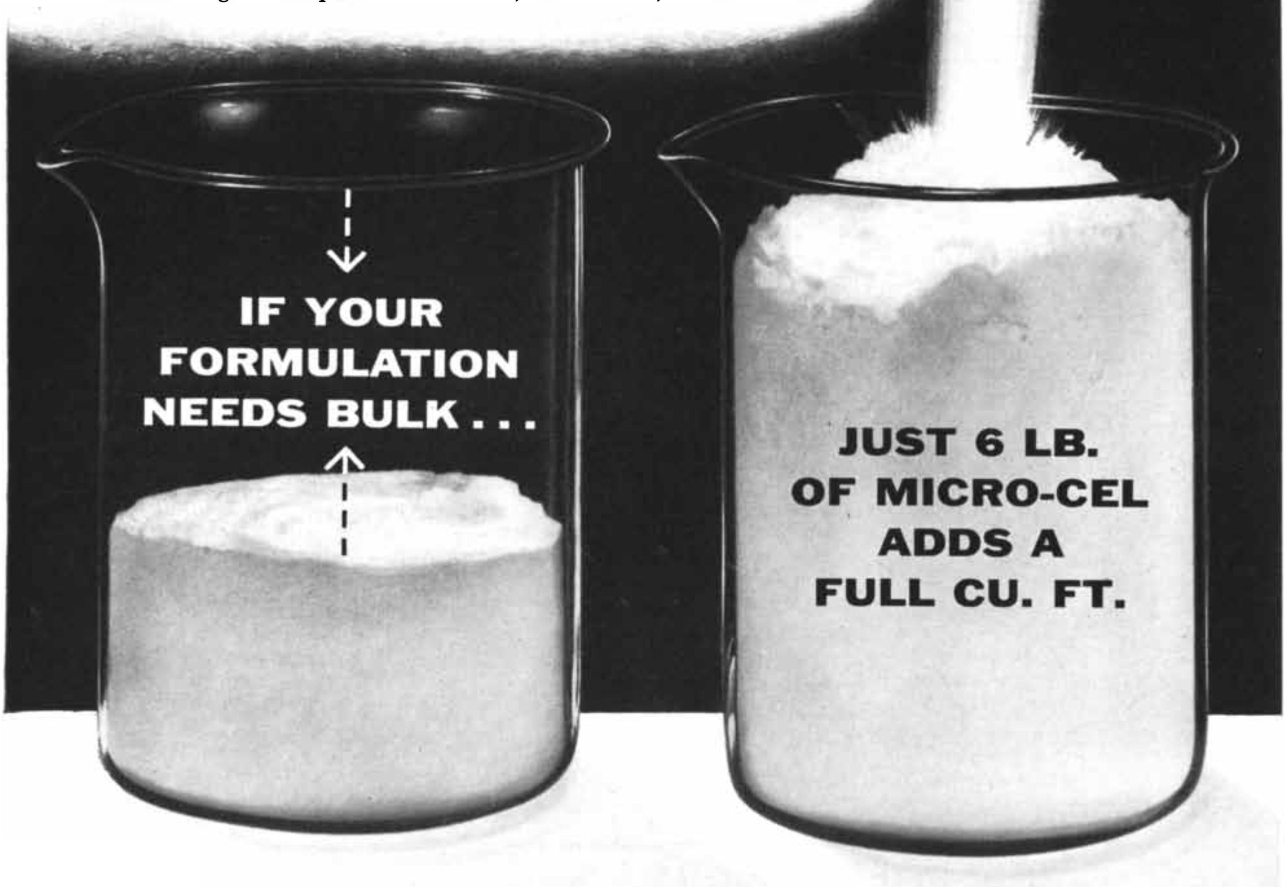

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Johns-Manville MICRO-CEL

A product of the Celite Division

THE AUTHORS

KRAFFT A. EHRICKE and GEORGE GAMOW ("A Rocket around the Moon") are respectively a rocket engineer and a theoretical physicist. Gamow, the physicist, is also well known as a writer (among his recent books are *Mr. Tompkins Learns the Facts of Life* and *The Moon*) and has written many articles for SCIENTIFIC AMERICAN. He was at George Washington University for 23 years; recently he shifted the center of his manifold activities to the University of Colorado. Ehricke, the rocket man, was born in Germany in 1917. He dates his interest in astronautics from the day when, as a boy of 13, he saw a film on space flight by the rocket pioneer Hermann Oberth. In 1942 he graduated as an aeronautical engineer from the Technical University of Berlin, where he studied under Hans Geiger. He worked on the power plant of the V-2 rocket, and after World War II headed the U. S. Army's gas dynamics group at Redstone Arsenal. Now he is assistant to the technical director of Convair-Astronautics.

GEORGE A. LLANO ("Sharks *v.* Men") considers himself a lichenologist, but the U. S. Air Force considers him its chief survival expert. At the Air Force's Arctic, Desert, Tropic Information Center, where he is a research specialist, he restricts his lichen-hunting to after hours. Llano was born in Cuba. His mother sent him to preparatory school in the U. S. to prepare for studying medicine at the University of Havana; instead, he went to Cornell University to study biology. While an undergraduate at Cornell, Llano had a fellowship to the government aquarium in Bermuda, where he worked on a collecting boat on the reefs. "Sharks were always a nuisance," he writes, "and I had many opportunities to observe them from the boat and while swimming or diving in the water. The local fishermen were afraid of sharks and feared for my safety, but I have always been a strong swimmer and I didn't know then what I know today." Llano did advanced work at Columbia, taught at Harvard, and was commissioned in the Air Force in 1944. After World War II he continued as a career officer, with time out for a Ph.D. and a year on a fellowship at the University of Uppsala.

W. BARRY WOOD, JR. ("Fever") is professor of microbiology at the Johns

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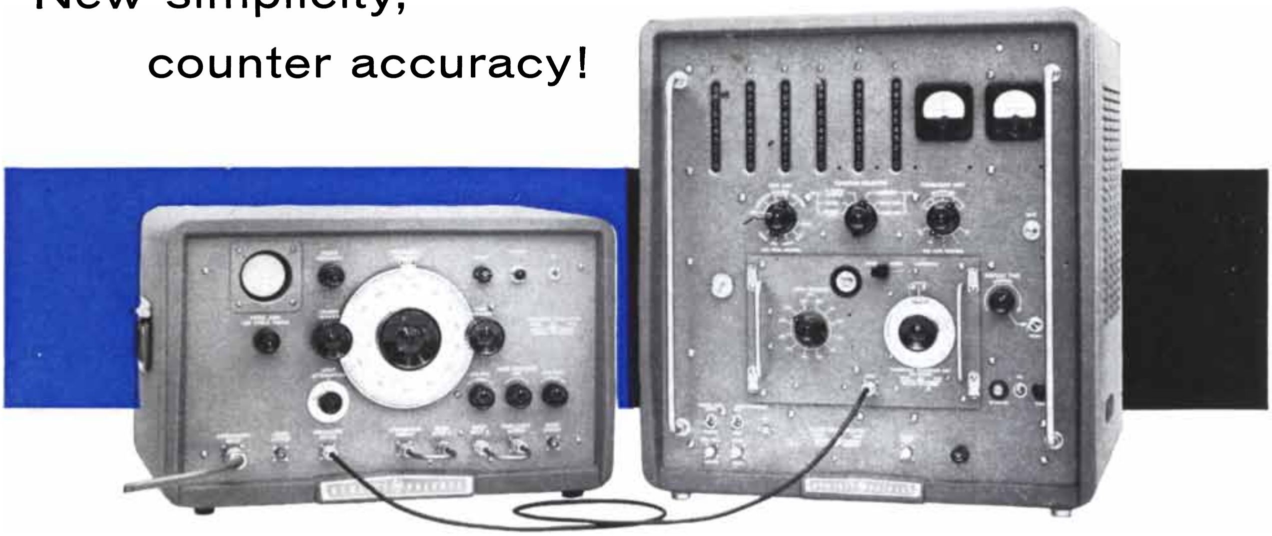

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-hp- 524B Electronic Counter

Measure frequency to 12 KMC on pulsed, AM, FM, CW and noisy circuits

Fast, convenient, simple set up

Just two *-hp-* instruments—Model 540A Transfer Oscillator and Model 524B Electronic Counter (with plug-ins) permit you to measure unknown frequency to 12 KMC with speed and accuracy.

Complex instrument arrangements and tedious trial-and-error work are eliminated. When approximate signal frequency is known, the 540A oscillator is merely tuned until one of its harmonics zero beats with the unknown. The multiplying factor is noted, and the 540A frequency measured precisely on the 524B Counter. The 524B reading, times the multiplying factor, is the unknown.

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The unique 540A/524B combination is particularly useful for swift CW and AM frequency determination, measuring center frequency or deviation range on FM signals, measuring frequency on high noise circuits and making high-accuracy measurements on pulsed signals.

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Oscillator Fundamental Frequency Range 100 to 220 MC. Harmonic Frequency Range to 12 KMC. Stability better than 0.002% change per minute after warmup. Output 2 v into 50 ohms. Attenuator range 20 to 80 db, into 50 ohms, low SWR. Amplifier 40 db variable gain, 1 v output. Self-contained oscilloscope 100 cps to 200 KC, vertical deflection sensitivity 5 mv rms/inch at mixer output. Prices: *-hp-* 540A Transfer Oscillator, $615.00; *-hp-* 524B Electronic Counter, $2,150.00; *-hp-* 525B Frequency Converter Unit, $250.00.

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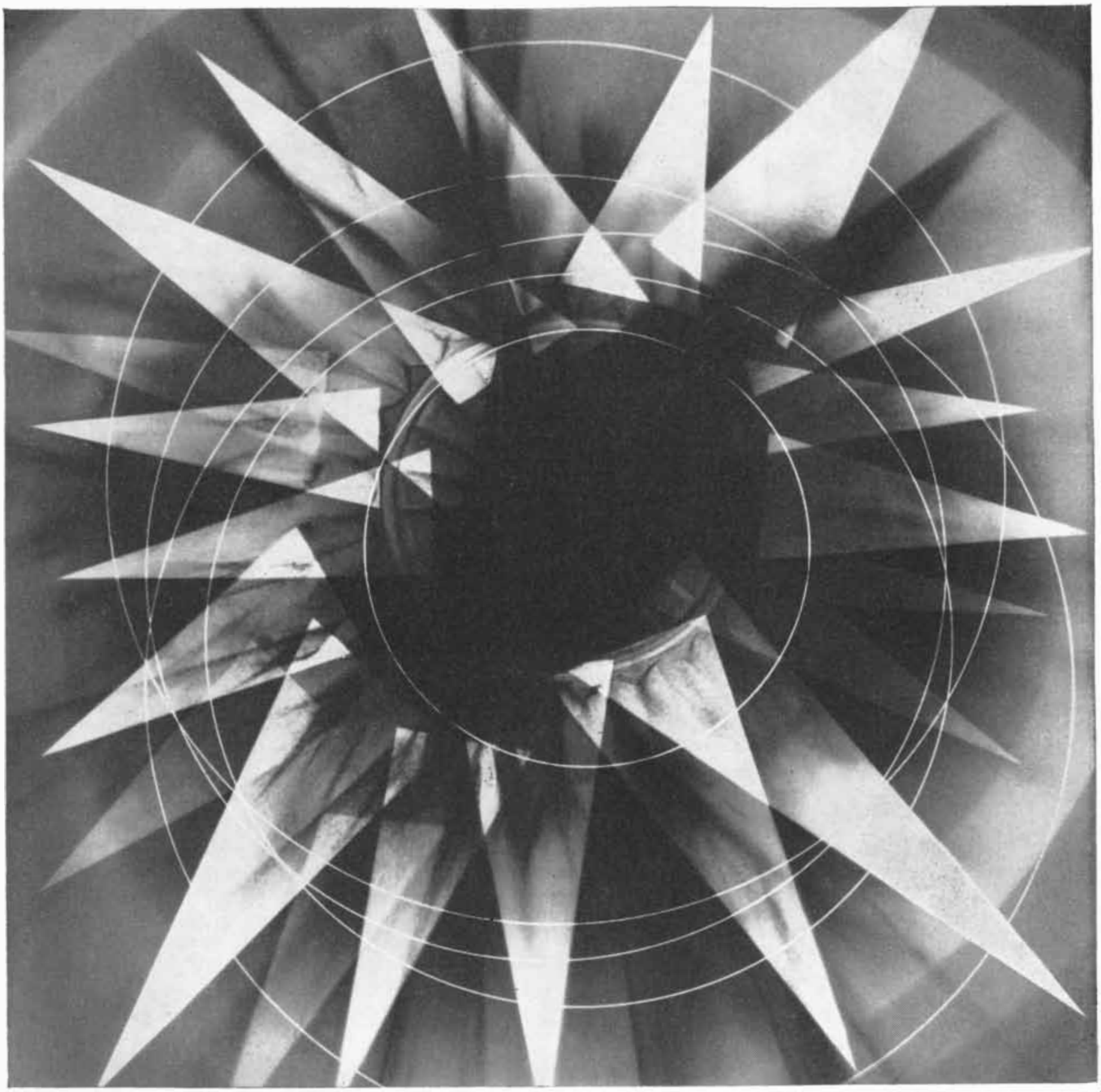
Complete instrumentation for frequency measurement

Hopkins University School of Medicine and a vice president of the University. Born in Milton, Mass., he graduated from Harvard College in 1932, after a career distinguished both in scholarship and athletics: he was an All-America quarterback. In the laboratory of Lawrence J. Henderson at Harvard he began a life-long interest in white blood-cells, which has led, among other things, to the theory on fever outlined in his article. Wood went to the Johns Hopkins for medical training and taught there until 1942, when he was called to head a department in the medical school of Washington University in St. Louis. Two years ago he returned to the Johns Hopkins. He is a trustee of the Rockefeller Foundation and a member of Harvard's Board of Overseers. His article "White Blood Cells *v.* Bacteria" appeared in SCIENTIFIC AMERICAN for February, 1951.

FRITS W. WENT ("Climate and Agriculture") is professor of plant physiology at the California Institute of Technology. He cultivates two fields of biological study: plant hormones and ecology. His classic work in the discovery of plant hormones was described by Frank B. Salisbury in the article "Plant Growth Substances" in the April SCIENTIFIC AMERICAN. Went has written several articles for this magazine; the most recent, "Air Pollution," appeared in the issue of May, 1955.

GEORGE E. HENRY ("Radiation Pressure") is a development engineer at the General Electric Company's Schenectady laboratory. He devotes most of his time to ultrasonics. Henry is also a professional in the sonic range: he was a cellist, teacher and conductor of the Chicago Civic Orchestra for 10 years before he took up physics in 1943 to contribute to the war effort. After wartime service as an instructor of Navy officer candidates in physics and electronics, he went back to teaching music as an assistant professor at Vassar College. At General Electric Henry has found in ultrasonics a happy merger of his two interests.

ERWIN W. MÜLLER ("Atoms Visualized"), inventor of the field emission microscope, is research professor of physics at Pennsylvania State University. He was born in Berlin in 1911 and received a Doctor of Engineering degree from the Technical University of Berlin in 1936. He then spent 10 years doing electron physics research in German industrial laboratories. After World



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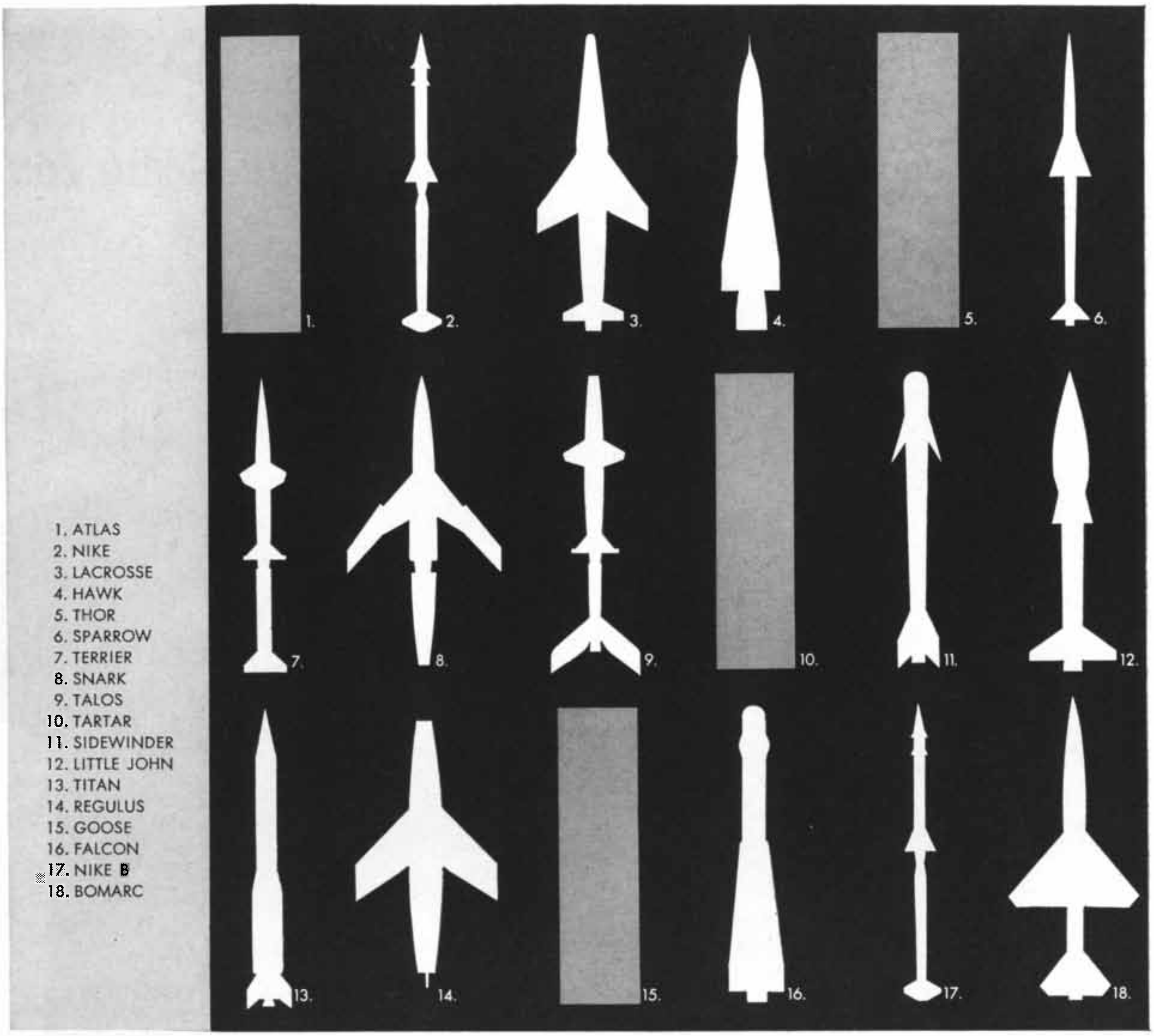
War II he became a division chief in the Kaiser Wilhelm Institute (now the Max Planck Institute). He taught for a year at the Free University of West Berlin, then came to the U. S.

EDWARD P. DOZIER ("The Hopi and the Tewa"), a Tewa Indian raised in the Santa Clara Pueblo, went to the University of New Mexico to extend his study of the Indian peoples and languages of the Southwest. After receiving an M.A. there in 1947, he obtained a Ph.D. in anthropology at the University of California at Los Angeles. A series of grants from the Social Science Research Council, the Wenner-Gren Foundation and the John Hay Whitney Foundation permitted him to live and work among the Tewa, the subject of his doctoral dissertation. Dozier taught for a year at the University of Oregon, then went to Northwestern University, where he is now assistant professor of anthropology. He is planning an expedition to study the mountain peoples of Luzon in the Philippines.

NORMAN L. MUNN ("The Evolution of Mind") is chairman of the psychology department of Bowdoin College. His *Psychology: The Fundamentals of Human Adjustment* is a well-known basic textbook which has been translated into French, Turkish, Finnish and Swedish. Munn was born in Adelaide, Australia, in 1902. He became an amateur weight-lifter and taught physical education at the Adelaide Y.M.C.A. Then he came to the U. S. to study at the Springfield Y.M.C.A. College and halfway through his college career developed an interest in psychology. He took a Ph.D. at Clark University. Munn was chairman of the psychology department of Vanderbilt University for several years before he went to Bowdoin in 1946. He has written a standard handbook on the psychology of laboratory rats and has conducted research on a number of other animals, including European minnows.

ERNEST NAGEL, who reviews *A Study of Thinking* in this issue, is John Dewey Professor of Philosophy at Columbia University. An authority on symbolic logic, he is co-author, with the late Morris R. Cohen, of *An Introduction to Logic and Scientific Method*. His latest book is *Sovereign Reason*, published in 1954. Of his several contributions to SCIENTIFIC AMERICAN, the most recent was "Gödel's Proof" (June, 1956), written in collaboration with his former student, James R. Newman.



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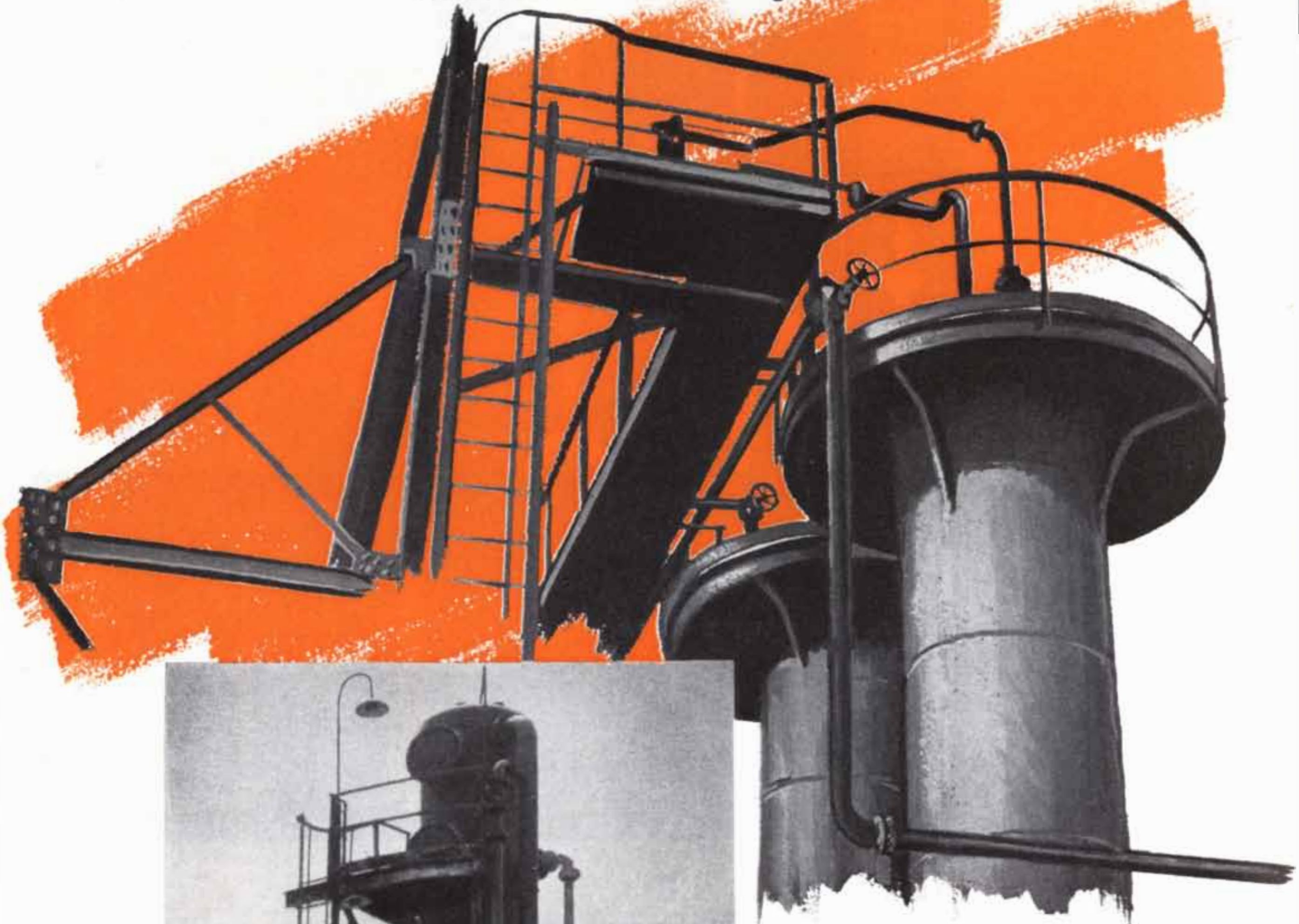

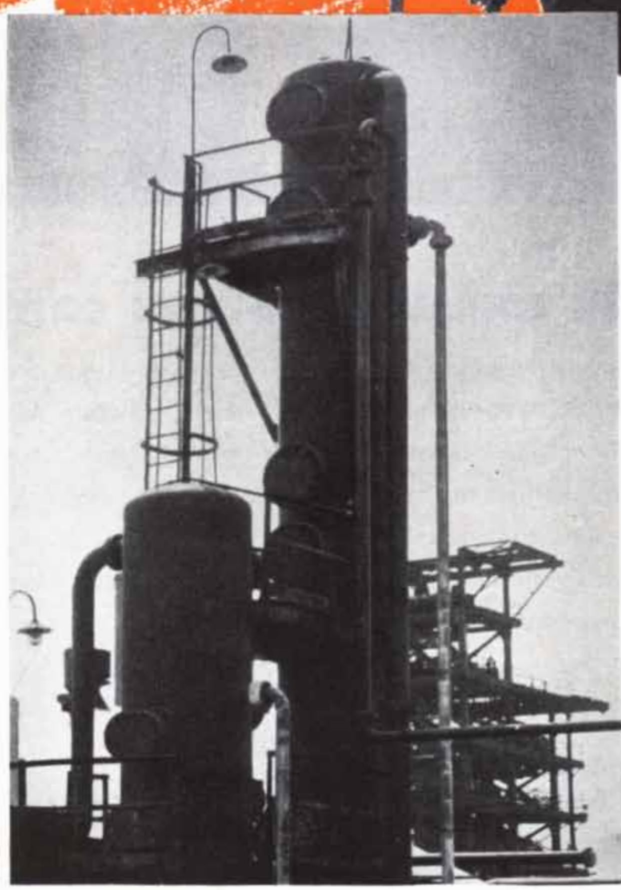

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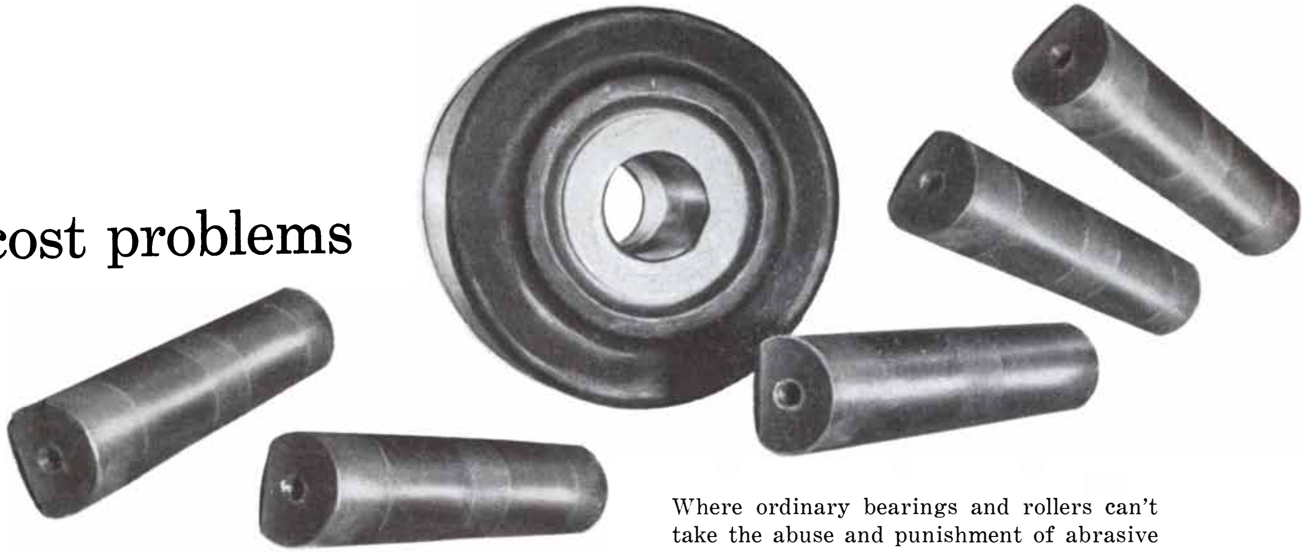

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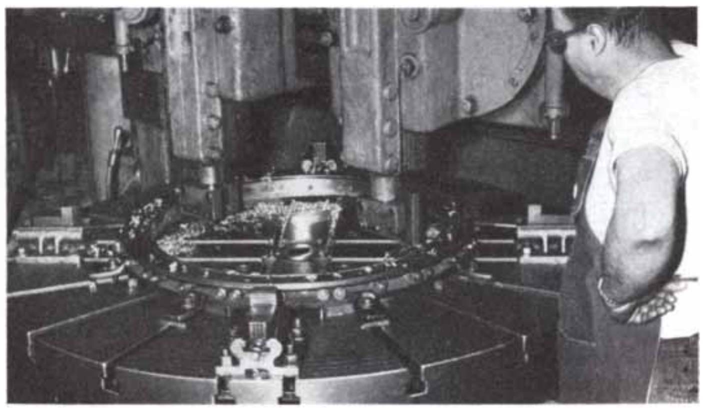

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▶ *New polyethylene pipe compound*
▶ *Ammonia data book*

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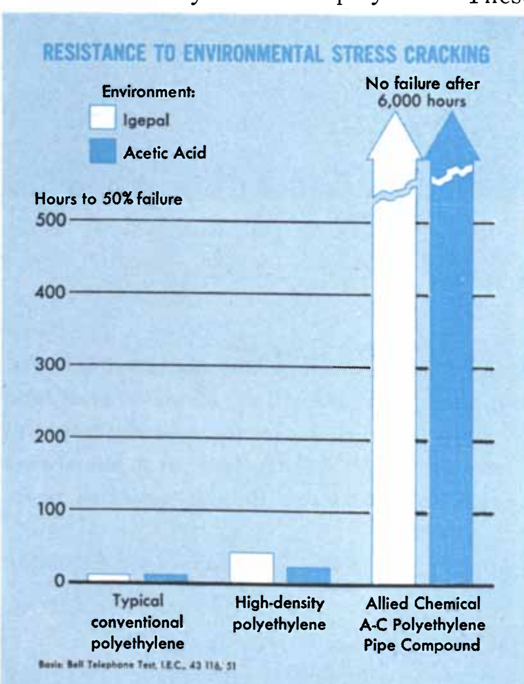
This distinctly different polyethylene resin made at low pressure is the best thing yet for extruding a superior polyethylene pipe. Pipe being made from the new A-C polyethylene pipe compound has high bursting strength, resistance to impact, shows no stress cracking, has superior heat resistance and resistance to chemicals, organic solvent and hydrocarbon liquids.

New plastic pipe made by Orangeburg Mfg. Co.



These properties are due to the high molecular weight—on the order of 750,000—and structure of the polyethylene molecule, not present in any other known polyethylene. These new qualities will greatly expand the acceptance of plastic pipe for water service and industrial applications. A common fault of some polyethylene pipe has been environmental stress cracking; this is entirely overcome in pipe made of this new resin.

Also, tests indicate the pipe will be suitable for carrying solvents and hydrocarbons for oil and gas pipe lines, a use denied to conventional polyethylene pipe. There is a growing need in this field for a flexible, tough pipe, resistant to the corrosive conditions which attack steel pipe.

A-C polyethylene pipe compound has an unusually high melt viscosity, reflecting its great molecular weight, and requires special techniques for manufacture of pipe.

The new resin is a companion product to a line of low molecular weight polyethylene products introduced on a commercial scale in 1954 by Allied. These are used in the injection molding of many household items, and as additives in paper coatings, polishes and printing inks.

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Ammonia data book

A new 68-page technical book on ammonia has been prepared by the largest ammonia producer, Allied's Nitrogen Division.

The comprehensive manual is actually a two-in-one piece: the first section on ammonia, and the second on ammonia liquor. Its contents include major uses, physical and chemical properties, specifications, shipping and storage procedures, physical tables, graphs and analytical procedures.

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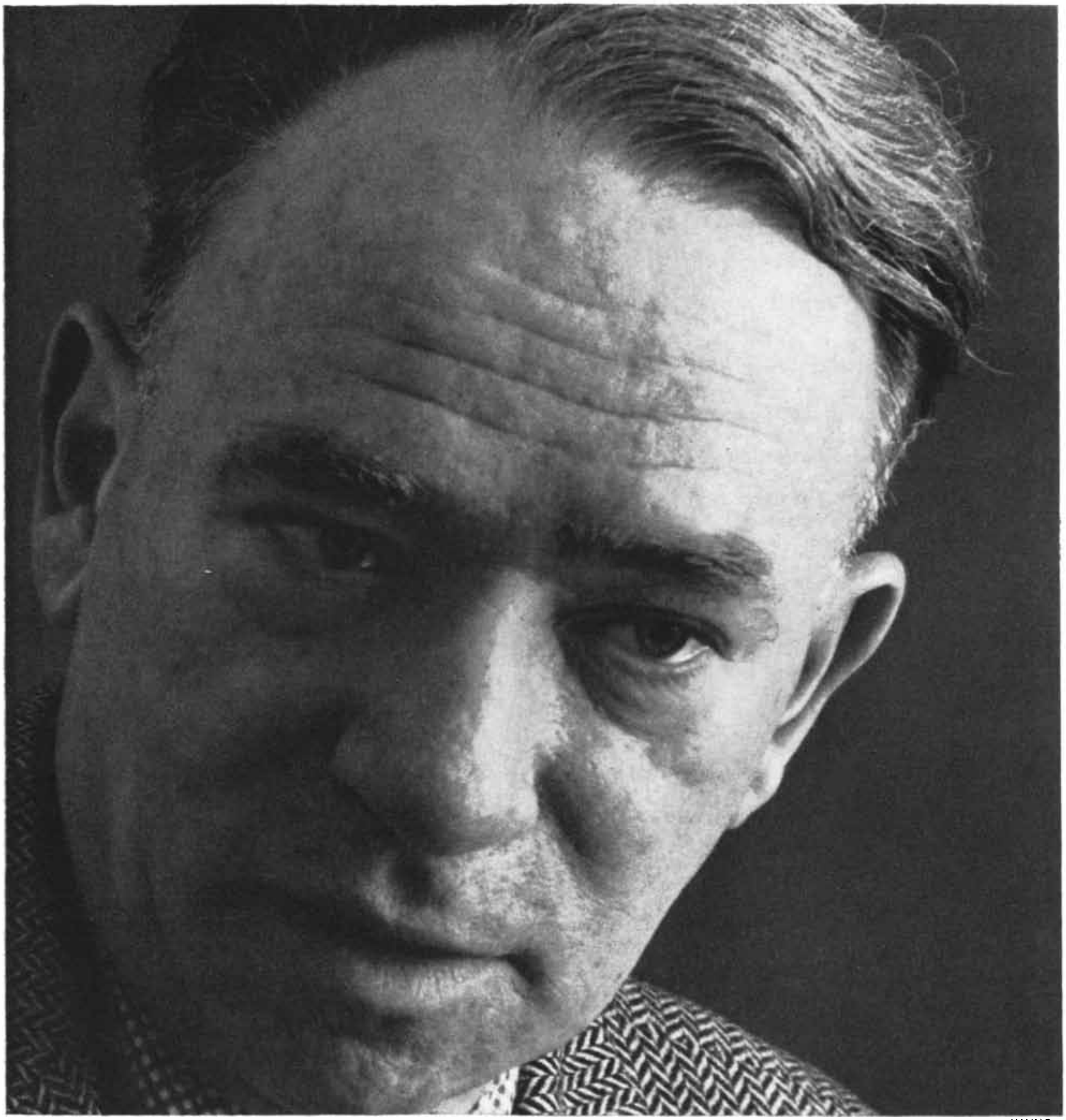


YAVNO

...on the prevention of total war

"Modern civilization is now faced with a task of fatal urgency. Unless man can find ways of limiting war, modern civilization itself may perish. The difficulties of limiting warfare today contrast with the capacity of major powers to wage total war with ever fewer restrictions and ever fewer survivors. Today, it is no longer a common belief in the dignity and destiny of man, but only prudence and fear, that can prevent total war. And yet, in the light of reason, the efforts to avert total war hold more promise of success than the hope for freedom from all war. It still is easier, as it has always been, for man to restrict war than to establish peace on earth."

—H. Speier, Head of the Social Science Division

Established 1845 SCIENTIFIC AMERICAN June, 1957 Volume 196 Number 6

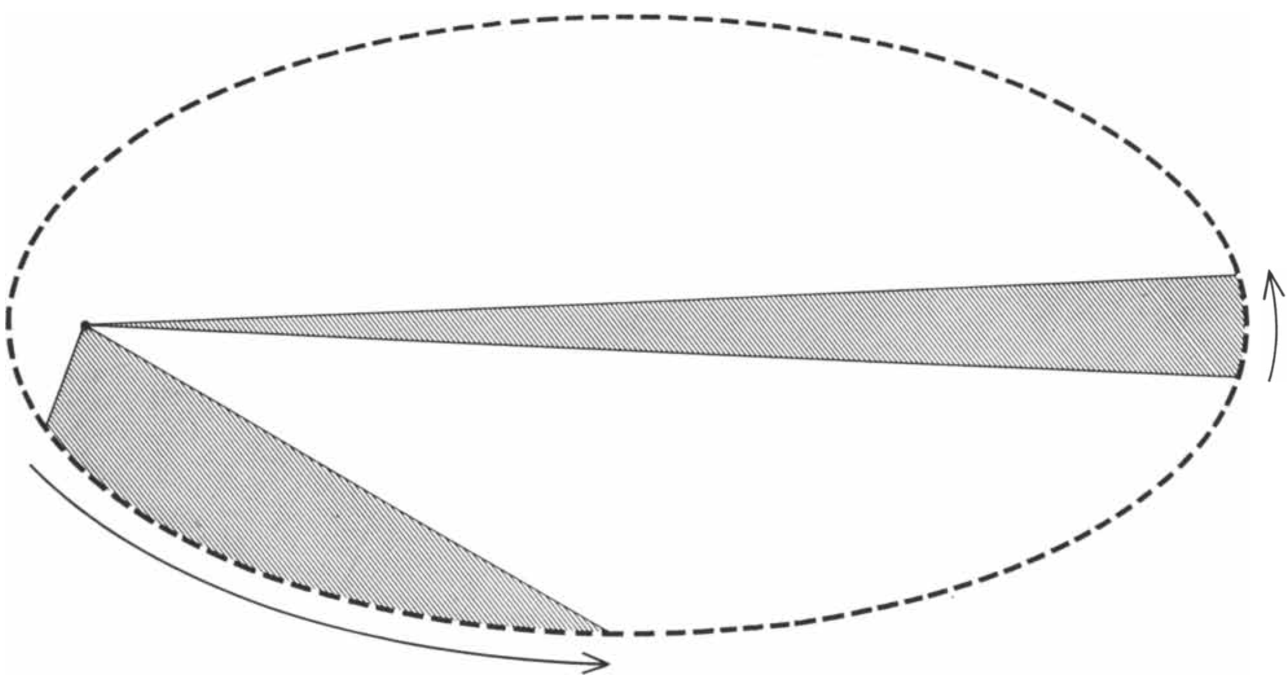
A Rocket around the Moon

After the artificial satellites have been launched, this may be the next step into space. The rapid progress of intercontinental missiles indicates that it may be closer than most people think

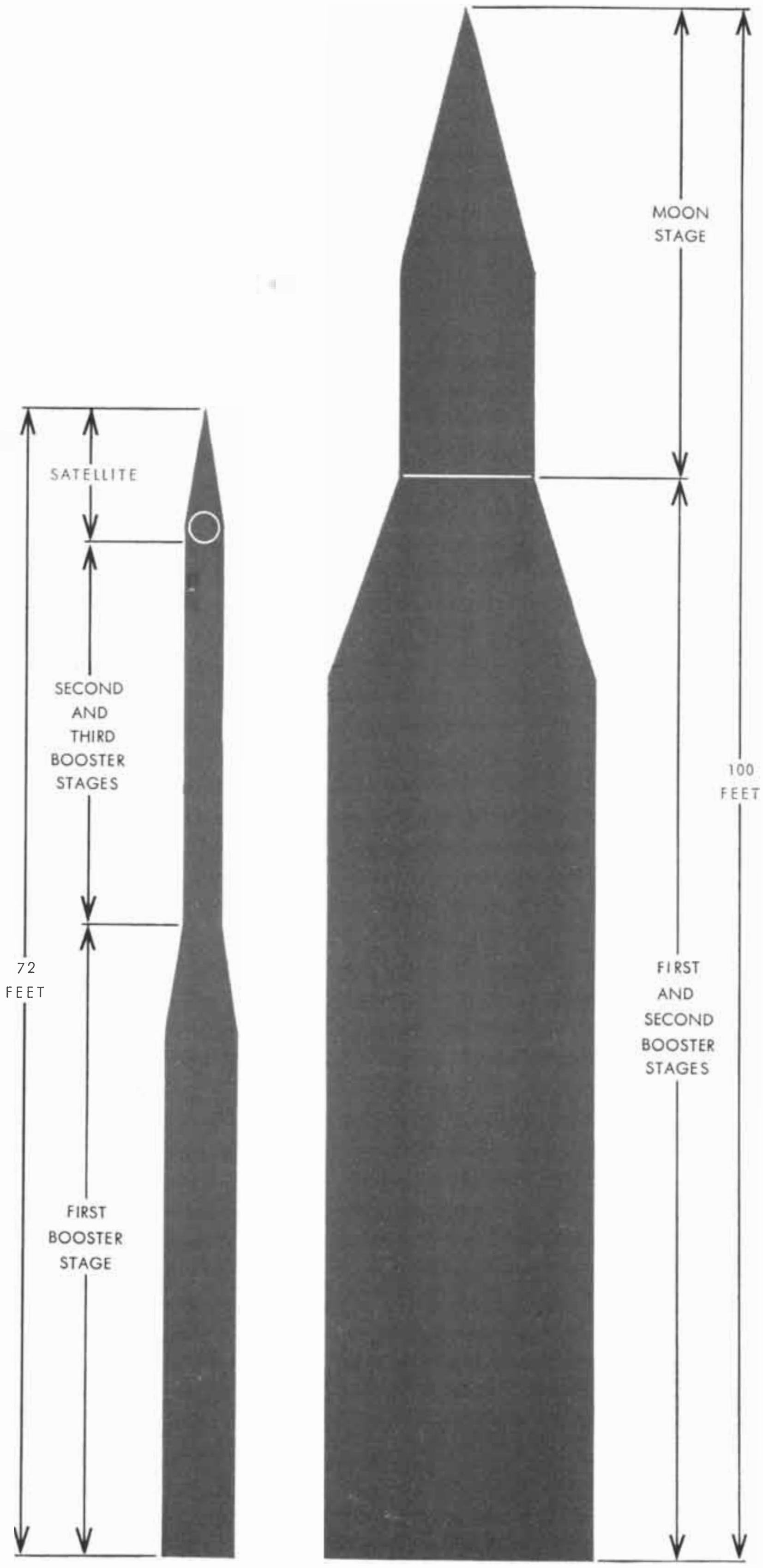
by Krafft A. Ehricke and George Gamow

Sometime in the coming months a silvery 20-pound sphere will be shot into the sky and will fly around the earth at a distance of 300 miles or more, where the atmosphere is so negligible that the vehicle will be practically out of contact with our planet. Once man has successfully launched this artificial satellite, the next interesting target in space, of course, will be the moon. How soon will we reach the moon? With luck and sufficient effort, we ought to be able to do it within five years.

We shall discuss here only a vehicle bearing instruments. The passenger-carrying spaceship is obviously still a long way off. It will have to be much larger and will have to solve the problem of getting back to the earth without burning up in the atmosphere, not to speak of the still more difficult problem of landing on and taking off from the moon. But apart from the thrill of travel-



LAW OF AREAS will determine the speed of a vehicle traveling in the orbits depicted on the following pages. A vehicle traveling in an elliptical orbit (*broken line*) around a massive body (*dot at left*) will sweep out equal areas of the ellipse in equal times. The shaded area at lower left has an area equal to that of the other shaded area. Thus the vehicle will travel faster at left than at right.

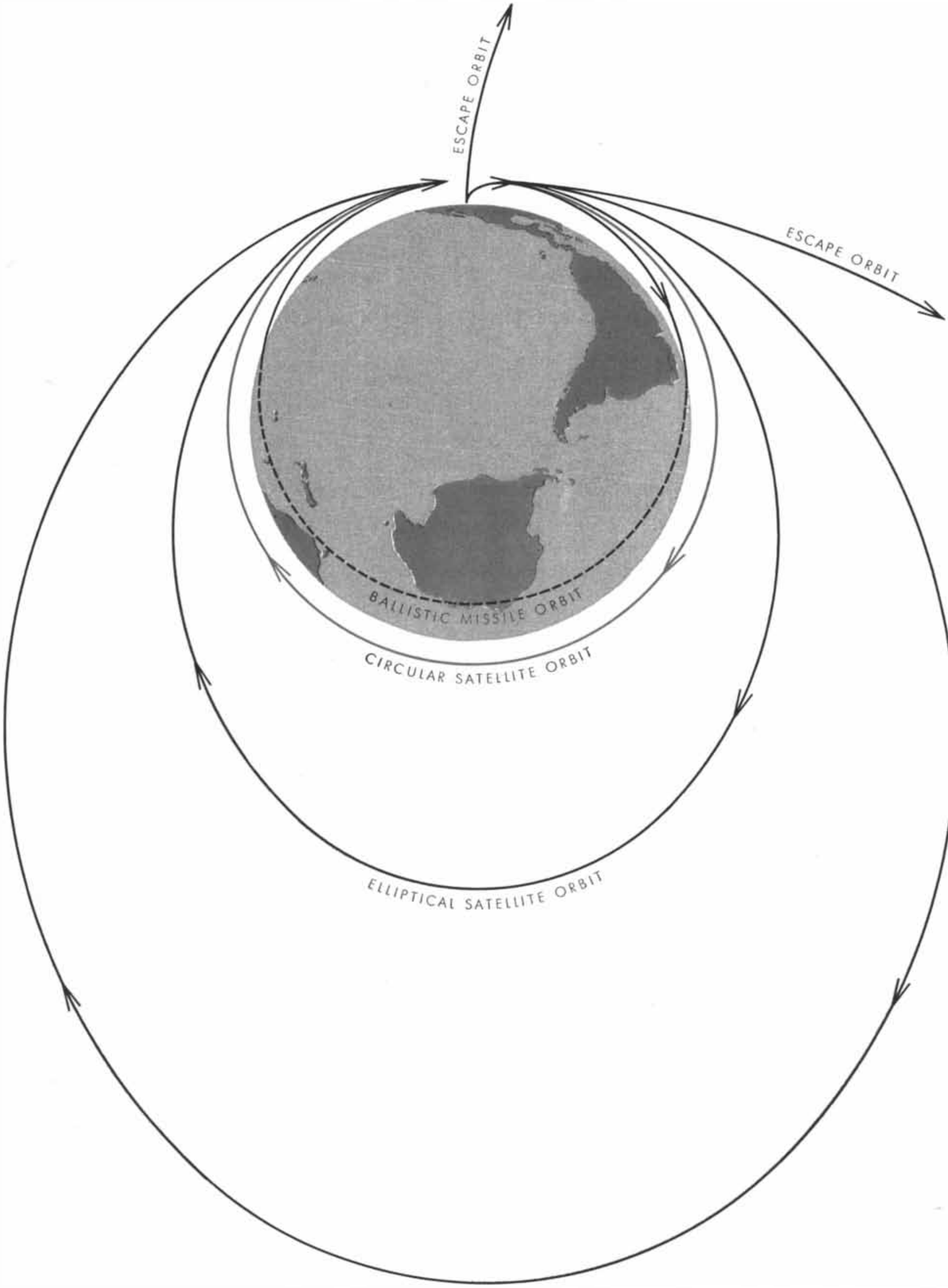


VANGUARD ROCKET *(left)*, **which will launch a satellite, is compared with a hypothetical moon rocket. The take-off weight of the moon rocket would be 240,000 pounds; its payload, 400 to 800 pounds. The moon stage would require a special high-energy propellant.**

ing to the moon, a vehicle equipped only with instruments can accomplish at least as much as human observers; in fact, pound for pound, well-designed recording instruments are more efficient. The trip to be considered in this article will be by an "instrumental vehicle" which will fly around the moon without landing (it would be fitting to name it *Cow*, after the well-known nursery-rhyme character). It will telecast its observations to us; the vehicle itself will burn up as a meteor because of friction with the air as soon as it returns to our atmosphere.

We need not dwell at length on how close our technology now is to the requirements for launching a vehicle into space. It will not need a great deal more power than the intercontinental ballistic missiles on which engineers are already working. The heavy ICBM will have enough initial velocity to fly a considerable distance around the globe before it crashes to earth. Unscrew the hydrogen bomb warhead from the rocket, substitute a 20-pound packet of instruments, add some power, and the instrumental vehicle will take off in an orbit which will carry it clean around the earth. If it is shot to a height of 300 miles to get it out of the atmosphere and then given a horizontal velocity of about 18,000 miles per hour, it will go around the earth in a circular orbit. (Actually the two operations will be combined in the satellite; the three-stage rocket will carry it up in a smooth curve so that it will reach the 300-mile altitude after traveling 1,500 miles around the earth from the starting point.) If the vehicle is accelerated to a velocity somewhat greater than 18,000 miles per hour, say 5 or 10 per cent greater, then its orbit will be not a circle but an ellipse; that is, it will swing out to an altitude considerably higher than 300 miles on the opposite side of the earth. We can draw a family of ellipses which show the successively larger orbits the rocket would follow when shot with higher and higher initial velocities [*see diagram on opposite page*].

There comes a velocity—about 40 per cent above that needed to hold the satellite in a circular orbit—at which the rocket will fly away from the earth never to return. This escape velocity is 25,500 miles per hour. Since we want our rocket to the moon to return, we must shoot it with an initial velocity slightly less than this. To despatch it on an elliptical orbit which will reach out to 70 times the radius of the earth (280,000 miles), we



ORBITS OF VEHICLES traveling around the earth will be determined by their velocities. The orbit of a ballistic missile will intersect the surface of the earth. A satellite with a circular orbit will require a higher velocity. A satellite with an elliptical orbit will require a still higher velocity. A vehicle with a velocity of 25,500 miles per hour will escape from the earth entirely.

would have to give it an initial velocity of 23,900 miles per hour.

The moon is about 240,000 miles away. In order to choose precisely the right velocity and flight path for its journey, we have to consider three astronomical influences that will affect its flight: (1) the attraction of the earth, (2) the attraction of the moon, and (3) the attraction of the sun. Reckoning only the influence of the earth, we would describe the path of the rocket by a perfectly regular ellipse [*see diagram at top of pages 50 and 51*]. But the moon and the sun begin to affect its flight as soon as it has traveled more than 4,000 miles from the earth.

For the moment let us disregard the sun and consider just the moon. As the rocket approaches, the moon's gravitational attraction of course becomes more significant, until, at a short distance, it dominates the rocket's flight. About 40,000 miles from the moon the rocket suddenly begins to speed up because of the moon's attraction. Its flight path also is distorted. If it does not come very close to the moon, the rocket will be deflected from a perfectly elliptical path but will still return to the earth [*see lower diagram at the right*]. However, at a certain distance (say 2,000 miles) the moon's gravitational field can wrench it from its orbit and send it flying off away from the earth [*diagram at top of pages 52 and 53*]. In other words, the acceleration by the moon, added to the rocket's original velocity, gives it an escape velocity which removes it from the earth's influence. As a matter of fact, comets coming close to Jupiter are known to have been thrown out of the solar system into interstellar space.

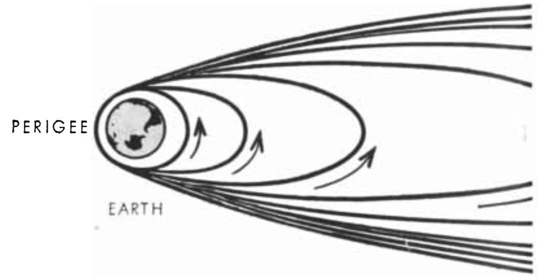
If the rocket comes considerably closer to the moon than 2,000 miles, it will not be thrown off; instead it will swing around the moon under the force of the moon's attraction and fly back toward the earth.

The sun's gravitational influence on the rocket would be comparatively weak, but sufficient to make a considerable difference in the shape of its orbit over the long journey. Allowing for the sun's effect, we can calculate an orbit which will take the rocket out to the moon's position in space at a given time, loop it around the moon and return it to the earth, the round trip taking about 157 hours [*see diagram at bottom of pages 52 and 53*]. Clearly it will require very precise calculation, and high accuracy in flight performance by the rocket, to arrange a trip that will bring the rocket back to the earth.

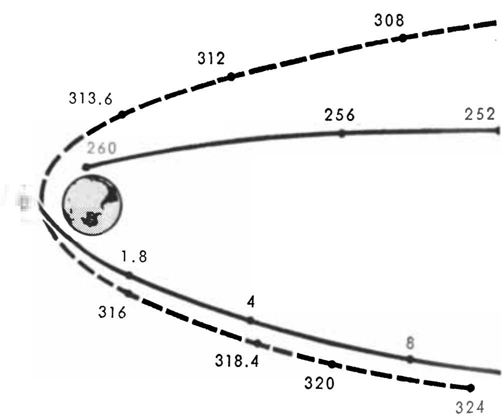
An interesting point is that the rocket will make a comparatively leisurely journey around the moon itself and spend a considerable amount of time in its vicinity. We can compute the speeds and times at various stages of the rocket's trip from Johannes Kepler's second law of planetary motion, which says that a body traveling in an elliptical orbit around another body sweeps out equal areas of the ellipse in equal times [*see diagram on page 47*]. The rocket will start from the earth at its highest speed and will gradually slow down. It will speed up somewhat as it approaches the moon, but at the far end of its orbit, where it swings around the moon and starts back toward the earth, it will be moving at a lazy pace—only a few hundred miles per hour. Thus the rocket will be in the moon's vicinity for about one third of the total elapsed time of its 157-hour trip, that is, it will have nearly 50 hours of close observing time.

As we have said, to get to the moon the rocket must be shot with something close to escape velocity. We can easily calculate how much power this would require for a vehicle of a specified size. How large would the rocket have to be? At a minimum, its payload should be 20 times that of our artificial satellite (*i.e.*, at least 400 pounds), for it will need navigation and guidance equipment, a television camera and other observing instruments, radio transmitters, batteries to power these, and so forth. This payload would call for a three-stage rocket with an initial weight 10 times that for the satellite, or about 240,000 pounds [*see diagrams on page 48*]. Such a rocket is technically feasible today.

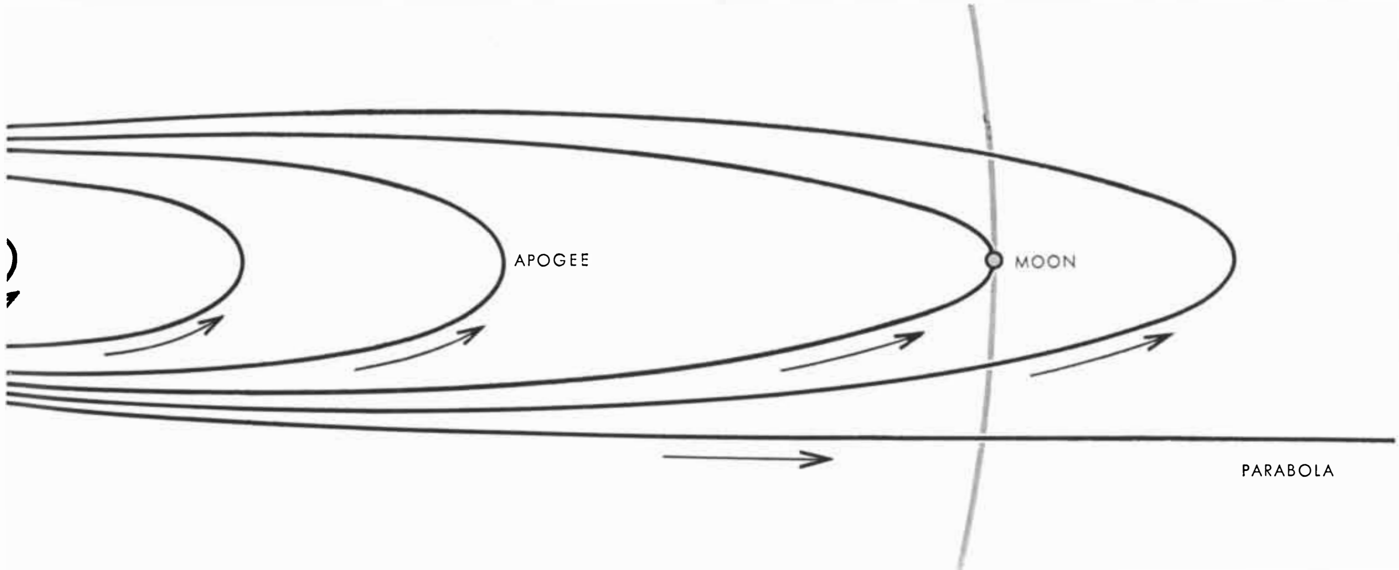
Having calculated the requirements for shooting a rocket to the moon and bringing it back to the earth, we may at this point consider briefly how the instrument capsule might be recovered. A vehicle which came back intact would be immensely more useful than one which could only broadcast to us the information it collected: it would provide us with clear pictures of the moon on film, evidences of meteor hits, and so on. Even at this early stage of planning the technical problem of recovering a moon rocket is by no means beyond the bounds of realistic calculation. The problem has two major parts. First, we must arrange the flight path so that the earth recaptures the rocket and brings it down. Assume that the orbit brings the rocket back close to the earth. If its direction as it flies near is horizontal to



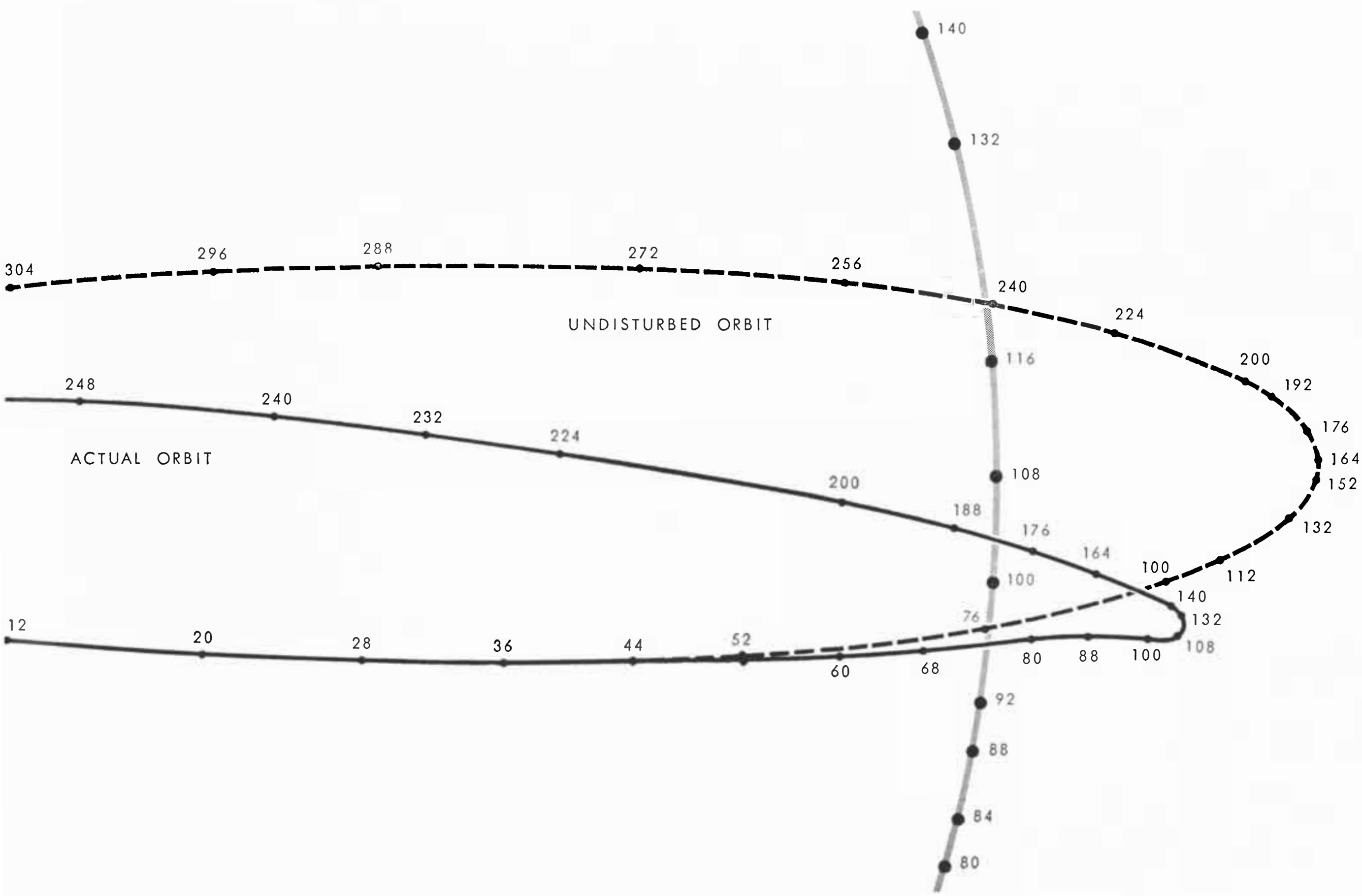
ELLIPTICAL ORBIT would be traveled by a hypothetical vehicle under the gravitational influence of the earth alone. The point



DISTORTED ORBIT would be traveled by a vehicle under the influence of both the



closest to the earth is perigee; the point farthest is apogee. A vehicle traveling in an orbit with its apogee at the distance of the moon from the earth would require little more velocity than a vehicle traveling in an orbit with its apogee at half that distance. A vehicle traveling in a parabolic orbit would escape from the earth. The distance of the moon is drawn to scale: 240,000 nautical miles.



earth and the moon. The numbers indicate the position of the moon and the vehicle in hours after the departure of the vehicle. The initial velocity of this vehicle is 23,832 miles per hour. It comes within 20,042 nautical miles of the moon after 94 hours.

the earth's surface, the rocket will merely round the earth and fly off again. If the rocket dips toward the earth at an angle very slightly below the horizontal, it will miss the earth but take shorter and shorter elliptical orbits around the earth and eventually fall in. The rocket will be captured on its first approach only if it is dipping toward the earth at an angle of at least 10 degrees at an altitude of 60 miles.

The second part of the problem is to prevent annihilation of the rocket as it plunges through the atmosphere toward the ground. Coming in at about 25,000 miles per hour, it will be slowed very rapidly by the resistance of the air—from 25,000 to about 300 miles per hour during the first minute. Air friction will heat the skin of the vehicle to almost 5,000 degrees centigrade. But it will reach the ground within six or seven minutes, and for this brief period the problem of preventing the capsule from burning up by means of insulation and a cooling system is not technically prohibitive.

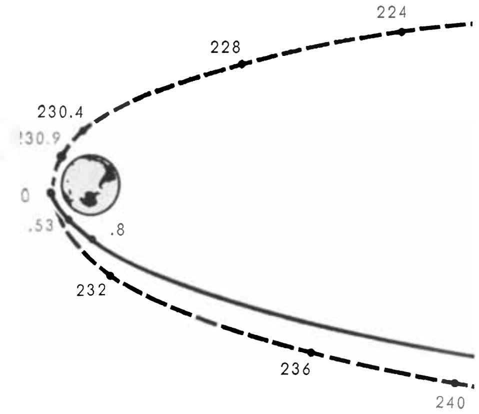
What sort of information will a round-the-moon rocket bring back to the earth? First of all, of course, it will give us our first views of the other side of the moon. Nobody believes that the other side is very different from the face it turns to us: doubtless the other half has the same dreary oceans of dust (*maria*), the same kinds of craters and so on. But think of the fun of giving names to a whole hemisphere full of new moonmarks! More seriously, the completed map of the moon will double our quantitative data on its features and may settle some arguments about the origin of those features. And who knows—perhaps some unexpected features will turn up.

Our rocket will also measure the moon's magnetic field, if any. This might help to resolve questions about the magnetism and structure of the earth as well as of the moon. The earth's general magnetic field is believed to be produced by convective currents in a molten core of iron. The moon, on the other hand, is supposed to contain little or no iron and to be solid at the core. Therefore it should have no magnetic field. If it proves to possess one after all, we shall have to revise our theories about the earth's magnetism or about the moon's composition and structure. If the moon lacks any magnetic field whatsoever, the confirmation will make many terrestrial scientists happy.

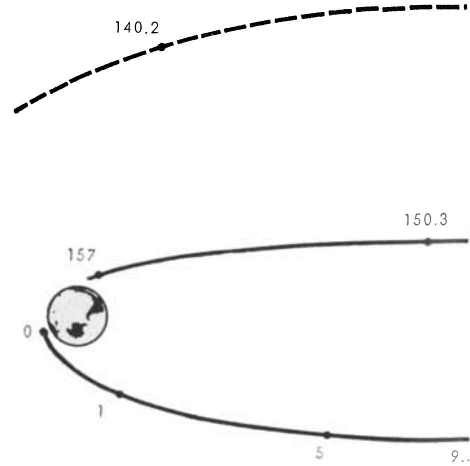
The possibility of actually bringing back some of the moon's material is a scientific bonanza so alluring that ingenious schemes have been proposed to accomplish it, even without landing on the moon. We might, for example, send a pair of rockets, one trailing the other closely by means of a homing device. The first rocket would drop a small atomic bomb on the moon, and the second would sweep up some of the debris blasted from the moon's surface. Since the moon has no atmosphere and comparatively little gravity, the bomb cloud would rise very high. The second rocket could dive into the cloud, collect some of the spray and emerge from its dive by means of an auxiliary jet. Of course such a maneuver would require a miracle of electronic guidance; the rocket would also have to be provided with equipment which could analyze the particles of collected material and transmit the information to us. But all this seems to lie within the realm of possibilities in the expected development of guided missiles during the next few years.

One of the many questions on which material from the moon might throw light is the origin of the mysterious tektites which have been discovered in a number of places on the surface of the earth. Tektites are rounded, colorful pieces of natural glass, ranging up to three inches in diameter. Varieties of them have been found in Czechoslovakia, the East Indies, Australia, Sweden, South America and various other parts of the world. They have a peculiar chemical composition (largely silica and alumina with substantial amounts of calcium and potassium), and they turn up in areas remote from volcanoes. Ever since F. E. Suess discovered and identified samples of them in Moravia and Bohemia early in this century, the source of these curious objects has mystified geologists. Many theories have been suggested. One is that they came from the moon. According to this theory, meteorites blasting the craters of the moon threw out sprays of molten droplets which escaped into space, and some fell upon the earth. The theory could be tested by comparing the composition of the tektites with the composition of material collected from the surface of the moon by a rocket.

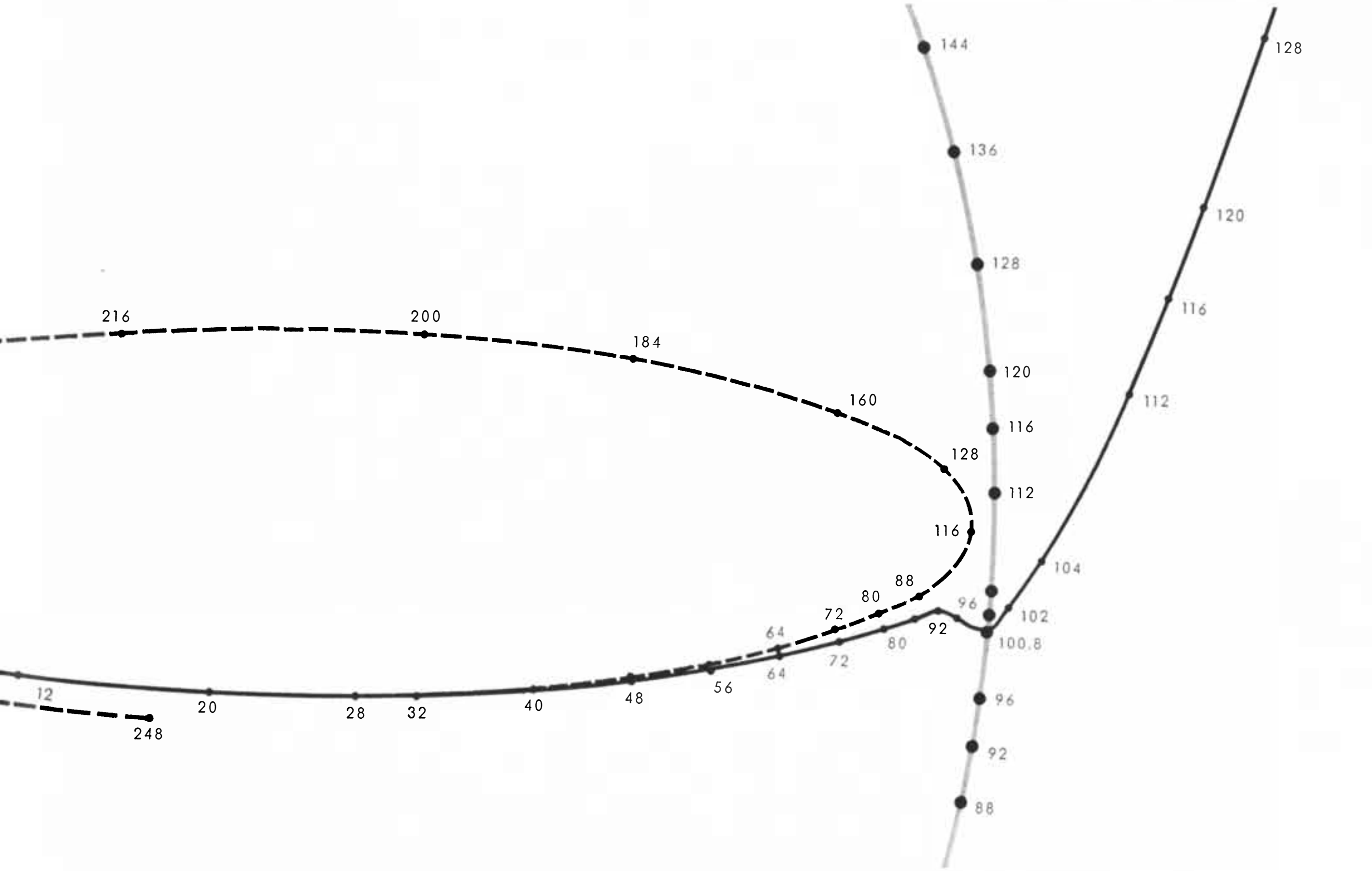
These are only a few samples of the scientific topics that could be explored by shooting a passengerless rocket around the moon. But when all is said and done, the paramount satisfaction will be the achievement itself. Something deep in the human spirit will be stirred when man succeeds in making a cow that jumps over the moon.



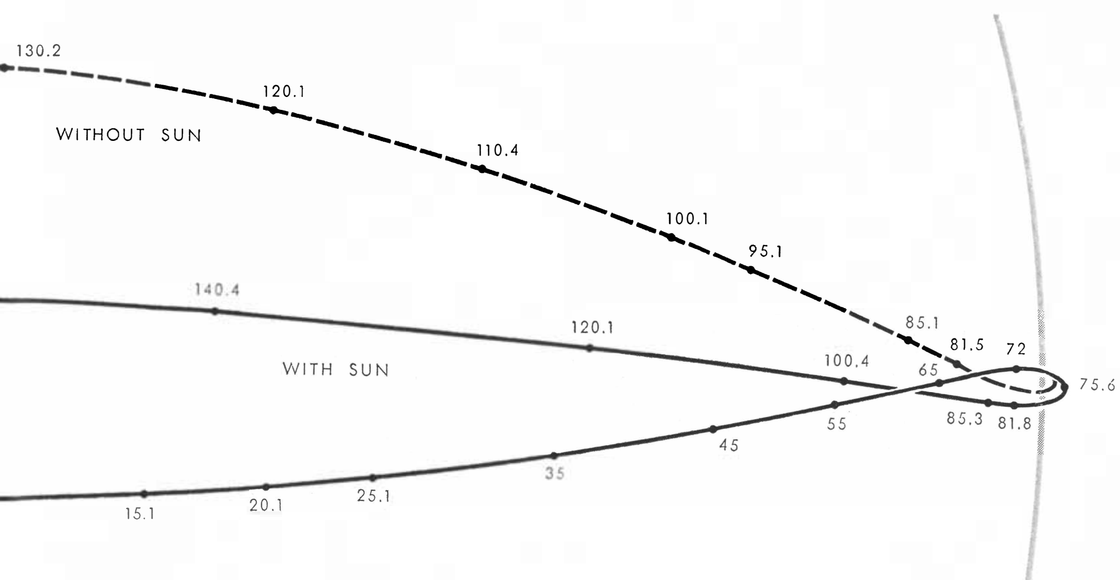
PULL OF THE MOON would have a stronger influence on the vehicle if the orbit



PULL OF THE SUN would enable the vehicle to make a close approach to the moon



of the vehicle brought it closer to the moon. This orbit would bring the vehicle within 2,050 nautical miles of the moon after 102 hours. The influence of the moon would then set the rocket on a new orbit. The initial velocity of this vehicle is 23,791 miles per hour.



without being thrown off into space. This orbit would bring the vehicle within 1,281 nautical miles of the moon 75.6 hours after its departure from the earth. The initial velocity of this vehicle is 23,827 miles per hour. This would be a practical orbit for the vehicle.

Sharks v. Men

Where and when is a shark likely to attack a man in the water? Some answers have begun to emerge from the geographical pattern of known attacks and underwater observations of shark behavior

by George A. Llano

In recent years the shark has enjoyed a certain amount of sharkish debate among authorities and quasi authorities. A U. S. Navy training manual during the late war belittled the danger of sharks to shipwrecked men and thereby started a debunking party. "The Shark Is a Sissy," said an article in a popular magazine, and went on to picture the fearsome-looking fish as one of the most cowardly things that swim, walk or fly. According to this school of thought, sharks are by nature timid and skulking creatures which can be sent scurrying in mortal fear by a smart slap and a harsh word. These authorities insist that a shark will attack man only if it is ravenously hungry or the man is absolutely helpless.

Why, then, the superstitious human dread of the "man-eating" shark, which is as old as the history of seafaring peoples? Islanders of the Pacific made a deity of the shark, and even today native divers in Red Sea waters are reported to call to sharks with friendly names to placate their evil spirit, as the Greeks called the Furies the Eumenides ("gracious ones"). The plain fact is that the ferociousness of the shark is too well documented by long experience to be dismissed as a legend. It is difficult to make light of the evidence when the remains of a human arm are found inside a shark. Off the coast of Australia near New South Wales and Queensland, the world's most shark-infested waters, more than 200 attacks on human beings have been recorded in the last 150 years. And devotees of the now-popular sport of skin-diving have lately given us some chilling accounts of their encounters with sharks.

On the other hand, it must be admitted that statistically shark bites are not one of the great hazards of man's existence. Only rarely do man and the shark come face to face. Nor is there any evidence that the "man-eating" shark has a special liking for human flesh. Furthermore, there are sharks, and there are sharks. Many species of them are indeed as harmless as minnows.

The sharks are an ancient and durable group, so nearly perfect in structure and so beautifully adapted to their environment that apparently they have not needed to change their structure or habits in all the eons of their existence. There are about 250 known species, and the largest of them—the whale shark, the basking shark and the sleeping shark—are the most inoffensive of all sea creatures. The sharks that have the teeth, jaws and instincts necessary for a rapacious way of life, and that have been incriminated as man-eaters, are limited to three families.

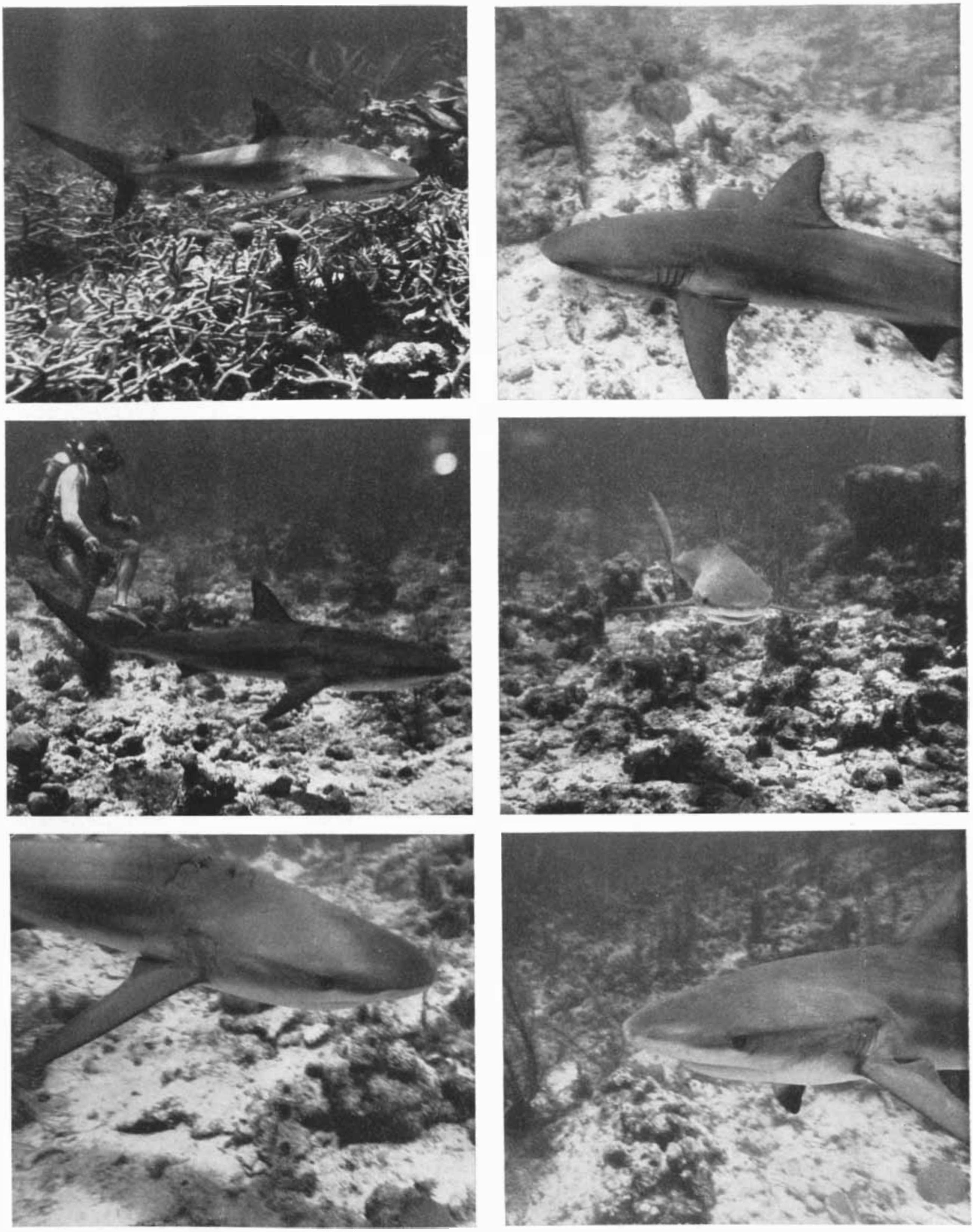
The great white shark, credited with being the most ferocious monster of the deep, is a member of the "mackerel" family. It is a heavily built, fast-swimming, far-ranging fish. Savagely aggressive, it has been known to attack boats. One authority describes it as having "a vast greediness after human flesh." At least three times in this century white sharks have made terrifying attacks on bathers on the U. S. coasts—in 1916 off New Jersey, in 1936 in Buzzards Bay (at the foot of Cape Cod) and in 1952 off southern California. Another genus in the mackerel family is the mako shark. Like the white shark, it is large, savage and widely distributed. A vigorous leaper, the mako is much hunted as a game fish.

The second group of dangerous sharks is known as the "requiem" family. The origin of the name is lost in antiquity, but it is certainly appropriate. The requiem group includes five genera and is probably the most numerous and widely distributed family of sharks. One of its members is the tiger shark, a fish of ill repute from the Antilles to the Antipodes. Australian pearl divers consider it the most vicious of all the sharks, and it is also greatly feared in the West Indies. The tiger, a sneaking scavenger, pursues its prey into the shallowest waters; it lurks around docks and haunts ships at anchor. It is without doubt the commonest large shark in the tropics. It feeds on anything, with little regard for edibility, and has been known to turn cannibal on its peers in size and ferocity.

Another member of the family with a reputation as a disagreeable fellow is the lemon shark. Like the tiger, it hangs around docks and ships. The lemon also is prone to run into brackish bays. This species is suspected of having been the culprit in a series of shark attacks on bathers in South Carolina waters between 1919 and 1933.

The blue shark, a representative of another genus in the requiem family, has had a bad reputation among sailors from time immemorial. Whether it has ever actually attacked a man is a matter of dispute, but its persistent attentions gave many a life-raft party a bad time during World War II. With its brilliant blue back and snow-white belly, this species is the most conspicuous and identifiable of all the sharks; most other sharks are drab gray or brown.

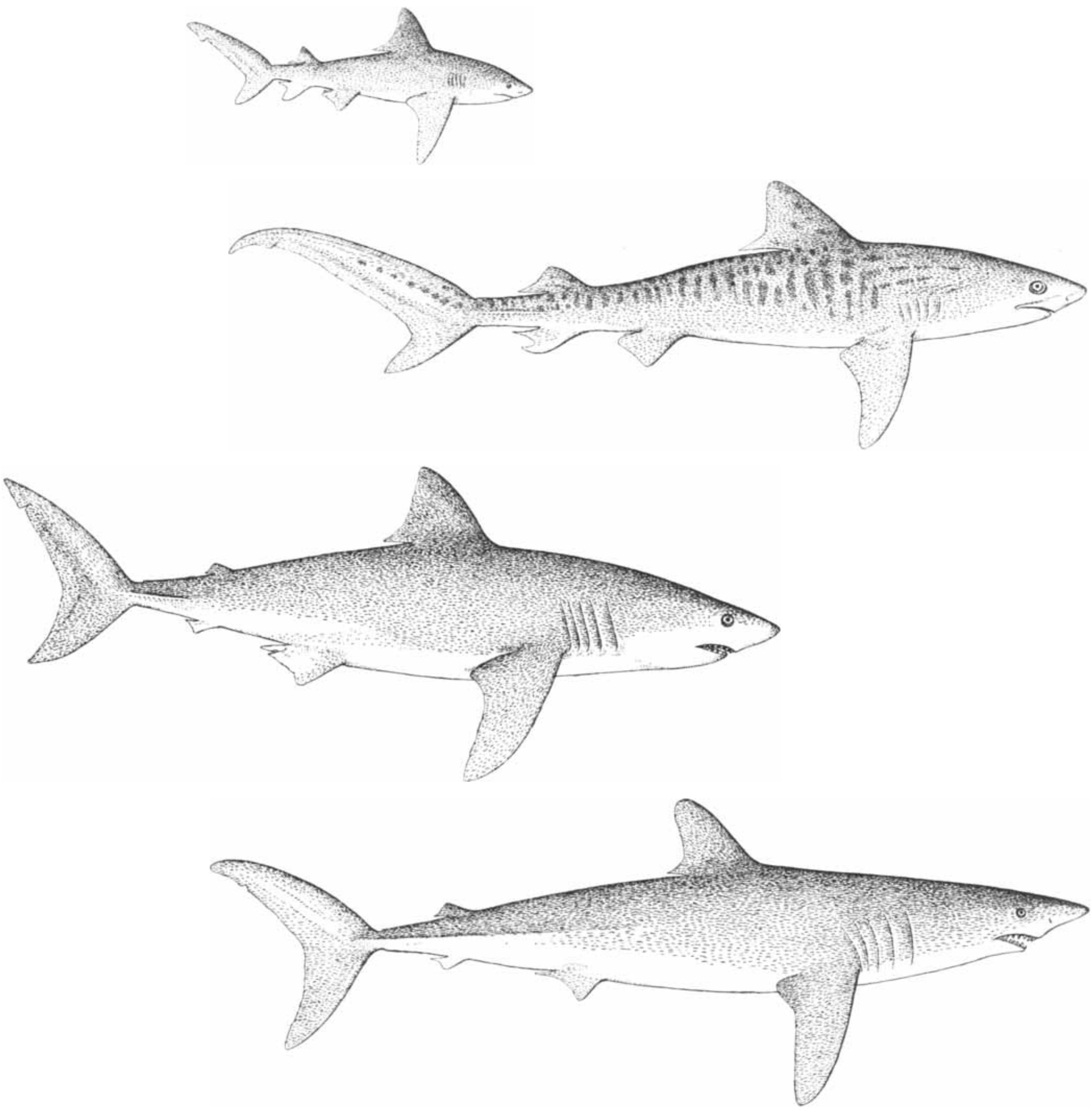
The genus with the most numerous population in the requiem family is *Carcharhinus*. Its species are found in all warm seas up to the 40th parallel. They range over the open ocean and in brackish and fresh waters. At least three species in the group live only in fresh water; one of them inhabits land-locked



ATTACK OF A SHARK on two free divers off Andros Island in the Bahamas is shown in this sequence of photographs. In the first two pictures the shark, probably of the dusky variety, approaches the divers. In the third it passes Carleton Ray after having charged him. Ray took no action except to push at the shark with his camera. In the last three pictures the shark approaches and circles Elgin Ciampi, who made the photographs. Ciampi kept the shark from coming into contact with him by making lunges at it. Finally the divers were able to back away from the shark, which remained in the area because it was attracted by the blood of a fish they had speared earlier. The fifth picture clearly shows old scars in the back of the shark, which was seven feet long.

Lake Nicaragua and makes it a feared body of water.

Incidentally, the common U. S. notion that sharks are a menace only on seacoasts is wrong. Not only are there inland species but marine sharks have been known to travel far upstream into continental and inland rivers. They have been reported in the Amazon; in the Senegal and Zambezi rivers of Africa; in the Ganges, Tigris and Euphrates of Asia; in the fresh waters of Malaya and Siam; in the upper Sarawak of Borneo; in the Fitzroy and Margaret rivers of Western Australia, and in a number of other places. The Ganges River shark has attacked pilgrims during their sacred bathing in the river and its tributaries. In Iran 27 shark attacks, half of them fatal, were reported during the period 1941 to 1949 in the Karun River near the town of Ahwaz, 90 miles from the Persian Gulf. The sharks in question, described as about four feet long, attacked men, women and children. Usually the victims were bitten on the ankles or calves while they were standing in knee-deep water. One victim was a British ambulance driver who had driven his vehicle into water about a foot deep to wash it. A shark seized him by the right ankle and pulled him off balance with a strong jerk. In the ensuing battle

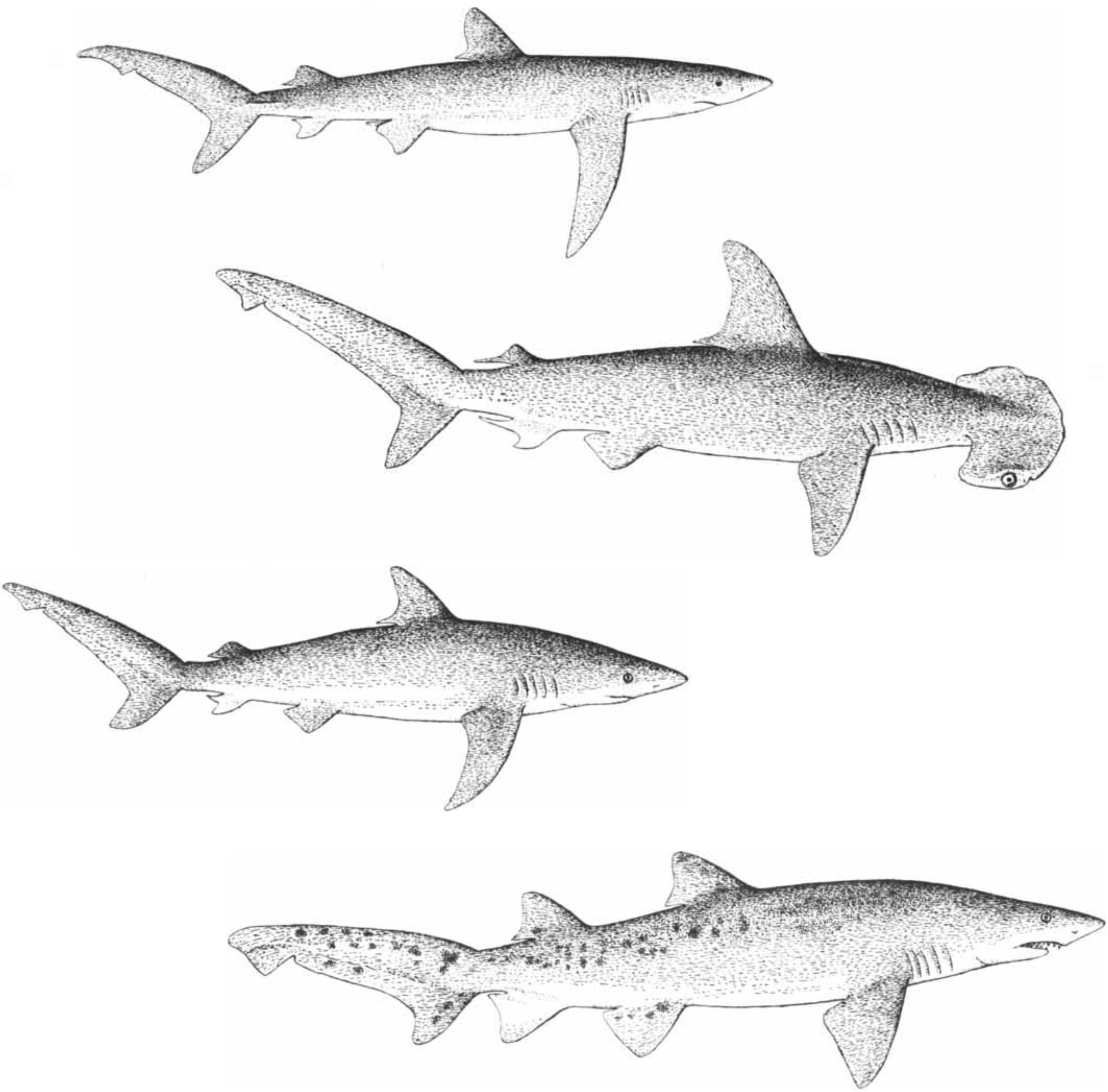


SPECIES OF SHARK known to have attacked men are depicted in these drawings. At the top of the page at left is the Lake Nicaragua shark (*Carcharhinus nicaraguensis*), a fresh-water species. Second from the top is the tiger shark (*Galeocerdo cuvier*). Third is the white shark (*Carcharodon carcharias*). Fourth is the mako shark (*Isurus oxyrinchus*). At the top of the page at right is the blue the fish almost tore off his right leg, stripped the tissues from his right arm and shredded his left hand and forearm.

The third family of sharks reported to attack man are the "hammerheads," so-called because of their large, rudder-like heads. They are dexterous swimmers and are often found close to the surface near beaches. A hammerhead is known to have attacked a bather off West Palm Beach in Florida in 1931.

To evaluate the shark hazard to man, sharkologists have made detailed studies of the geographical distribution and times of the recorded attacks. All authorities on the subject agree that the danger is greatest in tropical and subtropical seas: most of the attacks have occurred between 30 degrees north and 30 degrees south of the Equator. V. M. Coppleson, the foremost shark expert of Australia, has noted that sharks seem most prone to attack when the water temperature is 70 degrees Fahrenheit or higher. However, the temperature is certainly not decisive, for men have been killed by sharks in waters colder than 60 degrees. The hazard seems to be largely a statistical matter: attacks are most numerous in waters where the shark and man are active the year round.

In Australia sharks and people are in close proximity throughout the summer



shark (*Prionace glauca*). Second from the top is the hammerhead shark (*Sphyrna diplana*). Third is the dusky shark (*Carcharhinus obscurus*). Fourth is the sand shark (*Carcharias taurus*). Although the size of sharks of each species varies, these sharks are drawn roughly to scale. The scale is suggested by an average length for the white shark: 15 feet. White sharks can, however, reach 40 feet.

season from October to April, when the beaches are crowded with bathers and great numbers of sharks are drawn to inshore waters by schooling salmon and other fishes. Consequently shark attack there is an ever-present danger. The peak month is January, and the time of greatest risk seems to be between 3 and 4 p.m. Bathers have been assailed at various depths in the water and very close to the beach. Coppleson reported that more than 80 per cent of the attacks are fatal. Some beaches have had to erect steel nets around the bathing area. But sharks go on exacting a toll in unprotected waters, even in rivers, and from people in boats who carelessly dangle their feet or hands overboard. Occasionally the aggressive fishes even capsize small boats and attack the passengers.

Another very dangerous area is the waters of South Africa, where 23 persons were killed by sharks in the period 1940 to 1952, chiefly in the Indian Ocean off Natal. In the Northern Hemisphere, the West Indies are notoriously hazardous: during the past half-century 19 shark attacks, most of them fatal, have been reported in Caribbean waters, including the Florida coast. Sixty-five per cent of the bathers were struck in inshore waters.

Along the Eastern seaboard of the U. S. there have been 23 reported shark attacks on bathers over the past 40 years. Most of them took place near Charleston, S.C., and on the New Jersey shore. There were only two really dangerous years—1916 and 1933. Considering the great numbers of people who throng the Atlantic beaches in summer, the number of attacks in the half-century is remarkably low.

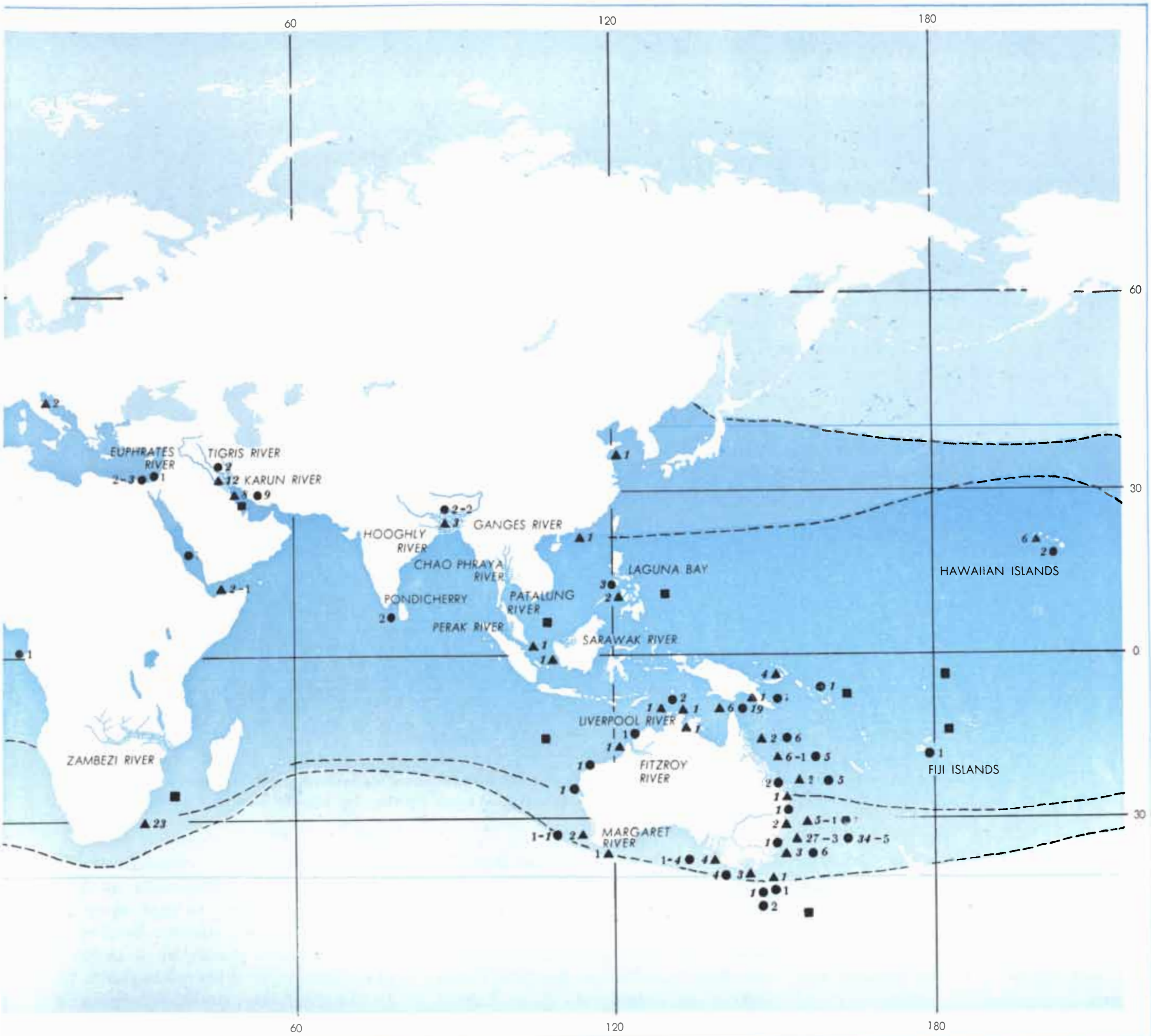
Western Europe has even less reason to fear the shark. The western Mediterranean, including the crowded Riviera, has not had a single verifiable shark attack in 100 years. The same cannot be said for the eastern half of that sea. In the Egyptian waters around Port Said there were five attacks on people within 10 years—three of them on the same day, August 8, 1899!

SHARK ATTACKS are located on this map of the world. The numbers beside the symbols (*see key at left*) indicate the number of attacks which occurred at that point. "Docu-

What sort of creature is the shark? What are its habits and disposition? There is no dearth of eyewitness accounts of its behavior, although these sometimes have to be taken with a grain of salt.

By nature sharks are roving freebooters. Apparently they feed around the clock, intensifying their feeding at night, when they are likely to come inshore. Their senses of vision and hearing apparently are not very important in the search for food. Some authorities credit them with unusual sense organs sensitive to movements, vibrations or chemical stimuli from their prey, particularly from wounded or dying fish. However that may be, unquestionably the shark's most important sense is smell; indeed, it has been aptly called "the swimming nose." A lone shark moves through the water like a hound tracking a faint scent. In packs, sharks become highly excited in the vicinity of food. Mobs of them will rapidly materialize out of nowhere when fish are speared, thrown overboard or immobilized by a dynamite blast.

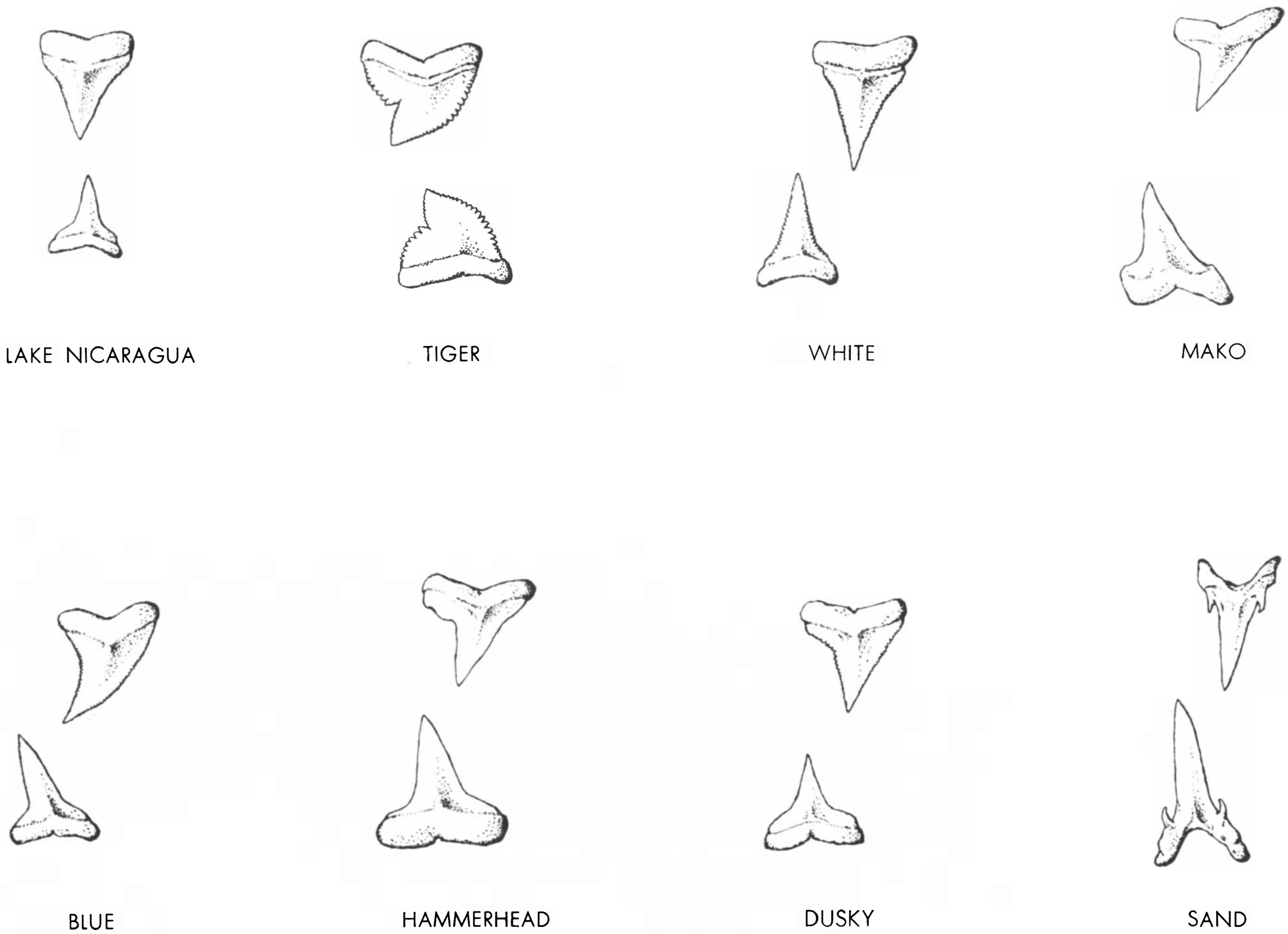
No one really knows under what circumstances a shark will attack a human being. But once it has had this experience, it seems to acquire a disposition to



mented" attacks were described by eyewitnesses; "reported" attacks, by secondhand reports. The line at 40 degrees North and South latitude is the limit of waters in which shark attacks are most likely to occur. The temperature of the water in the darkest colored area is always above 66.5 degrees Fahrenheit; here the danger of shark attack is constant. The temperature of the water in the lighter zone immediately north of this area is above 66.5 degrees in August; in the zone immediately south of the area, above 66.5 degrees in February. At these times the danger in the two zones is greater. The areas inhabited by fresh-water sharks are stippled and named.

repeat it. "In this respect," said Coppleson, "the man-eating shark appears to be somewhat analogous to the man-eating tiger." A shark that has attacked a man often remains in the area from season to season, attacking again and again. On several occasions observers have noted the curious fact that a shark will single out one individual in a crowd and confine its attacks to him, ignoring people who come to the victim's rescue. This was remarkably demonstrated in a shark attack on a 17-year-old boy, Barry Wilson, off the California coast in 1952. Five men swam to the boy's aid after he had been bitten. They put him on an inflated inner tube and began to push him toward shore. While they swam the several hundred yards to shore, the hovering shark circled deliberately around the group. It never touched or threatened the rescuers, but it succeeded in slipping through the cordon and fatally biting its victim again.

A shark bite is distinctive and unmistakable. It is usually crescent-shaped, but a deep bite leaves a cavity with tooth scratches and sometimes even tooth fragments on the periphery of the wound. Most commonly the bites are in the legs and buttocks, but of course the shark is also apt to bite the arms and



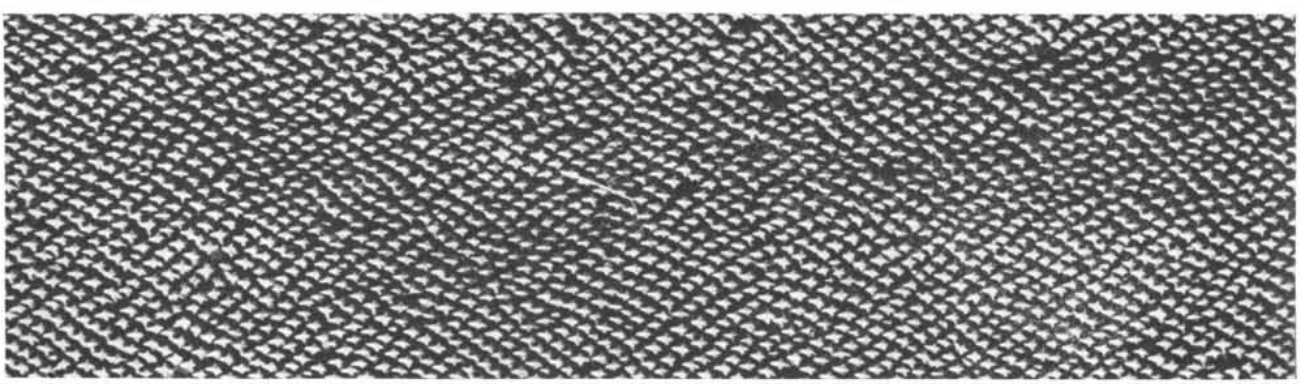
TEETH of the species of shark depicted on pages 56 and 57 are compared. They are not, however, drawn to scale. An upper and a lower tooth is represented for each species. Shark species which are very much like one another are usually identified by their teeth.

other parts of the body when the victim fights back. The reason shark bites are so often fatal is that when they sever an important artery, the victim loses a great deal of blood before he can be got to land, and he dies of hemorrhage and shock.

Sharks are proverbially indifferent to pain or injury and will go on attacking regardless of mortal wounds inflicted by human opponents or captors. No one has ever tested a shark's intelligence, but it is generally held to be of a very low order. The fish will bite blindly and viciously at oars or a boat or raft. Fishermen who indiscreetly haul live sharks into their boat are apt to regret it, for even a small shark can wreak lashing havoc upon the boat and crew. In one documented case the head of a decapitated shark bit off a sailor's index finger.

A shark's teeth are not its only weapons. Its rough shagreen skin cuts the flesh of a victim in the water as it swishes by. The shark can slash up an inflated life raft. One survivor lived to tell of a frenzied assault by a shark which all but reduced his raft to shreds.

Of the great mass attacks by sharks, one of the most disastrous took place in World War II. When the *Nova Scotia* was torpedoed at night off South Africa, more than 1,000 lives were lost, and



SKIN of some sharks has a rough "shagreen" texture. Thus, when a shark of this kind brushes past a man in the water, it is capable of inflicting a lacerating wound in his skin. The skin in this photograph is from a nurse shark; its texture is enlarged two diameters.

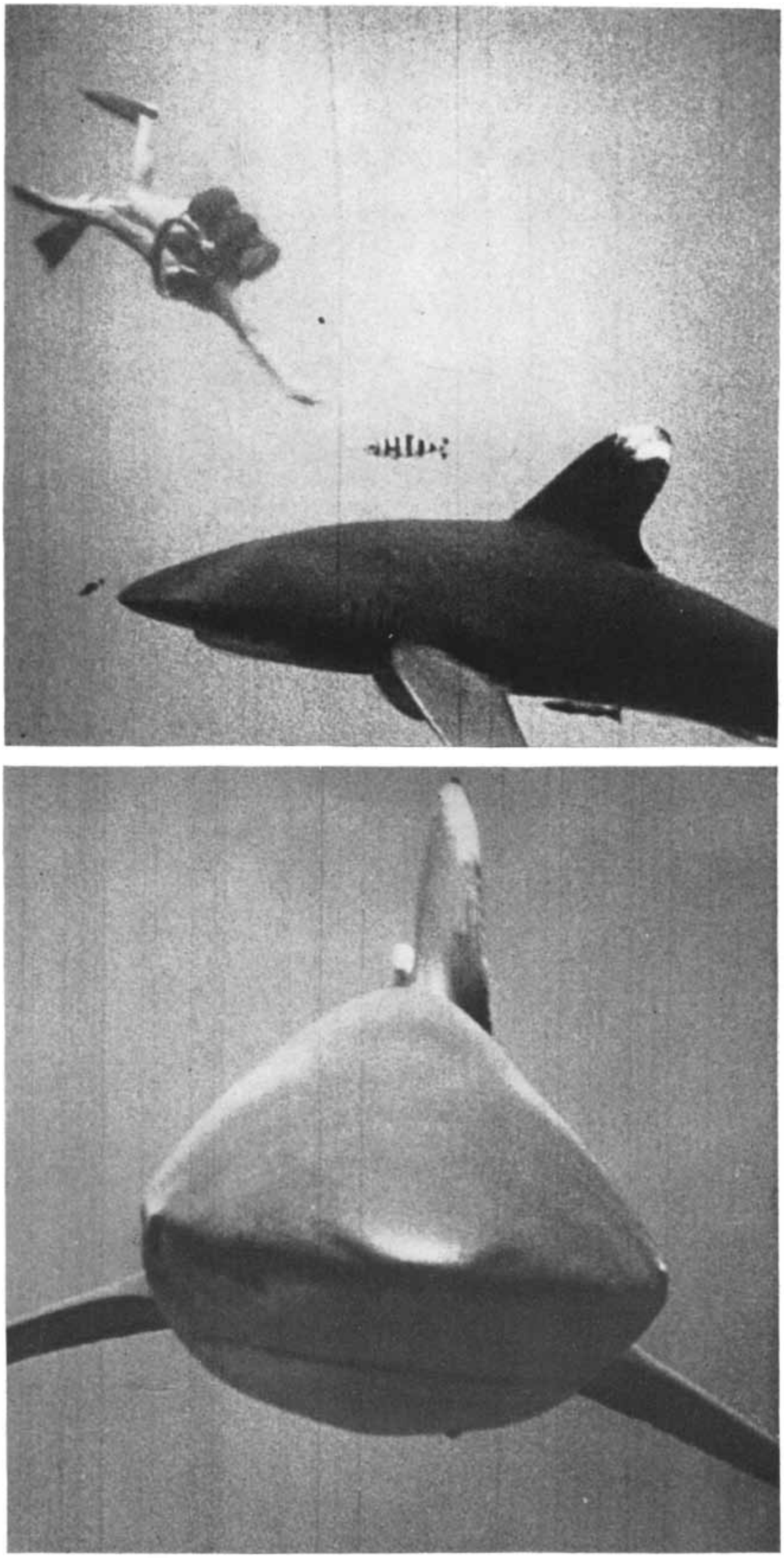
many of these persons were killed by sharks. In the early morning legless bodies of men were found floating in life belts.

We are indebted to sport divers for several recent accounts which cast new light on shark behavior. These divers have rarely been attacked, but the few who have tell of experiences disquieting enough to dictate caution. They describe unnerving ballets of groups of sharks which swept back and forth past the submerged man, whirling, pouncing, making passes at his legs, swimming off and sneaking back from unexpected directions. Some of the divers had the misfortune to spear sharks and suffer a counterattack which cost them badly torn feet and even face bites.

Jacques-Yves Cousteau, the greatest living expert on modern deep-sea diving, has reported two harrowing encounters with sharks. One was in the Red Sea, and Cousteau noted a couple of significant facts about it: (1) the shark saw him from a distance of 30 feet—certainly no evidence of poor vision, and (2) the attack was deliberate. Cousteau beat the shark to the safety of his raft, but he attributes his escape to the fact that the shark turned aside at the last moment.

Off the Cape Verde Islands of Portugal, Cousteau and his fellow diver Frédéric Dumas underwent a "trial by sharks" which undoubtedly stands out as a classic in the annals of undersea exploits. Fifty feet down both men found themselves closely pressed by an eight-foot gray shark, later joined by two five-footers and several blue sharks. The pack resisted all attempts to drive them off: they would shy away only to come back almost at once. The situation became increasingly desperate, and the two men used every method in the diver's book, flailing their arms, releasing bubbles from their air tanks and hooting through their masks with all their might. The sharks were not scared off by any of these tricks, by the shark "repellent" (copper acetate) strapped to the divers' legs or by a blow Cousteau gave one approaching shark on the nose with his heavy undersea camera. In Cousteau's words, the fishes seemed to "know what they wanted." Fortunately the two backtracking divers got out of the water just in time.

Cousteau asserts what is after all the only reliable generalization about sharks *v.* man: the creatures are unpredictable, and he who wishes to enter the shark's domain had better exercise discretion.



FAMOUS FREE DIVERS Jacques-Yves Cousteau and Frédéric Dumas were attacked by sharks during a dive in the open Atlantic. In the top photograph, made by Cousteau, a blue shark swims past Dumas. At bottom the shark makes a direct run at Cousteau, who drove it away by banging its nose with his camera. Both men got back to their ship safely.

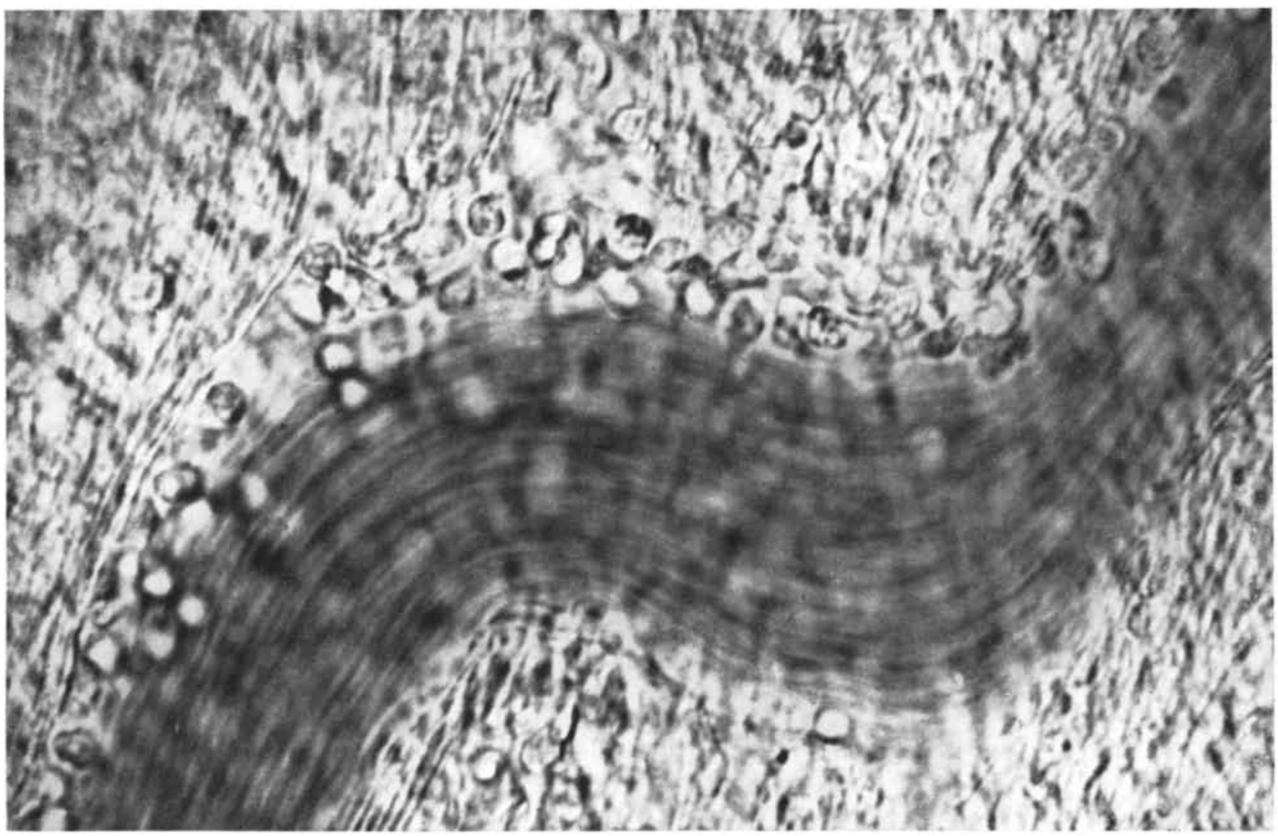
Fever

Brain centers act as the body's thermostat to maintain normal temperature. Fever may be produced when the white blood cells release a substance which raises the thermostat to high levels

by W. Barry Wood, Jr.

Although fever has been recognized as a cardinal sign of disease since the time of Hippocrates, its cause remains shrouded in obscurity. After more than 2,000 years of experience with this obvious manifestation of illness, modern medicine cannot yet answer the question as to why sickness is so often accompanied by a rise in body temperature.

Ancient physicians recognized fever by touch. In the early 17th century the Italian professor Sanctorius invented a crude clinical thermometer, and Gabriel Fahrenheit produced his efficient mercury instrument in 1714. But doctors did not begin to realize the medical possibilities of the thermometer until late in the 19th century. The real start of medical thermometry came as a result of one of the most extensive and methodical researches in the history of medicine. For 15 years, beginning in 1851, C. A. Wunderlich systematically recorded the body temperatures of all patients admitted to his clinic at the University of Leipzig. He accumulated a huge number of readings on nearly 25,000 patients, and eventually published a monumental monograph, *On the Temperature in Disease*. Wunderlich clearly demonstrated that body temperature reflected the course of typhus and other common diseases. He wrote: "The conviction of the immense and almost incalculable value of the



WHITE BLOOD CELLS stick to the wall of a blood vessel in response to an irritant. Drawing at right outlines the vessel and its capillary. The red cells, which are moving rapidly, appear as streaks in the photomicrograph. The white cells first stick to the thermometer . . . took fast possession of me, a conviction which I am bound to endeavour to wake and confirm in the minds of others." Largely as a result of Wunderlich's monograph, physicians all over Europe and America began to employ medical thermometers.

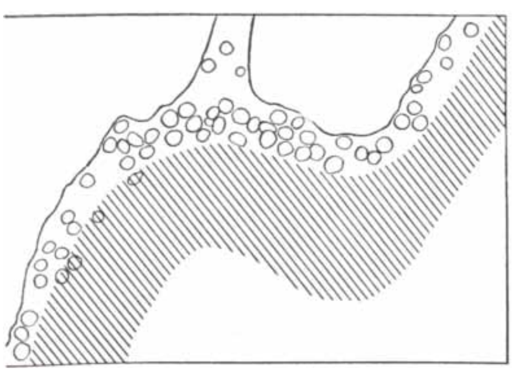
Several scientists had already suggested theories concerning the production of body heat. John Hunter, the celebrated British surgeon and physiologist, had shown that animals were able to resist external cold because they generated in themselves enough heat to counterbalance the loss. In 1780 Antoine Lavoisier, the discoverer of oxygen, had theorized that body heat was produced primarily by the chemical combination of oxygen with hydrogen and carbon during respiration. He concluded that the principal seat of warmth production was in the lungs. But Lavoisier's theory was made untenable by, among other things, the discovery that the temperature of a decapitated animal fell rapidly even when artificial respiration was applied to keep it alive and convert venous blood to arterial blood in its lungs. The German chemist Justus von Liebig later proved that animal heat is generated by the combustion of foodstuffs in the tissues of the body, and still later it was shown that heat production and loss are under the control of the nervous system.

Today we know something about the mechanisms regulating the body temperature, but we still have no proved theory as to the basic cause of fever in disease. Certain crucial links in the necessary chain of evidence are still lacking.

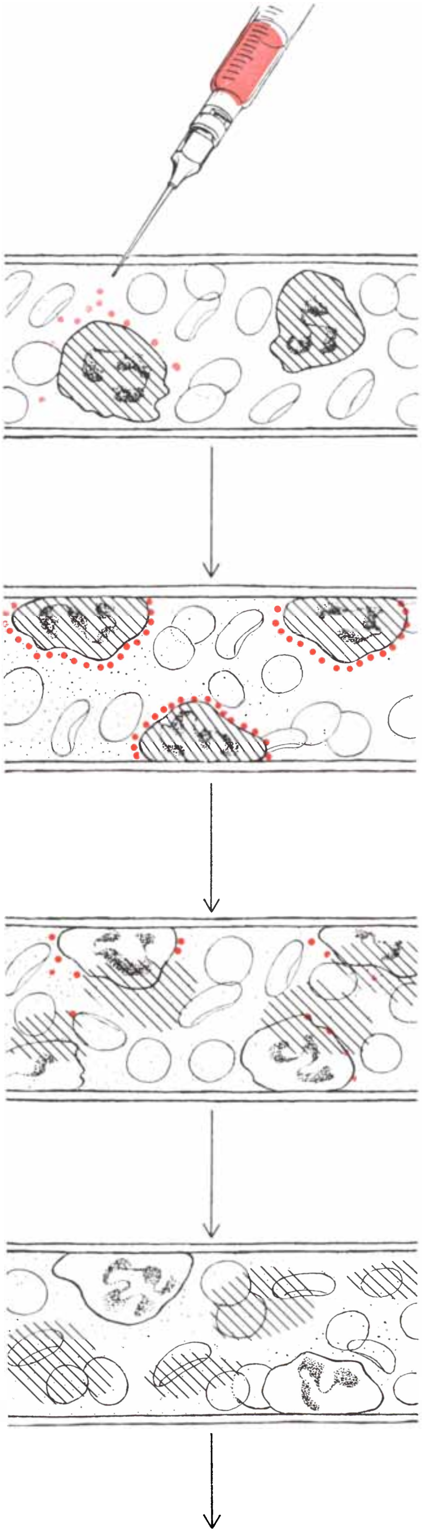
Let us begin by considering the real meaning of the term "normal temperature." The familiar arrow on clinical thermometers is at 98.6 degrees Fahrenheit. Just how meaningful is this standard of normality? Here is a record of the oral temperatures of 276 presumably healthy medical students taken one morning between 8 and 9 a.m. [*chart at top of page 65*]. Not only do the individual temperatures vary widely, but their median is 98.1 degrees, not 98.6. The fact that this average is below "normal" might be interpreted as merely reflecting the low ardor of medical students at this early hour in the morning; actually, as is well known, the temperature of the human body follows a daily curve which is lowest in the early morning and highest in the evening. Had the medical students been tested at 4 p.m. rather than at 8 a.m., their average oral temperatures would doubtless have been significantly higher—probably above 98.6 degrees F. What about the wide range of individual variation? Here again we know that circumstances other than illness can raise or lower the reading. Mouth breathing, talking or a cold drink will make a mouth thermometer register below "normal"; on the other hand, hot weather, emotional stress, strenuous exercise or ovulation in the menstrual cycle may elevate the temperature. Clearly the sharp arrow marking the point of normality on the thermometer is misleading; it would be far more realistic to indicate "normal" by a band covering a range.

The rectal temperature is more constant than the oral, but even this measurement does not necessarily reflect the true internal temperature of the body. Readings made with thermocouples inserted deeply in skeletal muscles, or in abdominal organs such as the liver, are often considerably above the rectal temperature. The temperature difference between the internal organs and the skin may at times amount to several degrees F. As everyone knows, the body's surface temperature, particularly on the hands and feet, fluctuates considerably.

The fact that the general body temperature remains relatively constant, in spite of the many factors acting upon it, is altogether remarkable. Nature has endowed the human organism with an extraordinarily efficient system of heat control. In a cold climate the body speeds up its metabolic production of heat. It reacts to cold with exercise, shivering, unconscious tensing of muscles and the ingestion of more food. At the same time it reduces heat loss to a minimum by cutting down the rate of circulation of blood to the skin. In hot weath-



side of the vessel that is nearest the injury, in this case in the tissues above vessel.



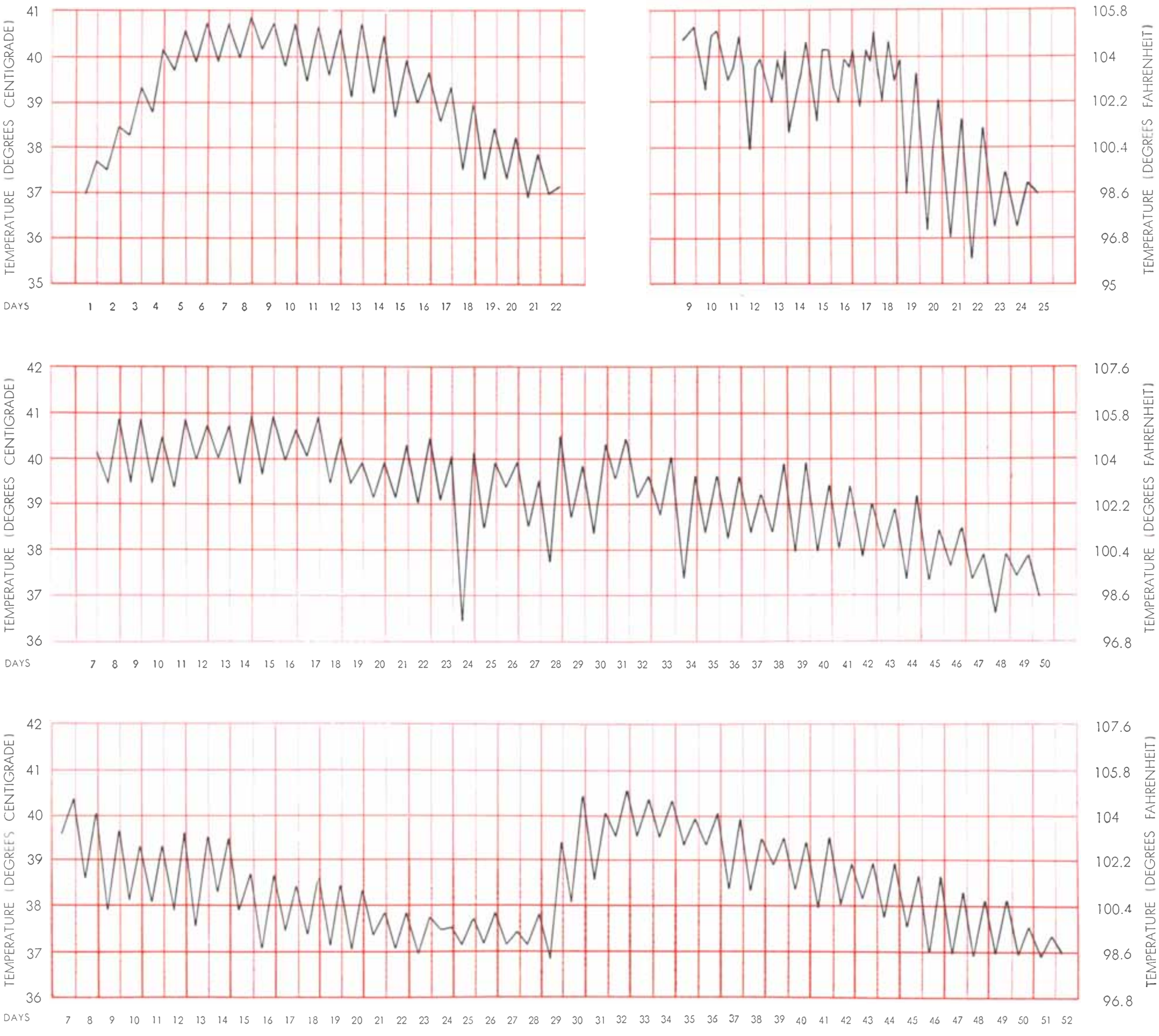
TYPHOID VACCINE injected into the bloodstream (*top drawing*) probably causes the polymorphonuclear white cells to stick to the sides of the vessel (*second*) and release a fever-producing substance, or pyrogen (*third*). The pyrogen apparently travels through the bloodstream (*fourth*) to the temperature-regulating centers in the brain, which react to it by producing fever.

er, on the other hand, it accelerates the dissipation of body heat by increasing the circulation to the skin, by sweating and by faster respiration. Notwithstanding all the environmental variables, the body generally maintains a practically perfect thermal balance.

Were this not the case, the human organism could not long survive, for many of the biochemical processes involved in its metabolism are highly vulnerable to thermal change. A drop of internal temperature below the normal range would inhibit critical enzyme reactions; high temperatures would denature body proteins, inactivate enzymes irreversibly and damage cells irreparably. In fact, the human body cannot withstand a fever as high as 108 degrees F. for very long, although temperatures as high as 112 degrees have been tolerated for brief periods. It has considerably more tolerance to low temperatures, provided the body has been cooled under very carefully controlled conditions.

How is this intricate physiological machinery controlled? What brings about the increased circulation in the skin and the outpouring of sweat which allows a man during moderate exercise to double his heat output and still maintain a normal body temperature? What shuts down these mechanisms to conserve heat during exposure to cold? What makes an individual shiver in a cold environment?

Two lines of evidence indicate that there are important thermoregulatory centers in the hypothalamic region of the brain. First, when a patient dies with so-called "neurogenic fever"—caused by a stroke, a severe brain injury or a brain tumor—it is almost invariably found that the hypothalamus was involved. Secondly, experimental operations on animals have proved the existence of temperature-regulating centers in the hypothalamus. These centers are of two distinct kinds. In the front part of the hypothala-



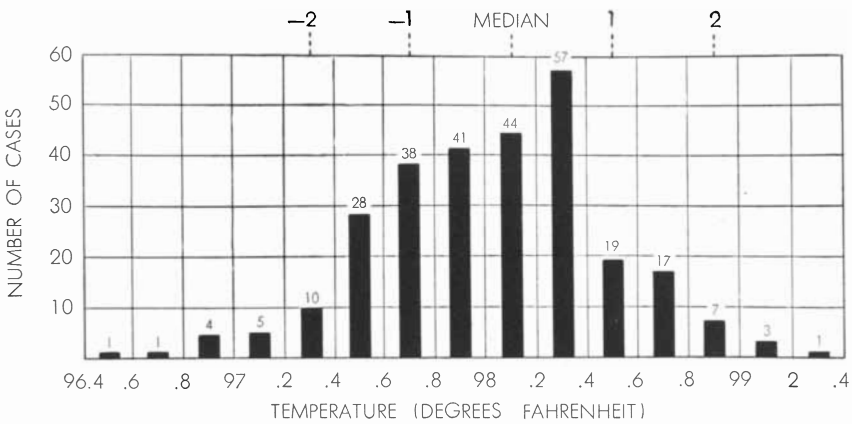
FEVER REACTION IN TYPHOID FEVER of different types was one of the first studies in relating temperature changes to disease. The charts above are based on the original charts published by C. A. Wunderlich in 1867. At top are cases of mild (*left*) and abortive (*right*) types of typhoid; severe typhoid is charted in the middle; at bottom is the chart of a case with relapse.

mus are centers having to do with the prevention of overheating; in the rear of the hypothalamus and the front of the midbrain are centers concerned with protection against cold. Appropriate stimulation of the former areas in cats, for example, causes panting, dilation of the blood vessels in the skin and activity of the sweat glands in the animal's foot pads. Destruction of the cold-protective centers, on the other hand, knocks out the ability of the animal to shiver, to constrict its peripheral blood vessels and to raise its muscle tone. In fact, by a proper combination of operations on the hypothalamus a warm-blooded animal can be transformed temporarily into one something like the cold-blooded reptile, whose body temperature goes up and down with that of the environment.

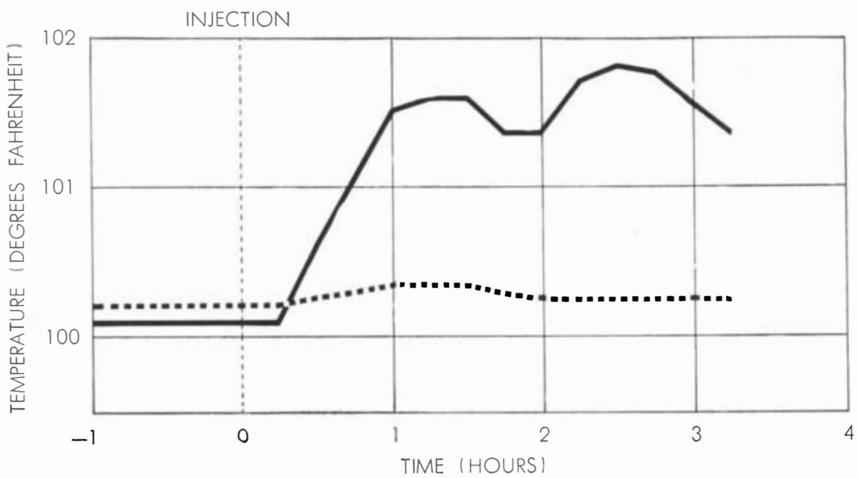
Thanks to such experiments the fever resulting from damage to the brain is reasonably well understood. But what about the more common types of fever, such as those accompanying infections and other diseases? It is here that modern medical knowledge is most deficient.

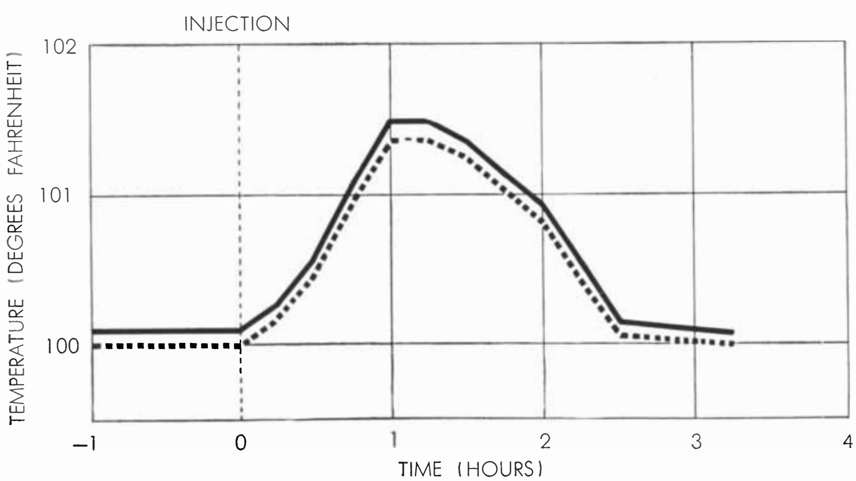
In 1837 Hunter drew attention to the fact that the tissues at the site where a surgical operation had been performed often felt warm to the touch. Thirteen years later a German army surgeon, Georg Zimmerman, suggested that fever might in some way be related to inflammation. Not until nearly a century later was experimental evidence obtained to support his hypothesis.

The chain of evidence begins with a report made in 1948 by Paul B. Beeson, then professor of medicine at Emory University (he is now at Yale). Beeson extracted a fever-producing substance from certain white blood cells (the type called polymorphonuclear) which make up most of the exudate in acute inflammation. A number of substances which could produce fever had previously been discovered: they are foreign substances, principally extracts from bacteria, which, when injected into rabbits intravenously, cause them to develop a rise in temperature. But Beeson's extract from a rabbit's own white blood cells behaved very differently from these foreign substances. The latter are highly resistant to heat, produce fever only after a delay of 20 to 30 minutes, and cause the animal to develop a tolerance (*i.e.*, a markedly reduced response) when they are injected repeatedly. In contrast, the white-cell extract, as Beeson's collaborator Ivan Bennett demonstrated by a beautiful series of experi-

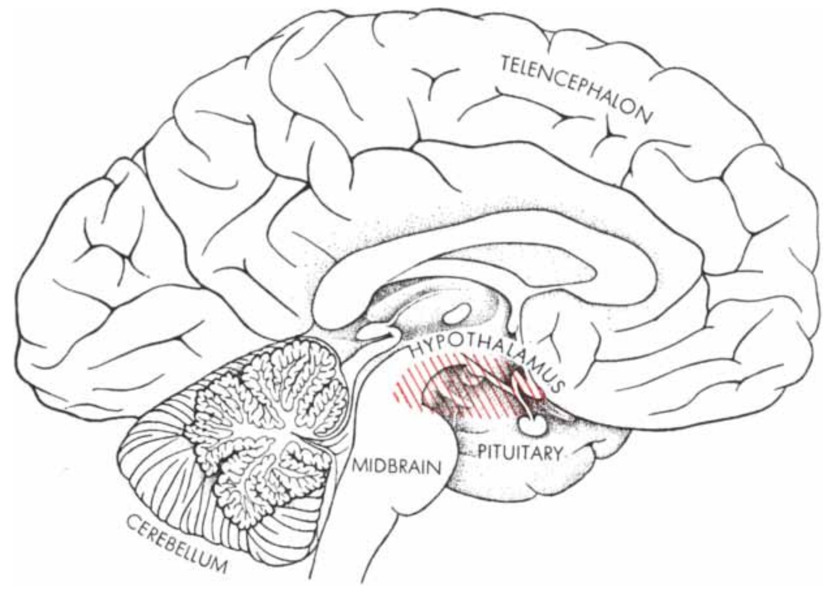


RANGE OF NORMAL TEMPERATURES of 276 healthy medical students is shown on this chart from a study by A. C. Ivy at Northwestern University. Temperatures were taken between 8 a.m. and 9 a.m. The median and standard deviations are marked by broken lines.

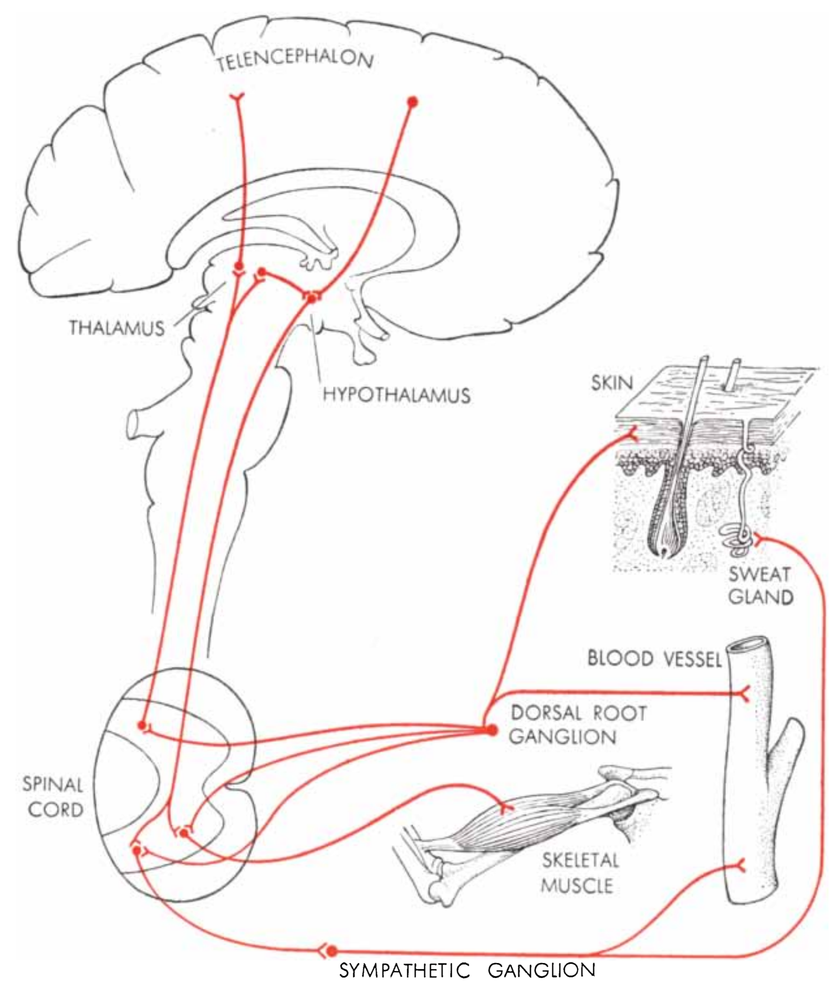




TEMPERATURE CHARTS of normal (*solid line*) and "tolerant" rabbits (*broken line*) are markedly different after the injection of typhoid vaccine (*upper chart*). Tolerant and normal rabbits react in the same way to an injection of white-cell extract (*lower chart*).



TEMPERATURE CONTROL CENTERS are shown in color in this cross section of the human brain. Centers in the front part of the hypothalamus prevent overheating; those in the rear part of the hypothalamus and front of the midbrain prevent excessive cooling. The locations were determined by experiments on dogs, but may be analogous in human brain.



NERVE CONNECTIONS of the temperature-regulating centers bring in messages from other parts of the brain. Impulses are sent out to blood vessels, muscle, skin and sweat glands via interconnections in spinal cord and nerve ganglia. The organs are not in scale.

ments, is easily destroyed by heat, raises the animal's temperature promptly and does not generate tolerance.

Beeson was prompted to suggest that disease liberates this substance from the polymorphonuclear white blood cells so that it acts upon the temperature-regulating centers of the brain to induce fever. If this is the case, an artificial injection of a bacterial extract, an infection, cancer and other diseases may all produce fever by affecting these white cells, causing them to release their "pyrogen" (fever-inducing substance), which in turn acts upon the hypothalamic centers. There is now considerable evidence to support this hypothesis.

First, there is the fact that the white-cell extract does not produce tolerance when repeatedly injected into an animal, as a foreign pyrogen does. This is what we should expect of the agent directly responsible for fever; if the animal became tolerant to it, no fever would last more than a few days.

Secondly, injection of a bacterial pyrogen sharply reduces the white blood cell count, and experiments strongly indicate that the injected substance damages the white cells in the blood.

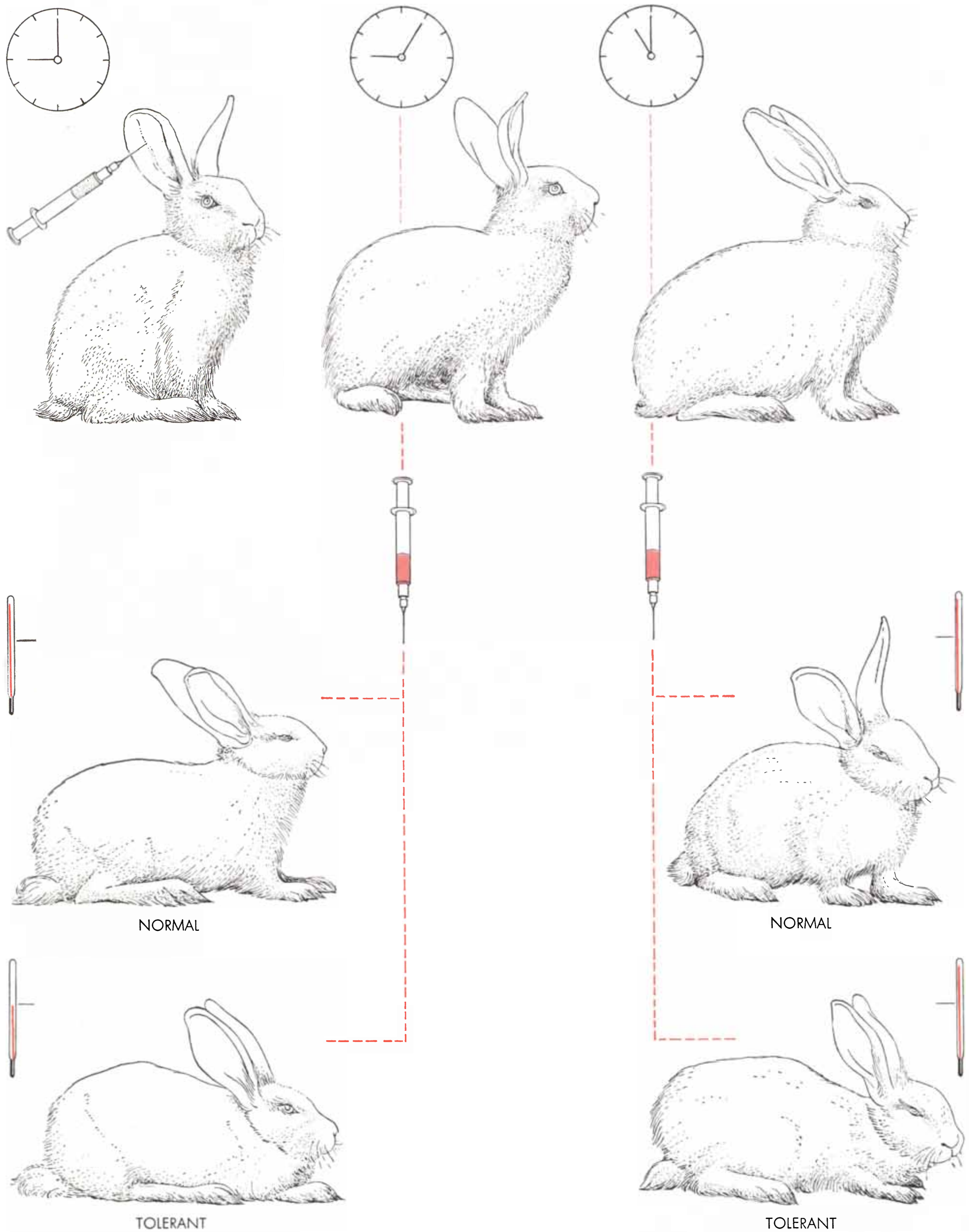
Thirdly, Elisha Atkins and the writer have demonstrated that after rabbits have been injected intravenously with typhoid vaccine, the rabbits' blood comes to contain a second substance which has all the properties of the pyrogen released by white cells.

Fourthly, M. Kenton King, working with the author, has shown that the pyrogenic substance found in the fluid of an inflammation comes mainly from the polymorphonuclear white cells, and that these cells still retain their ability to perform other important functions.

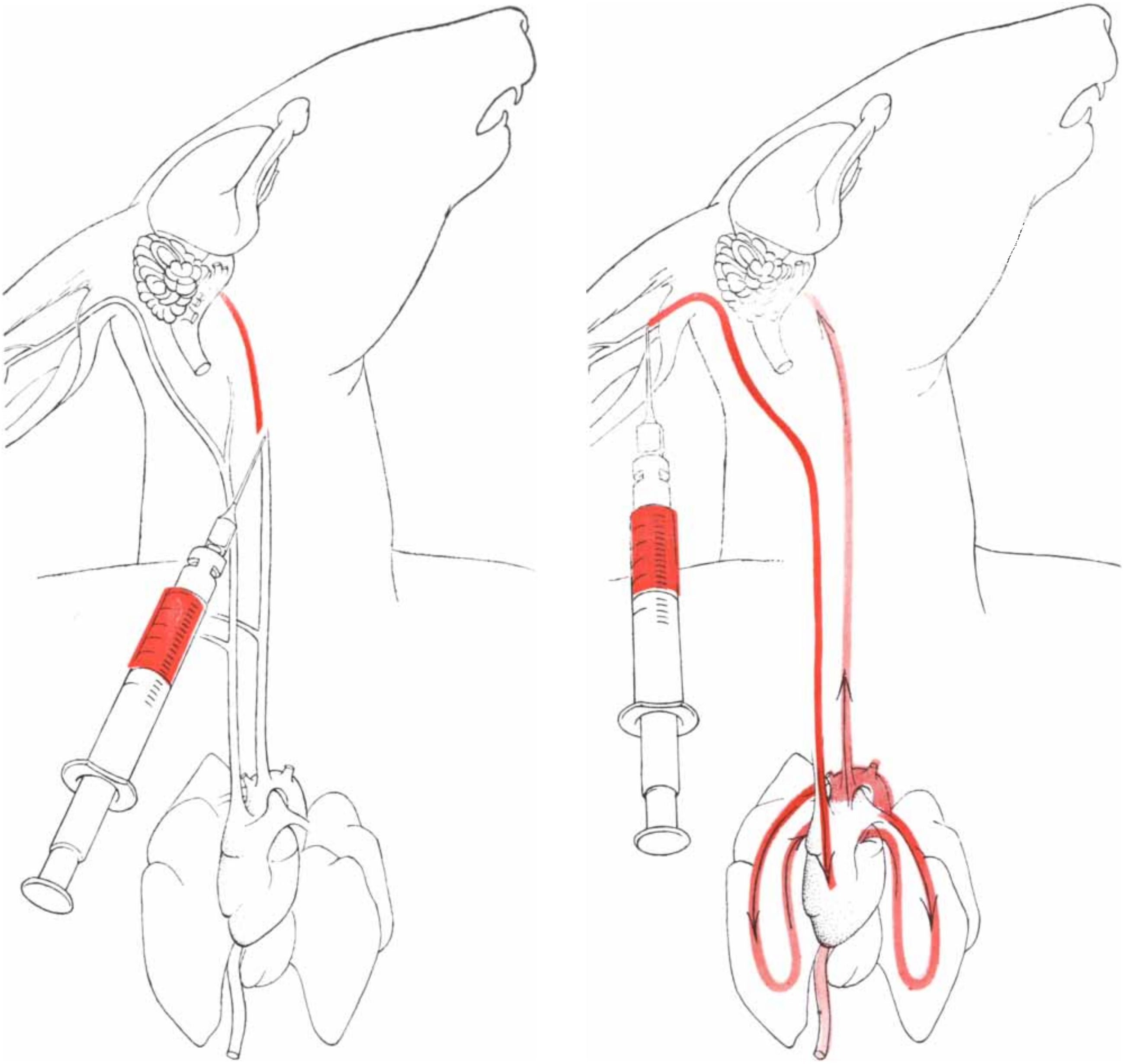
Finally, by means of an ingenious technique for injecting substances into the blood entering the brain, King has demonstrated that the pyrogens produced in the body act directly upon the hypothalamus, whereas foreign pyrogens act upon it only indirectly by damaging the white cells.

All this strongly supports the theory that the fever of disease is produced by a substance which is released from injured cells and travels via the bloodstream to the temperature-regulating centers in the hypothalamus and midbrain. In practically all forms of disease characterized by fever, there is some inflammation in or about the diseased tissues. This basic reaction of living tissue to cellular damage may be the primary source of fever.

Attractive as this theory now seems,



EXPERIMENTS WITH RABBITS demonstrated that fever from typhoid vaccine involved two factors. Rabbit at top was injected with the vaccine. Two blood samples were taken from it. Serum from the five-minute sample was injected into two rabbits (*left*), one normal (*upper*) and one made "tolerant" by previous typhoid injections (*lower*). Similar rabbits (*right*) received serum from the two-hour sample. Of the first pair, only the normal rabbit developed fever (*shown on thermometer*). Both rabbits of the second pair developed fever. Temperature curves of the rabbits would be similar to those on page 65. Evidently a vaccine pyrogen produced fever in the first case, but pyrogen released by the rabbit's own cells in response to the vaccine produced fever in the second case.



INJECTION OF WHITE-CELL PYROGEN into a rabbit's carotid artery (*left*) produces a greater reaction than injection into the ear vein (*right*). This experiment was designed to show that the white-cell pyrogen acts on brain centers. Material injected into the carotid goes directly to the brain, but material injected into the ear vein thins out during its circuitous passage to the brain. Bacterial pyrogen is equally effective by either route of injection, indicating that it does not act primarily on the brain.

two important questions remain unanswered. First, in some infections, notably tuberculosis, the inflammatory exudate is made up almost entirely of monocytes, and so far no pyrogen has been found in this type of white cell. What, then, is responsible for the fever that accompanies tuberculosis? Another aspect of this question arises from Atkin's recent discovery that injection of the influenza virus causes the release of pyrogen into the blood, although this infection seems to act upon the lymph-cell system rather than upon polymorphonuclear cells. Here again all efforts to extract a pyrogen from lymph cells have been without avail. We can only guess at a possible explanation: perhaps in these cases polymorphonuclear white cells are present in sufficient amount to produce the necessary pyrogen, or possibly monocytes and lymph cells do contain pyrogen which our relatively crude methods of assay are as yet unable to detect.

The second troublesome point is that, while the fever-producing substance is readily obtainable at a site of inflammation, no one has yet succeeded in finding it in the bloodstream. Bennett has been able to detect the pyrogen in lymph draining from infected abdominal cavities of rabbits, but not in the blood. It may be that the amount in the blood is so small that it is very difficult to detect. This possibility is now being carefully examined.

Although the evidence is still not complete, it appears likely that the "cell injury" theory of fever will soon be substantiated. Indeed, the day may be close at hand when physicians will understand for the first time why sickness is accompanied by fever.

Kodak reports to laboratories on:

filling other people's tank cars . . . duodecupling the speed of dental x-ray film . . . how photocopying frays red tape

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By such graphics as above, we have for some years preached to the chemical industry that folly lies in attempting larger-than-laboratory-scale organic syntheses that we can be persuaded to perform instead.

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Though there has been no limit on scope, there has been one on volume, but we have not dwelt on it.* Now our purpose is to announce that for the following broad classes of synthetic chemical operations the volume limit is, for practical purposes, off:

Acetylation, the business of wielding acetic acid, acetic anhydride, or the gas ketene to attach CH_3CO groups to alcohols, phenols, or amines. We have been participant in and supplier to the acetylation trade for 30 bountiful years—cellulose acetylated for film base, plastics, and fibers; vitamins A and E acetylated to protect them from oxidation; harshly acidic but merciful salicylic acid acetylated to get it to the gut past the mouth and stomach as the gentle aspirin; and basicity equally well obliterated as amines are acetylated to amides or anilides.

Aldol-type condensations, wherein a simple aldehyde or ketone molecule lassoes one of its fellows, using one of its hydrogen atoms as a lariat, and as the enclasped twain form themselves into something like acetaldol, butyraldol, diacetone alcohol, 2,2-bis(hydroxymethyl) butyraldehyde, or hydroxypivalaldehyde, the molecular subassemblies start building into merchandise of higher value.

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All things else being equal, the new *Kodak Periapical Ultra-Speed Dental X-ray Film* requires one twelfth the x-ray exposure that dental x-ray film used to need.

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This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

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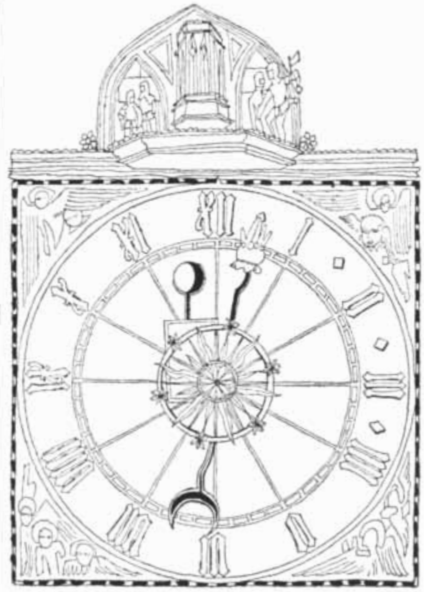
SCIENCE AND



Big Bang from Outer Space

A cosmic-ray particle with the "almost incredible" energy of seven billion billion electron volts was detected last month by Bruno Rossi and a group of co-workers at the Massachusetts Institute of Technology. This is almost a billion times more energy than has been produced in the largest man-made accelerating machines.

The M.I.T. physicists caught an immense shower of electrons from a cascade of atomic collisions set off by the collision of the primary cosmic particle with an atom high in the atmosphere. They were able to detect the event because they had 11 large scintillation counters set out on a 50-acre field. The count indicated that 1.4 billion electrons had rained down in this single shower. Whether the primary particle was a proton or a heavier nucleus is not known.

Rossi said the energy of the particle suggests that either cosmic rays come from outside our galaxy or the galaxy is bigger than has been supposed. If cosmic particles acquire their high energies through acceleration by magnetic fields in space, as the current theory about them maintains, no particle could be accelerated to the energy just observed within the space of the Milky Way. Therefore if the particle originated within our system, the galaxy must be thicker than the flat disk suggested by the extent of the observed Milky Way; it might even be spherical. Alternatively, the particle might have come into our galaxy from some other system.

Rossi's group estimates that 10 such energetic particles strike somewhere on the earth every second, which would mean that one should hit the 50-acre station every eight years or so. The figure is an extrapolation of measurements at low energies. British cosmic-ray workers also have recently detected a couple of particles in the billion-billion-electron-volt range. M.I.T. is planning a 5,000-acre station to increase the rate of detecting rare cosmic-ray events.

Flying Blind

"Inertial guidance," a self-contained navigating system which requires no signal from the outside world except the pull of gravity, was described last month by engineers at the Massachusetts Institute of Technology. Under development since 1939, the system has already successfully guided a B-29 across the U. S., the announcement said. On this flight, which took place four years ago, the bomber's controls were untouched by human hands from the Boston take-off to a point 10 miles from the Los Angeles airport.

Essentially the inertial navigator finds its position at each point in a journey by comparing the direction of a plumb bob there with the direction at the starting point. The angle between the two tells the distance from the starting point: *e.g.*, an angle of 90 degrees between two plumb lines means that they are separated by one quarter of the earth's circumference.

In order to make the comparison the device must be able to do two things: locate the plumb lines with respect to a fixed reference system, and determine the true downward direction at every point regardless of the motion of the vehicle. The first task is accomplished by means of gyroscopes. These devices tend to spin in a fixed plane, and thus three of them spinning on mutually perpendicular axes establish a system of coordinate axes fixed in space. The verticals are then located with respect to these coordinates. Determining the true vertical in a moving vehicle is difficult because the plumb bob is affected by forces due to acceleration as well as to gravity. For example, a pendulum suspended from the ceiling of an accelerating train will not hang straight down. The guidance system contains three "accelerometers" which sense the vehicle's acceleration in the forward-backward, right-left and up-down directions. This information is fed to a computer which corrects for accelerations and establishes the true direction of the pull of gravity.

A further correction is needed for the rotation of the earth. Since the gyros maintain a fixed direction in space and do not follow the spinning earth, the vertical direction continually changes with respect to their axes even at a fixed point on the earth. Thus the total change in the vertical between any two points in a trip is made up of a change due to the earth's motion and one due to the motion of the vehicle over the earth. The first change proceeds at a constant rate and is compensated by turning the entire reference system with an accurate clock drive.

Because it receives no signals from outside, the inertial guidance system is immune to radio jamming or vagaries of weather or magnetic conditions. It sends out no signals and hence cannot be detected. The system can be used in planes, missiles and ships.

Charles S. Draper and Walter Wrigley have directed the inertial guidance program at M.I.T. A number of private corporations are active in the research and development.

More Science Graduates

For the first time in six years the U. S. production curve for technical manpower has turned upward. In 1956 there was a 15 per cent increase of bachelor degrees in science and 17 per cent in engineering over 1955, according to figures recently released by the Office of Education. There was little change, however, in the number of advanced degrees. A total of 41,849 students earned baccalaureates in science in 1956, and 26,312 in engineering.

Biology, a field in which the number of graduates had been slowly but steadily declining, showed the biggest jump—from 9,050 to 12,566, or an increase of 39 per cent. Graduates in the physical sciences increased 15 per cent, from 10,516 to 11,672.

German Renunciation

A group of leading West German physicists recently announced that they will not cooperate in any way in the production, testing or use of nuclear weapons. "We believe that a small country like the [West German] Federal Republic can best protect itself and help world peace if it expressly and voluntarily renounces possession of atomic weapons of any kind," they declared. The statement was signed by 18 scientists, including several who worked on atomic energy research in Germany during World War II.

Among the signers were Max Born, Werner Heisenberg, Otto Hahn and Max von Laue, all Nobel laureates.

New Champion

The U.S.S.R. has announced that its new proton synchrotron ("synchrophasotron") has gone into operation and achieved an energy of 10 billion electron volts. It outstrips the University of California Bevatron, of which it is a scaled-up version, by 3.7 Bev. The Soviet machine is expected to lose its lead in about three years, when the 25-Bev machines now building at the Brookhaven National Laboratory and the European Council for Nuclear Research in Geneva are completed.

Pole-to-Pole Hookup

To synchronize the activities of observers all over the earth during the International Geophysical Year, a worldwide communications network has been set up with its center at Fort Belvoir, Va. Embracing commercial, military and meteorological communications facilities of 40 nations, the system has proved capable of reaching the remotest outpost in less than eight hours. It is by far the largest network ever put together.

During the period of the IGY, which begins July 1, regular observations will be made on the sun and ionosphere from many points on the globe. The readings will be relayed to Belvoir via regional stations in Amsterdam, Moscow, Tokyo, Sydney and Anchorage. When the reports indicate unusual activity, an alert will be sent out to all registered observers, to obtain simultaneous measurements on cosmic rays, auroras, terrestrial magnetism, radio reception and so on.

Roger C. Moore of the National Bureau of Standards heads the agency that will issue alerts.

Superconductivity Theory

A new theory which appears to go farther than any previous one to explain the mystery of superconductivity has been proposed by John Bardeen (a

SILICONE NEWS

DOW CORNING

New Silicones Solve Old Problems

- New fluorosilicone rubber resists jet fuels, solvents, heat and cold
- Silicone-glass laminates superior to light metal for high temperature use
- Invisible silicone surface for glass containers speeds bottling, packing

FLUOROSILICONE RUBBER — is a new kind of heat and cold resistant rubber developed by Dow Corning research chemists in conjunction with the Materials Laboratory of Wright Air Development Center. Identified as Silastic LS-53*, it stays rubbery at temperatures from —80 to 400 F . . . but most remarkable feature is its outstanding resistance to the fuels, oils and solvents that limit the use of ordinary rubbers.

As illustrated, O-rings made of Silastic LS-53 swell only 20% when immersed in an aromatic jet engine fuel while those made of the best general purpose silicone rubbers swell over 200%. Presently limited to use in essential Air Force applications, new fluorosilicone rubber should help solve many problems for commercial aircraft, chemical, petroleum and automotive industries . . . wherever rubber parts are exposed to oils, solvents and extreme temperatures.

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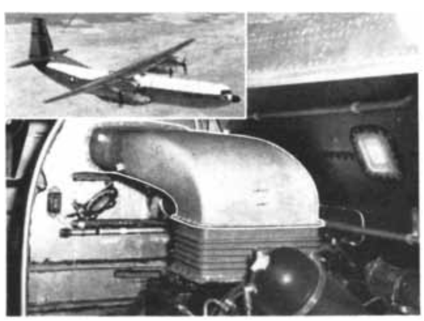
"WHAT'S A SILICONE?" — is answered in a documentary movie available free of charge for showings to industrial management, production and engineering audiences. In full color and sound, this informative 16 mm film shows silicones in action . . . helping designers, improving products, solving production and maintenance problems. No. 41

WHERE THE SPOT'S HOT — a growing number of designers and materials engineers are specifying silicone-glass laminates in place of metal parts. Here's why: laminates made with glass cloth and Dow Corning silicone resins retain a higher strength-to-weight ratio at "hot" temperatures than many light metals; another reason—large and complicated pieces are easier to shape—simple plaster forms replace dies required to fabricate metal parts.

Typical application: Ducts used in the heating and air conditioning system of the C-133, a giant military turboprop transport now in production at Douglas' Long Beach Division. Tests prove the silicone-glass laminate ducts withstand jarring punishment, like engine backfiring, that might split stainless steel ducts. Many other promising commercial applications now in development. No. 42



NO MORE JAM-UPS — A durable, invisible "silicone surface" for glass bottles and jars permits food packers and volume bottlers like Pepsi-Cola to get greater output from filling equipment. Treated bottles have better "slip", so there is less wedging and jamming on filling lines. The Dow Corning silicone surface also provides greater resistance to bruising and scratching . . . thus, line breakage is sharply reduced; appearance and life of all types of glass containers is improved. Applied to exterior of new containers by glass manufacturers, the silicone surface is available at little or no extra cost. No. 43

TREAT FOR FEET— Shoe Saver, silicone water repellent for do-it-yourself application to all kinds of shoes and boots . . . leather, canvas, suede. . . is proving to be a popular repeat item at shoe counters, repair shops, sporting goods stores. Just swab it on—Shoe Saver keeps feet dry . . . keeps leather soft so shoes stay comfortable . . . protects against water and waterborne stains, keeps shoes new looking longer. Retails at $1.00 a bottle—enough for 2 to 4 pair of shoes.

ALL NEW — 1957 Guide to Dow Corning Silicones has just been released. Completely indexed, this illustrated 12-page reference contains up-to-date information on properties and applications for silicones of most commercial interest. No. 44

FOR MORE INFORMATION on silicones used in these applications, circle reference nos. in coupon.

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CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST. GOBAIN, PARIS co-winner of the 1956 Nobel prize in physics for his work on the transistor), L. N. Cooper and J. R. Schrieffer, all of the University of Illinois. They set forth their theory in a brief letter in *The Physical Review*.

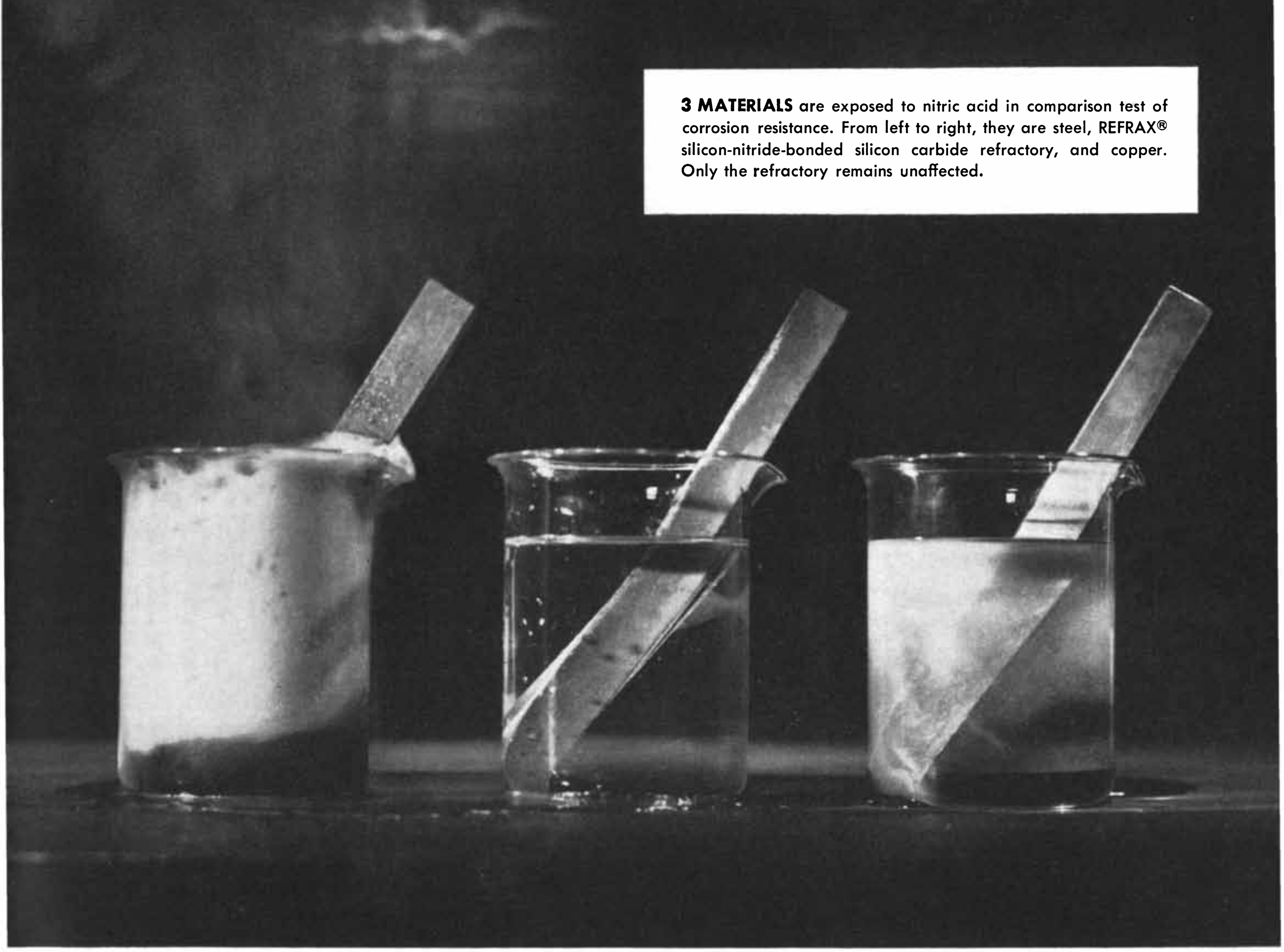
The key to superconductivity, they believe, lies in an attractive force, resulting from the minor vibrations of electrons in a very cold crystal, which unites the outer electrons of atoms in a coherent group. If one electron in the group moves, the others follow in the same direction. Thus they do not get in one another's way. Moreover, these electrons act as if other particles were not present.

Other physicists had recognized that superconductivity must depend on some such coherent behavior of the electrons, but no one could explain how the coherence came about. The new theory seems to do this and more. Starting from fundamental principles of quantum mechanics, it produces an equation describing the coherent electron state and correctly predicts the critical temperatures at which superconductivity disappears in various materials. It also explains the previously mysterious fact that magnetic fields cannot exist in superconductors. It gives a rule for deciding whether or not a given element or compound can become superconducting.

Lipid Survey

Most heart disease is caused by atherosclerosis, a pathological condition of the artery walls in which they swell up with deposits of yellow fat. Probably all middle-aged adults have atherosclerosis in some degree. Many physicians believe that the condition can be detected by high levels of cholesterol or other fatty substances in the blood; John W. Gofman and his colleagues at the Donner Laboratory of the University of California have argued that certain low-density lipoproteins, in which cholesterol is contained, are correlated with coronary disease.

To test the Donner hypothesis, the National Advisory Heart Council six years ago asked for a massive statistical investigation by the Donner Laboratory in collaboration with the Cleveland Clinic Foundation, the nutrition department of the Harvard School of Public Health and the biophysics department of the University of Pittsburgh. It took the four laboratories about two years to agree on the standards for the tests. Then they selected about 5,000 healthy male subjects over 40, established their lipoprotein levels and followed up their medical history. Of the 5,000 subjects,



3 MATERIALS are exposed to nitric acid in comparison test of corrosion resistance. From left to right, they are steel, REFRAX® silicon-nitride-bonded silicon carbide refractory, and copper. Only the refractory remains unaffected.

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82 developed coronary disease during the two-year follow-up period.

In the end the Donner Laboratory and the other three groups failed to agree on the significance of the lipoprotein levels. The other three, in a separate report published in the journal *Circulation*, said that one of the two suspect classes of lipoproteins did tend to be high in the group of 82 victims as a whole but they added that cholesterol levels in the group were higher. They denied that either test was accurate enough to predict future coronary disease in individual cases: 38 per cent of the 82 who had heart disease had shown below-average lipoprotein levels, and a third of the victims had been below average in cholesterol level.

The Donner group, in its minority report, evaluated the statistics by its own method and declared that this was more accurate and showed results which supported its theory.

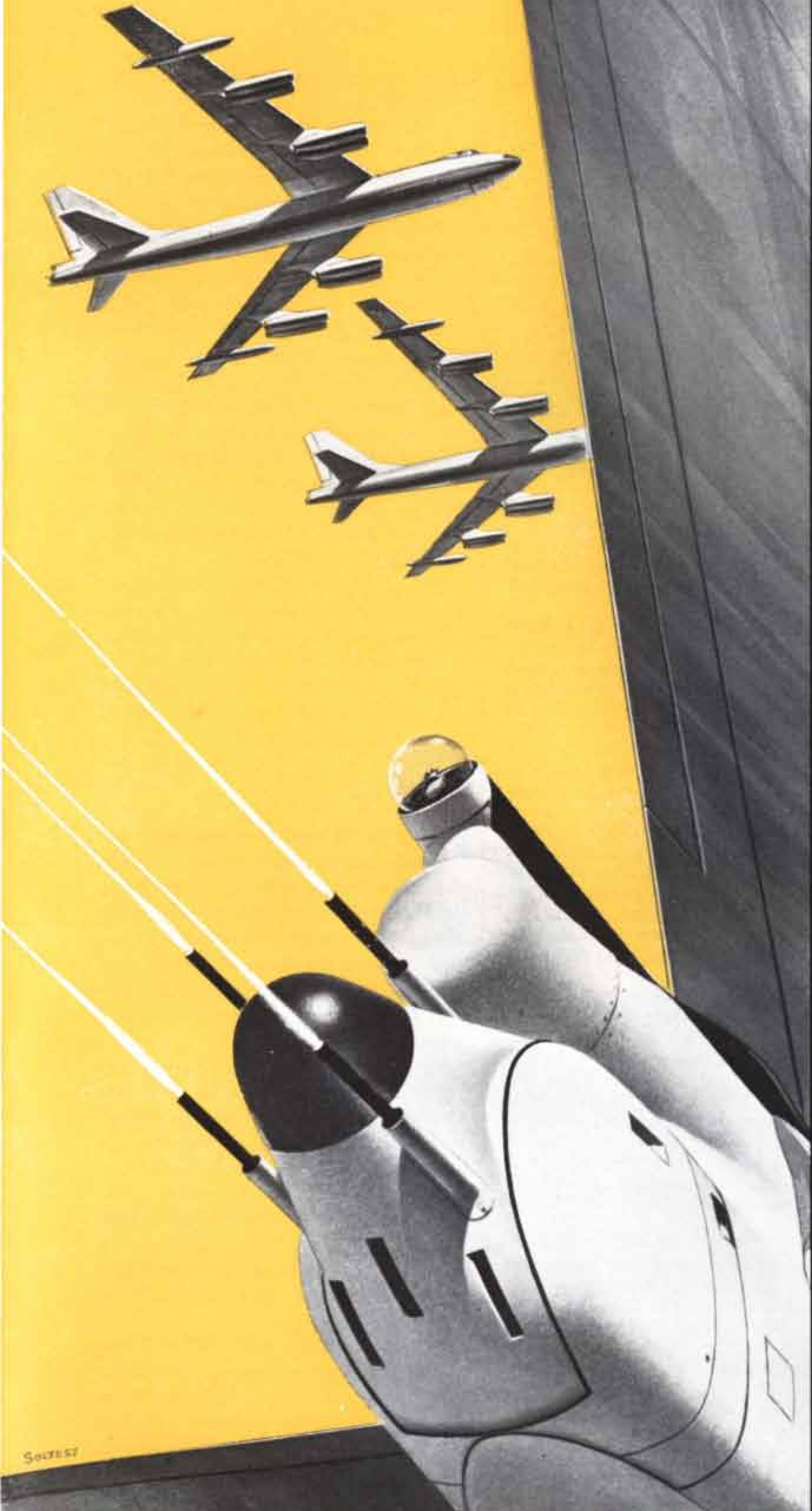
Vital Free Radicals

Photosynthesis depends on the action of free radicals, according to a team of scientists at Washington University in St. Louis directed by the botanist Barry Commoner and the physicists Richard E. Norberg and Jonathan Townsend.

They used a radio-frequency spectrometer to detect the presence of free radicals by the magnetic effect of their unpaired spinning electrons. When they mixed an enzyme with its substrates in a glass tube, free radicals appeared within a few minutes and then disappeared as the reaction came to completion. Green chloroplasts from plant leaves, when exposed to strong light, also released free radicals, which quickly disappeared when the light was turned off. The group finally examined living cells of the microscopic plant *Chlorella*. The spectroscope showed that they contain a free radical apparently identical with a complex radical (made up of chlorophyll and protein) in spinach chloroplasts. This finding is said to be the first proof that free radicals are formed in the activity of a living cell.

Speak Up!

The telephone could do a lot more work if it were not limited by the human speaker, says an article in *The Bell System Technical Journal*. The authors, J. R. Pierce and J. E. Karlin, found that persons reading from lists, even of very short, familiar words, could convey no more than 40 to 50 "bits" of information per second. A telephone easily has



ROCKET POWER PROGRESS REPORT

Servicing Rocket Engines

Part I: Know-How

by Fred Barker

Supervisor of the Product Service Department at Reaction Motors, Inc., Mr. Barker coordinates the activities which keep rocket engines on their good behavior. A graduate of New York University, with a B.S. in M.E., he has had diverse experience in engineering—including test, manufacturing liaison and customer service liaison. Mr. Barker joined RMI in 1949.

"Know-how" in any business is the result of thorough training and experience on specific products. RMI Product Service Department personnel get a complete grounding on their products right from the development stages through field installation and operation. The know-how thus attained is turned into a direct benefit for all RMI customers.

Key service engineers and service representatives join a project during early development, work actively with Engineering, Component Development, Assembly, Test and Inspection Departments. Mock-ups are reviewed from the standpoint of service—i.e., whether proper consideration has been given installation, accessibility and serviceability of components and the overall powerplants.

When a project is ready to move into the field, these same key men act as instructors, conducting training programs to impart their accumulated knowledge to customer personnel and other service representatives. With our ROR powerplant (rocket-on-rotor for helicopters), for instance, Sikorsky, Navy and Marine Corps personnel attended training programs at RMI and in the field. Scope of these programs covered the rocket powerplant, its installation and operation in the Sikorsky HRS helicopter, and the use, transfer and storage of the hydrogen peroxide propellant. Once ROR settled into operations at the Marine Corps Air Station, Quantico, Virginia, the service representative's know-how assumed a stand-by character. Training programs were repeated or amplified only as required by personnel changes or powerplant modifications.

Safety is a major item in each RMI representative's assignment, because safe use of the powerplant and safe handling of propellants are of paramount importance. Safety is improved by service representatives through on-the-spot lectures and training programs, whereby procedures and policies are outlined and integrated into the activities routine. Again, at Quantico, an admirable safety record has been achieved and maintained in just this fashion. There, over the past few years, our service representative has assisted the Marines in safely utilizing the ROR powerplant and the hydrogen peroxide fuel for their HRS helicopters. The result is found in the simplicity of powerplant operations, peroxide handling and storage area procedures, and in the attainment of a "no personnel injured" safety record.

Obviously, know-how is of importance in a clutch situation. Wisely applied, it leads to the right decision and the proper corrective action on the scene of a problem. The recently launched Glenn L. Martin No. 13 Viking missile provides a case in point. Pre-static firing inspection revealed discrepancies in some components of our 20,000-pound thrust rocket engine. Normal field maintenance sufficed for all but one difficulty: a valve seat and poppet, scored by foreign material, required lapping to meet leakage specifications—but no lapping compound was on hand. Our service representative used common household cleanser, lapped the poppet and seat to within leakage specifications, and the program moved on with only minor delay. This difficulty remained minor only because prompt and proper handling prevented development of a major program obstacle. Immediate action was required; immediate action was taken.

In Part II, we shall examine the function of the service engineer and service representative in various areas of Product Improvement.

5240

If you desire one or more reprints of Mr. Barker's article, or would like to receive further information about employment at RMI, write to our Information Services Coordinator, Reaction Motors, Inc., 90 Ford Road, Denville, N. J.

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The Bell investigators wanted to know just how fast people could speak and what factors limited their speed. Since tests had shown that a speaker can transmit information most rapidly by reading a written message aloud, the experimenters prepared lists of words for reading. Employees at the Bell Telephone Laboratories were then timed in reading these lists, as well as simple prose passages and "scrambled" prose. Reading speeds were found to depend mainly on the time required for the person to recognize the word to be read. Words of one syllable were recognized more quickly than longer ones. But a two-syllable word could be read much more rapidly than two one-syllable words.

An interesting sidelight of the tests was the discovery that engineers at the Laboratories could read faster than their secretaries, who in turn read faster than waitresses and porters. Pierce and Karlin suggest that reading speed may be correlated with vocabulary size.

The "Break-off"

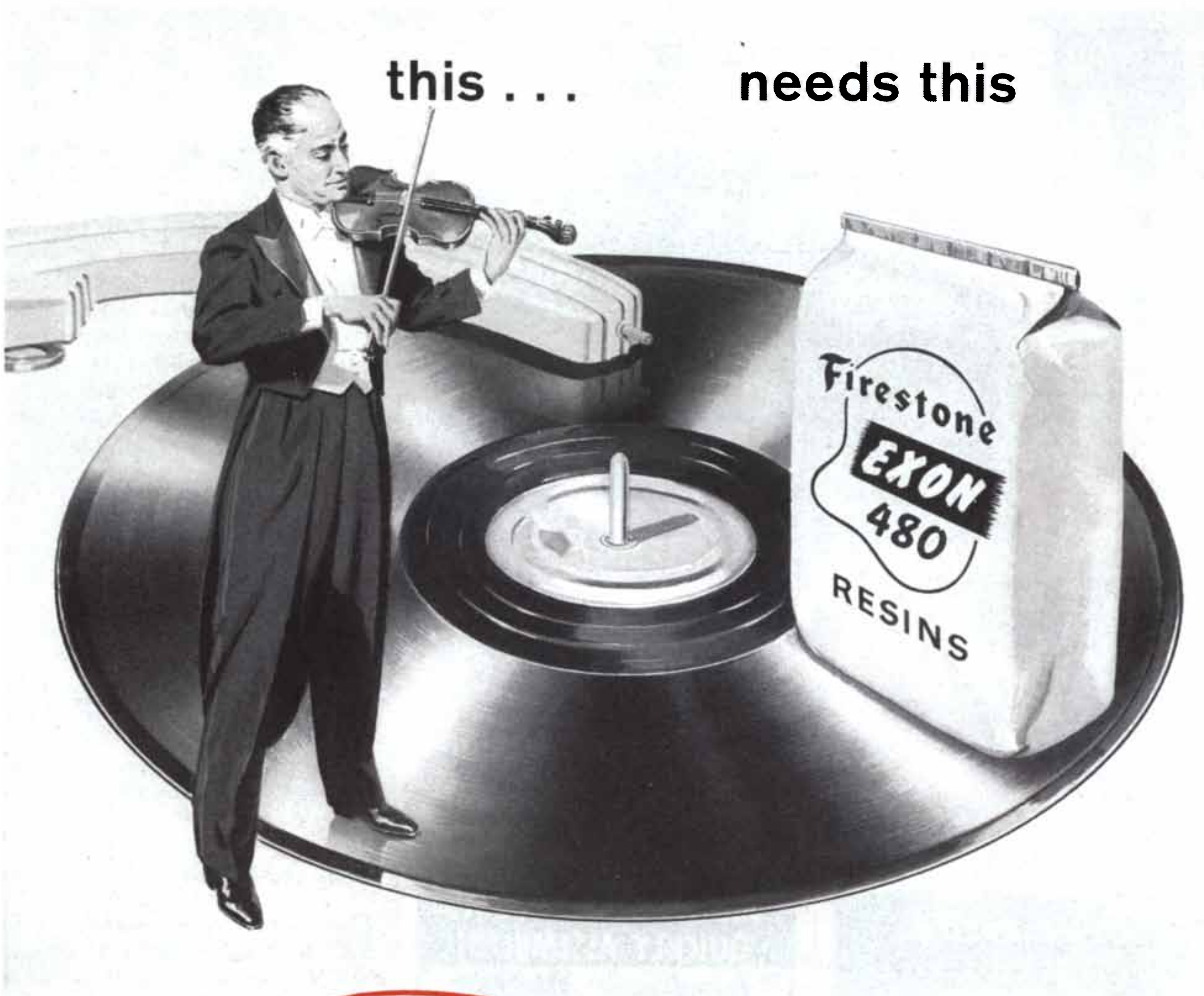
Psychologists have discovered a strange psychological phenomenon of flight at very high altitudes. Jet pilots flying alone sometimes feel that they are in another world, completely detached from earth. Among 137 Navy and Marine jet pilots interviewed the feeling is so common that they have given it a name—"break-off."

Some of the pilots are exhilarated during the experience, saying they feel "like a giant" or feel nearer to God. Others become anxious, and sometimes fear to move in their seats.

The pilots are reticent about the sensation partly because they think it may sound "corny" or "silly." One of the younger pilots expressed relief when he learned that others had had the same experience.

Of the 48 men who had felt the break-off, some of them had been through it many times. The experience was most frequent among men who flew the fastest planes. The sensation usually came when a flier was alone at altitudes above 30,000 feet with relatively little to do. The effect disappeared when the pilot returned to a lower altitude, joined up with another plane or turned his attention to a problem associated with flight. In general the pilots did not think it affected their ability to operate the plane, and a few thought it actually helped them.

The investigators who made the study



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for the Navy reported their findings in *The Journal of Aviation Medicine.*

Bone-Age Man?

The Australopithecine ape-man of South Africa has just moved up a notch on the I.Q. scale. Raymond A. Dart, of the University of the Witwatersrand, had suspected for some time that the ape-men made tools: he had found, among other things, that the double knot on a thigh bone matched double dents in the skulls of Australopithecines. On a routine visit to the British Museum in London, Dart confirmed his suspicion. In a display case he found the thigh bone of a large South African antelope broken off at mid-shaft. Wedged into the hollow of the shaft was the core of a gazelle's horn, providing the broken bone with a handle. The horn was fitted too perfectly to be anything but a deliberately made tool.

Dart believes that if Australopithecines could make such a club they could make many two-part tools. In a recent issue of *Nature* he conjectured that sooner or later someone will find in South Africa a stick capped with a hollow horn-tip—the first Australopithecine spear.

Clams and Cobalt

Two "killer" clams analyzed at the U. S. Naval Radiological Defense Laboratory showed an astonishing talent for concentrating cobalt. The clams had been taken from one of the Marshall Islands in a nuclear-weapons test area as samples for tests of residual radioactivity. They proved to have substantial amounts of radioactive cobalt 60, although the bomb could not have produced more than a trace amount in the area (cobalt 60 is not a product of nuclear fission). Apparently the clams had accumulated their Co-60 from the water during the two years since the test.

The Navy scientists emphasized the enormous concentrating capacity the clam must have to accumulate cobalt 60 "from an environment which to all intents and purposes was infinitely dilute." One clam contained one third of a microcurie of the isotope; the other had one tenth of a microcurie. The danger level for man is considered to be about three microcuries of cobalt 60.

The Navy scientists wondered whether this talent was an exclusive property of killer clams. They tried putting clams from San Francisco Bay into water containing a little cobalt and found that these clams also collect the element.


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TOMATO PLANTS were grown in the phytotron (the Earhart Plant Research Laboratory of the California Institute of Technology). During the day both plants grew at 86 degrees Fahrenheit, a temperature at which tomato plants grow well. During the night the plant at left was subjected to a temperature too high for fruit set. The plant at right was grown at the proper night temperature.

CLIMATE AND AGRICULTURE

Man traditionally seeks to extend the range of a cultivated plant by trial and error. This range is now forecast in the "phytotron," a laboratory which reproduces the various environments of plants

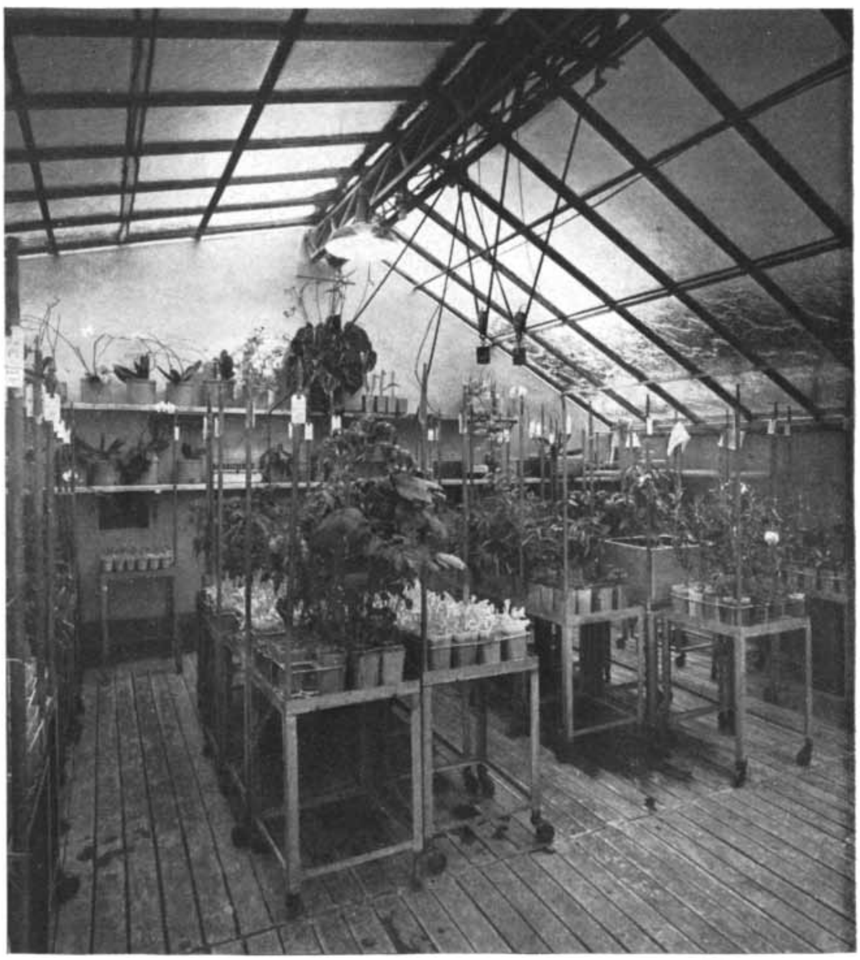
by Frits W. Went

In our elaborately industrialized country we tend to lose sight of the fact that modern man's life still depends fundamentally on agriculture. And it is difficult to appreciate how insecure this foundation is, from the standpoint of feeding a growing population. Only by prodigies of toil and invention has civilized man been able to wrest enough food from the soil to keep pace with his increasing needs. The invention of systematic agriculture was itself a remarkable technical achievement: to make it possible the original farmers had to develop crop plants (wheat, rice and so forth) and techniques of plowing, sowing, irrigation, weeding and fighting pests and diseases. Nowadays farming is a highly sophisticated technology. By mass production methods each farm worker now can produce enough food for 17 persons; research has brought most of the important crop diseases and pests under effective control; scientific soil management makes it possible to get high yields from the same soil year after year; transportation facilities mitigate local crop failures by distributing food quickly over whole continents; modern preserving methods make fresh food available all year round.

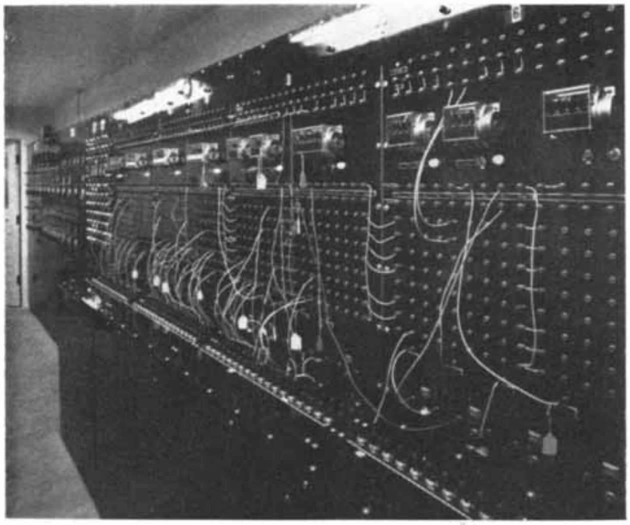
The one great factor that man has not yet learned to control is climate. Droughts, floods, freezes, tornadoes, hailstorms still make farming an uncertain enterprise, even in the U. S. And more subtle climatic aberrations may work even more havoc upon our crops.

The latter point is brought into sharp focus by a look at the annual figures for production of tomatoes in the U. S. The yield of tomatoes per acre in many states fluctuates enormously from one year to another. It is less variable in California than in states with more changeable climates. There cannot be much doubt that differences in weather from year to year are mainly responsible for these variations in yield. A number of other crops, such as beans, peas and various fruits, also suffer from climatic vicissitudes. What are these damaging climatic influences, so unobtrusive that it is difficult to detect them, let alone measure their effects? Plainly they must have to do with factors such as the amount of sunlight, temperature and humidity.

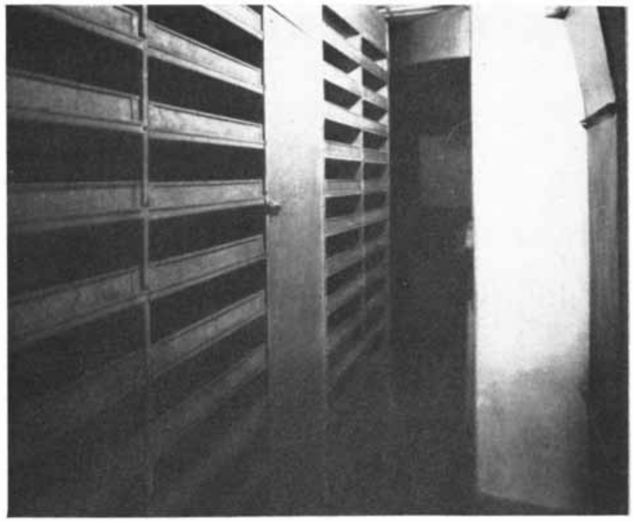
For nearly a decade we have been carrying on an investigation of the effects of climatic factors on plant produc-



GREENHOUSE in the Earhart Laboratory is one of 54 separate rooms in it where plants grow. Outside the laboratory it is night; here daylight is artificially lengthened for the purposes of an experiment. The roof of the greenhouse is cooled by a steady flow of water.



CONTROL ROOM of the Earhart Laboratory centralizes the regulation of light, temperature and humidity in all of its rooms.



TRAYS OF CHARCOAL remove contaminants from air taken into the laboratory. Air in greenhouses is replaced twice a minute.

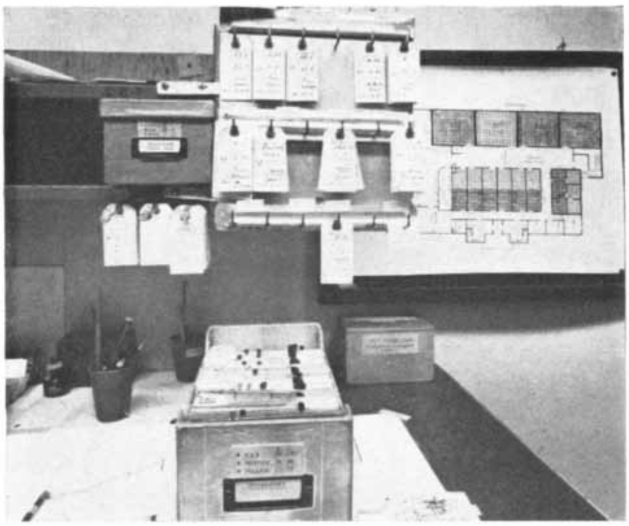
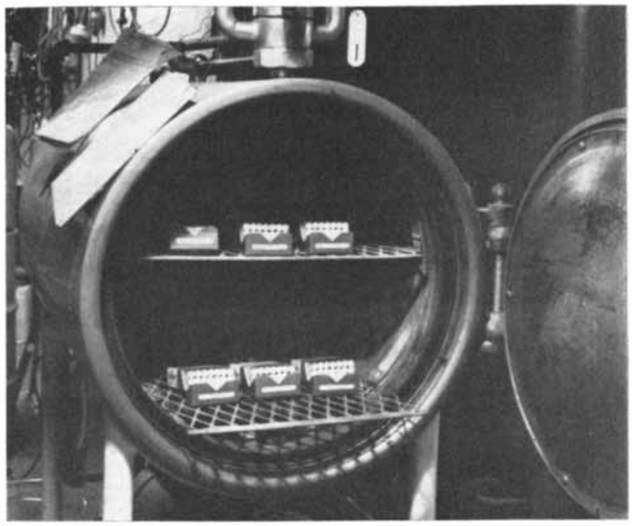
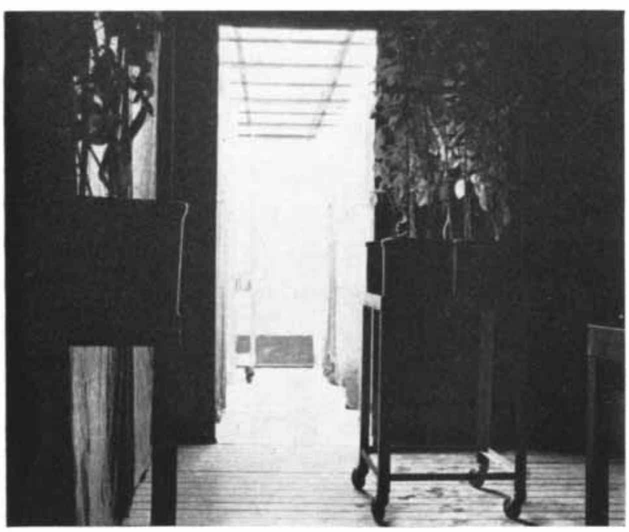


CHART at right has a space for each wheeled table in the entire laboratory. Tags to the left of the chart are reservations for tables.



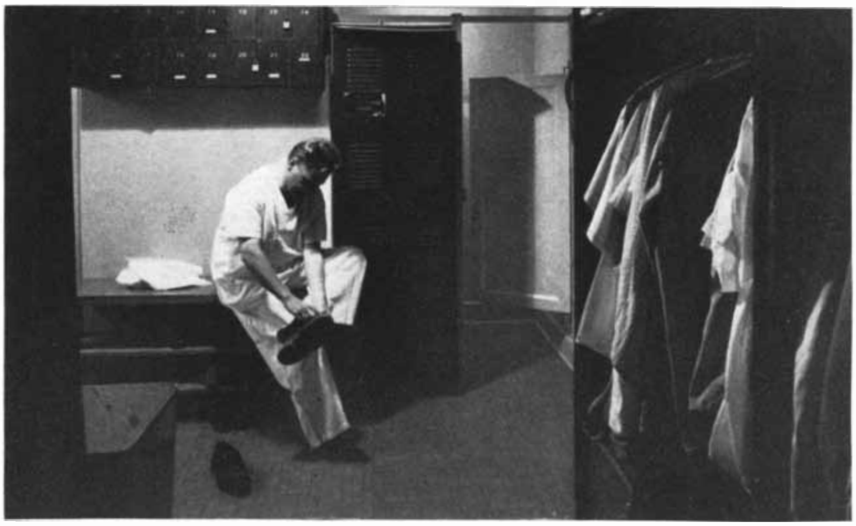
CIGARETTES smoked by workers in the laboratory are sterilized in autoclave to inactivate plant disease organisms in the tobacco.



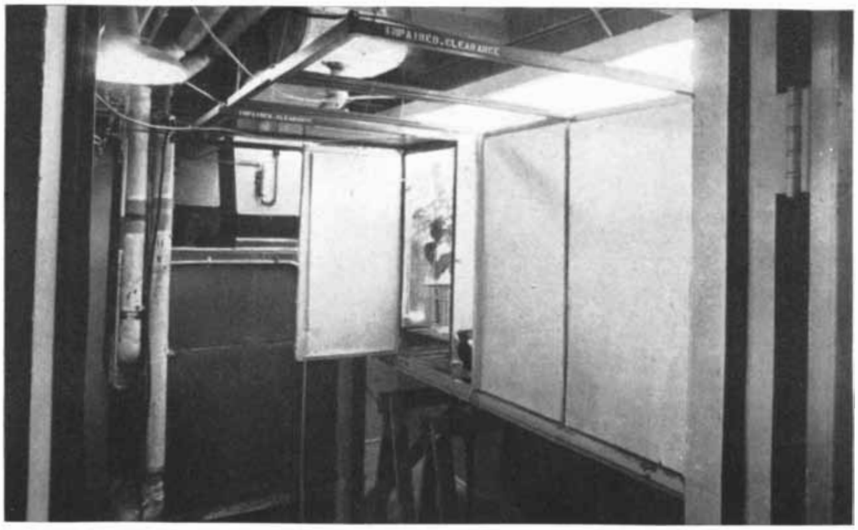
NIGHT ROOM is one of several used to provide a controlled dark period for greenhouse plants. Door was opened to make photograph.

WIND TUNNEL is used to grow plants under various wind conditions. Artificial daylight is provided by the fluorescent lamps at top.

COOLING WATER is sprayed on the roof of a greenhouse in the laboratory. Most of the solar heat which accumulates in the greenhouses is removed by the rapid circulation of air.



CHANGE ROOM is used by men who enter the laboratory to remove their street clothes (which may harbor insects or other disease organisms) and to don laboratory garments.



ARTIFICIALLY LIGHTED CABINETS are used to grow plants at the same temperature but under different light conditions. They may be darkened by electrically operated doors.

tion in our "phytotron" at the California Institute of Technology. It all began with a study of the growth of tomato plants under controlled conditions. The generosity of Miss L. Clark and the technical and scientific knowledge of H. O. Eversole had provided two fully air-conditioned greenhouses, and I decided to study first the response of plants to the relative humidity of the air. Since the temperature had to be high to produce a low enough humidity, I chose the tomato, a warmth-loving plant, as the subject of the experiments.

We kept both greenhouses at a constant temperature of 79 degrees Fahrenheit but set the relative humidity in one at 70 per cent and in the other at 40 per cent. The humidity apparently made no difference: the tomato plants grew at about the same rapid rate in both greenhouses. But we found that all the plants did rather poorly under the conditions we had established. They failed to develop a rich green color, were a little spindly and, worst of all, produced no fruits. From the several hundred plants we raised during the first year in these greenhouses we got only four ripe tomatoes!

Tomato-growing experts who saw the plants offered all sorts of explanations for the lack of fruit set, but none of their suggestions for changes in the culture of the plant helped. Finally we tried lowering the temperature of one of the greenhouses to 64 degrees F. The tomato plants in that greenhouse immediately started to set fruit, and it ripened normally. This seemed very strange, considering that tomatoes in the field grow and bear well at average temperatures much higher than the 79 degrees we had maintained in our greenhouses. We soon determined by experiments that the plants needed a daily cycle of temperature change, and that they did best if the night temperature (*i.e.*, during the dark period of the plant's growth) was near 64 degrees.

The Phytotron

It was plain that we needed much more detailed information to understand the effects of individual climatic factors on plants. The Earhart Foundation made a generous grant of $407,000 (to which it later added $74,000) for the construction and operation of a set of greenhouses in which all sorts of climatic factors can be controlled. This building, known as the Earhart Plant Research Laboratory, is popularly called the "phytotron" from *phyton* (the Greek word for plant) and *tron* (suggesting the contribution of physics to its remarkable equipment).

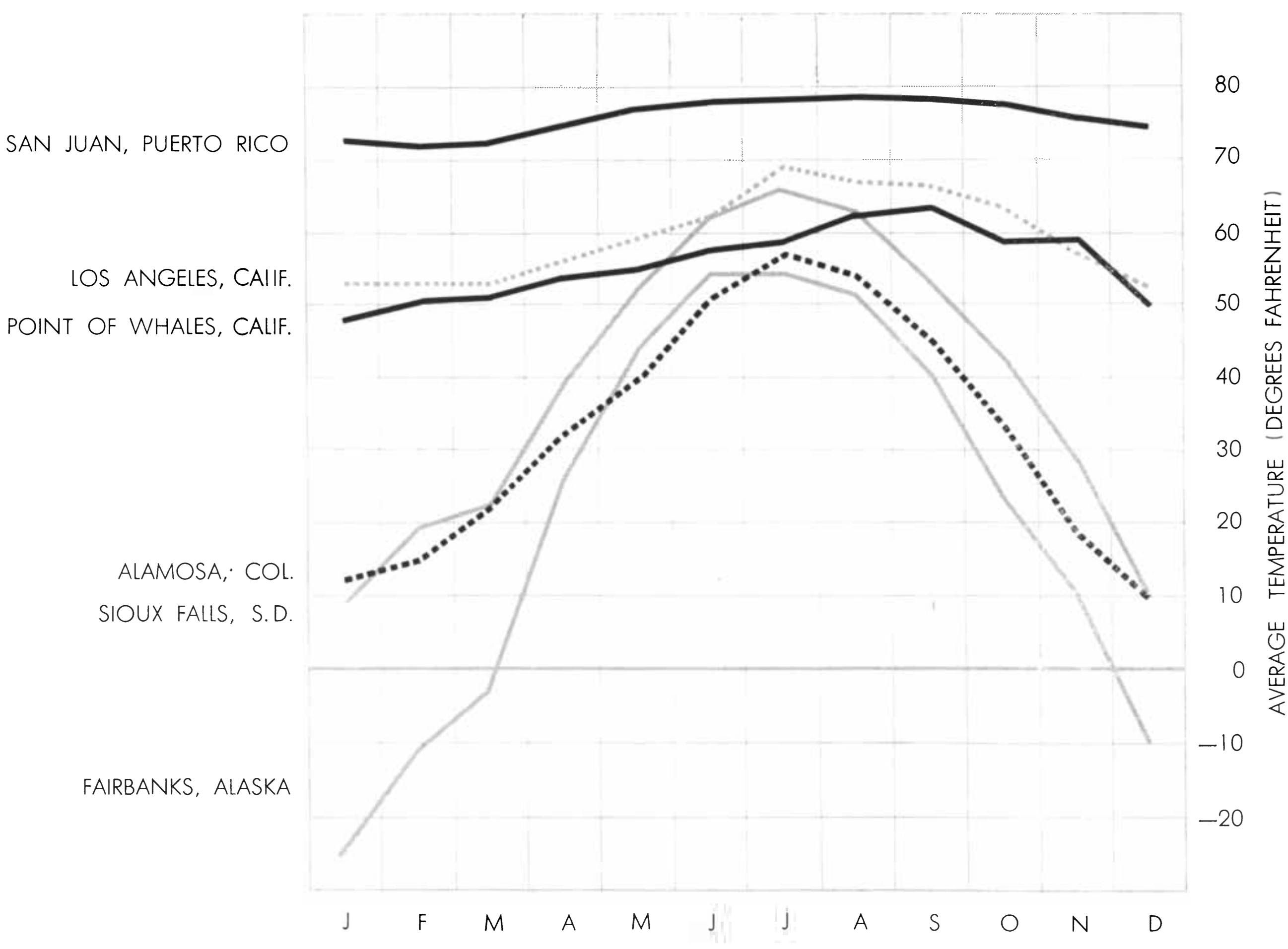
To give an idea of what the Earhart Laboratory is, let us make a quick tour through it. From the outside it looks like a big, pleasant house with large windows. But just inside the front door you are at once confronted with two doors, marked "Ladies" and "Gentlemen." Before you can enter the laboratory, you are required, like every visitor and worker there, to go to a dressing room to wash your hands, comb your hair and change your street clothes for freshly laundered laboratory garments, to make sure that you will bring no insects or diseases into the laboratory.

Inside the building you find yourself in a remarkable atmosphere, free of any trace of insects, dust or smog. When you pass through the door into a greenhouse, you are suddenly in a new world, filled with plants on which a shimmering light plays. The shimmer is the result of water spraying on the glass roof, the purpose of the water being to absorb most of the sun's infrared radiation, which is not used in plant growth. The air feels perfectly fresh and pleasant, not muggy as in conventional greenhouses. Conditioned air circulates constantly throughout the greenhouse, entering through slots in the floor and leaving by ventilators in the walls. The air is completely replaced twice each minute. It removes most of the solar heat; at noon the greenhouse absorbs so much heat from the sun that during the half minute the circulating air spends in the room its temperature is raised by seven degrees. The ventilating system keeps the air moving so evenly that there are no stagnant spots, and all the plants within a greenhouse are subjected to exactly the same temperature and humidity.

The warmest greenhouse in the group is kept at 86 degrees during the day, summer and winter, but it does not feel too warm and is pleasant to walk in. You are, in fact, surprised to learn the actual air temperature. As every skier knows, the temperature of the air is less important, so far as the feeling of cold or warmth on our skin is concerned, than radiation. Moreover, the relative humidity of the air has a large influence on our perception of heat: dry air feels much cooler than humid air at the same temperature. And thirdly, air in motion feels cooler than quiet air at the same temperature.

Factors of Climate

A complete tour of the Earhart Laboratory would take us to 54 separate rooms where plants grow: individual greenhouses, darkrooms, artificially lighted compartments. All the plants stand on wheeled tables, so that they can easily be moved to any one of 54 different environments. We can combine a high daytime temperature with a high or low night temperature, vary the length of illumination, subject plants to artificial rain, to wind or to special gases. The particular variables that we manipulate in the laboratory are day temperature, night temperature, light intensity, duration of daily illumination, light



VARIATION OF NIGHT TEMPERATURE for 24-hour periods over the year increases with latitude. Over several years the average night temperature in Fairbanks varied from —25 degrees F. to 54 degrees. In San Juan it varied only from 72 degrees to 79 degrees.

quality, relative humidity of the air, wind, rain and gas content of the air. All other variables are excluded as much as possible, so that we can concentrate on the ones we have chosen. We keep the nutrition and soil conditions uniform by growing all the plants in vermiculite or gravel or a mixture of the two and watering them with a standard nutrient solution, which is piped into all greenhouses and growing-rooms. We can, of course, change the feeding of plants for special studies.

We grow many different plants together in the same greenhouse. Commercial growers generally use separate greenhouses for their different crop plants, each adjusted to the best growing conditions for its inhabitants. But our purpose is to test given plants under a wide variety of conditions. We may have tomatoes, peas, potatoes, African violets and a number of varieties of orchids all in the same greenhouse, measuring their various responses to the same temperature. In another greenhouse you may see desert plants growing next to coffee, barley, spinach, carnations and dozens of other plants—each in an experiment with different objectives.

Having walked through the greenhouses, let us look into the artificially lighted rooms. There are 13 groups of these, each serviced by a separate air-conditioner. A group is divided into separate compartments by sliding doors, making it possible to keep plants in the different compartments at the same temperatures but under different light treatments. The plants are on tables of adjustable height, so that as they grow taller they can be kept at precisely the same distance from the light by lowering the table. Time clocks turn the lights on and off automatically. The plants can be wheeled into adjoining dark compartments on their trucks.

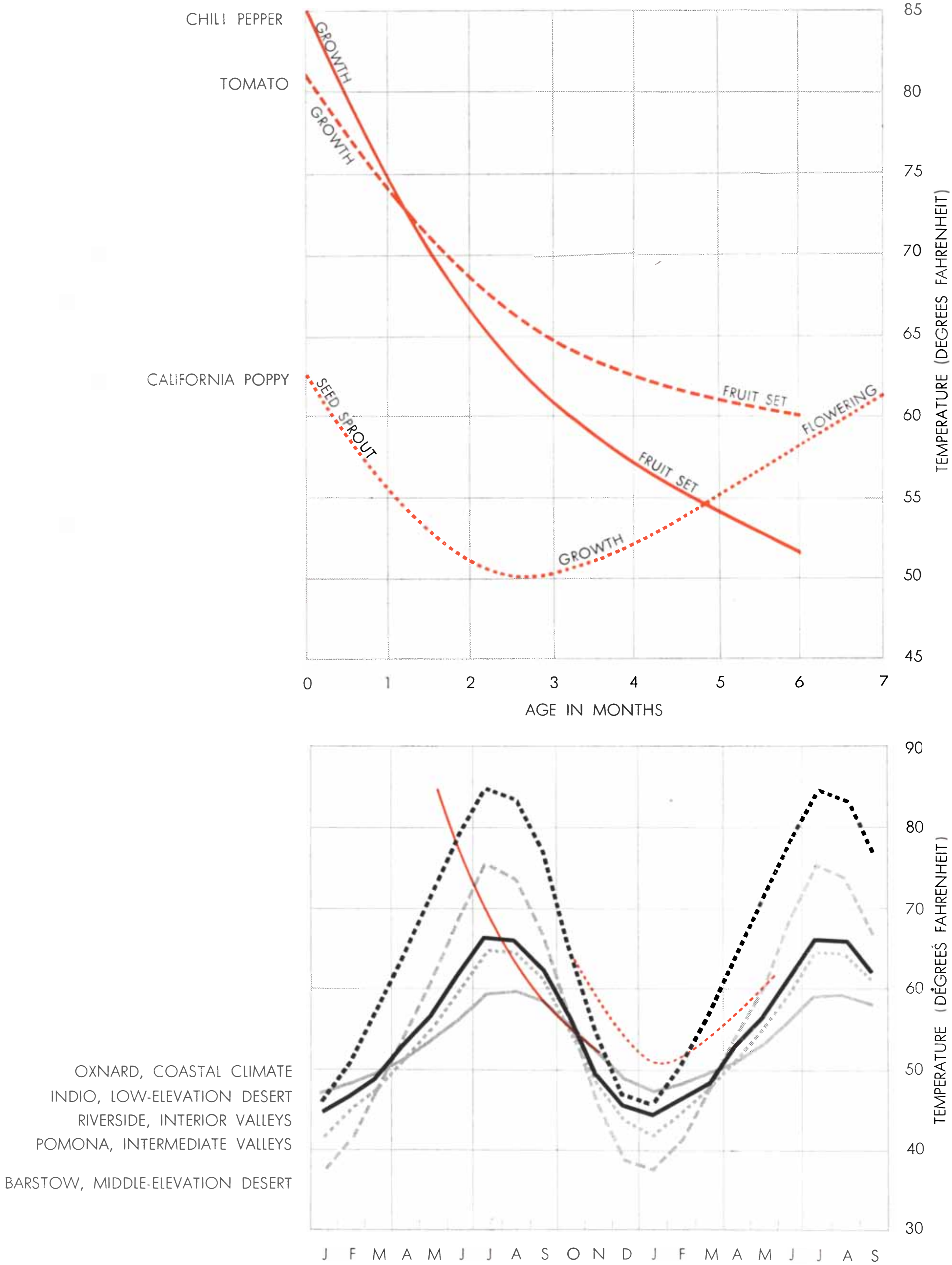
The temperature range in the artificially lighted rooms is from 38 to 86 degrees F.—a range which includes the temperature extremes at which tropical plants and alpine plants grow best. In the greenhouses we maintain day temperatures between 63 and 86 degrees and night temperatures between 53 and 73. The temperature is always lowered during the night, because most plants need this daily change to achieve their best growth.

When we come to the control and machinery areas, you will get a vivid idea of the complexity of the laboratory and the multiplicity of operations needed to keep it going. Located strategically in the center of the main floor is a control room with long panels covered with dials and recorders, showing exactly what the conditions are in every room. Here the superintendent of the building reigns over the controls, and here also the complicated administration to insure the best use of the growing space is carried out. In the basement we find labyrinths of air ducts and pipes for conveying hot and cold water, compressed air, nutrient solutions, deionized water, ordinary tap water and so on. There is a separate air conditioner for each of the rooms upstairs. Also in the basement are a general laboratory, shops, photographic rooms, etc.

One of the major problems that had to be solved to make the laboratory possible was filtering of the incoming air. Since much of the air conditioning is carried out through evaporative cooling, large volumes of air have to be taken into the building. All this air has to be filtered clean of dust, insects, disease spores and smog—no small matter in a city such as Pasadena where the air is contaminated with oxidation products of gasoline vapors which are toxic to plants. The capacity of our air-filtering system is approximately one ton of air per minute. Gradually all the difficulties involved in the filtering process were ironed out, and we now have completely clean air in the laboratory.

Plants and Temperature

Now that we have looked over the laboratory, let us review some of the things that have been learned about plants and climate by experiments during its seven and one half years of operation. We shall start with the daily alternation of warm and cool temperatures that plants need, as we found in our original experiments with tomatoes. From extensions of those experiments we now know that most varieties of tomato plants require almost the same night temperature to set fruit. This explains why tomato production is usually very low in the tropics: the night temperatures there are above the optimal fruit-setting range. On the other hand, in cool climates the night temperatures are likely to be too low. The tomato yield is most reliable in California, where a relatively stable air mass during the summer insures fairly consistent night temperatures in the appropriate range. In areas such as the Southwest and the East, the great fluctuations in summer night temperatures make tomato production very variable. In some years there are only a few weeks of optimal night temperatures, and the crop is small. We are testing in our laboratory



OPTIMUM NIGHT TEMPERATURES for various stages in the life of three annual plants are given by the curves in the diagram at the top. The curves in the diagram at the bottom give the average night temperatures during 1950 and 1951 for four locations in California. By fitting the curves at the top to the curves at the bottom it is possible to determine when it is best to plant these species. The curves are fitted for the chili pepper (*in color at left in the bottom diagram*) and the California poppy (*center*).

new varieties of tomatoes which breeders hope will tolerate a wider range of night temperatures, and indications are that the effort to breed a less sensitive tomato will be successful.

The potato plant, a close relative of the tomato, has in general the same temperature response; that is to say, it will form tubers only if the night temperatures fall within a rather narrow range. The optimal range is between 50 and 57 degrees F., about 10 degrees below the best range for tomatoes. This explains why the most successful potato-growing areas are mainly in the northern regions, such as Idaho, Maine, Ireland and northern Europe. In the central valley of California potatoes can be grown in the spring and late fall, but not during the middle of summer. In the tropics potato production is possible in the mountains, where the night temperatures are within the proper range. We have found that the important thing is the temperature to which the top of the potato plant is exposed: artificial heating or cooling of the soil has very little effect on the formation of tubers.

The response of sugar beets to temperature is somewhat more complicated. The plant grows best, at least in the case of warm-climate varieties, when the night temperature is about 68 degrees, but this is poor for sugar production. Sugar beets grown on a regime of 68-degree nights produce monstrous tubers with a very low sugar content. They develop the highest sugar content when they are exposed to considerably lower night temperatures and also get comparatively little nitrogen nutrition. This suggests that the best sequence of conditions for beet sugar is a warm summer and early nitrogen feeding, while the plant is growing, followed by sunny autumn weather (for photosynthesis of sugar) with cold nights near freezing.

Peas and sweet peas grow mainly during the day and are little affected by the night temperature. They do best at daytime temperatures below 70 degrees; as soon as the regular daily temperature goes above 80 or 85 degrees, they start to die. In warm climates they can be grown only as winter crops.

The responses of a large number of other plants to day and night temperatures have been investigated, and for each of them an optimal range was established. Representative ranges for a few garden plants are shown in the accompanying chart [*see page 92*]. As temperatures depart from the optimum, the growth of a plant becomes poorer and poorer, until it fails entirely. For example, African violets will die within weeks or months when they are kept continuously at the growing conditions which are best for the English daisy, whereas the English daisy dies when it is kept under the conditions best for the African violet.

If we lay such a chart over the climatic chart compiled by meteorologists for a particular locality, we can readily see the most favorable growing season for any given plant [*see opposite page*]. Within California we have a considerable range of climates: near the coast, because of the effect of the ocean, the daily and seasonal temperature variations are comparatively small; farther inland we have a drier climate and greater temperature fluctuations.

Perennial Plants

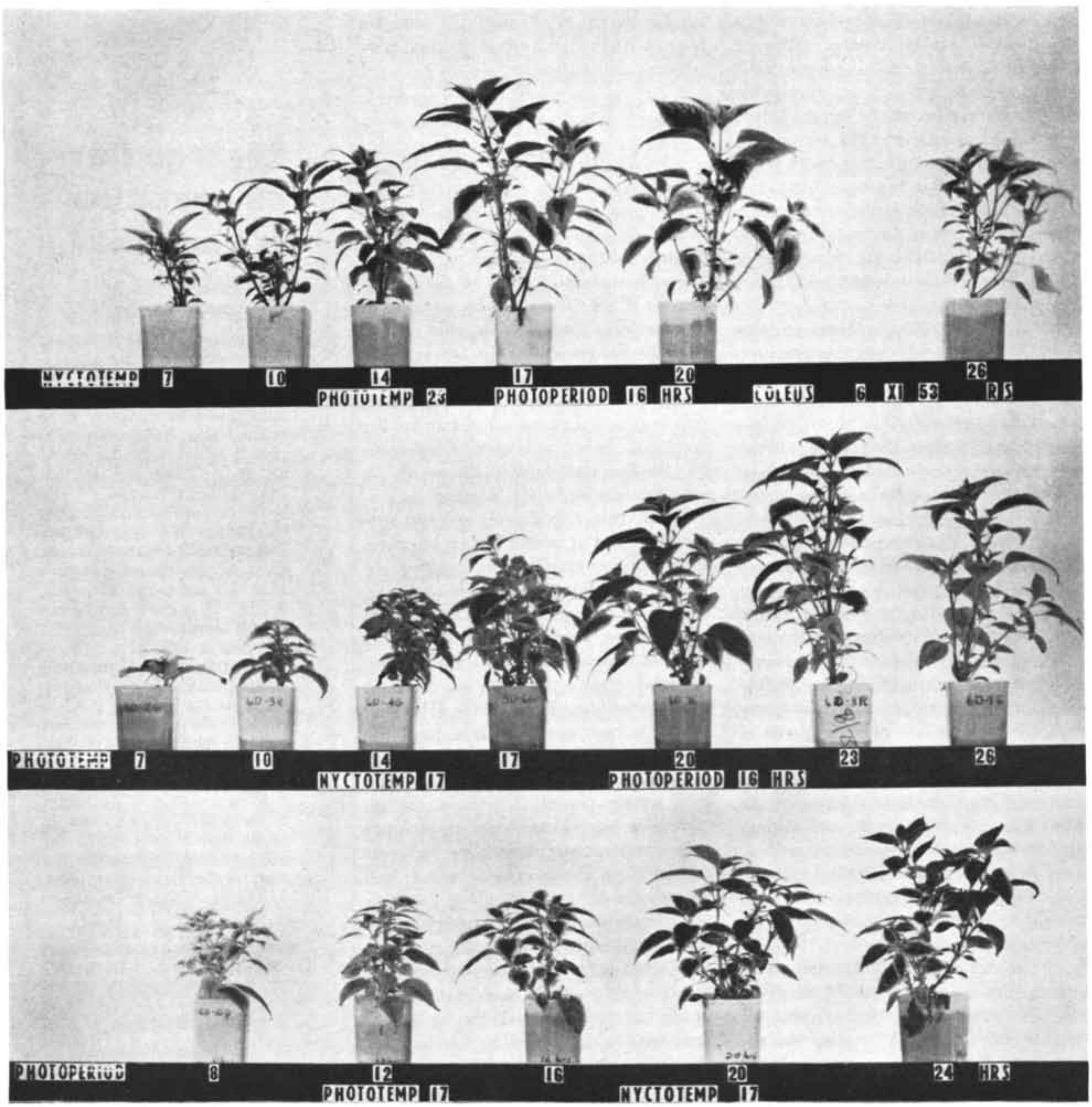
Most perennials of temperate climates depend upon cycles of temperature change. For instance, tulips will not flower in a completely even climate. There is a different optimal temperature for each successive stage of the plant's growth. First there must be a period of temperatures under 50 degrees to prepare for the growth of the flower stalk; the stalk then requires 63 degrees for its best growth; finally, if it is to produce new leaves and flowers in the following season, the tulip needs about 80 degrees. For the hyacinth these requirements are all approximately 10 degrees higher. The onion starts its flowers at a low temperature, but it needs higher temperatures for other growth processes.

The biennial plants, such as beets, carrots and foxgloves, spend their first year making a rosette of leaves and a tap root which becomes filled with storage food. They are more or less dormant over the winter. Then in the following spring a long stem develops from the center of the rosette, and this produces flowers and fruits. They must have the cold winter period: if a beet, for instance, is kept instead at continuously high temperatures, it will live for years and grow to enormous size, but it will never form flowers.

Most of our deciduous trees also require a sequence of warm summers and cold winters. A peach or pear will not open its leaf or flower buds in the spring unless the tree has passed through a sufficiently cold winter. This chilling requirement has not been worked out in great detail, but in general it seems that the temperature must be below 40 degrees for several months. The requirement varies with the tree and the variety: the peach varieties that normally grow in cold climates require a longer period of low temperatures than peaches normally growing in warmer climates. Thus a peach that does well in the St. Louis area will not leaf out in southern California, whereas a southern California peach transplanted to St. Louis is apt to sprout during a warm spell in the middle of winter because its moderate cold requirement has been fulfilled too soon.

The deciduous trees are controlled by climate in two ways: by changes in the temperature and by changes in the length of the day [see "The Control of Flowering," by Aubrey W. Naylor; Scientific American, May, 1952]. A peach or pear tree senses the approach of autumn through the decrease in day length; its buds then begin to go into the dormant state. If a peach tree is kept continuously on long days in the laboratory, it will go on growing vegetatively without forming resting buds. In nature the sequence of long days, short days, cold temperatures and warm temperatures synchronizes the peach tree with the progression of seasons. The tree's response is complex. Two successive cold winters, separated by a warm summer, are needed—the first for the initiation of new flower buds during the following summer and the second to prepare for the flowering of these buds.

Warm-climate evergreen shrubs such as camellias also have a dual control by seasonal fluctuations in temperature and



RESULTS OF EXPERIMENT on coleus plants in the Earhart Laboratory are recorded by photograph. The plants in the top row were subjected to various night temperatures ("nyctotemp"). The temperatures are given in degrees centigrade below each plant. The day temperature ("phototemp") and the length of the day ("photoperiod") were kept constant. The plants in the middle row were subjected to various day temperatures; the plants in the bottom row, to various photoperiods. Date of experiment is at upper right.

day length. In their case the flower buds are formed during high summer temperatures and the flowers open during the next winter. For vegetative growth they must have long days. Therefore camellias do well only when subjected to sufficient seasonal variations.

Many tropical plants, *e.g.*, palms and hibiscus, develop leaves and flowers all the year around. The reason they cannot be grown in a temperate climate is that their vegetative growths would be killed by frost. Yet even some tropical plants, such as the royal poinciana, respond to a yearly cycle—namely, the cycle of rainy and dry seasons.

Strawberry Flavor

Obviously climate exerts its influence upon plants by affecting their biochemistry. Concerning this we do not yet have much specific information. But we do find definite effects of climatic factors upon the taste and other qualities of fruits. Using the tongue as an analytical instrument, we have investigated the influences of various factors upon the flavor of strawberries.

When strawberry plants are grown in warm or moderate temperatures, the fruits are red, sweet and slightly acid, but they have no strawberry flavor! To develop flavor they must ripen at daytime temperatures of about 50 degrees. By various experiments we learned that the plants have to be exposed to the right light and temperature conditions for at least a week to acquire the full strawberry aroma.

These results explain why generally the first strawberries of the season taste best. They ripen while the early morning temperature is about 50 degrees. Later in the spring and during the summer the strawberry crop is practically without aroma, because the ripening fruit does not receive the proper temperature at any time during the day. At high altitudes, or far north, low morning temperatures occur even during summer, and strawberries from Alaska, northern Sweden or the high Rockies taste marvelous at any time.

With this information it should be possible to grow strawberries deliberately under conditions in which full flavor develops, producing a product of reproducibly high quality. For it is after all the flavor for which we pay 40 cents a basket; the amount of sugar and acid contained in a basket of strawberries (if bought separately) would be worth less than one cent.

It is possible that in many other fruits the same factors are important for flavor development. Probably the excellent taste of northern apples is due to the low temperatures during the last days of ripening, especially in the morning. Breeders of fruit give the main emphasis to its keeping quality and appearance, but growers ought to pay as much attention to flavor, which is the basis on which we buy fruits in the first place. With more experiments we may obtain knowledge of the conditions under which flavor can be developed most effectively.

Control of Climate

Since agriculture is the backbone of our existence, and since climate is a decisive factor in crop production, what can we do about it? This is a problem of such magnitude that it certainly should occupy many of our best brains, and research and development groups in agroclimatology should be active all over the world. Every agricultural experiment station and agricultural college has groups of scientists studying plant diseases and pests, breeding new varieties, determining proper soil treatments, developing agricultural implements and machinery. But only a few places have research teams in agroclimatology. Among these are the Drexel Institute of Technology's Research Laboratory of Climatology, the Department of Agronomy at the University of Wisconsin and the College of Agriculture at the University of California.

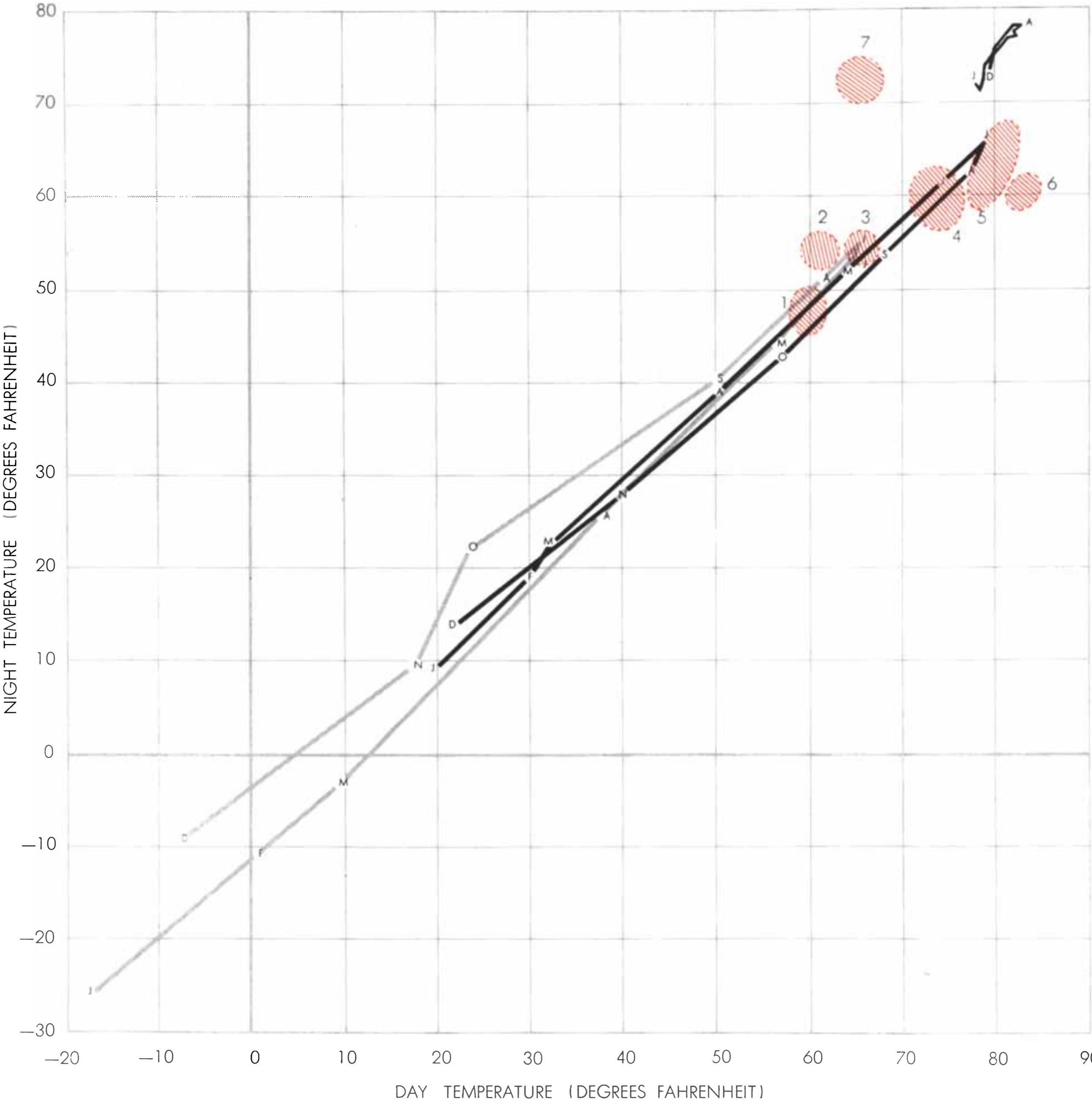
Such a team should comprise meteorologists, climatologists, agriculturists and plant physiologists. A phytotron of the kind we have at Cal Tech is a necessary instrument for the investigation. Now that the need for such a laboratory has been recognized, we can expect that in the near future a number will be built, not only for basic research but also for the solution of many problems in agriculture, horticulture and forestry.

Not much can be done about improving the selection of climate for the great staple crops, such as wheat, rice and cotton, for these crops are already generally grown in the most favorable areas, as a result of experience, economic forces (the profit margin is narrow) and the development of varieties adapted to local conditions. The specialty crops, on the other hand, are tried everywhere, with more or less (usually less) success. Agroclimatology can advise as to whether such crops are likely to succeed in a given locality and which varieties are the best to plant.

It can also be helpful with weather warnings. One of the best examples is the frost warning system for citrus growers in southern California. During the winter farmers receive a daily report by radio on the expected minimum temperature in each area. They are told at what hour temperatures will drop to the point where their orchard heaters need to be fired. This service is so reliable that farmers know when they can sleep soundly through the night and when they must organize crews to light the heaters. In the Netherlands the Meteorological Institute has an efficient warning service against outbreaks of potato blight. It tells potato growers when the climatic factors threaten spread of the disease, so that they can spray their fields with Bordeaux mixture in time.

Similar warning services are being developed for many other farming operations. For instance, calculations of the rate of water loss by the soil make it possible to tell farmers when and how much they must irrigate their fields. If reliable long-range weather forecasting can be developed, whole new possibilities will open up for agroclimatology. Experts will then be able to recommend what varieties of a plant (*e.g.*, tomato) should be planted for the best yield.

There are already a number of ways in which farmers can control climatic factors in the field to some extent. They can accelerate the flowering of chrysanthemums and other plants by means of electric lights or curtains which artificially regulate the day length. We have found that it is possible to induce tomato plants to set fruit as early as May or June in Pasadena by covering them with



OPTIMUM DAY AND NIGHT TEMPERATURES for seven plants are indicated by the areas in color on this diagram. The plants are the English daisy (1), stock (2), ageratum (3), China aster (4), zinnia (5), petunia (6), African violet (7). The average day and night temperatures for three locations are also plotted. The long gray curve plots the temperatures for Fairbanks, Alaska; the long black curve, for Sioux Falls, S.D.; the short black curve at upper right, for San Juan, Puerto Rico. The letters on the curves indicate months of the year. Where the curve for a locality intersects the colored area for a plant, the plant will grow well there.

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dark cloth during the late afternoon, when the temperature is in the proper range for fruit set. These plants start to form tomatoes at least a month ahead of uncovered plants. A more inexpensive way to obtain early fruit set is to plant the tomatoes along the east side of a wall or a shade tree, so that they are shaded and start their night activities early in the evening, while the temperature is still high enough.

As we learn more about plant responses to climate, we undoubtedly will find more ways to control their growth, and it is a comforting thought that technology is so advanced in our present world that almost any technical problem can be solved if it is urgent enough.

Climate-Tailored Plants

We have considered the possibilities of adjusting climate to plants; to what extent can we adjust plants to a climate? There is very little scientific evidence to support the idea that over the course of time a given variety of plant can become acclimated to conditions for which it is not originally suited. The soundest scheme is to attempt to breed new varieties which are fitted to the climate. This of course has been tried by many plant breeders and in many experiment stations. Every state of the Union has an experiment station with its own breeding program seeking to adapt cereals and other plants to the particular climatic conditions in that state. One of the great difficulties in these breeding programs is that there are minor differences in climate from year to year. The plants selected in one year may not be appropriate for typical conditions.

With the phytotron, in which the critical climatic factors can be controlled, it should be possible to select varieties which are specifically adjusted to particular climates. We are conducting such a program at the present time to breed tomato plants which will set fruit at comparatively high night temperatures in places such as Texas; the research program is financed by the Campbell Soup Company, the largest single grower of tomatoes in the U. S. Starting with varieties which are able to set at high temperatures but produce inferior tomatoes, we have found that by cross-breeding we can transfer their high-temperature tolerance to good tomato varieties. By such breeding it should be possible to develop a series of forms suitable for different climates.

The examples discussed in this article should make it clear that a great future lies ahead for the field of agroclimatology. The Earhart Laboratory has already shown in a number of cases that experiments under carefully controlled conditions can greatly cut down the expense of field testing. For example, it has assisted the U. S. Forest Service in selecting cover plants which are likely to grow well on mountainsides in southern California. In another project we found that the herb called the American hellebore (*Veratrum viride*), which had failed in all field experiments, needed six months of freezing temperatures followed by six months of very cool weather. The plant was then tried at high elevations in the mountains of northern Washington and grew successfully there. In these cases climate turned out to be the most important selective factor, and this is probably true of many plants.

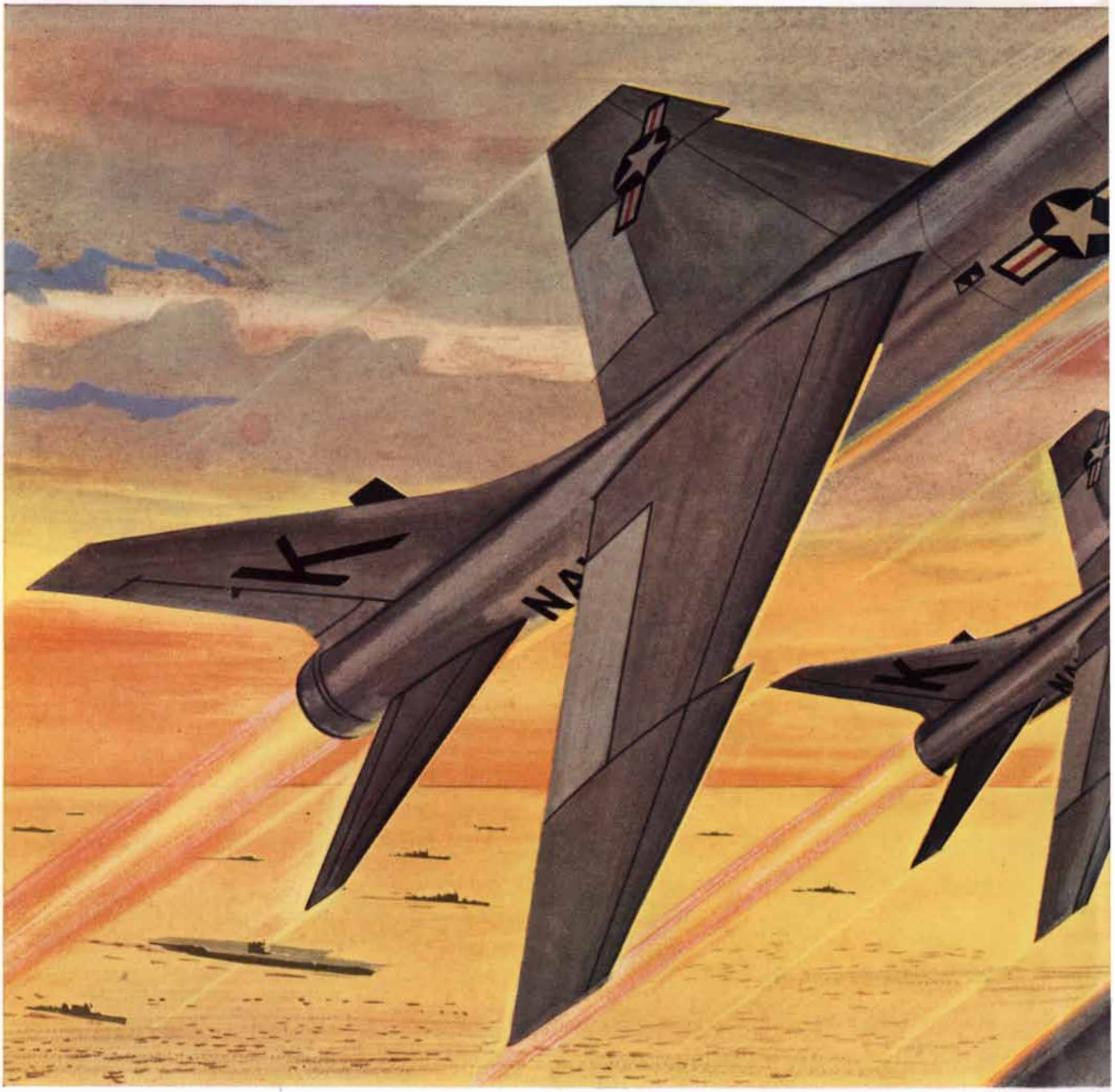
More from the Sun

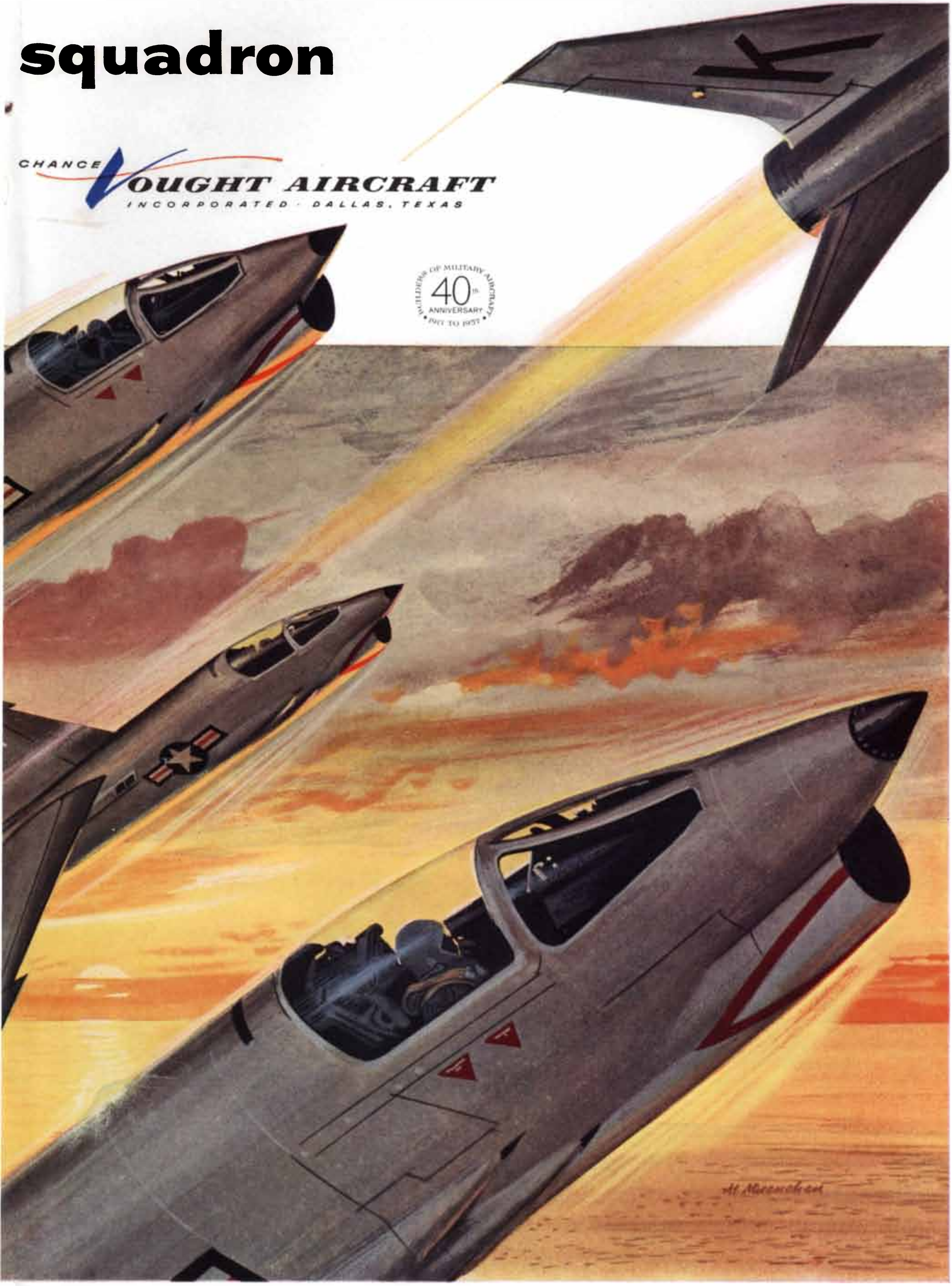
Basically the most important climatic factor that man seeks to put to use in agriculture is the energy of sunlight. Our present methods capture only a small part of the available energy. Laboratory experiments show that a plant can convert 10 per cent or more of the incident light energy into chemical energy in the form of its organic products. But in practice we harvest as plant material no more than 2 per cent of the solar energy that falls on a field of, say, corn or sugar beets. One reason for this relative inefficiency is that an annual, starting anew from seed, covers only a small percentage of the surface of the field in the early part of the season. Perennial crop plants provide more coverage and absorb more solar energy over the season, but most of their production goes into unusable leaves and branches.

Obviously these facts offer a vast field of research for students of climate and plant production. The objectives must be to get better coverage of the earth's surface with plants and to improve the efficiency of conversion of sunlight into chemical energy. Already it has been found that algae in a nutrient solution can transform light into organic energy two or three times more efficiently than the higher plants. However, a rather elaborate setup is needed to cultivate algae effectively; the expenditure of an equal amount of ingenuity and technological effort could make the higher plants just as efficient in absorbing the sun's energy.

Climate is one of our major natural resources. By learning exactly what the relationships are between climatic factors and plants we should be able to make far greater use of this resource.

Utility boxes molded of Tenite Polyethylene by Werner Manufacturing Co., Brookfield, Illinois.





RADIATION PRESSURE

Light and sound, although apparently intangible, actually exert a tiny pressure on objects in their path. A review of the theoretical and experimental studies of this effect

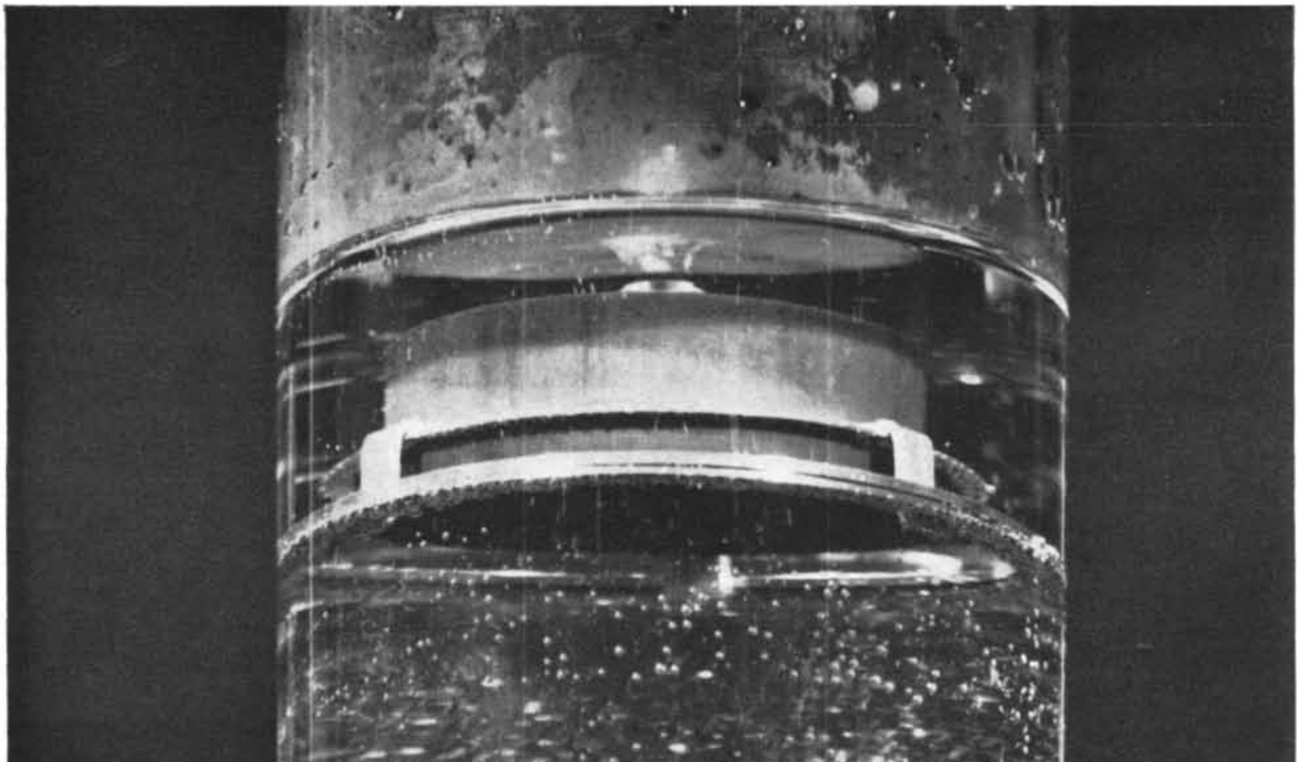
by George E. Henry

A person hit by a golf ball is easily persuaded that a moving object exerts force upon an obstacle in its path. If you try to tell him that the same principle holds when a beam of light from a flashlight hits him, he is apt to be a great deal more skeptical. Yet there is no difficulty in proving this on theoretical grounds, and it can be verified by experiments. The force felt by the obstacle is measured by the rate of reduction of the ball's momentum (mass times velocity) but it can be measured just as well in terms of the reduction of the ball's kinetic energy. A beam of light exerts such a force, or pressure, because it too carries energy.

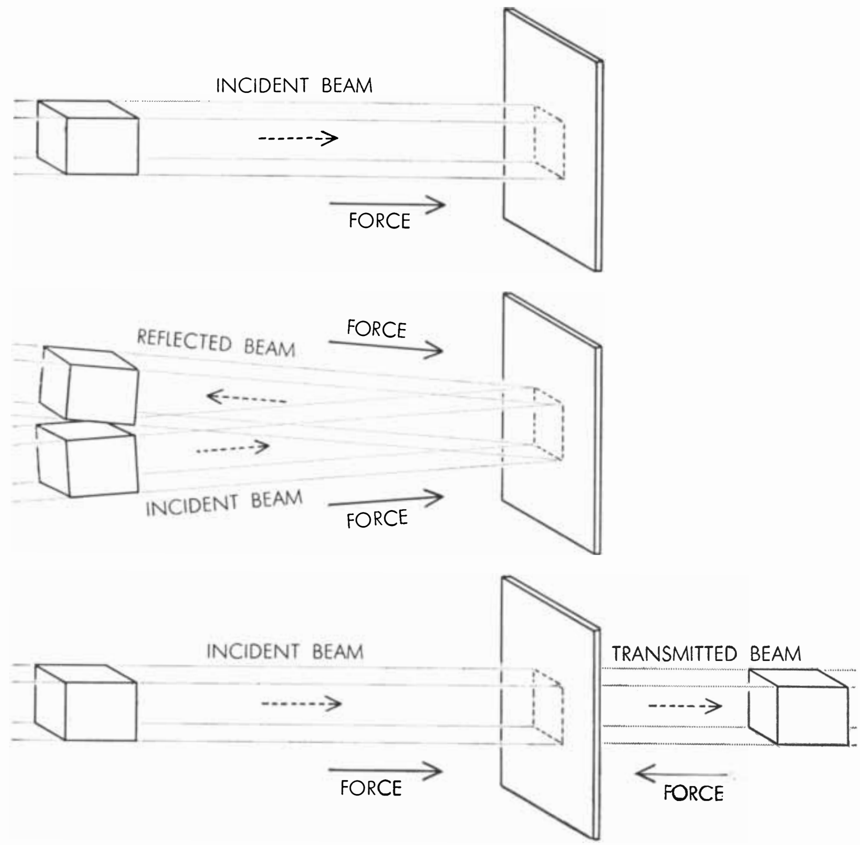
In the case of light this force is, of course, unimaginably feeble. If we could summon up all the thrust from the beams of a million flashlights, it would barely support the weight of a postage stamp!

The example suggests that in relating force to power, some factor besides energy must be taken into account. It was James Clerk Maxwell who first explained that factor in quantitative terms. He proved that when an object is hit by a continuous stream of energy, the force upon the absorbing obstacle is proportional to the advancing stream's energy content *per unit length*. Here, then, is the answer. The energy in the beam of light is spread thin: the beam does not contain much energy per unit of distance. A continuous stream of golf balls, though moving at a snail's pace (compared to the speed of light), would be heavily packed with energy in every foot. The force a golf ball exerts depends upon its dense packing of energy.

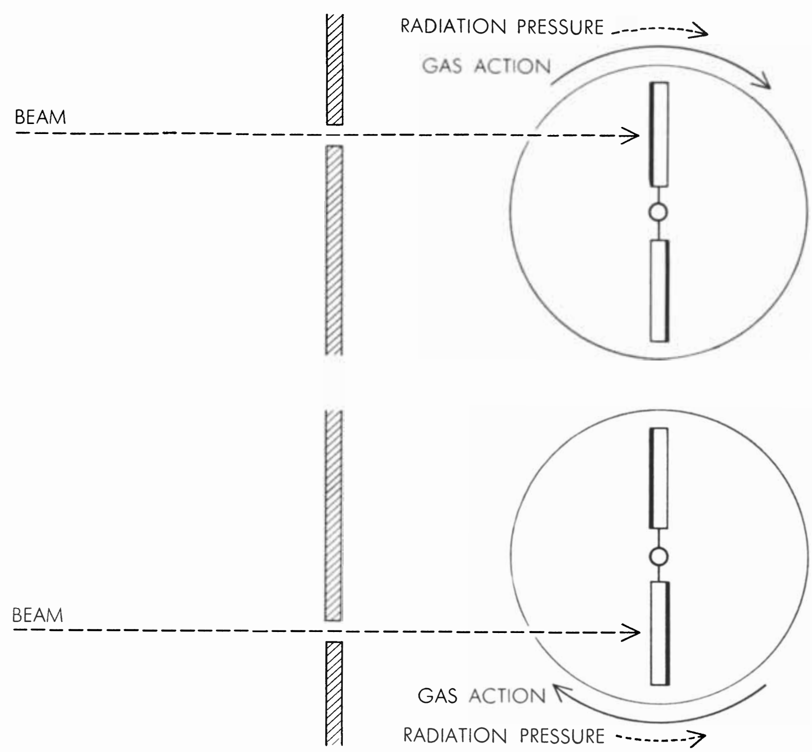
This comparison of light rays with a swarm of golf balls may remind readers of Isaac Newton's corpuscular theory



SOUND-WAVE PRESSURE is measured by directing an acoustic beam up through a liquid to strike the underside of a float in middle. Radiation pressure causes the float to rise a little, pushing an additional length of the small mast above the liquid surface.



PRESSURE FROM A BEAM of radiation depends on the amount of energy in a unit volume of the beam (*rectangular boxes*). Upon striking a surface a beam may be absorbed (*top*), reflected (*center*) or partly transmitted. Both incoming and outgoing beams exert a force.



PRESSURE FROM LIGHT was measured with two glass plates silvered on one side. When light hits silver directly (*top*), its pressure and the impacts of gas molecules twist the plates in the same direction. When light passes through glass (*bottom*), the twists are opposed.

of light. Indeed, many early advocates of the theory that light consisted of minute particles, rather than waves, tried to prove their thesis by demonstrating that a ray of light would push against an obstacle. No one succeeded in detecting such pressure, either in nature or with laboratory equipment, and by the latter part of the 19th century the theory of radiation pressure seemed hopeless, along with the corpuscular concept of light. Then in 1873 Maxwell revived the theory by showing that waves exerted pressure! This is surely one of the great ironies in the history of science: the very phenomenon that was supposed to disprove the wave theory of light was in fact demonstrated on the basis of the argument that light had the nature of waves. Maxwell observed:

"In a medium in which waves are propagated there is a pressure in the direction normal [at right angles] to the waves, and numerically equal to the energy in a unit of volume." He followed up his mathematical proof of this proposition with a suggestion that a practical demonstration should be possible. "Thus, if in strong sunlight the energy of the light which falls on one square foot is 83.4 foot-pounds per second, the mean energy in one cubic foot of sunlight is about .0000000882 of a foot-pound, and the mean pressure on a square foot is .0000000882 of a pound weight. A flat body exposed to sunlight would experience this pressure on its illuminated side only and would therefore be repelled from the side on which the light falls. It is probable that a much greater energy of radiation might be obtained by means of the concentrated rays of the electric lamp. Such rays falling on a thin metallic disk, delicately suspended in a vacuum, might perhaps produce an observable mechanical effect."

This put the matter squarely up to the experimentalists, and they were not slow to accept the challenge. Two years after Maxwell's suggestion, William Crookes exhibited to the members of the Royal Society in London his famous light radiometer—an instrument which is still an item of scenery in many jewelers' show windows. A needle standing upright in a small evacuated glass container supports a rotary set of vanes or baffles, painted white on one side, black on the other. The dark side of each vane absorbs most of the light striking it; the white side reflects it. Since the reflection of light almost doubles the force exerted by the impinging light, the white faces should in theory retreat from the source of light. But when

Crookes exposed his scientific plaything to light, it ran in the wrong direction! The kinetic theory of gases provided Crookes with the explanation. The vacuum enclosed by the bulb was not perfect; therefore air molecules must be hitting and rebounding from the vane faces. They would bounce off with a higher velocity from the warmed dark faces than from the cooler white faces. Thus the recoil would have a greater effect on the dark sides, and these would retreat from the light.

Unfortunately this left radiation pressure itself still undemonstrated. The problem continued to thwart experimenters for another quarter-century. Then success came in two places at once. In 1901 a Russian, Peter Lebedev in Moscow, and a pair of Americans, Ernest Fox Nichols and Gordon F. Hull at Dartmouth College, almost simultaneously solved the 200-year-old problem with very similar experiments.

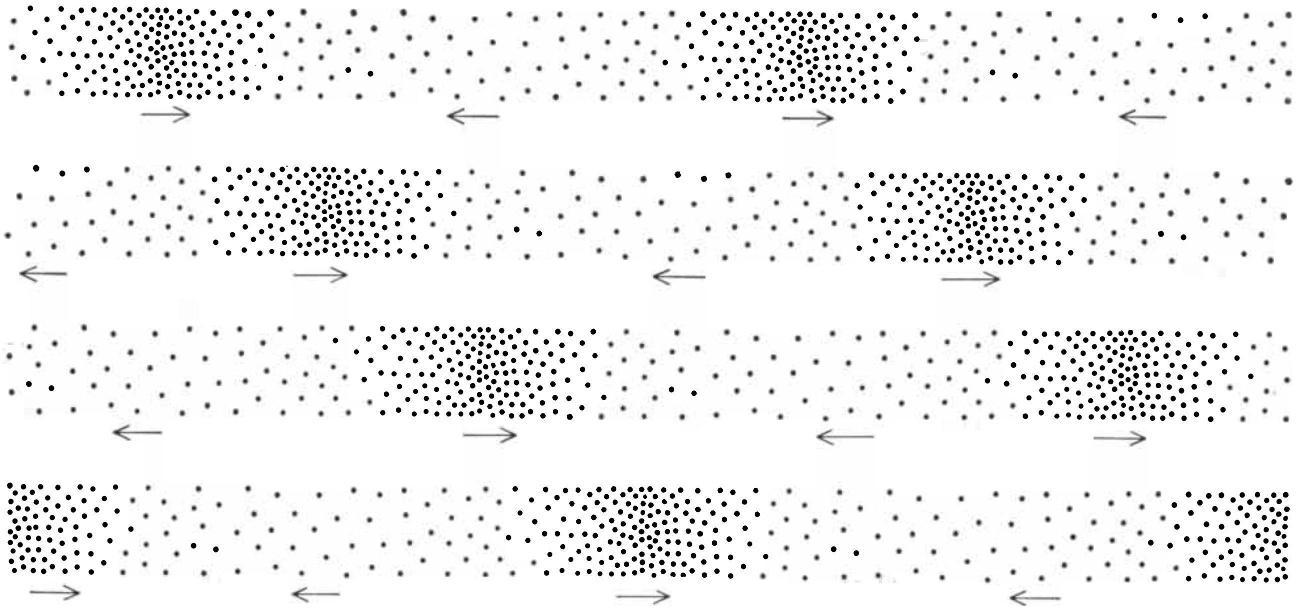
In both experiments a torsion pendulum in an evacuated chamber served as the basic sensing mechanism. The twist of the long, delicate quartz thread would measure the effect of the light on the target. To distinguish the radiation pressure from the large masking effect of recoiling air molecules in the necessarily imperfect vacuum, the two laboratories used different methods. Nichols and Hull had a pair of target vanes. They were glass disks silvered on one side—one on the side facing the light, the other on the side facing away [*see lower diagrams on opposite page*]. One disk was exposed to the light at a time. When the silvered side faced the light, the warming of the thin layer of metal on the surface drove the disk away from the light. The twist of the thread in this case would represent both radiation pressure and the air effect—that is, the two would add together. When the light beam was directed at the disk whose silvered face was on the other side, there should be a contrary effect. Radiation pressure would still act to push the disk away from the light. But the air-recoil effect would push it toward the light, because the light passed through the glass and warmed the metal film on the far side. Thus in this case the radiation pressure would be subtracted from the force of the air action. If there was indeed such a thing as radiation pressure, it should be detectable by a measurable difference between the twists of the torsion pendulum in the two cases—air action plus radiation pressure and air action minus radiation pressure.

The great problem had always been that the force of the recoil action of molecules on a light-absorbing surface is at least 10,000 times greater than the direct pressure of a light ray. Nichols and Hull brought the comparative measurements within the range of detectability by means of two stratagems which greatly reduced the warming effect: first, their silvered reflecting surface minimized the heat absorption, and secondly, they used a shutter at their strong light source and gave the disks only brief exposures. They found that the deflections of the torsion pendulum did indeed show a measurable difference in the two opposite cases, and the existence of radiation pressure was at long last proved.

Lebedev, following a similar line of reasoning, contrived a somewhat more complicated experimental arrangement, involving target vanes made of several different materials in different thicknesses. In one of his constructions no fewer than eight tiny disks, no two alike, dangled around the central stem of the torsion pendulum. He sprayed this inverted Christmas tree with light of different colors to prove that radiation pressure was independent of wavelength! Lebedev's results, like those of Nichols and Hull, agreed well with the values predicted by theory. The long, frustrating effort to demonstrate the pressure of light had ended in triumph.

Among the examples of radiation-pressure phenomena in nature, none is more spectacular than the peculiar behavior of comets. As far back as 1619 Johannes Kepler suggested that their immense, luminous tails, always streaming in the direction away from the sun, could be accounted for by the pressure of sunlight, pushing material away from the comet head. A century later the mathematician Leonhard Euler added the considerable weight of his opinion in support of Kepler. Modern physical investigations have abundantly confirmed Kepler's supposition. It is now known, however, that other phenomena besides radiation pressure are involved. The comet warms up as it approaches the sun. Gas is evolved and spewed out of its head in various directions. These streams of matter are acted upon by radiation pressure along their entire length; those that point sunward are gradually bent back, like jets of smoke in a breeze. The stuff so emitted is lost to the comet forever; the comet's weak gravitation could never recover material so remote and diffused. But a comet, like the snakes of folklore, can grow a new tail.

In the case of a massive body such as the earth, the sun's thrust of radiation is



SOUND WAVE is shown in four successive stages as it moves from left to right. Dots represent particles of air or other material through which the wave is traveling. Arrows under each stage show the direction of motion of the particles at that moment.

overwhelmed by its incomparably greater gravity. The total pressure of sunlight on our planet comes to something like 100,000 tons. If this seems a lot of force, let us reflect that the pull of solar gravity upon us amounts to about four million million million tons!

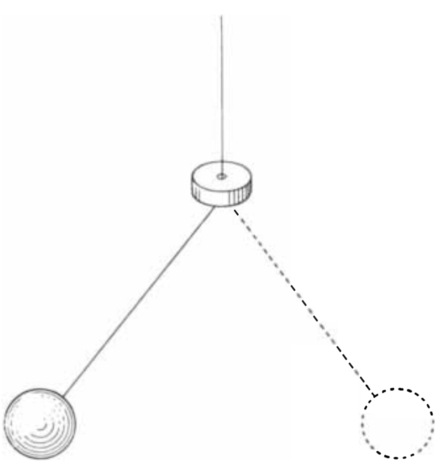
Radiation pressure becomes a much more respectable force in the body of a massive bright star. Here each particle of matter repels its neighbors with its spear of light. The repulsive force of radiation is passed on from particle to particle on a long and tortuous journey from the deep interior outward. Thus at any point in the star, radiation pressure and gas pressure together support the weight of the layers of material above. The proportion of support contributed by radiation pressure is typically of the order of a few per cent.

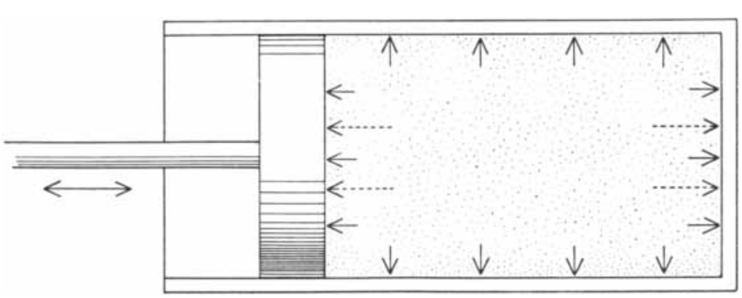
This brief excursion into astrophysics very fittingly concludes our discussion of the pressure of light. Study of the phenomenon, through the centuries, has been closely tied in with theories and speculations about the nature of light itself. There is every promise that research on light pressure will go on telling us more about our universe. But the pressure of light is not likely to figure largely in our daily lives. Light beams will not propel our vehicles or push open our doors. And the radiometers in the opticians' show windows can be expected to continue to spin backwards!

In the 20th century, physicists have proceeded to investigate another form of radiation pressure—the radiation pressure of sound. This story is rather different from the quest for evidence of light pressure. Answers have come more quickly: we have had the benefit of sophisticated electronic equipment and intensive wartime research on underwater acoustics. And the radiation pressure of sound has some practical uses.

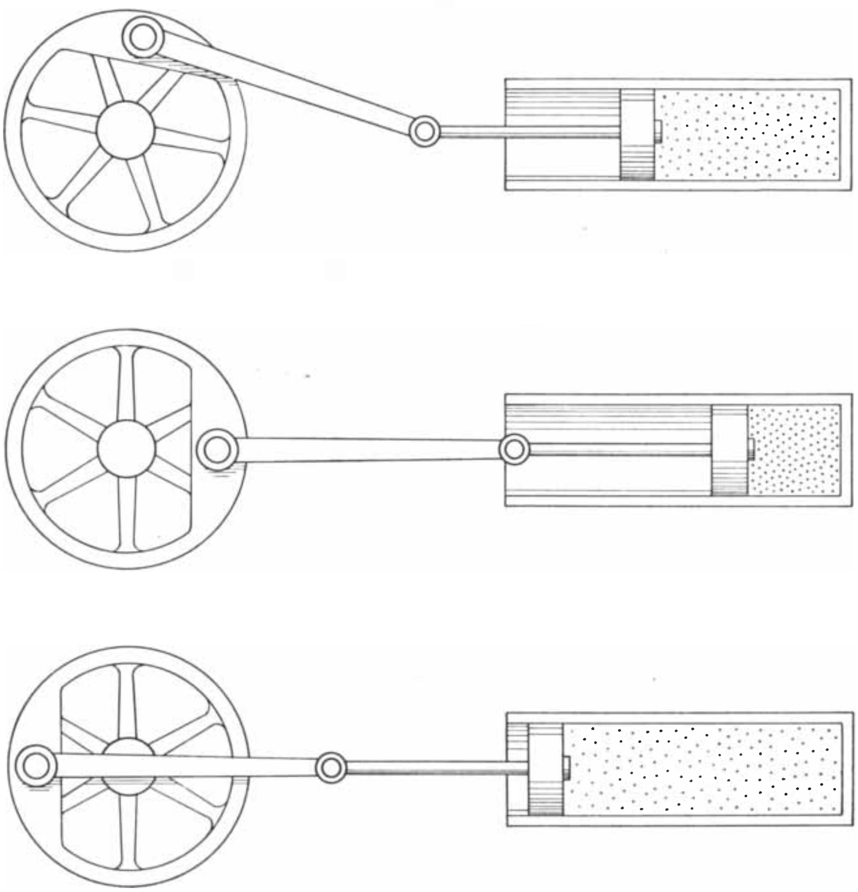
First we must make clear what is meant by the "radiation pressure of sound." Is not sound itself essentially a pressure phenomenon, produced by the alternate compression and rarefaction of the medium through which it moves? True enough, and we have to look at this process in intimate detail to find the distinct property designated as "radiation pressure."

Let us picture a sound wave traveling in air from left to right across the stage of a huge theatre, in which we sit as spectators. We can imagine the wave

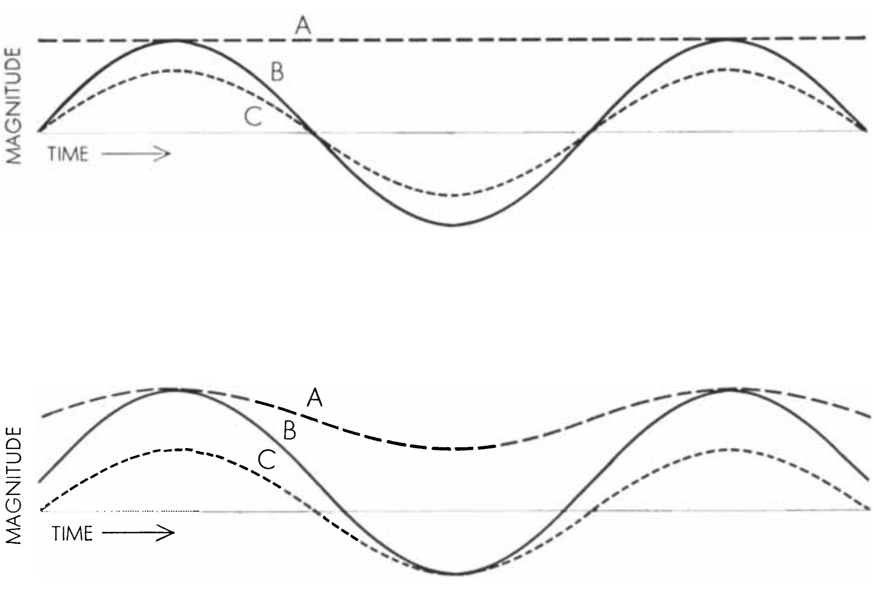




THEORETICAL MODELS to demonstrate radiation pressure were proposed by Lord Rayleigh. At left a swinging pendulum forces a ring upward along the supporting string. At right a vibrating piston sends a sound wave through a gas, producing two types of pressure.



TRAPPED GAS subjected to repeated compression and decompression helps explain radiation pressure. Increase in pressure when piston moves to right is slightly greater than decrease when it moves to left. Thus there is an increased average pressure against walls.



SOUND PRESSURE (*curve B*) is obtained by multiplying particle speeds (*curve C*) by specific resistance of medium through which the wave travels (*curve A*). If resistance were constant (*top*), increases and decreases in pressure would cancel. The actual resistance is greater in dense than in rarefied regions, so increases in pressure outweigh decreases (*bottom*).

itself to be made visible by the introduction of millions of tiny specks of colored powder, and we must further suppose its travel to be slowed down sufficiently to be followed by the eye. If we concentrate our attention on one spot in the air, we see a continual and regular change in the density of the colored smoke, the particles being now closely packed, now spread apart. If we then widen our field of vision, we see what causes the periodic variation in density: alternate waves of compression and rarefaction cross the stage in regular procession from left to right. The individual particles of powder do not themselves march across the stage: they move to and fro within a limited range, and only the wave marches [*see diagram at top of page 102*].

If we look closely enough, we discover the most significant fact of all. The specks moving to the right are those which find themselves in a close-packed concentration; those moving to the left are in a rarefaction region. The resistance to motion of the particles of course is slightly higher in the regions of density than it is in the regions of rarefaction. Now a fundamental law of physics says that pressure is the product of motion times the specific resistance. Therefore the pressure toward the right must be slightly greater than toward the left. This means that the wave exerts a net excess of pressure in the direction of its travel, which should be felt as a direct force by an obstacle standing at the right end of the stage.

In the first decade of this century several experimenters—Lebedev in Moscow, Robert Williams Wood in Baltimore and others—demonstrated this acoustic radiation pressure by means of simple acoustic radiometers, using the crackle of sparks for a noise source. But it was Lord Rayleigh of England who laid the theoretical foundation for understanding the phenomenon.

Rayleigh wished to consider the total pressure exerted by a sound wave. Therefore he imagined a system in which sound was propagated in a closed cylinder containing an ideally behaving gas: that is, the sound completely filled the cylinder. Rayleigh calculated that the pressure exerted by the sound radiation on the far wall of the cylinder (*i.e.*, at the end of its path) would be equal to the energy per unit volume in the cylinder plus an amount which depended on the heating of the gas by the sound-wave compressions.

Sir Joseph Larmor in England and Paul Langevin in France undertook to examine the more normal case of the

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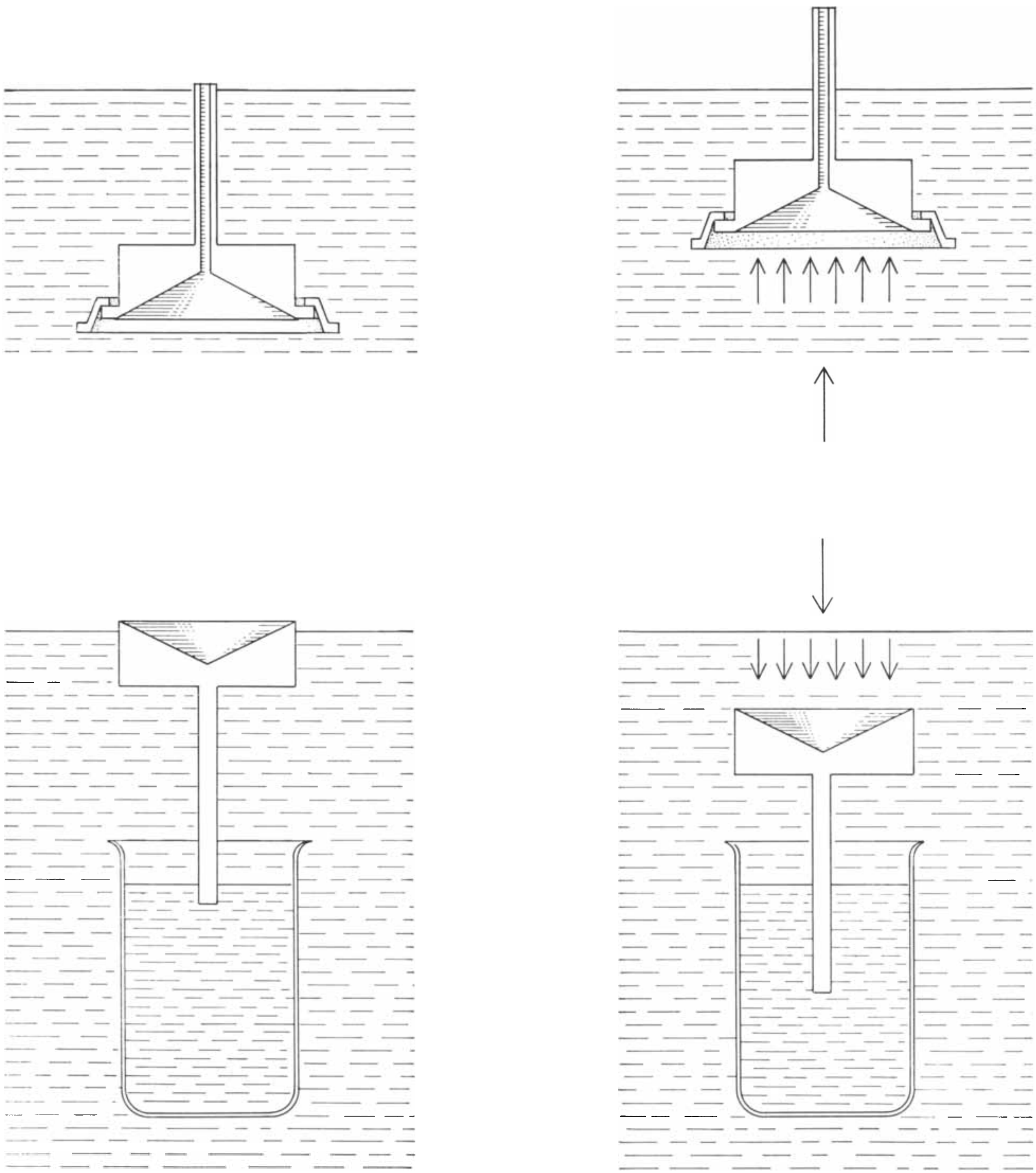
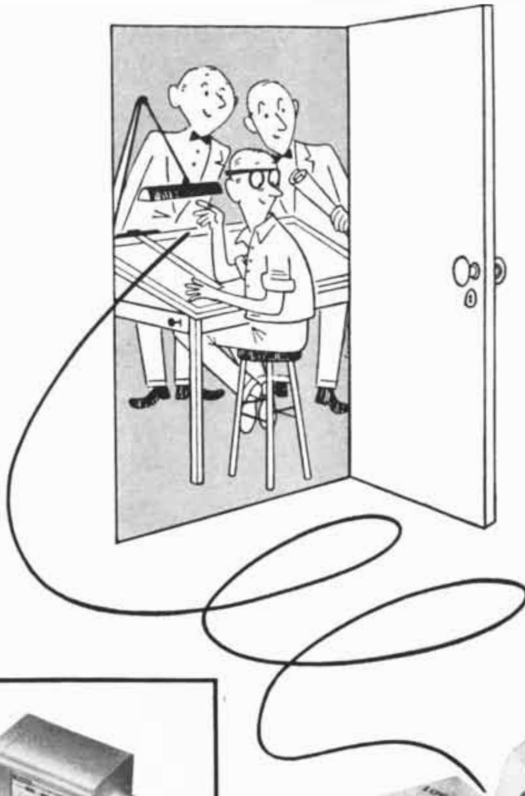
pressure of sound against an obstacle in the open atmosphere. Both arrived independently at the answer that the broadside pressure upon an absorbing obstacle would be equal to just the energy per unit volume in the incident beam. This result, often called the "Langevin equation," of course agrees with Maxwell's conclusion about the pressure of light. Its apparent (but not actual) disagreement from Rayleigh's equation was later explained by Léon Brillouin, then a young physicist working for his doctorate at the Ecole Normale Supérieure in Paris. He reasoned that the Rayleigh pressure (*i.e.*, in a closed cylinder) consists of two separate parts. The part corresponding to the "Langevin pressure" is felt only by the target wall in the path of the wave. This part, in other words, is directional. The other part is quite different: it is really an excess "hydrostatic" pressure, exerted equally in all directions. The lateral walls are subjected only to this second, and less important, kind of sound radiation pressure. If we open the container at some point, or consider the open atmosphere, the hydrostatic pressure disappears and we are left with just the



BUOYS are used to measure the radiation pressure of sound. At top an upward beam raises a buoy, forcing its thin mast partly out of water. The rise is proportional to the upward thrust. At bottom a downward beam forces the buoy mast farther into a heavy liquid.



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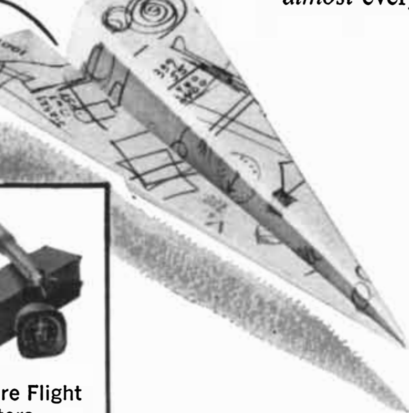

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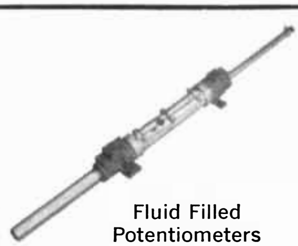

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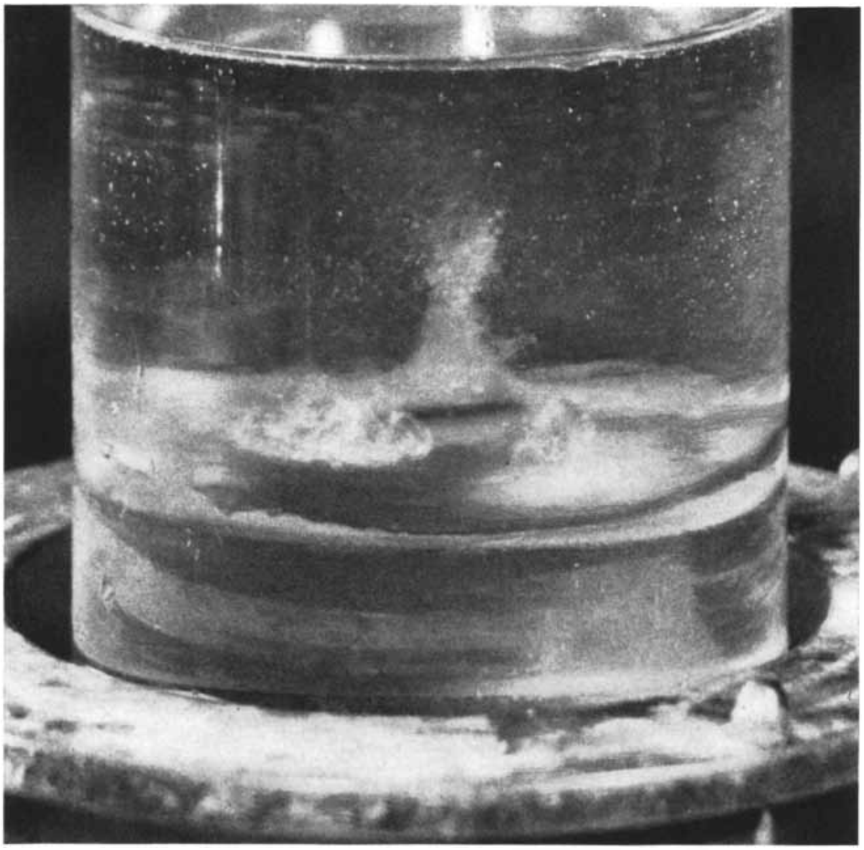
Langevin pressure. This directional pressure has the same value whether we are dealing with an open or closed system.

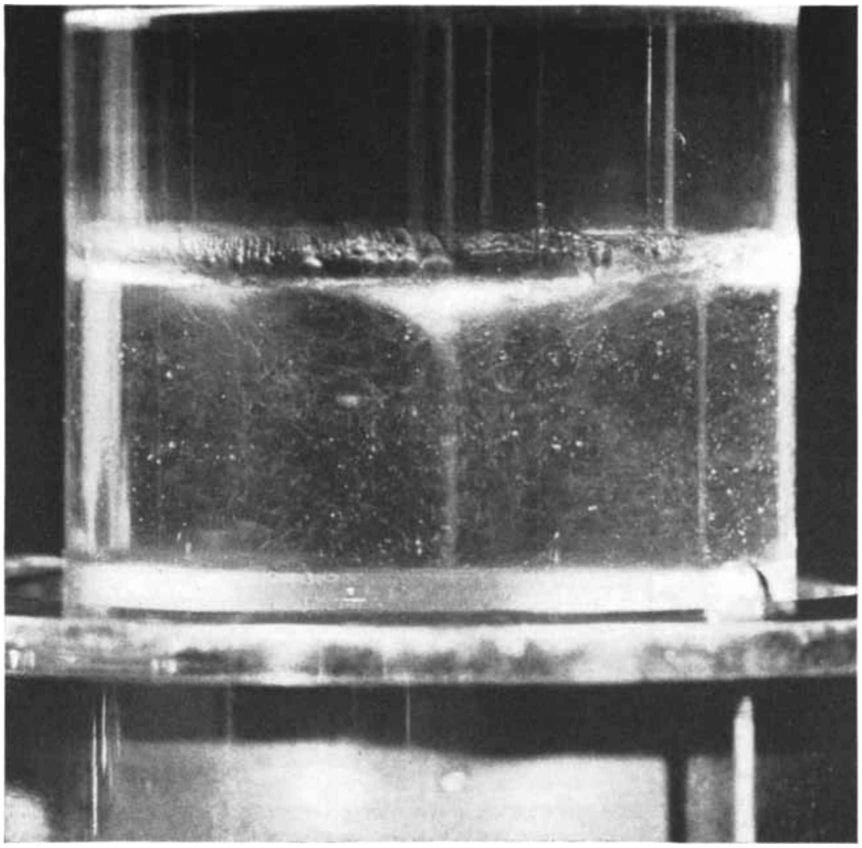
Experimental work on acoustic radiation pressure has been greatly facilitated during the past two decades by the opening of the new field of underwater sound and the extension of experiments into the ultrasonic region. The use of water instead of air as an acoustic medium simplifies the problem of generating high-power sound—and high power is needed if the radiation pressure is to be more than faintly detectable. And by going to frequencies above the audible range of sound the experimenter makes life easy for himself in two ways. The size of his apparatus can be reduced, in keeping with the reduction in wavelength, and he can get more power.

By now at least one demonstration of acoustic radiation pressure is familiar to many people. It is the fountain produced in a liquid by an ultrasonic generator. The vigorous eruption is due in part to the direct push on the resisting liquid by the ultrasonic beam and in part to backward reflection of the beam at the surface of the liquid, which results in lengthwise expansion of the column of insonated liquid, thereby causing it to "blow its top" into the unresisting air.

We now have a bewildering variety of vanes, gauges, floats and buoys to measure the strength of a sound field or the acoustic power output of an ultrasonic generator. Some of these are delicate torsion pendulums. Among the devices we use in our laboratory is a buoy which is reminiscent of the classic little toy known as the Cartesian diver (responding to air pressure in a closed vessel). Our little buoy, submerged in water, has a mast sticking up from its center. The ultrasonic beam is aimed at the bottom of the buoy from below, and the upward pressure pushes the mast farther out of the water. The mast rises to just the point where its increase in weight, because of emergence from the water, is equal to the upward force. Thus the rise of the mast measures the power of the ultrasonic beam.

Ultrasonics and the studies of radiation pressure, along with other new developments, have greatly extended the old science of acoustics. The new acoustics is concerned with many matters which the early students of sound could not have dreamed of, including investigations of states of matter and such unexpected applications as the use of sound to dissipate fog.





BOUNDARY BETWEEN LIQUIDS in which sound travels at different speeds is displaced when subjected to a sound beam. In liquid where speed is lower the energy per unit volume is greater, which means a greater pressure. Hence this liquid pushes into the other. At top trichloroethylene pushes up into water; at bottom a petroleum solvent pushes water down.

there's a future in this crystal

TRIMETHYLOLPROPANE BECOMES A COMMERCIAL CHEMICAL THROUGH CELANESE ALDOL PRODUCTION

The properties of this free-flowing flaked polyol have always intrigued the chemist. Its ability to improve the quality of paints, protective coatings, and particularly the exciting new polyurethane foams, promised Trimethylolpropane a big role in these and other applications. But, until Celanese developed a method for high volume, low cost production, the usefulness of Trimethylolpropane was severely limited.

New aldol processing units at the Celanese Chemcel Plant in Bishop, Texas, are now turning out commercial quantities of Trimethylolpropane—making available to manufacturers a product possessing low water content, low melting characteristics, and exceptionally high purity.

The development of Trimethylolpropane into a commercially practical chemical is an example of how Celanese research and product development teams are finding new ways to give industry what it needs in more productive basic and intermediate materials.

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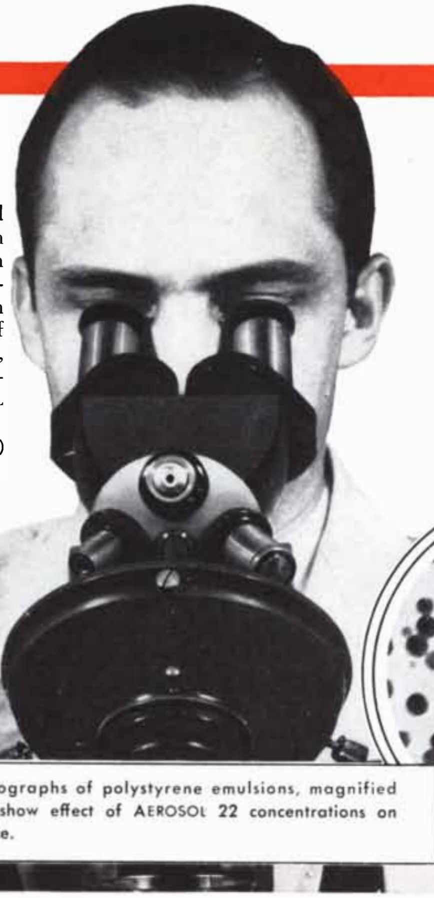
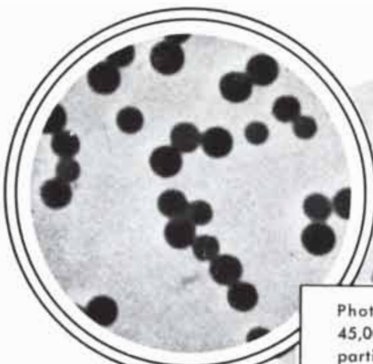
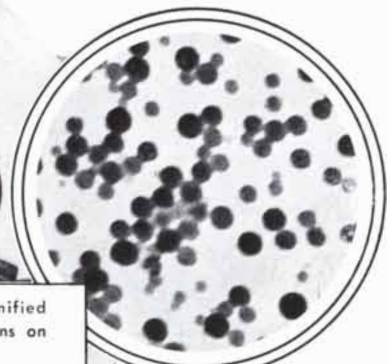
Life on the Chemical Newsfront



BETTER CONTROL of particle size, in both uniformity and range, is one of the important effects attainable through the use of AEROSOL® Surface Active Agents in emulsion polymerization. These agents have various wetting, emulsifying and solubilizing properties, and by proper selection they can improve the solubilization and emulsification of monomers and resins, rate and degree of polymerization, viscosity of emulsions and stability during and after reaction. As a guide, a new technical bulletin on AEROSOL Surface Active Agents is available on request.

(Industrial Chemicals Division, Dept. A)

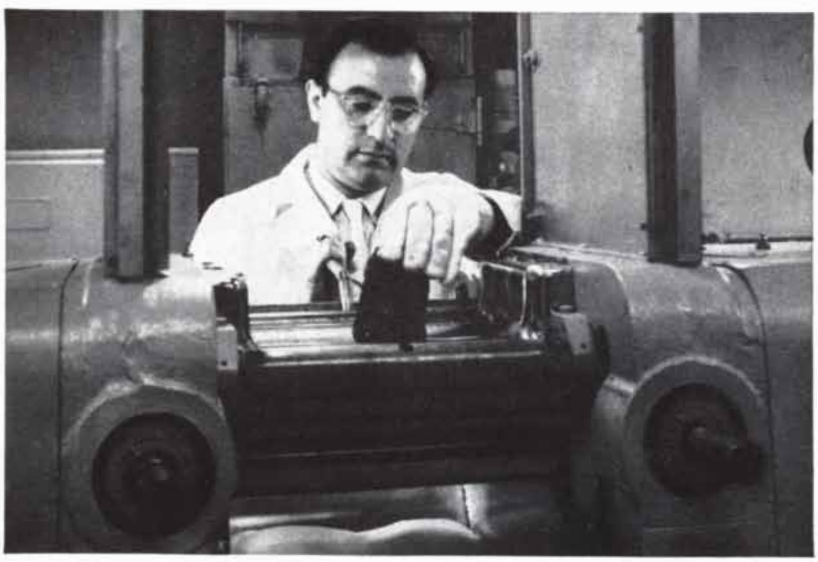




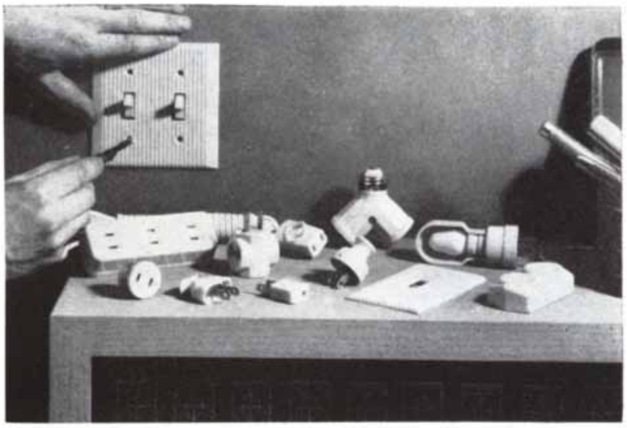
Photomicrographs of polystyrene emulsions, magnified 45,000× show effect of AEROSOL 22 concentrations on particle size.

AEROSOL 22 @ .5% of monomer

AEROSOL 22 @ 3% of monomer



ECONOMICAL COLORING of transparent polystyrene plastic is made possible by such oil-soluble dyes as CALCO® Oil Blue ZV, one of many developed with the aid of such equipment as the plastics mill shown here in use at Cyanamid's Plastic Application Laboratory. Such dyes tend to dissolve in polystyrene and have high tinctorial power. Therefore, they yield clear, bright, highly transparent color effects at low cost. They are particularly adaptable to the coloring of jewels and transparencies. Good stability to heat, ease of application and good light fastness make them widely useful. (Organic Chemicals Div.)

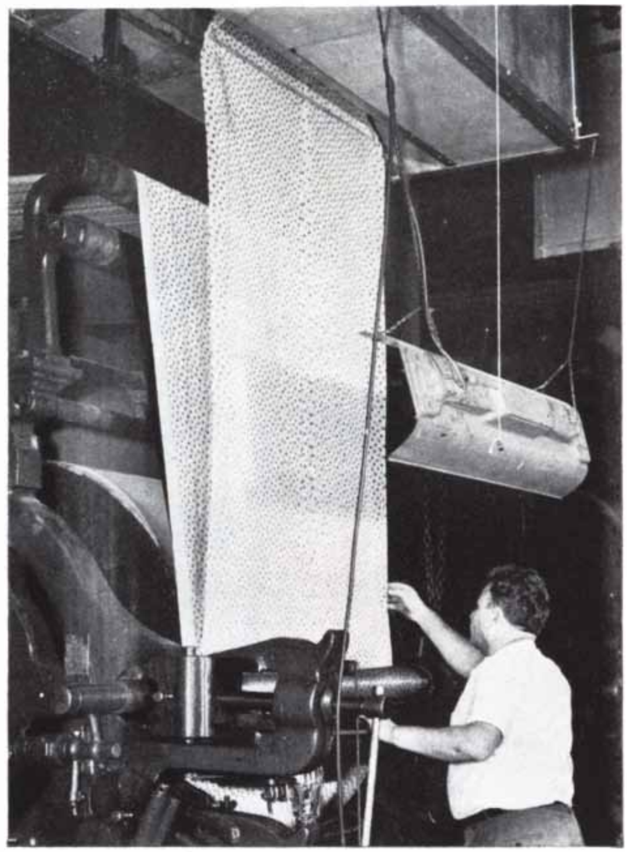


MODERN TOUCH IN WIRING DEVICES. Home styling today favors light, cheerful colors. This note is carried out perfectly in smartly styled wiring devices molded of ivory-colored BEETLE® Urea Molding Compound. Its hard, smooth surface resists discoloration and scratching, and safe service is insured by the excellent insulating properties of BEETLE Urea Molding Compound.

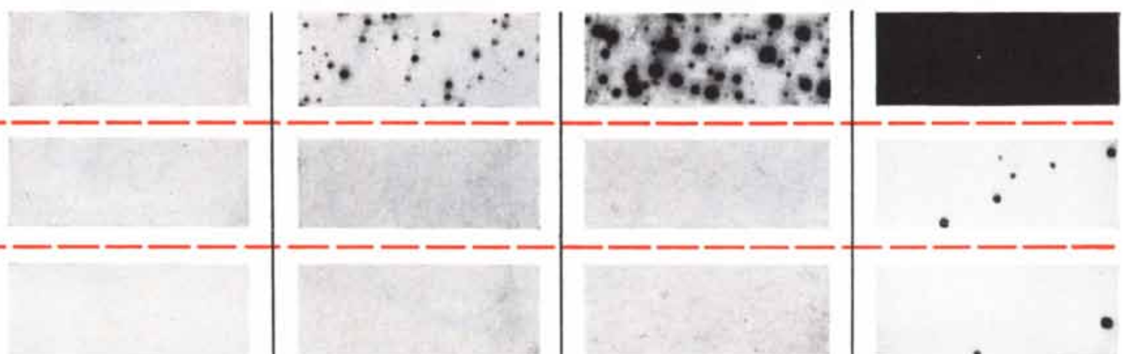
(Plastics and Resins Division)

A NEW METHOD FOR PRINTING VAT DYES from an oil-in-water emulsion has been introduced by Cyanamid. Printing vat dyes from this emulsion system† not only eliminates the troublesome starch found in conventional vat dye printing pastes, but offers many significant advantages in cost, color value, brightness of shade, running properties, and in the preparation of the emulsion as compared to conventional vat gums. Detailed information and technical assistance on the Vat Color Emulsion Printing System may be secured by writing. (Organic Chemicals Division)

†Cyanamid U. S. Pat. No. 2,597,281



PVC EXPOSED TO FLORIDA WEATHER



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TEST PANELS SHOW HOW UV 9* Ultraviolet Absorber protects polyvinyl chloride against discoloration and deterioration when exposed outdoors. The clear control sample deteriorated completely, while samples containing UV 9 Absorber showed little degradation. Because of this striking performance, PVC uses in playthings, garden furniture, awnings, greenhouses and signs are more promising than ever. Added to PVC, polyester resins, methacrylate and styrene polymers, UV 9 protects them by converting ultraviolet radiation to harmless energy.

*Trademark (New Product Development Dept. A)

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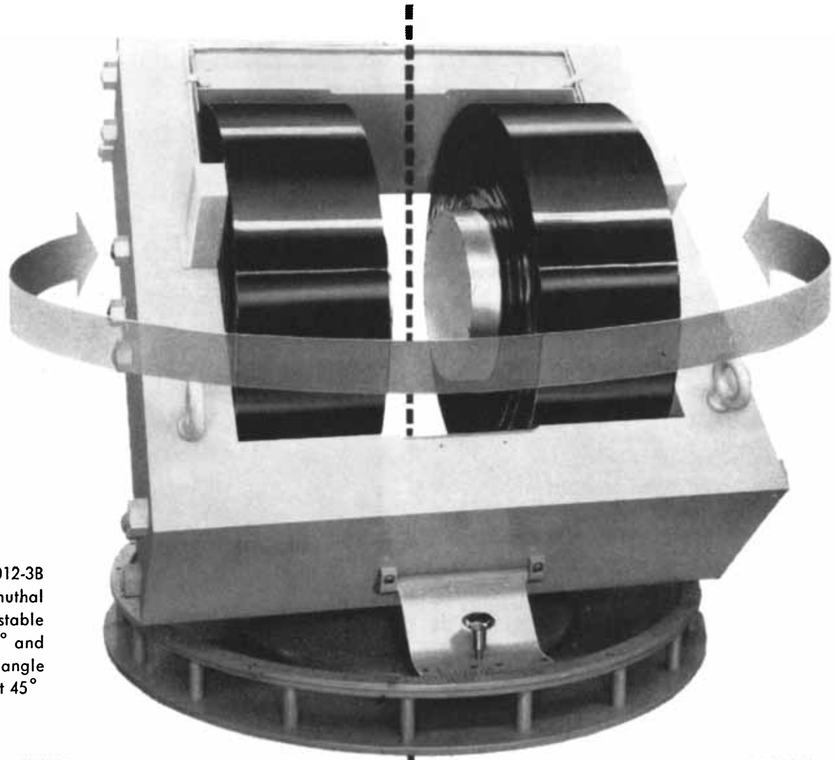
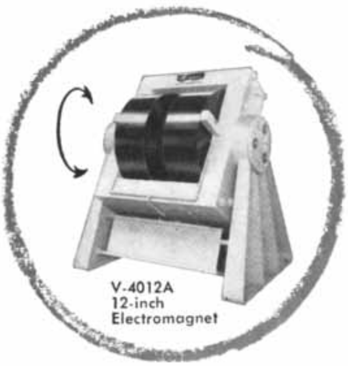


Varian Model V-4012-3B Rotating Magnet with azimuthal angle continuously adjustable between 0° and 190° and horizontal axis angle fixed at 45°



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Electromagnet

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If your experiment requires a precise magnetic field with adjustable orientation relative to the sample, the problem is easily solved by this new version of Varian's twelve-inch electromagnet. The difficult problems of rotating the sample along with its complex supports and accompanying apparatus need not be considered.

Time stability of the magnetic field can be achieved through use of the matching Model V-2100A Regulated Magnet Power Supply. Field uniformity of a high order is assured through Varian's demonstrated know-how in producing magnets of incomparable homogeneity. And as is the case with all Varian magnets, the user may specify desired air gap configurations within certain wide limits.

Varian's standard line includes three basic electromagnet groups: the 12-inch, the 6-inch and the 4-inch (all available with matched power supplies). In turn, the basic 12-inch group now includes three members: the V-4012-3B rotating version pictured above; the standard V-4012A with rotatability about a horizontal axis; and the V-4012A-HR version which is shimmed to provide extraordinary uniformity demanded by the Varian Super High Resolution Nuclear Magnetic Resonance Spectrometer.

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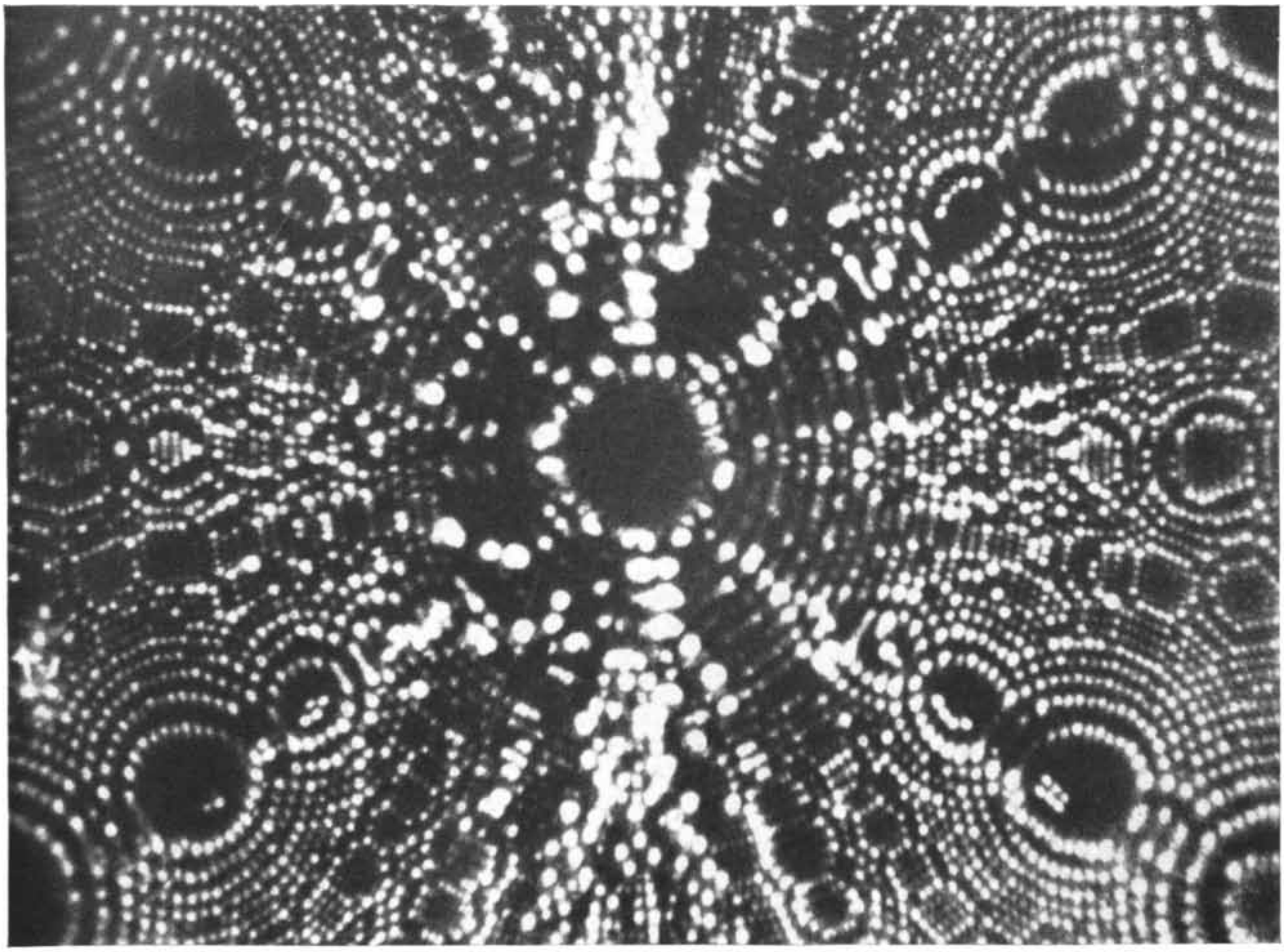
ATOMS VISUALIZED

The field ion microscope makes pictures of atoms in a metal crystal by accelerating positive ions from a fine needle of the metal to a fluorescent screen

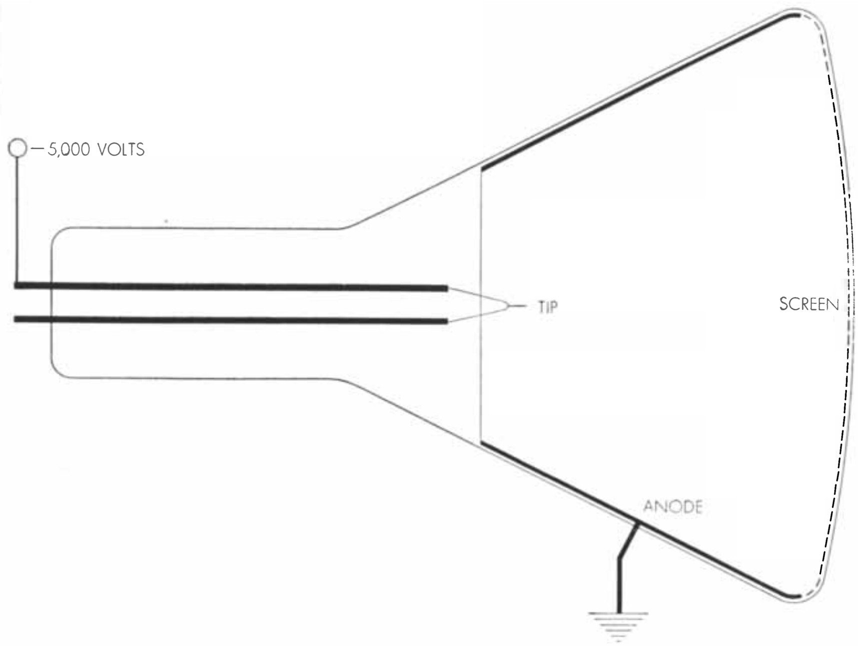
by Erwin W. Müller

The picture on the cover of this issue of SCIENTIFIC AMERICAN is a photograph of atoms. Nonsense, you may say; atoms are much too small to be visible in any microscope, and, besides, they could not possibly be colored, for they are a great deal smaller than a wavelength of light. I have to confess that the colors are a photographic trick, but the fact remains that this is an actual photograph of individual atoms—tungsten atoms on a needle tip a thousand times finer than the tip of an ordinary pin. The picture was produced with a new microscope which has made it possible for the first time to photograph atoms as the building stones of a piece of matter. With this tool we can watch the fascinating changes in a metal crystal as atoms are added or torn out of the lattice.

The instrument is an improved version of the field emission microscope which I introduced in 1936 and de-



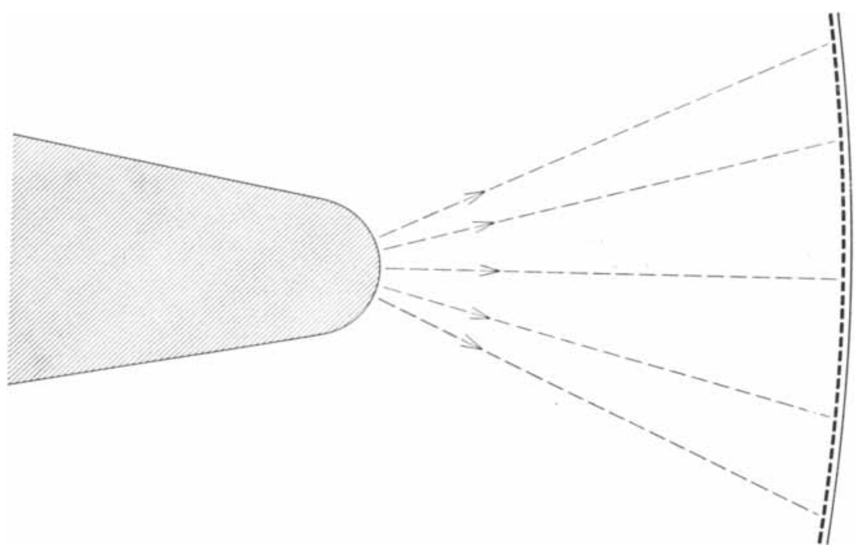
ATOMS IN A CRYSTAL of tungsten appear as small luminous spots in this photograph of the fluorescent screen of a field ion microscope at Pennsylvania State University. The atoms, in the tip of a tungsten needle, are enlarged some two million diameters.



FIELD EMISSION MICROSCOPE, the forerunner of the field ion microscope, is schematically depicted in cross section. A fuzzy image of the atoms in the tip of an extremely fine needle (*center*) is formed on a fluorescent screen by a stream of electrons from the tip.

scribed in an article in this magazine several years ago ["A New Microscope," by Erwin W. Müller; Scientific American, May, 1952]. In principle the field emission microscope is a very simple device, resembling a television tube. It has a fluorescent screen and a fine metal needle which corresponds to the electron gun of the cathode-ray tube. By means of a high electric voltage we strip particles off the rounded needle tip and fire them at the screen, where they form a picture of the atomic structure of the tip surface. The needle is very slender indeed: its round tip has a radius of only 1,000 Angstrom units (one 100,000th of a centimeter). The picture magnifies the tip surface a million times.

This magnification is sufficient to make individual atoms visible. In the original version of the microscope, however, the image is not sharp enough to separate the atoms. Its resolution (*i.e.*, the narrowest distance at which



ELECTRONS which form the image of the field emission microscope are simply emitted by the rounded tip of the needle, here enormously enlarged and moved close to the screen.

TUNGSTEN NEEDLE of the field emission microscope (*left*) is compared with the tip of an ordinary pin in this photomicrograph.

one object can be distinguished from an adjacent one) is about 20 Angstroms, whereas the atoms on the needle tip are only from three to 10 Angstroms apart. Consequently the original microscope shows only fuzzy images of a few large, prominent atoms.

The resolution obtainable with that first version of the field emission microscope is inherently limited by the fact that the particles emitted from the needle tip are electrons. Unfortunately elec-

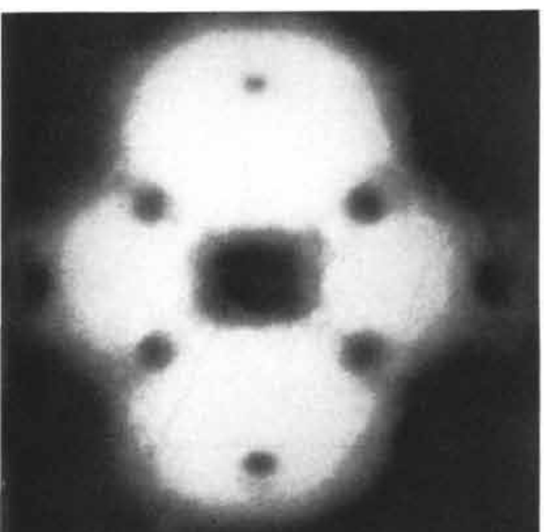
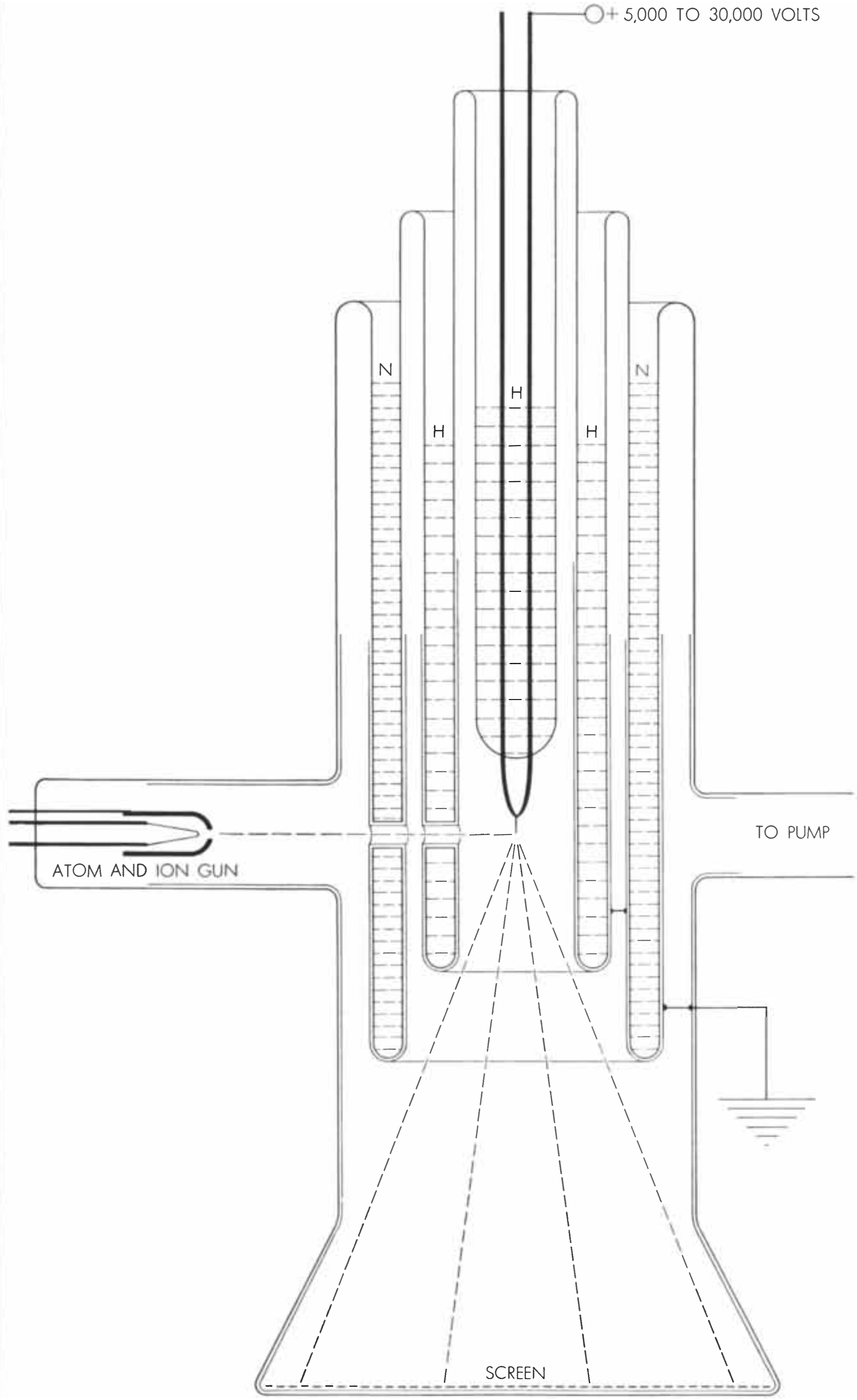


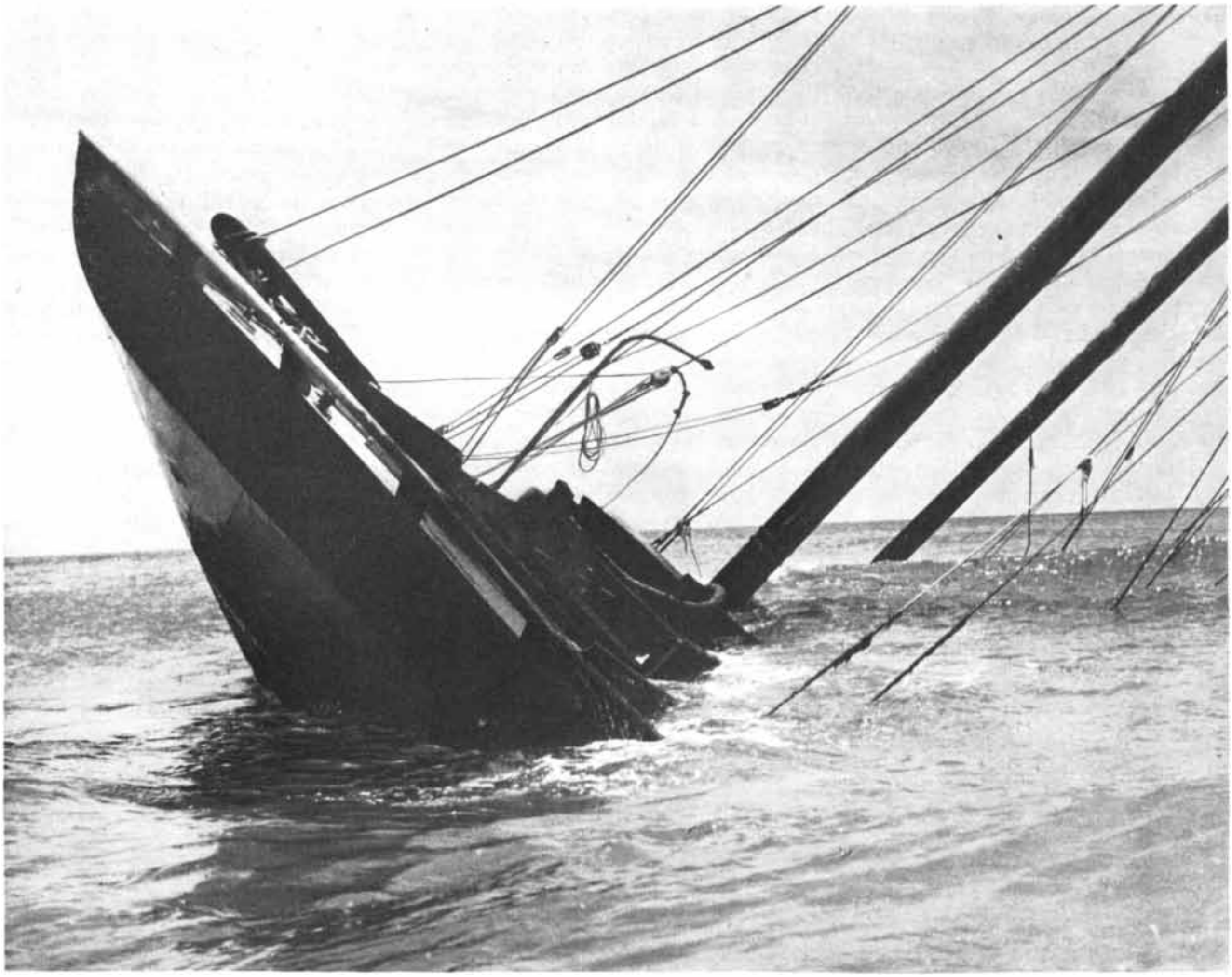
IMAGE of field emission microscope shows symmetry of crystal planes, but no atoms.

trons are apt to stray a little instead of traveling straight to the screen. That is, they spread out like shot from a shotgun. Moreover the electrons, behaving as waves, produce a diffraction effect. The result is that they give a fuzzy image of the point source on the needle tip from which they came.

A little thought about physical principles suggests a way to overcome these limitations. Suppose we use heavier particles (*e.g.*, ionized atoms) instead of electrons. Since the heavier particles have a much shorter wavelength, there will be less wave interference and therefore less diffraction. More important, we



FIELD ION MICROSCOPE is a modification of the field emission microscope. Where the needle of the field electron microscope is charged negatively, the needle of the field ion microscope is charged positively. The positive ions which form its image are made from a thin gas of helium atoms introduced into the microscope. The needle is cooled by an arrangement of vessels containing liquid nitrogen (N) and hydrogen (H). The crystal lattice of the needle may be experimentally damaged by bombarding it with the gun at left.



A timely warning from nickel might have made a difference

The sea seldom offers a clue to what lurks beneath its surface. But man can find out.

He beams sound waves to the ocean floor. And listens as they come bouncing back. The technique is called "echo sounding." It's the modern way to probe the depths . . . to map sea-bottom contour . . . to locate schools of fish . . to avoid reefs and other underwater obstructions.

One of the principal types of instruments (the fathometer) used in echo sounding depends on nickel for sending and receiving the telltale waves. Nickel, you see, has a rather unusual physical property called *magnetostriction . . .*

This simply means that it changes dimensions when exposed to a magnetic field. And it can be made to contract and return to its original dimensions rapidly enough to generate powerful sound waves.

Of course, nickel has other useful properties. Strength and toughness, for example. Resistance to corrosion. Electrical conductivity. But *magnetostriction* is the vital one here. And nickel is about the only readily available metal that offers so much of it.

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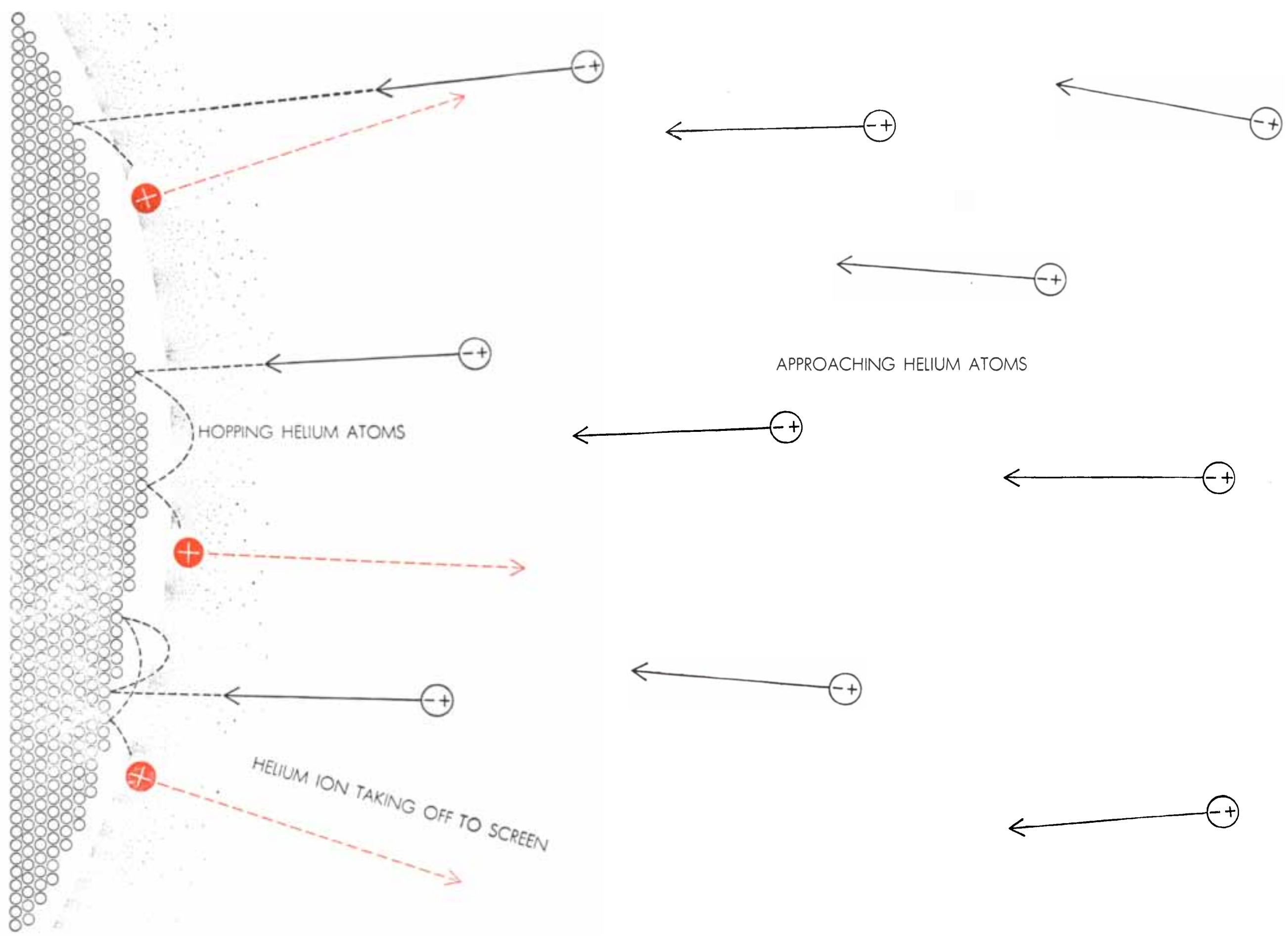
can reduce the shotgun spread of the heavier particles by cooling the needle tip to a very low temperature—a stratagem which does not work with electrons.

I therefore decided to modify the microscope to employ positive ions (atoms with an electron removed) as the projectiles. Now you cannot tear atoms out of a metal as easily as you can electrons. Very well, then, let us bring gas atoms up to the needle tip, ionize them there, and thus provide ourselves with a supply of projectiles. The gas we shall use is helium. We put a little helium in the microscope tube—not much, because we want the gas to be thin enough so that the ions will not collide with atoms on their way to the screen. We apply a high positive voltage to the needle tip, creating an electric field amounting to 400 million volts per centimeter at the curved surface of the tip. Now when a helium atom comes very close to the tip, one of its electrons jumps to the tip, and then the positively ionized helium atom is immediately propelled by the high positive voltage on the needle tip toward the screen at the other end of the tube. In this manner thousands of helium atoms are ionized at protrusions on the needle-tip surface (*e.g.*, steps in the crystal lattice), and they stream to the screen, reproducing there an image of each atom in the rows forming the lattice steps [*see photographs on pages 120 and 121*].

The reason the tip must be cooled is that many helium atoms reach it without being ionized; at ordinary temperatures these bounce off obliquely in random directions. If we cool the tip to somewhere near absolute zero, the gas atoms will stick to it for a while and lose their kinetic energy. As they are re-evaporated, they hop about on the tip surface [*see diagram below*]. They cannot become ionized unless they hop at least five Angstroms away from the surface. If the temperature of the needle tip is kept at about 21 degrees above absolute zero, five Angstroms will be the average hopping height of the helium atoms, and they are most likely to reach this height above protrusions (*e.g.*, lattice steps) on the tip surface, where the electrical field is exceptionally strong.

The principal features of the microscope are depicted in the accompanying diagram [*page 116*]. The tip is cooled by means of liquid hydrogen, enclosed within an outer mantle of liquid nitrogen. Voltages up to 30,000 volts can be applied to the tip; to prevent electrical discharges within the tube which would break down the voltage, the glass walls of the tube are covered with a conductive coating which serves as a ground electrode. Helium atoms (or electrons or metal atoms) are introduced into the evacuated tube by a gun firing them at the needle tip from the side of the tube. The tip itself may be as small as 70 Angstroms in radius, giving a magnification of 10 million on the screen (the magnification is determined by the distance to



CREATION OF IONS in the field ion microscope is outlined in this supermicroscopic diagram. The atoms in the crystal lattice of the needle tip are at left. Neutral helium atoms (— +) introduced into the microscope land on the needle surface and momentarily stick to it. When they depart from the surface, they encounter regions above steps in the lattice where the electric field is exceptionally strong (*heavier stippling*). At a distance of five Angstrom units the helium atoms lose an electron to the positively charged needle surface and become positive ions (*color*). They are repelled by the positive needle and travel to the screen of the microscope.

To engineers interested in entering the field of

INERTIAL GUIDANCE

E. V. Stearns (left), head of the Inertial Guidance Department, discusses navigation systems mechanization with Inertial Guidance Scientist R. L. McKenzie (center) and Senior Electronics Scientist D. G. Peterson.

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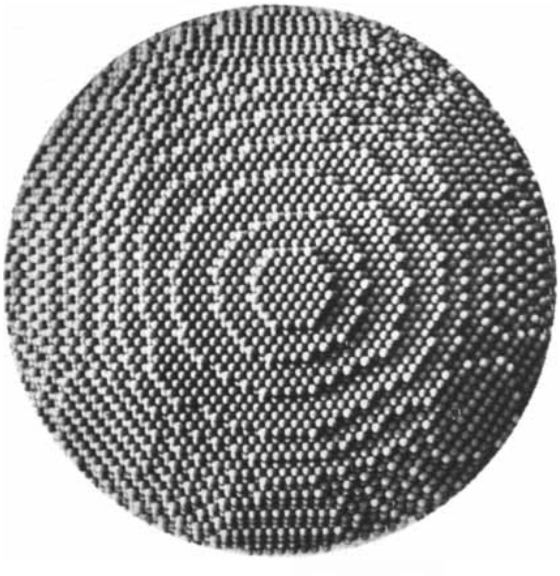
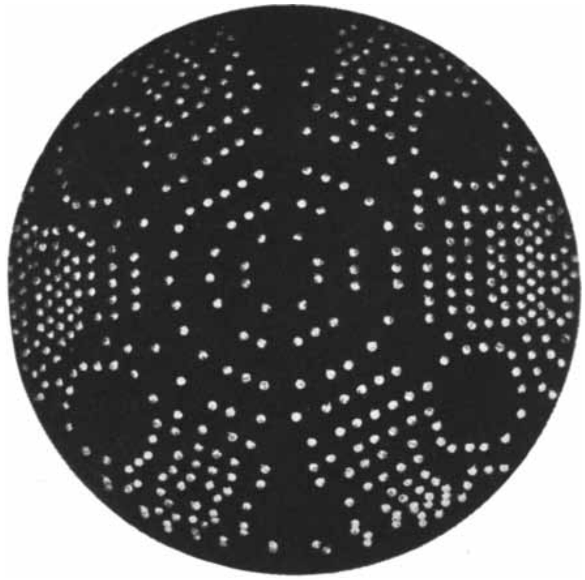


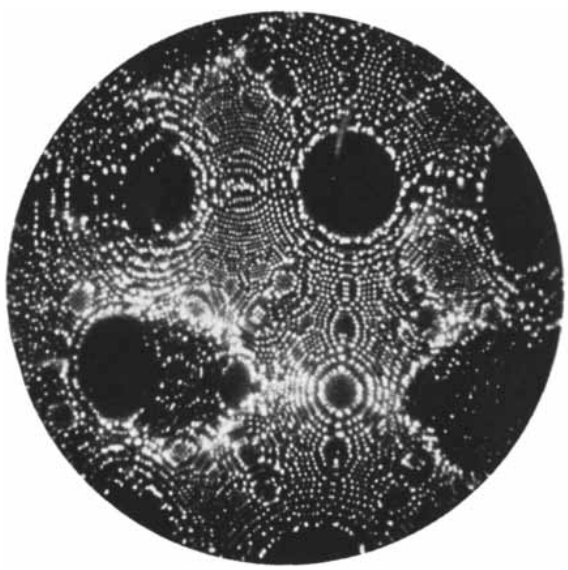


MODEL OF TUNGSTEN NEEDLE TIP (radius: 130 Angstrom units) at left is made of cork balls. The balls at the corners of planes of atoms in the crystal lattice are covered with luminescent paint; the photograph in center, made in the dark, shows their loca-

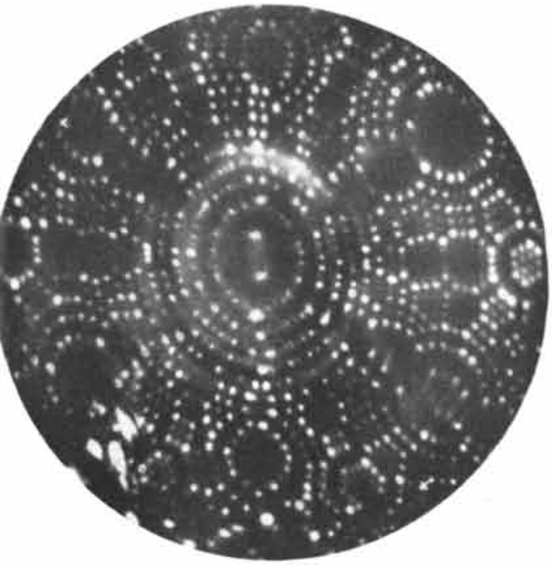
the screen divided by the radius of the tip). But a tip of this size sends so few ions to the screen that the image is extremely faint. For most experiments we use a tip of 1,000 Angstroms or 500 Angstroms radius, the latter yielding a magnification of two million. These tips produce images bright enough to be recorded by sensitive film with an exposure time of one minute.

The preparation of such fine needle tips is, needless to say, a major problem. They are made by extremely careful and tricky etching of a fine wire. After a tip of the desired size has been etched, it must be polished, because its surface is rough (on the atomic scale) and is covered with a layer of oxidized metal, adsorbed oxygen or other contaminants. To finish the tip we insert it in the microscope and apply a very strong electric field, amounting sometimes to more than 500 million volts per centimeter. The field evaporates off the contaminants and the rough top layer of metal atoms, producing a smooth surface of regular lattice steps. As the field cleans and smooths the tip, we can watch the peeling process on the screen.

Once the tip has been polished, it stays clean indefinitely, so long as the strong electric field used for observing in the microscope is turned on. This is a remarkable situation, as any physicist or chemist will recognize. Even at the highest vacuum achievable in the laboratory today, a surface will become covered with a layer of gas molecules within an hour. In the ion emission microscope, thanks to the high electric field, not a single contaminating atom or molecule is deposited on the needle



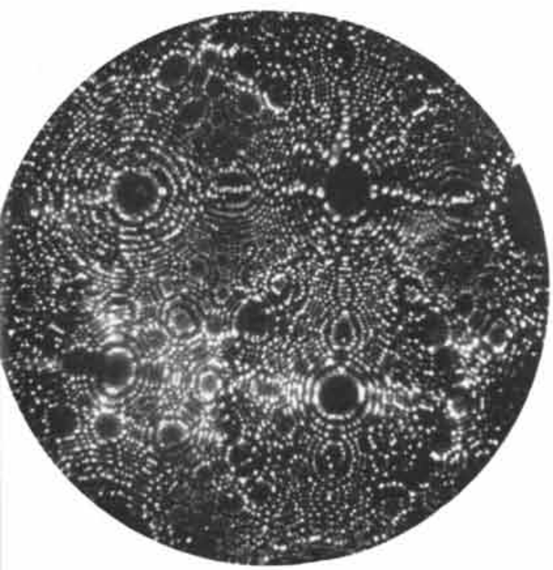
RHENIUM NEEDLE TIP is shown in these field ion microscope pictures. The three pictures show successive stages in the evaporation of rhenium atoms from the surface of the needle under the influence of the electric field; as the evaporation proceeds, the



tion. At right is a field ion picture of a tungsten needle tip (radius: 160 Angstroms).

tip. We can study ideal surfaces and experimentally faulted ones in their pristine state.

Why are the atoms colored in the picture shown on the cover? The coloring is simply a device to highlight atomic alterations of the tip surface. If we want to see the results of treatments of the tip which remove or add a few atoms or shift atoms around, it is helpful to label them with markers. Our problem is like that of an astronomer comparing two photographs of a section of



configuration of the crystal lattice changes. The tip is enlarged some 750,000 diameters.

the sky to find a new or variable star which should be present in the second but not in the first. He must hunt for it among thousands of stars on his plate. Similarly a few new atoms are difficult to find among the thousands of atoms in a photograph of the needle tip. To mark the changes, we developed a technique employing superimposed photographs in different colors. Let us say we wish to submit the needle tip to a treatment which will deposit a few atoms on the tip and remove a few. We photograph the black-and-white picture of the tip made before the treatment in green light, and the post-treatment picture in red light. Now we superimpose the red print on the green and make a color photograph of the composite picture with a conventional camera. Wherever the positions of the atoms are unchanged, the atoms will look yellow—the sum of red and green. Where we see green dots, these must mark atoms which were present in the first picture but were removed before the second. Red dots, on the other hand, mark atoms recorded only in the second picture—*i.e.*, new atoms added to the tip surface by the experimental treatment.

By this means we not only can see atomic changes on the surface of the metallic tip but also can determine some properties of the atoms involved. For instance, the strength of the voltage used to evaporate atoms from the tip tells us what the binding energy of the green (*i.e.*, removed) atoms was.

The technique now permits us to study metals at the atomic level with a precision never before possible. Bombarding a sample with fast ions or neutrons from a nuclear reactor, we can see the effect of the impact of a single particle on the structure of the crystal lattice. We can investigate the atomic details of dislocations or faults in the metal and can observe the results of treatments such as annealing. We may even be able to unveil some of the mysteries of the action of catalysts.

So far we have obtained good images only of metals such as tungsten, rhenium, tantalum and molybdenum and some of their highly refractory alloys—carbides and nitrides. The technique at present is limited to the very hard metals. But they may serve as models to yield information about the softer metals. It has always been the belief of physicists that the behavior of "simple cases" such as an ideally perfect surface can give insight into the ordinary—and more complex—systems with which we have to deal in everyday technology.

in the **Cement Industry**

Expenditure of $8,800

Indefinitely !

One of many maintenance savings made by the Huron Portland Cement Company with the help of Socony Mobil

Located at Alpena, Michigan, is the world's largest single cement plant. To assure its continuous operation at minimum maintenance cost, Huron Portland Cement Company relies on a Socony Mobil Program of Correct Lubrication. Here's an example of this comprehensive service in action:

Problem: Pinion gears on four kilns were wearing excessively . . . so also were the huge girth gears. In time, girth-gear teeth became so roughened that new pinion gears would be quickly damaged when installed. How to avoid the costly job of replacing the girth gears was the problem facing the Company.

Solution: After consultation with Huron Portland personnel, Mobil engineers recommended a special Mobil lubricant compound that cut wear on pinion gears . . . at the same time helped smooth up the girth-gear teeth. Result—girth-gear life was extended indefinitely . . . $8,800 saved on just one kiln.

Service like this has helped this cement company continually improve profits through increased production . . . reduced maintenance costs. Perhaps it can do the same for your plant.

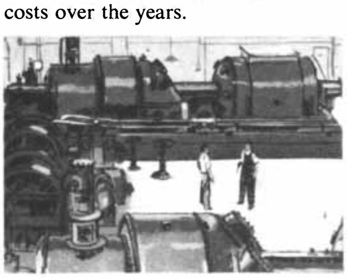
Other ways Mobil Correct Lubrication cut costs

Exceptionally long product life—4 Allis-Chalmers generators supply power for entire Huron Portland Cement plant. Same fill of Mobil D.T.E. oil has been in continuous use in one of these generators for over ten years. Units have not shut down once due to lubrication failure. In fact, latest samples show oil to be in "like new" condition . . . good for many more years.

Gear maintenance cost cut—Mobil engineers surveyed planetary-type gear sets that drive mills, kilns and other machinery. As a result, they recommended a single wide-range lubricant in place of three products formerly used. Qualities of this Mobil product eliminated periodic need to clean sludge from gear cases . . . extended oil fill life 100% . . . produced savings in storage and handling.

Engineering assistance cut downtime—Mobil engineers cooperated with Huron Portland in investigating cause of bearing and tooth failures on gear reducers. It was found that gears had been purchased from different suppliers and that tooth sizes varied. Mobil suggested purchasing new gears from one supplier. Mobil engineers also suggested that grooving in pressure area of split-bushing bearings be removed. When this was done, gear reducer trouble ceased . . . downtime was sharply cut.

Complete Mobil service—Supplying Huron Portland with top-quality lubricants is only a part of the comprehensive Mobil program. Mobil field personnel, engineers and sales representatives work closely with Huron Portland's maintenance personnel. They conduct in-plant training courses, make analyses of products in use, submit periodic reports on benefits achieved. No wonder records show a continual reduction in maintenance costs over the years.



Correct Lubrication

A proved program to reduce maintenance costs

SOCONY MOBIL OIL COMPANY, INC., and Affiliates: MAGNOLIA PETROLEUM CO., GENERAL PETROLEUM CORP., MOBIL OVERSEAS OIL CO., INC.

FIRST MESA in Arizona, the site of the coexistence of the Hopi and the Tewa Pueblo Indians, is shown in this aerial photograph. In the foreground is Tewa Village. At the center and far tip of the mesa, respectively, are the Hopi villages of Sichomovi and Walpi.

The Hopi and the Tewa

A tale of two adjacent villages which maintained distinct cultures for two centuries. Then a change in social environment brought them together, demonstrating one way in which minorities are assimilated

by Edward P. Dozier

The problem of the relations between a dominant population and a minority—Negroes, Jews or an immigrant group—is one of the most interesting, as well as one of the most important, in the realm of social science. Sociologists and anthropologists have carried out many and varied studies in efforts to understand the factors that make for assimilation, on the one hand, or separation, on the other [see "The Jewish Community of Rome," by Leslie C. and Stephen P. Dunn; SCIENTIFIC AMERICAN, March]. This article will report a case study of an altogether unique situation. It concerns two groups of Pueblo Indians living side by side in the mesa country of Arizona. Ethnically and in many other ways they are very alike. Yet for more than 200 years they remained aliens in practically the same village. Then, through what might be considered a historical accident, the two groups were rapidly brought together, barriers fell and they began to live in happy harmony.

The groups are the Hopi and a small colony of families descended from Tewa Indians of the Santa Fe area. In 1949-50, as a graduate student in anthropology, I spent a year living with these people, and since then I have been able to revisit them several times, following up the study on foundation grants. To learn anything about their history and culture it was necessary to establish trustful relations with them and assure them that information was sought only to advance scientific knowledge. Unfortunately the sacred and colorful ceremonies of the Pueblo Indians have in the past been made to appear ludicrous in sensational magazine articles; the Indians now prohibit photographs of these events and have closed many of them to white observers.

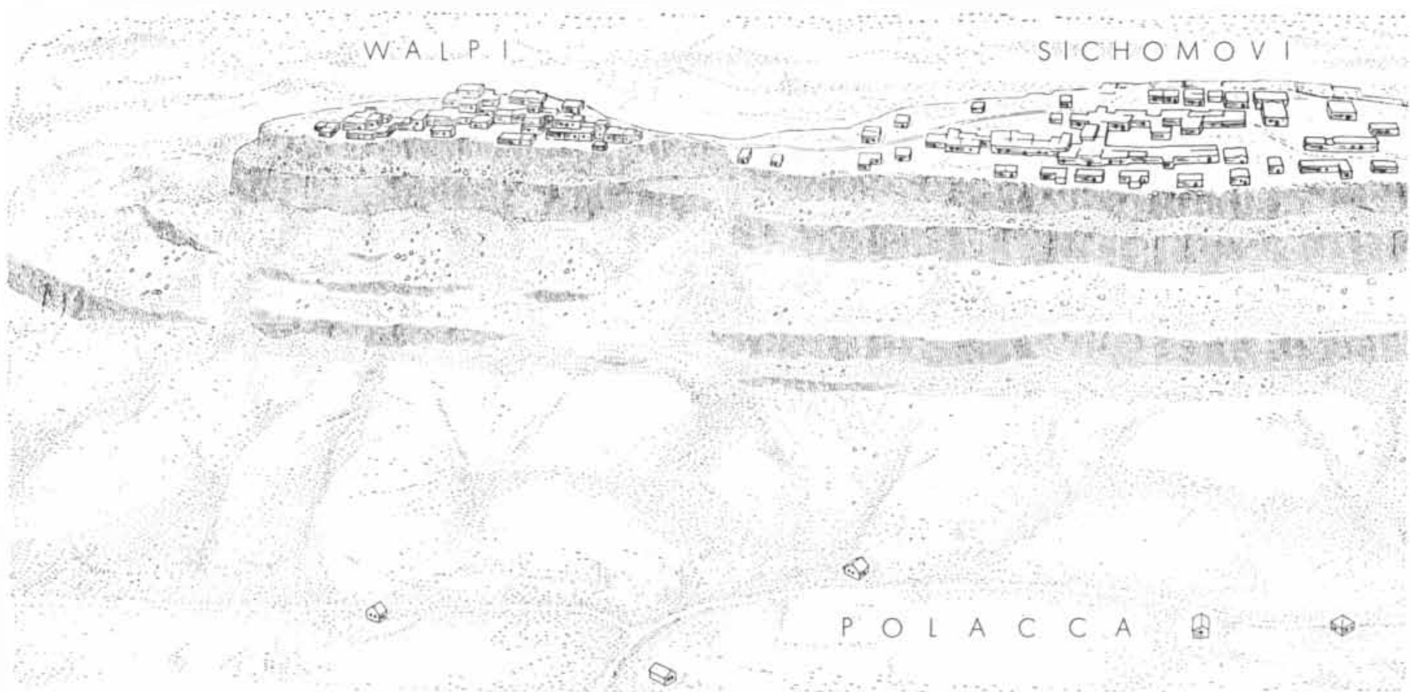
Our story begins with the Spanish occupation of the Southwest in the 16th century. The coming of the Spaniards fell as a catastrophe upon the peaceful Pueblo Indians in the Santa Fe area. The white man's diseases and fanatical attempts to Christianize and "civilize" the Indians took a great toll of the Pueblos' lives. Finally in 1680 the Indians rebelled and drove the Spaniards from Santa Fe.

Among the leaders of the rebellion were a Tewa group who lived in five "pueblos" (towns of mud-walled

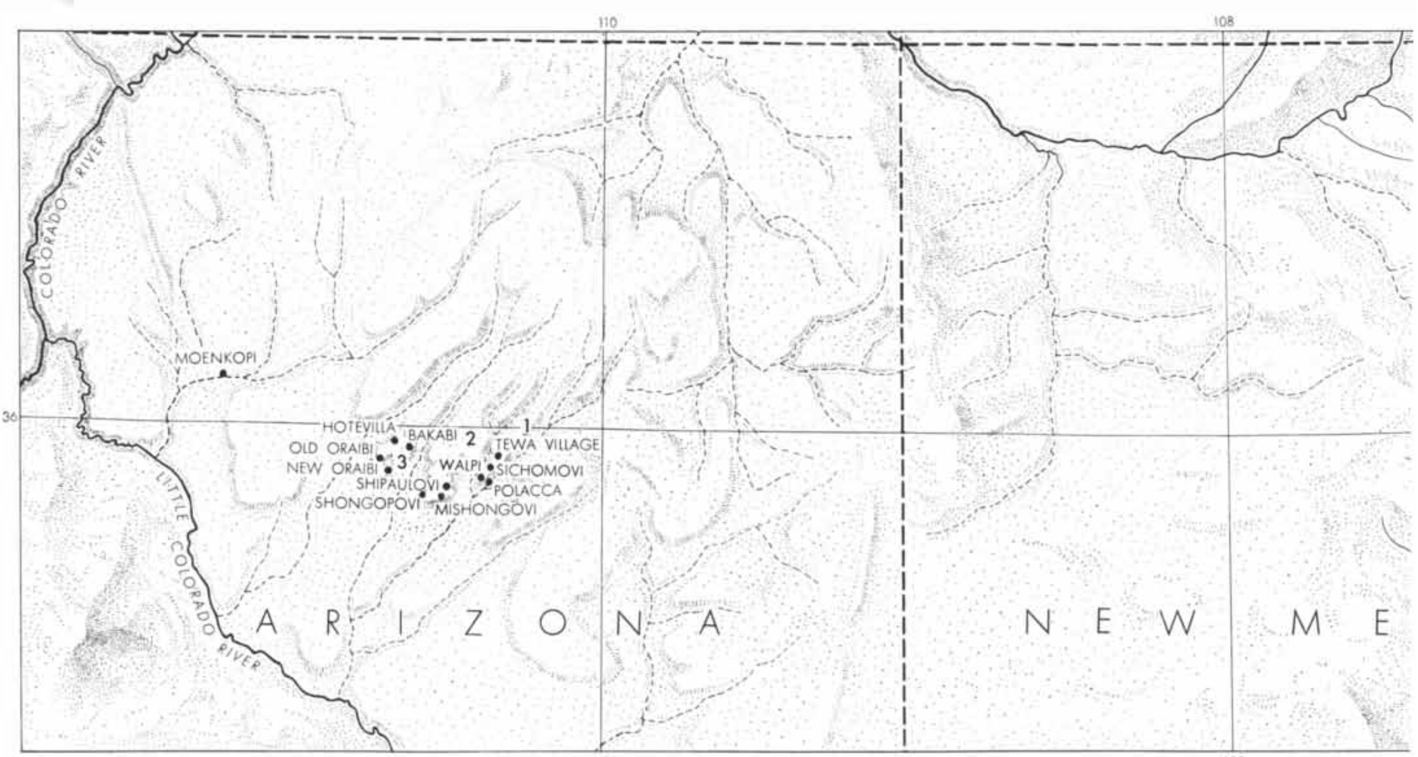
POLACCA VILLAGE at the foot of First Mesa is named for its Tewa founder, Tom Polacca. Modeled on the pattern of the whites' villages, it helped gain Hopi respect for the Tewa.

houses) south and east of Santa Fe. They had numbered some 4,000; now they were reduced to less than 1,000. When the Spaniards were driven out, these people moved into Santa Fe. But 13 years later Don Diego de Vargas returned with a well-armed Spanish force and quickly subdued them. Most of the Tewa in the town were taken as slaves; a few hundred resettled in a village north of Santa Fe. Three years later these Tewa, still rebellious and suffering repeated Spanish punitive expeditions, made a final raid on the city, killed their Catholic missionary and fled 400 miles west to the mesa country of the Hopi Indians.

The 200 men, women and children who made the journey did not find the bounteous welcome they had expected. According to a legend which their de-

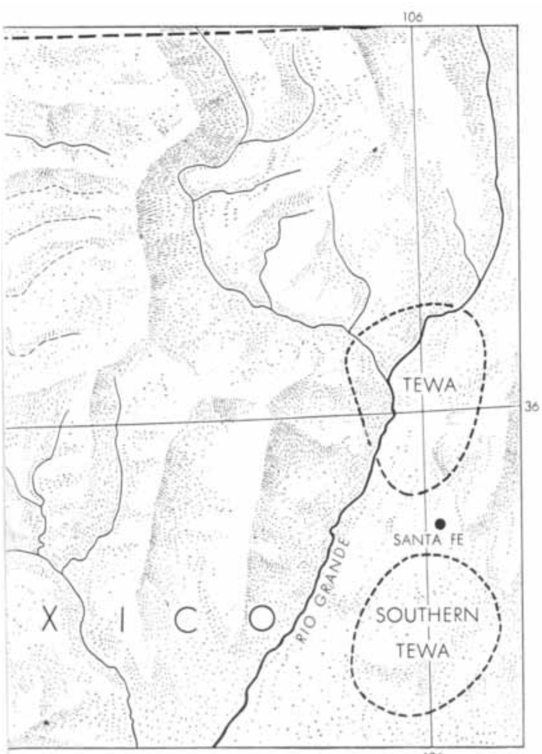


FIRST MESA COMMUNITIES are represented here as they are seen from the east. Though Sichomovi and Tewa Village are architecturally identical, and to all appearances are joined on the mesa, the unmarked border between the villages was well established in



LAND OF THE PUEBLO INDIANS is shown in this map. South of Santa Fe (*right*) is the original home of the Tewa who migrated to Hopi territory (*left*). These people are now called the Southern Tewa. The area north of Santa Fe is still inhabited by a Tewa scendants have kept alive from generation to generation, Hopi chiefs had repeatedly invited the Tewa to come, promising them land, food, sexual privileges with the Hopi women and assistance in settling in a permanent home. These inducements were offered be-

the minds of the two Indian groups during the 200-year period of mutual hostility.



group. The numbers 1, 2 and 3 at left represent the First, Second and Third mesas.

TEWA WOMAN clad in traditional garments stands before a *kiva*, the meeting place of secret religious societies, in Tewa Village. Such clothes are worn only on festive occasions.

cause the Hopi needed the doughty Tewa as warriors to drive off their enemies. But after the Tewa had performed this service, says the legend, the Hopi failed to make good their promises, and the Tewa received only a meager village site at the end of a mesa (a flat-topped finger of land bordered by ravines). The Tewa responded by putting a "curse" upon the Hopi. They dug a pit between their village and the neighboring Hopi one, made the Hopi spit into the pit, then spat upon the spittle of the Hopi and filled the pit with earth. This action was intended to seal the Tewa culture forever from appropriation by the Hopi.

Whether or not this legend is literally true, it has been effective in keeping the two peoples separate for hundreds of years. It has reinforced basic psychological and social factors which operated against assimilation.

First, and perhaps most important, the Tewa were a small but proud minority—only about 200 against several thousand Hopi. They refused to be assimilated; the passive Hopi, on the other hand, made no effort to impose their language or customs on the handful of militarily useful newcomers.

Secondly, while the two peoples were alike in many respects—both of them Pueblo Indian tribes of farmers at about the same technological level and with much the same ceremonial forms—they were temperamentally very different. The Tewa had come from a border region where they had constantly had to defend themselves against the Plains Indians and later against the Spaniards. They had lived in a country of rivers—the Rio Grande and its tributaries—in which it was possible to work with nature to irrigate their crops. They had been exposed to a century of Spanish example in asserting control over the environment. As a result the Tewa had developed a high measure of active self-reliance.

The Hopi, in contrast, lived in a region where men easily persuaded themselves that there was little they could do about the environment. In the mesa country there were no streams, and agriculture was at the mercy of the weather. They planted maize, beans and melons in the flat washes below their mesas—a

series of finger-like projections at the southern end of the great Black Mesa which runs north almost into Utah. When too little rain fell, their plants withered and died in the hot sun; when it poured, raging floods uprooted the plants and washed them away. Thus weather was the most important concern of the Hopi, and it shaped their attitude toward nature and human existence.

The contrasting attitudes of the Tewa and the Hopi are expressed in their religious beliefs and practices. The Tewa religion has its share of magical concepts, but they fortify their appeals to magic with practical steps. Their medicine men not only perform magical rites but also administer medicinal herbs, massage and treatments for the injured: they are expert in setting broken bones. Their songs and dances exalt warrior prowess. When enemies threatened in the past, they formed war parties to meet them. In any crisis the Tewa offer prayers and then take action.

In the Hopi religion the dominant theme is reliance on the mystical forces which are believed to control the weather and natural environment. Elaborate ceremonies have been developed to coax these powers to favor the petitioners with bountiful harvests. The Hopi believe that if their rites and ceremonies are properly and regularly performed with a "good heart," there will always be enough to eat and everyone will be healthy. They depend upon the magical powers not only to provide rain for their crops but also to thwart sickness and ward off their enemies; rather than take up arms against attackers they appeal to the deities to deflect or immobilize the enemy. The deities believed to control the destinies of men are a group of vaguely conceived ancestral gods called the *katcina*. In the Hopi ceremonies men dressed in elaborate masked costumes represent these gods. The Hopi also carve dolls in the likeness of the deities and give them to young girls as fertility symbols. At regular intervals during the year the members of secret fraternal organizations go into retreats and emerge to perform rites to propitiate the gods. One of these ceremonies is the annual Snake Dance performed by the Hopi Snake Society.

The religious differences between the Tewa and the Hopi clearly illustrate the nature of the two peoples—the one aggressive and self-reliant, the other passive and mystical. From the start their incompatibility of outlook, together with the Tewa's resentment as an unhonored minority, made them hostile neighbors. The Hopi feared and disliked their protectors; the Tewa responded with aloofness and contempt.

The Tewa took up residence on what is known as the First Mesa. Their village, which the Tewa call Tewa and the Hopi call Hano, adjoins a Hopi village named Sichomovi. Thus the Tewa live literally next door to the Hopi. Their houses are indistinguishable; Tewa Village has all the appearances of a typical Hopi town. But for more than 250 years both groups have been keenly aware of a sharp boundary separating the two villages.

The sharpest division is in language. With constant invocation of the curse against transmission of their culture and secrets to the Hopi, the Tewa have restricted their language to their own group. Even when a Hopi marries a Tewa, the Hopi spouse does not learn the Tewa language. The Tewa, on the other hand, do speak Hopi: to maintain necessary communication they have become bilingual. Yet they have succeeded in defending their own language so well that only a single Hopi term has crept into the Tewa language in two and a half centuries. And this word has gained only a partial entry. It is the expression for "thank you": the Tewa men now use the Hopi term for "thank you," but the Tewa women still use the Tewa term.

The Tewa have borrowed a major social institution from the Hopi; it is, however, an institution which serves to preserve their exclusiveness. This acquisition is the Hopi system of maternal descent. In the Tewa village, as among the Hopi, women are the important members of the family. They own the land and houses, dispense the food and make the important decisions. The men perform religious rites, exercise disciplinary powers, support the family and teach the children how to "make a living," but they have little authority in the home. Residence and the family allegiance belong strictly to the mother. When a man marries, he goes to live in his wife's house, but he frequently visits his mother's house and considers that his home.

It is clear that this system supports the Tewa determination to maintain their own culture. A Tewa household is impervious to Hopi influence, even in cases of intermarriage. The Hopi husband would find it extremely difficult to impose Hopi values and customs on his children, even if he were disposed to do so. Any attempt at such subversion would be countered by the mother's au-

...and one for the pot!

Witches of old brewed heroic broths to encourage visions, prognostications, spells, and spasms. Even unrequited love yielded to these near-lethal potions. Add the tail of a cat, the ear of a rabbit, sixteen varieties of tree roots, and a few "trigger" ingredients, known only to the witches guild . . . and stand back!

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thority and by reminders of the curse.

The Tewa have maintained an important difference in social organization from their neighbors. A Hopi village is a loose aggregation of clans. The maternal clans are virtually autonomous units. Once a year the clan heads meet to discuss the welfare of the village, but by and large ceremonial and political activities are controlled by the individual clans. The Tewa village, on the other hand, has a centralized organization. It is divided into two general units. The members of one group are called "winter people," of the other, "summer people." Every child is initiated into one of the two groups between the ages of six and 10. Each group has its own *kiva* (ceremonial house) and its own chief. The two chiefs cooperate in conducting the village's ceremonial and governmental activities, and each has certain special responsibilities for one half of the year. The general form of this organization is characteristic of all Tewa pueblos in New Mexico, and the Tewa who came to live on the First Mesa in Arizona have retained its major outlines.

For two centuries the Tewa and Hopi villages, despite their physical proximity, remained separate social islands. Intermarriage was discouraged or forbidden. The Tewa population continued to be a small minority: it still numbered only 200. The Hopi tolerated this independent group as mercenaries who performed useful functions as protectors and go-betweens in their relations with outsiders. They turned over to the Tewa the handling of all their relations with other Indian tribes and with the white authorities, but the Hopi looked down upon these functions as work suitable only for inferiors.

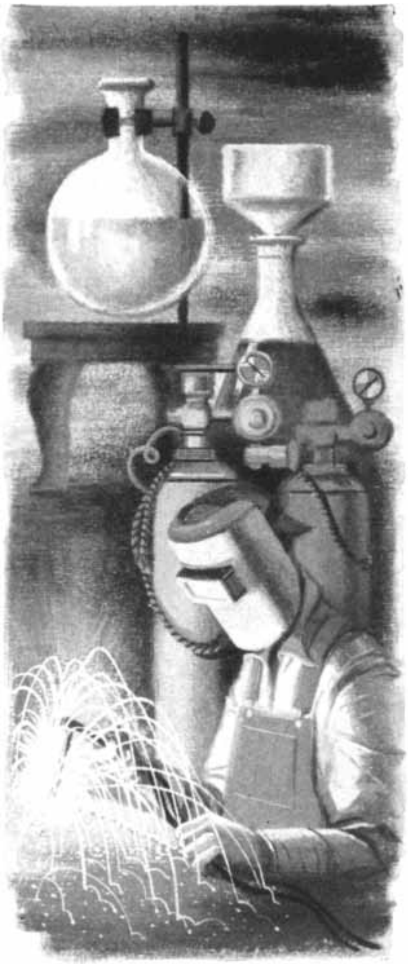
This state of arm's-length separation might have continued indefinitely if whites had not begun to move into the mesa country of the Hopis toward the end of the last century. The new white settlers had no intention of introducing social changes among the Indians; indeed, they were probably unaware of the differences between the Hopi and the Tewa. But their coming brought a change in cultural climate which had a subtle and powerful effect upon the Indian community.

The Tewa suddenly found themselves in a situation in which their qualities were highly valued. The white scheme of values favored the practical and aggressive spirit over the mystical. The practical Tewa readily and enthusiastically took to stock-raising, wagework and the white man's schools. Their chil-

DIDYMIUM

A plentiful and economical rare earth mixture

a report by LINDSAY



You have often watched a welder at work, watched briefly that is, because the intense glare, even at a safe distance, forced you to turn your eyes away. And you wondered perhaps how it is that a welder, even with protective goggles, can focus his eyes on a welding spot for minutes at a time.

The secret, of course, is *Didymium*. The lenses in the welder's goggles, and in the glass blower's goggles, too, are made with didymium which completely absorbs yellow sodium light, thereby reducing glare and eye fatigue.

WHAT IS DIDYMIUM?

In 1842, a European chemist named Mosander separated from a crude rare earth mixture some material he called "didymium." He thought it was a new element. Actually it was a mixture of rare earths predominantly neodymium and praseodymium. Classically, didymium means a mixture of Nd and Pr. However, commercially, the name didymium is restricted to the cerium-free group of rare earths extracted from monazite ore, since the composition of the mixture is reasonably constant.

Didymium is the basic material from which all the other rare earths except cerium are produced. Lindsay produces didymium in various forms for different applications. For example:

Didymium Carbonate—pink powder, insoluble in water, soluble in acids.

Didymium Oxide—brown powder, insoluble in alkalis, soluble in acids.

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Sm_2O_3	4%
Other rare earths and yttrium oxides	2%

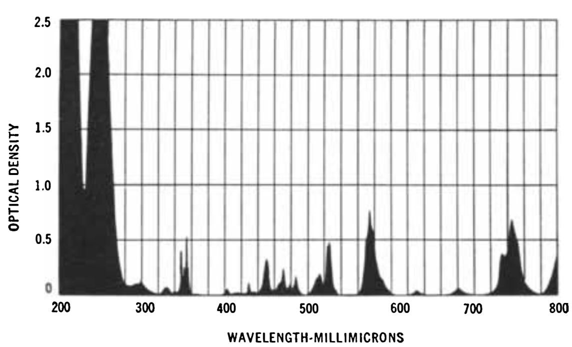
Didymium is one of the most economical forms of rare earth mixtures and is available for prompt shipments in carload quantities. It is useful for the coloring characteristics of Nd and Pr and for some of the other rare earth properties where purity is of secondary importance.

In addition to its extensive application in the production of lenses for welders' and glass blowers' goggles, didymium has other important uses. In coloring and decolorizing of glass. As a porcelain coloring agent. In light filters for calibration of instruments. To control the temperature coefficient of capacitance in barium-titanate ceramic condensers for radio and electronic use (U.S. Pat. 2,398,008). In stainless steels which are forged hot (U.S. Pat. 2,553,330).

We'd like to tempt you to investigate didymium and other rare earth salts as possible materials for use in your chemical and manufacturing processes. The very fact that important companies in a wide cross-section of industry, through their own research, have discovered profitable applications for the rare earths may intrigue your own research people.

We can be helpful to you and will be pleased to supply any information we can. Please keep in mind that we produce rare earths in purities up to 99.9% and higher in some cases (which is an achievement in itself). Shipments, depending on the salts you may need, can be made to fit your schedules in quantities from a gram to a carload.

Absorption Spectrum of **DIDYMIUM CHLORIDE SOLUTION** *from monazite containing 1 g. rare earth oxide/100 ml. compared with water in 5 cm. cells*



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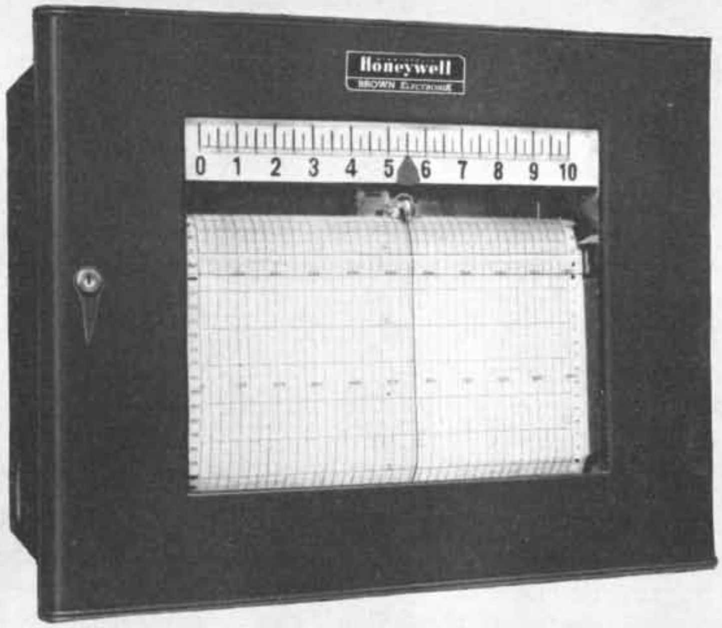
dren, already trained in two languages, learned English more quickly than the Hopi's. Moreover, their higher ardor as a minority spurred them to excel in the classroom. They became models for the Hopi children.

The Hopi began to develop a new respect for the Tewa. The Tewa's role as emissaries and interpreters to the white people grew in importance and prestige. Their value orientation, remarkably like that of the new white residents, no longer had to take a back seat. The Hopi saw that "it paid to be like the whites." They were greatly impressed by the achievements of some of the Tewa in this new climate. One of these was Tom Polacca, an interpreter who spoke five languages (Tewa, Hopi, Navaho, Spanish and English) and had been a leader in contacts with the U. S. Indian Service and other outsiders. He became a prosperous livestock raiser, built a large house below the First Mesa and started a new community which is now named Polacca Village. Equally impressive were the accomplishments of a Tewa woman named Nampeyo. She revived the art of pottery-making, copying old designs exacavated from Indian ruins in the area, and this quickly became an important industry, not only among the Tewa but also among the Hopi villagers.

With remarkable speed the antagonism and distinctions between the Hopi and Tewa began to disappear. The Tewa were accepted as "equals" and shed their onus as a minority. Their population grew: it has doubled in the past half-century. Intermarriage became common. The Hopi and Tewa worked together in pottery manufacture, in cattle cooperatives and even in religious rituals and ceremonies. The ancient legend that had divided the groups faded in influence, and social differences began to disappear. Curiously the Tewa have remained clannish about their language, but since they are equally fluent in Hopi, there are no barriers to communication.

Today hostility between the two groups has virtually disappeared. Only the old men try to keep alive the ancient Hopi "injustices," but the young people tend to laugh off their admonitions and bury the memory of the "curse."

The history of this little episode in human relations may hold some useful lessons. Social scientists differ on the possibility of manipulating human societies to desired ends, but one may hope that case studies such as this one will help mankind to find cures for groups in conflict and trouble.



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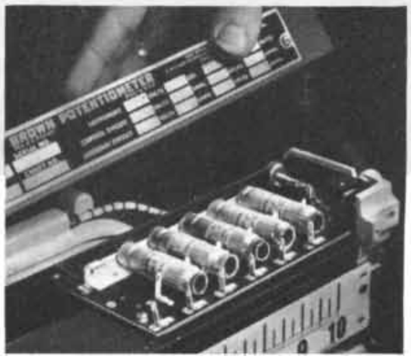

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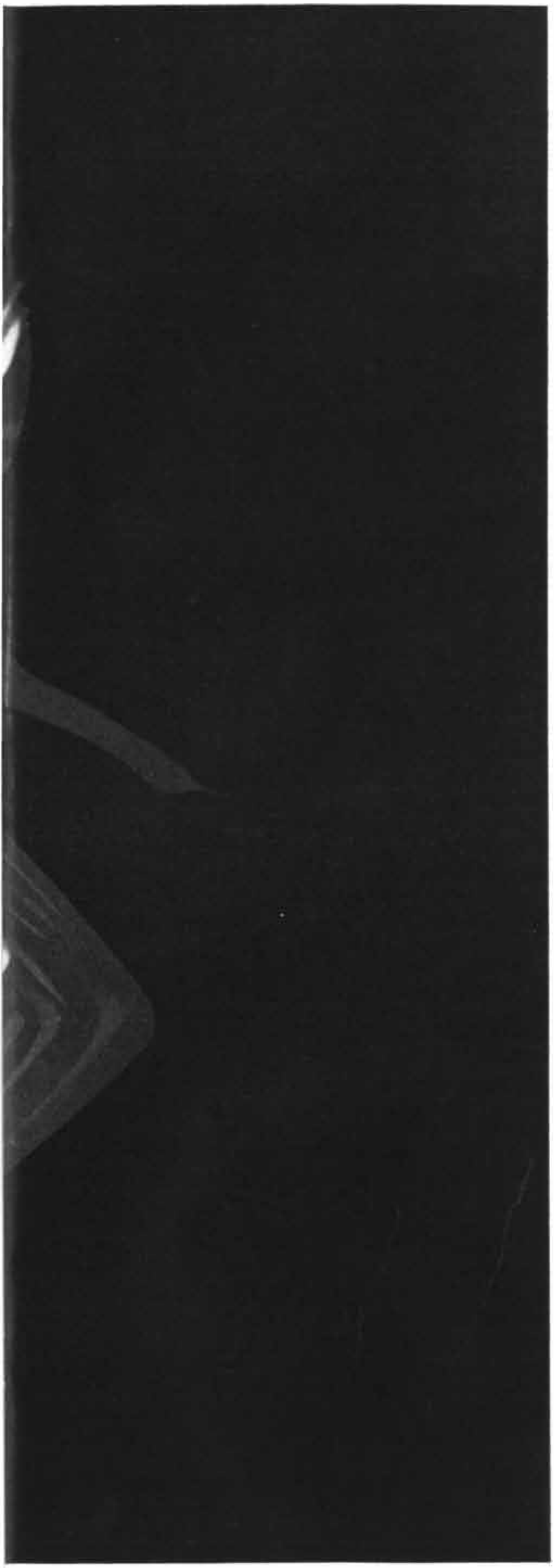
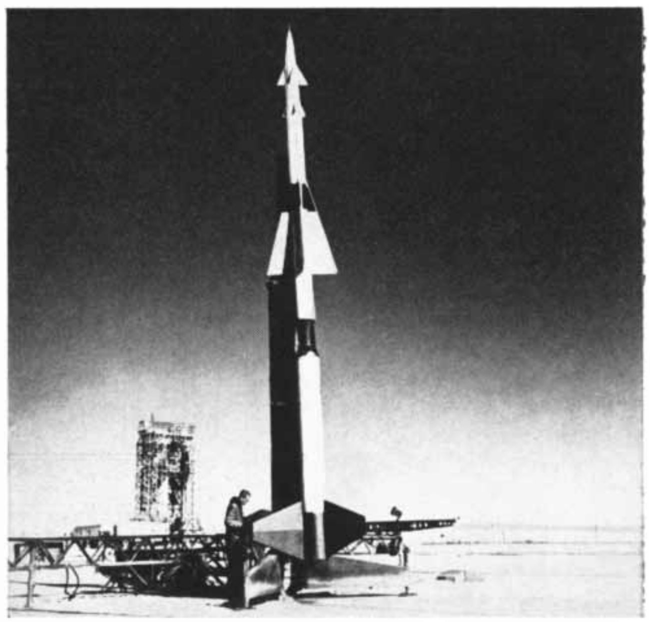




THE EVOLUTION OF MIND

An essay, based on some classic observations of experimental psychology, on how the intelligence of man basically differs from the mental capacity of animals from ants to chimpanzees

by Norman L. Munn

No one has ever seen a mind. A surgeon cutting into the brain sees only nerves and blood vessels; to learn what is going on in the brain he must ask the patient. An electroencephalogram (recording of brain waves) can show whether the brain is thinking, but it tells nothing about what is being thought. Only through communication, language, can we get any sort of direct picture of the workings of the mind. We are therefore under a certain basic handicap in attempting to fathom the mental life of animals below man.

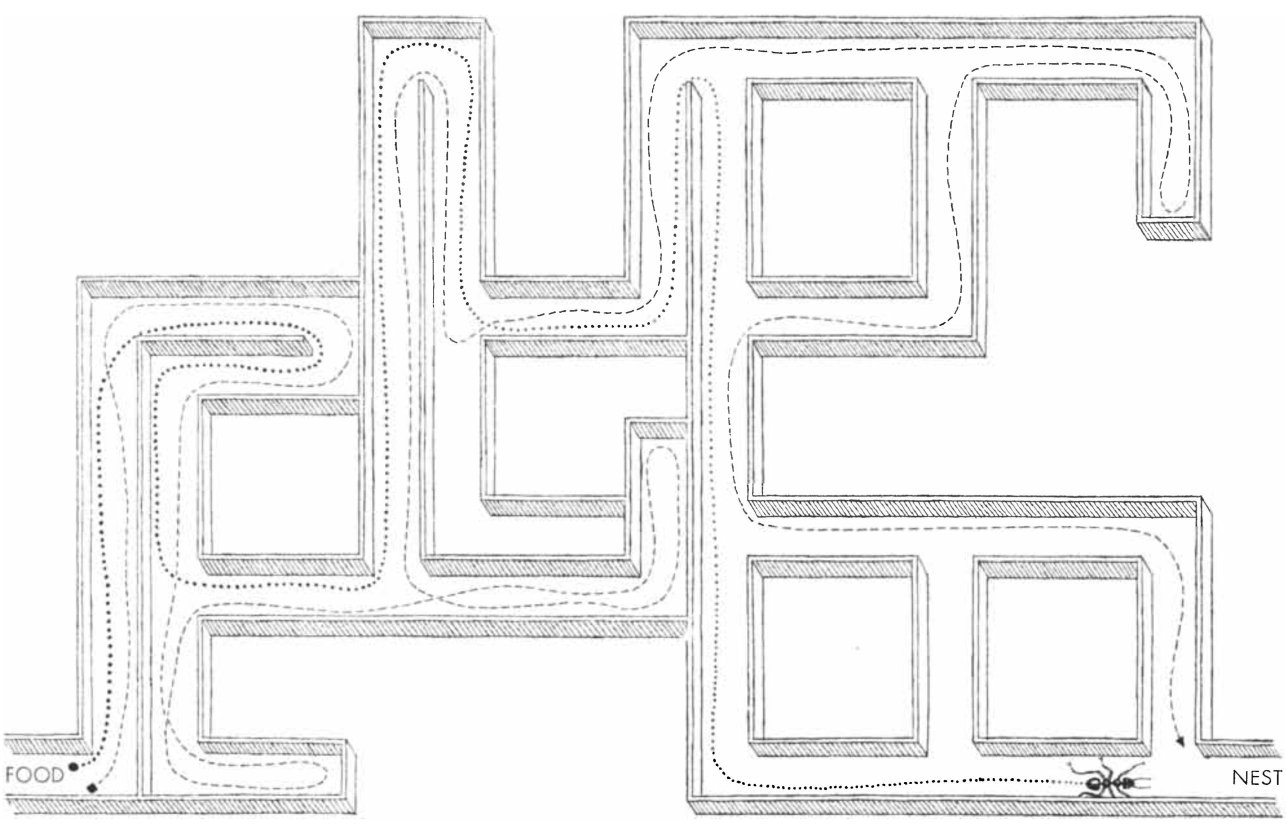
There is an ancient Chinese story which illustrates the ingenuous human attitude in this matter. It runs:

Chuang Tzu and Hui Tzu were standing on the bridge across the Hao River. Chuang Tzu said, "Look how the minnows are shooting to and fro! How joyful they are!"

"You are not a fish," said Hui Tzu. "How can you know that the fishes are joyful?"

"You are not I," answered Chuang Tzu. "How can you know I do not know about the joy of the fishes? . . . I know it from my own joy of the water."

Modern psychology does its best to suppress the intuitive, or anthropomorphic, approach and seeks to find out how an animal's mind works by studying its behavior. As everyone knows, there has been a vast amount of experimental



ANT learned the shortest route to its nest in an experiment devised by T. C. Schneirla. The thin broken line traces the route of the ant on an early trial; the route is full of errors. The dotted line traces the correct route, which the ant learned after many trials.

work on animals of all sorts, testing their responses in controlled situations to learn about their mental processes. My purpose is to review some of these experiments and see what light they shed on the evolution of the mind.

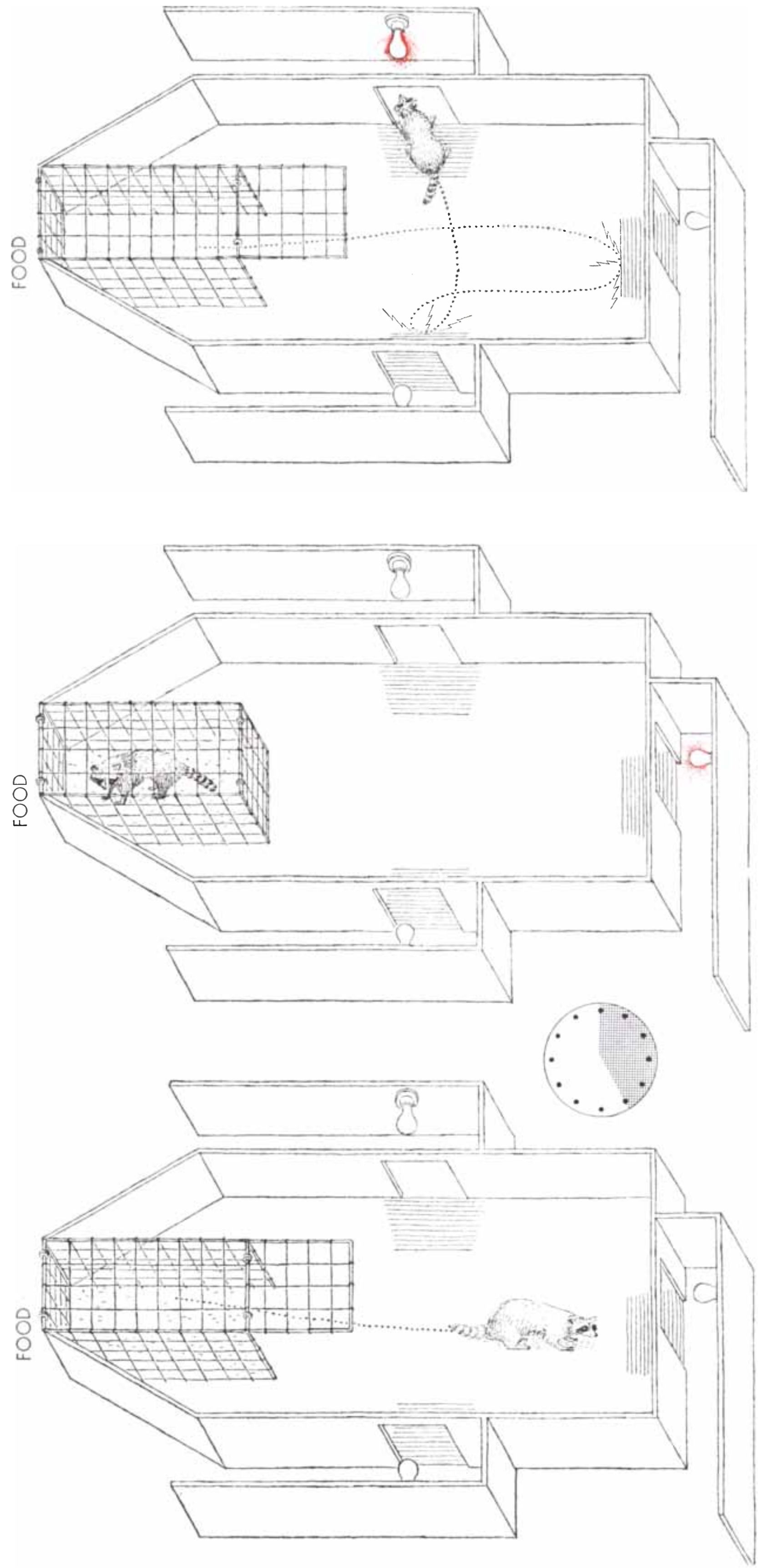
Here is an ant. It exhibits an extremely complex pattern of behavior. Does this signify intelligence or is the behavior purely automatic? We observe, for example, that the animal attacks every foreign ant that enters its territory. Does it recognize the newcomer as a stranger and anticipate a potential danger to its own group? Or is it merely reacting automatically to a strange odor from the newcomer? As a test we extract some juice from a strange ant and smear a little of it on a member of the ant nest. When the ant returns to its own nest, its nest-mates become greatly excited; they quickly attack and kill it. No, in this respect the ants are not acting with intelligence but simply as automatons, responding blindly to an odor in accordance with mechanisms which nature has built into them.

Nevertheless ants are capable of learning: their behavior can be modified. If we had enough patience, we might even teach them not to attack ants with a strange odor. T. C. Schneirla, the well-known student of ant behavior, found that ants could master a maze test, learning to avoid blind alleys and get home without error [*see diagram on opposite page*].

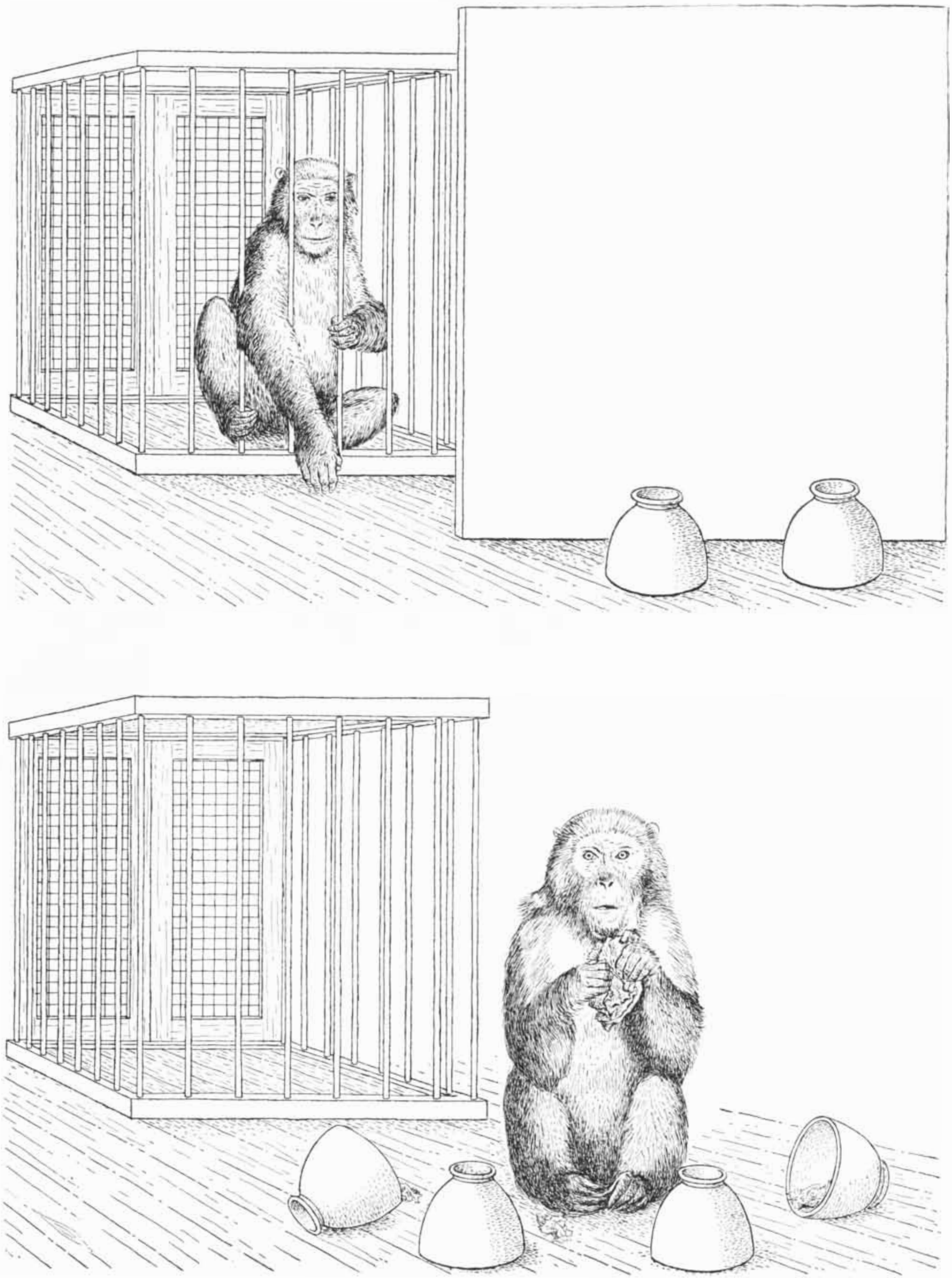
Learning of all sorts of mazes by many different animals at various levels of evolution has demonstrated that practically all animals are modifiable to some degree. There is a fairly regular sequence of ability; as we go up the scale, we find the higher forms learning faster and mastering more complex mazes. The ant is rather far up the ladder.

When we get to the mammals, the maze becomes an inadequate test of intelligence. The learning problem (making the proper turns in the proper sequence) is just too simple. In this sort of learning rats can beat college students, and have done so repeatedly. So it is apparent that at the rat level and above we must make our tests more subtle, because new mental abilities beyond sheer modifiability begin to emerge.

The first of these is the ability to think of something in its absence—that is, to represent or symbolize a stimulus which was present but is now gone. This capacity is usually examined by a delayed-reaction test. In one such test the animal is released in a room with three identical



RACCOON learns that if it goes to a lighted door, it can go through a passage to food; if it goes to an unlighted door, it receives an electric shock (*top*). A light is then turned on (*middle*) and turned off. Twenty-five seconds later the animal goes to the right door (*bottom*).



MONKEY remembers under which of two cups a piece of lettuce was placed, in some cases even after the cups have been concealed by a screen for 24 hours (*top*). The monkey can also remember under which two of four cups two pieces of lettuce have been placed.

exit doors. The animal first learns that if it goes to the door where an electric bulb is lighted (any one of the three may be turned on), it can go through to a passage to food; if it goes to either of the other doors, it receives a shock from an electric grid. After the animal has learned to choose the lighted door every time, it is given the delayed-reaction test. The subject sees the light at a certain door; then the light is turned off and the animal is held in the restraining cage for a certain interval before it is released. How good is it at remembering where the light was? A rat or a dog will go to the correct door—so long as it is allowed to point its head toward this door while it is waiting, and can follow its nose straight to the door after it is released. But if we turn the animal around, so that it loses its muscular cues, the rat or dog cannot remember the position of the light.

However, a raccoon, comparatively a very wise animal, passes this test with flying colors. It does not need to point: it will pace up and down in its restraining cage until released and then go directly to the door where the light was. Something other than muscular tensions, something in the raccoon's nervous system, must represent the absent light. This memory in the raccoon case lasts for about 25 seconds.

Experiments in which parts of the brain of an animal are removed clearly show that this something involves the brain's frontal lobes. If both of the frontal lobes are removed or damaged, the animal fails in the delayed-reaction test. But lesions in other areas of the brain do not seriously impair performance on the test.

As we ascend the scale from rat to man, animals are able to perform delayed responses of increasing complexity. A monkey, for instance, can make a delayed choice correctly without preliminary training. Directing the monkey's attention to a pair of inverted cups, we slip a piece of lettuce under one of them and then hide the cups with a screen or take the monkey for a walk. After a certain interval the animal is allowed to go to the cups; he gets the lettuce only if he turns over the correct one. He must remember whether the lettuce was placed under the cup on the right or the left (he gets no help from the odor because both cups were smeared with lettuce juice). Some monkeys can remember the correct cup consistently even after a delay of 24 hours.

Now we make the problem more complicated by presenting several pairs of cups and placing food under one cup of each pair—either the right or the left at random. The animal, after the delay, is released to go from pair to pair, selecting the food cup in each. Monkeys and chimpanzees were compared on this test. The chimpanzees of course far surpassed the monkeys, both in accuracy and in span of memory.

The most interesting thing about this experiment is that the monkeys and chimpanzees remember not only *where* the food is hidden but also *what* was put under the cup. If we put a banana beneath a cup and then surreptitiously replace it with lettuce during the delay interval, the animal, upon picking up the cup and finding lettuce where he expected banana, will hunt around for the missing banana and may have a temper tantrum.

The ability to represent or symbolize an experience when the stimulus is absent is an extremely important step in mental evolution: it prepares the way for understanding and thinking. Once the brain can *think of* an object or event, it can begin to put two and two together, to solve problems by reasoning instead of by overt trial and error.

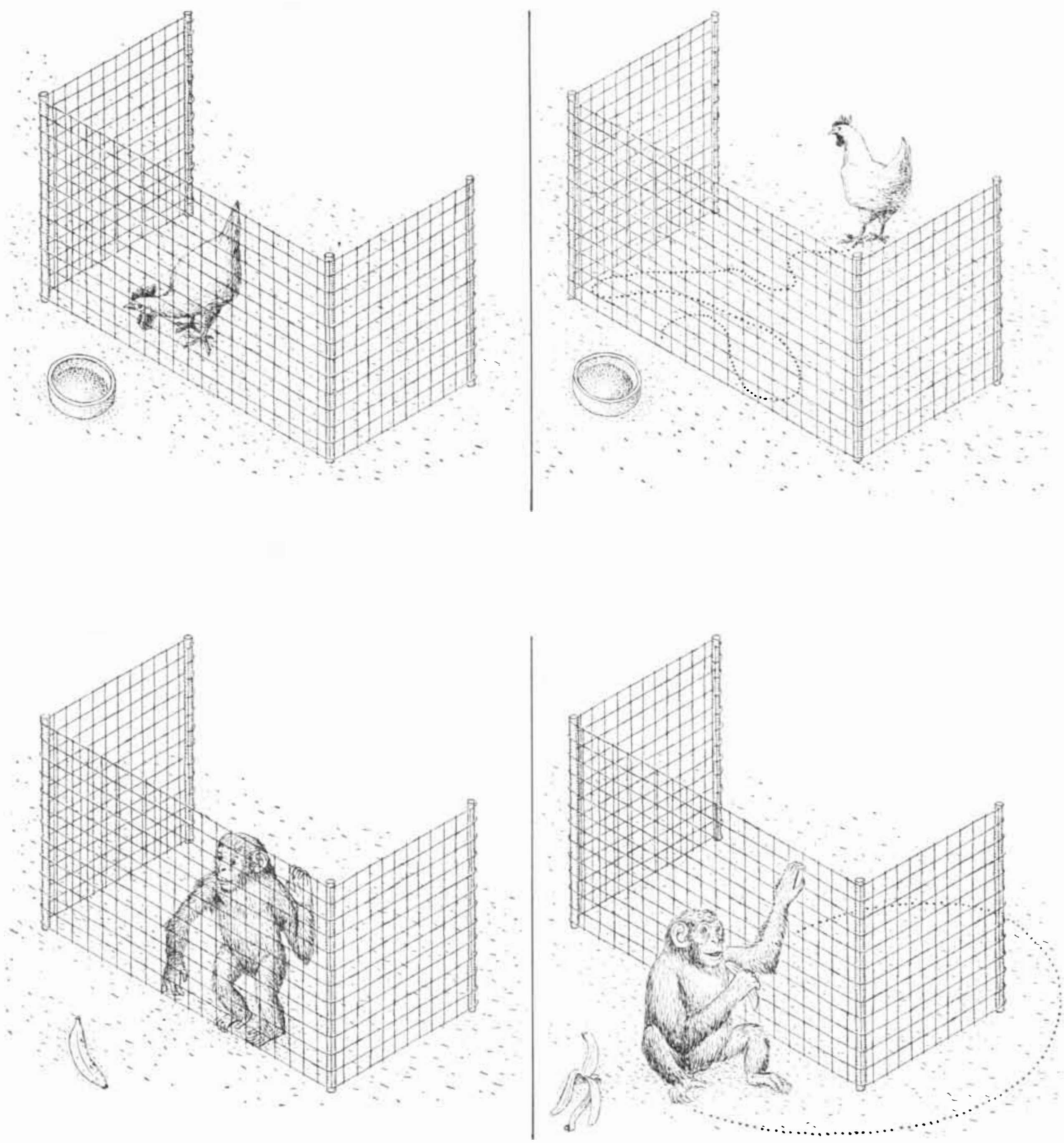
Here is a test which illustrates the point. The animal is placed behind a wire mesh or glass screen through which it can see a dish of food on the other side [*illustration on next page*]. To reach the food it must go around the barrier. A chicken or a rat, put to this test, fails to understand the situation: it will claw at the barrier again and again in an effort to get at the food. Finally it begins to run about at random and may accidentally come upon the food. If we now put the animal back behind the screen, it will repeat its attacks on the screen but this time will give them up sooner and find the food in less time than before. After several trials, the animal eventually learns to run immediately around the barrier to the food.

A monkey or a chimpanzee, on the other hand, quickly sizes up the situation. It goes around the barrier to the food without delay and without false moves. A primate can work out the situation implicitly within the brain: it can put two and two together and observe what leads to what. That is to say, it learns by observing as well as by acting. These close relatives of ours have what Wolfgang Köhler, the famous Gestalt psychologist, calls insight.

The extent of their insight must be tested with more complex problems. A banana is placed high above the head of a chimpanzee in a cage. Various possible aids to reaching the banana are present—sticks, boxes, a hanging rope. Is a chimpanzee capable of inventive use of them? Indeed it is. Chimpanzees have been known to stack boxes and climb up on them, to use a long stick much as a pole-vaulter does, to reach the banana by swinging on a rope Tarzan fashion, even to insert one bamboo pole into the end of another to make a stick long enough to reach the food. They have been known to lick a piece of straw so that ants will stick to it and then lay it on the ground, wait till the insects have swarmed over it and lick off the captured ants.

Sometimes chimps even outsmart the professor. Robert M. Yerkes liked to tell about the chimp to whom he presented a problem which he thought had just three solutions, only to have the animal solve it by a fourth way which had never occurred to the professor. Köhler describes a similar experience. He had provided some boxes and various other objects by which a chimpanzee might reach a banana hung nine feet high. But the chimp, after looking over the situation, took Köhler by the hand, led him to a position beneath the banana and scrambled up on the professor's shoulders to grab the banana!

Let us proceed to a more subtle problem, devised by the late Walter S. Hunter. It is a maze, but of a very sophisticated type. The apparatus consists of a T-shaped arrangement of alleys [*see diagram on page 148*]. The subject starts at the foot of the T, goes to the head



CHICKEN does not go directly to food behind a wire fence. After trying to reach the food through the fence (*upper left*), it moves about at random and may accidentally find the food (*upper right*). A chimpanzee in the same situation will go directly to the food.

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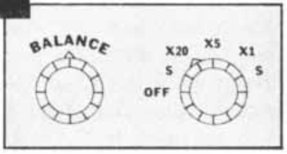

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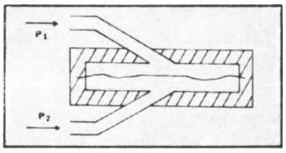
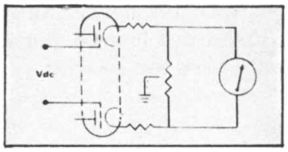
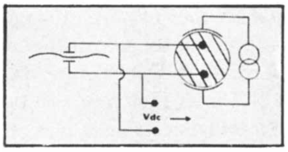


Pressure differential moves beryllium-copper diaphragm.



Output applied to cathode follower to drive meter.



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and, turning either into the right or left arm of the T, returns by a passage to the starting point. Now to win the reward (and avoid electric shocks for making the wrong turns), the subject must go through the run four times, making a right turn at the head of the T the first time around, another right turn on the second trip, a left turn on the third trip and another left turn on the fourth trip. In other words, the animal has to learn that the correct sequence is right, right, left, left. There are no light cues, no muscle cues, no signs of any kind to tell him what the proper sequence may be. In a sense the animal must learn what *principle* is in the experimenter's mind. He must figure this out by implicit processes in the brain, using symbols to represent the "trials."

On this test a rat fails completely. Even after 2,000 trials it still has only a chance percentage of successes in its runs. A raccoon or a cat solves the problem in from 500 to 800 trials. A monkey or a chimpanzee learns the correct sequence in 100 trials, more or less.

Since there is nothing in the layout to give the answer by inspection, a human subject has to start out with trials as the lower animals do. But it takes an adult only a few trips to catch on; the subject suddenly exclaims, "Oh, I get it. I'm supposed to go twice to the right and twice to the left." The number of trials an individual subject needs correlates fairly well with his I.Q. as measured by written intelligence tests.

A child under three years of age cannot solve this problem. Children do not surpass animals on the test until they begin to verbalize it. Obviously verbalization is not essential, for animals could not solve the problem if it were, but it certainly helps. Words are symbols *par excellence*. They can represent experiences, and they can bridge gaps to establish relations.

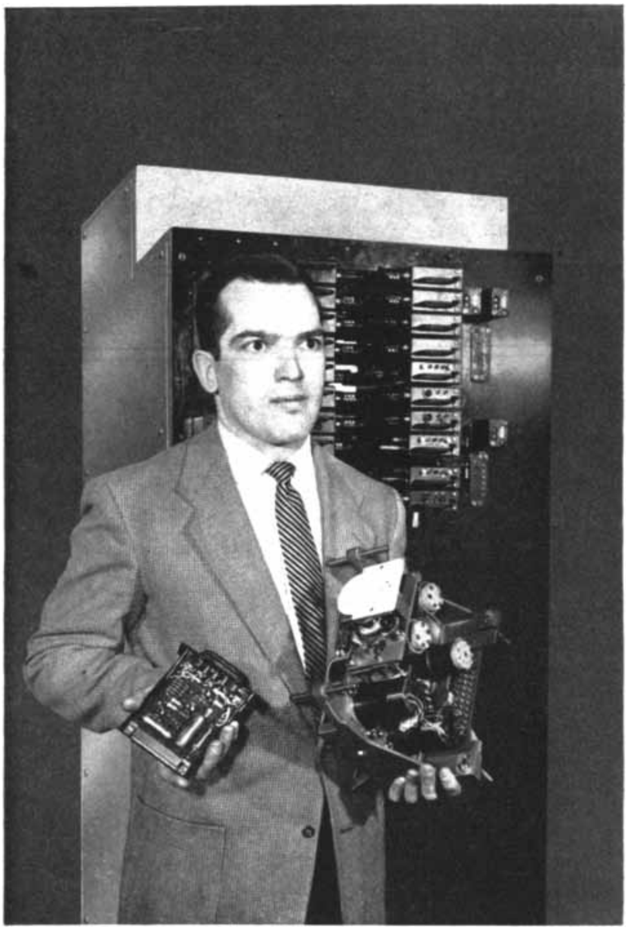
Here, then, is another important stage in the evolution of the mind—by far the most important. A chimpanzee, intelligent as it is (in its first year or two it shows more intelligence than a human baby), simply cannot master language. It can be taught to speak a few words, but each word takes months and five words seem to be about its limit. Moreover, it never gets to use words as we use them. It speaks a word only to get what it wants and only on command; it voices words only to its teacher, never to other people or to another chimpanzee; it never puts two words together. It speaks reluctantly, after all other efforts to get something have failed, as if speaking were extremely painful.

CHIMPANZEE startled psychologist Wolfgang Köhler by leading him to a point beneath a hanging banana and climbing up his shoulder to reach it. Köhler had thought the chimpanzee would use another solution.

In fact, it does not speak to its own kind; there is no evidence of a chimpanzee language. Its spontaneous vocal noises are called forth only when it is emotionally aroused, and apparently they have no linguistic significance beyond alerting another chimpanzee.

This has always been a great mystery: Why do the almost-human apes, though capable of mental symbolization, fail to cross the bridge to speech? They have sufficient vocal equipment—can make a wide range of sounds—but words, one might say, fail them. We begin to get some light on the reasons when we look at the ape's brain. The brain of a full-grown chimpanzee weighs only about one pound—one third as much as ours. The ratio of its brain weight to its body weight is one to 150; in human beings it is about one to 50. That is to say, with a body as large and complex as our own, the chimpanzee has only one third as much brain to manage it. Furthermore, in the ape's brain the frontal area, which is concerned with associations and symbolic functions, is much smaller in relation to the rest of the brain than ours. It seems to lack entirely the section in the left frontal lobe known as Broca's area, a part of the human brain known to be involved in speech.

An ape has no spontaneous babble of sounds, as a human baby does. This was clearly illustrated by the famous female chimpanzee named Viki, who was reared exactly as a child in the home of Keith Hayes and his wife, at the Yerkes Laboratories of Primate Biology. Mrs. Hayes's popular book, *The Ape in Our House*, gives considerable attention to Viki's language training. Viki never babbled: she was silent except when emotionally aroused. Since she had no urge to talk, it was decided to make Viki speak for her supper, as a dog might be taught to bark for it. When she made a worried little sound ("oo oo") on being deprived of her milk, she was rewarded with the milk. After five weeks of such training, she emitted one day a loud "ahhh," accompanied by facial contortions. Thereafter she would make the "ah" sound when commanded to speak. Mrs. Hayes then trained her to say "Mama" by pressing her lips together and releasing them as she said "ahhh" for food. After



Robert Rossler, FICo engineer, holding plug-in analog modules — a transistorized amplifier unit and an electro-mechanical unit. Electronic panel of analog computer is in background.

FICo digital engineer Peter Carbone holding digital module, comprised of easily removable transistorized printed circuits. Rack-type digital computer is in background.

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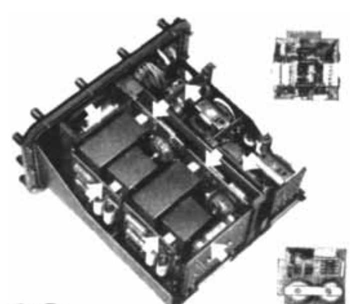
FICo modular techniques as applied to an amplifier for an airborne navigational system. Arrows point to printed circuit amplifiers. Two typical cards are shown at right.



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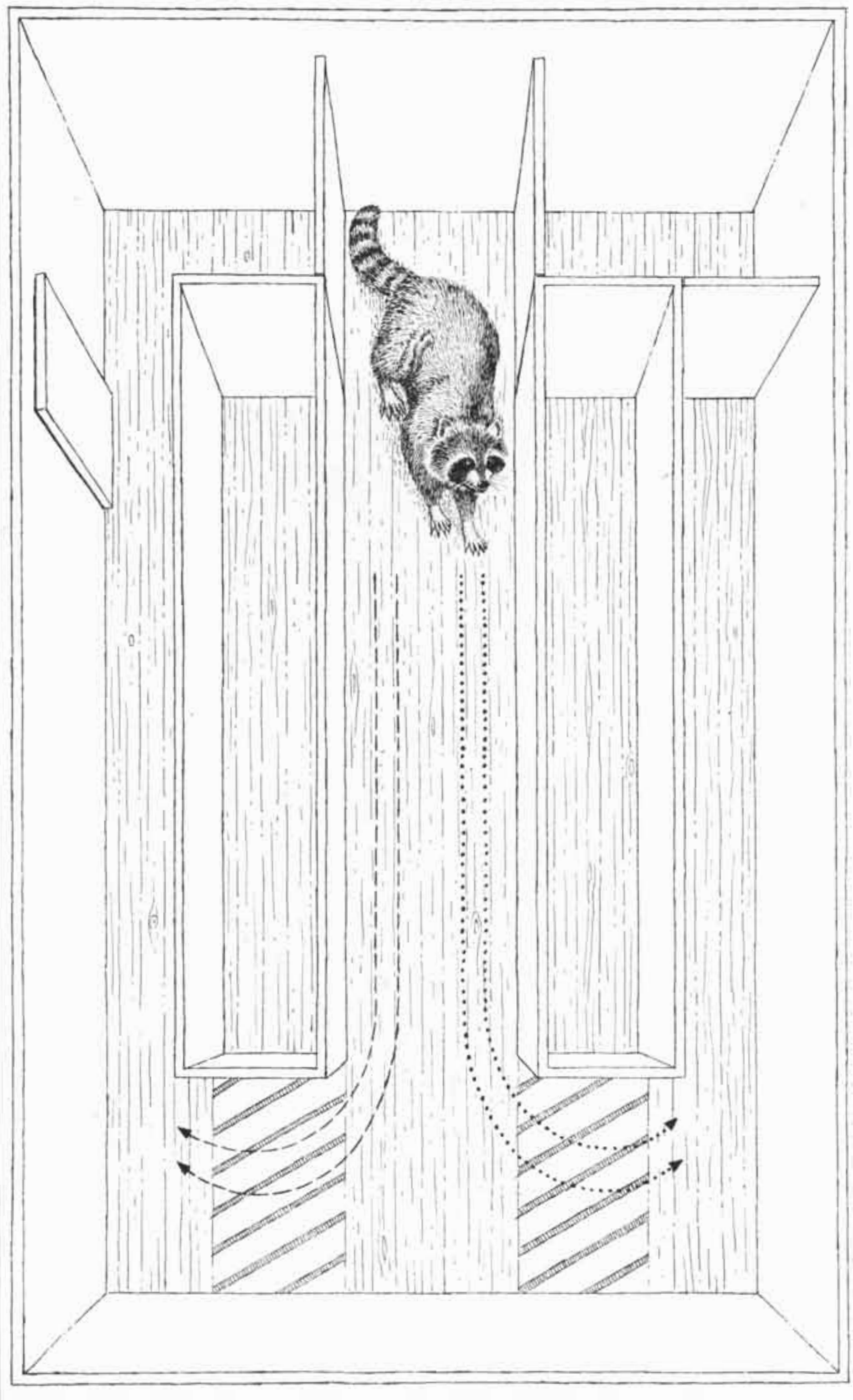
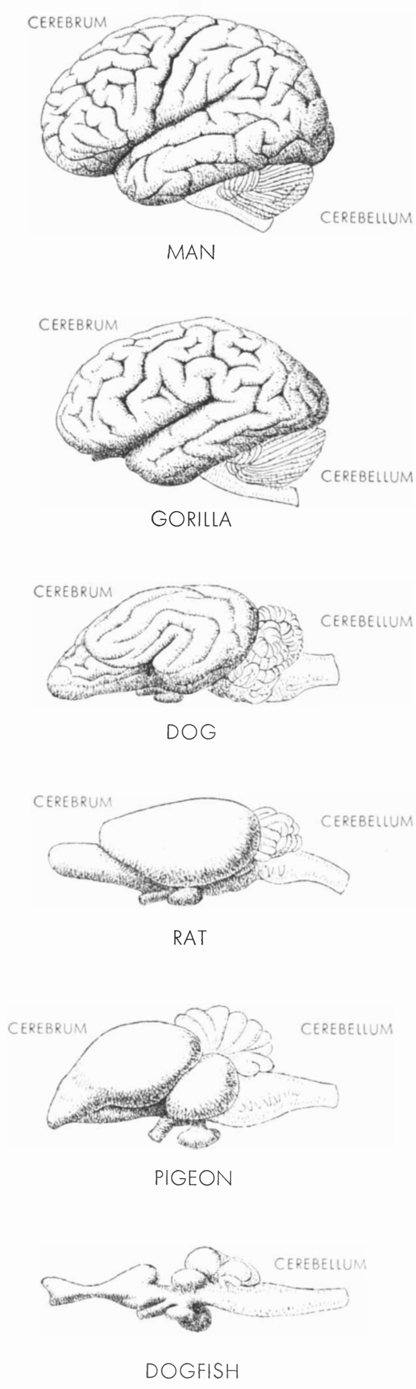
a few weeks Viki was saying "Mama" by herself. The word "papa" was laboriously added to her vocabulary after she had learned to imitate a Bronx cheer. Then Viki learned to say "cup" by repeating the sounds "k" and "p" in rapid succession. Later she added "ch," to ask for a drink, and a click of her teeth, asking to be taken for a ride in the car. But she never used any of her five "words" for social purposes or for egocentric expression. She "spoke" only when there was no other way of getting what she wanted. She gave no evidence of insight into the meaning of language.

How different it is when children learn language! The sudden insight which is part of this process was most dramatically revealed by the experience



T-SHAPED MAZE was used to present a difficult problem to animals. In order to win a reward and avoid electric shocks (*administered by diagonal electrodes at bottom*), the animal had to make four correct turns. Starting at the foot of the T (*top*), it had to make a right turn, return through a door to the foot of the T, make another right turn and two left turns.

of Helen Keller. Anne Sullivan, her teacher, told how Helen discovered her first word, as it was spelled out in her hand. One morning during her seventh year the child asked the name for water by pointing to it and patting her teacher's hand. Miss Sullivan spelled the word in the manual alphabet. Later, when they went out to the well for water, the teacher made Helen hold her mug under the pump spout while she spelled "w-a-t-e-r" into the child's free hand. "The word," says Miss Sullivan, "coming so close upon the sensation of cold water rushing over her hand, seemed to startle her. She dropped the mug and stood as one transfixed. A new light came into her face. She spelled 'water' several times. Then she dropped on the ground and asked for its name and pointed to the pump and trellis, and suddenly turning round she asked for my name. I spelled 'teacher.' Just then the nurse brought Helen's little sister into the pump-house and Helen spelled 'baby' and pointed to the nurse. All the way back to the house she was highly excited, and learned the name of every object she touched, so that in a few hours she had added 30 new words to her vocabulary." The next day Helen was like "a radiant fairy," going from object to object and naming it.



CEREBRUM AND CEREBELLUM of six species are compared in these drawings. The brains are not drawn to the same scale.

The discovery that everything has a name is "like an intellectual revolution," as the German philosopher Ernst Cassirer pointed out in his *An Essay on Man.* "The child begins to see the world in a new light. It has learned the use of words, not merely as mechanical signs and signals, but as an entirely new instrument of thought."

This insight is beyond the reach of any animal. Even the most intelligent subhuman animal reacts only to sounds, not to the meaning of words. The late Edward Lee Thorndike once demonstrated the point with an experiment on his cats. He had trained them so that when he said, "I must feed those cats," they dashed to the food box, even when he put no food in it. One day, to test their understanding of his words, he exclaimed at the cats' meal time: "Today is Tuesday." The cats instantly sped to the box. The words "My name is Thorndike" evoked the same response.

"What's in a name?" asked Shakespeare. "A rose by any other name would smell as sweet." Perhaps, but the naming of things is the great difference that separates the human mind from animal minds. Somehow or other man's brain evolved to the stage where he was able not only to think of things (through images or whatever animals use) but also to see the value of using names for them. With language, the human species entered a new world, began to think more clearly. became capable of reflecting on the past and penetrating the future, gained mastery of the environment. The future of infrahuman animals lies with nature, with mutations and natural selection, but man's future is largely under his own control, thanks to the gift of language.

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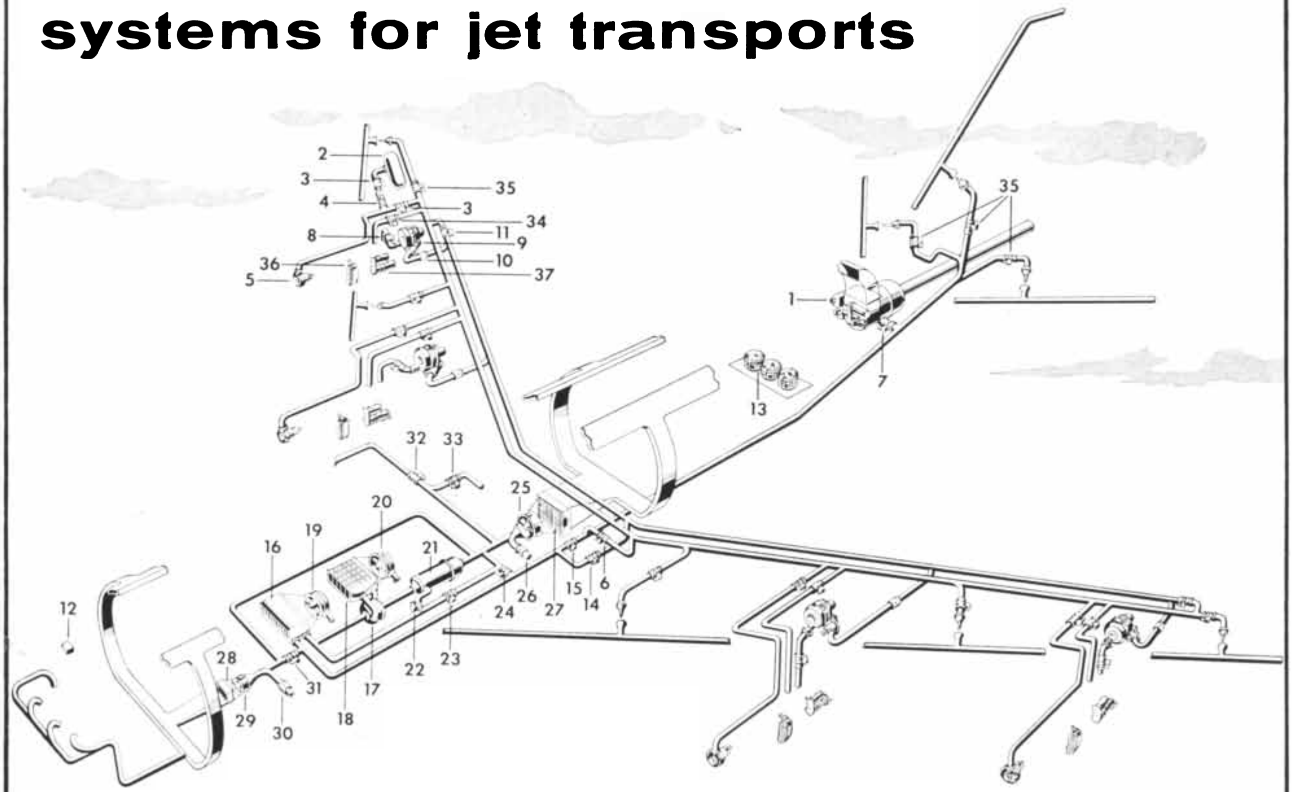

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19. Primary Heat Exchanger Cooling Air Fan
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22. Water Separator Anti-icing Control Valve
23. Turbine By-pass Valve
24. Cabin Hot By-pass Valve
25. Cabin Recirculating Fan
26. Cabin Recirculating Fan Check Valve
27. Cabin Electric Heater
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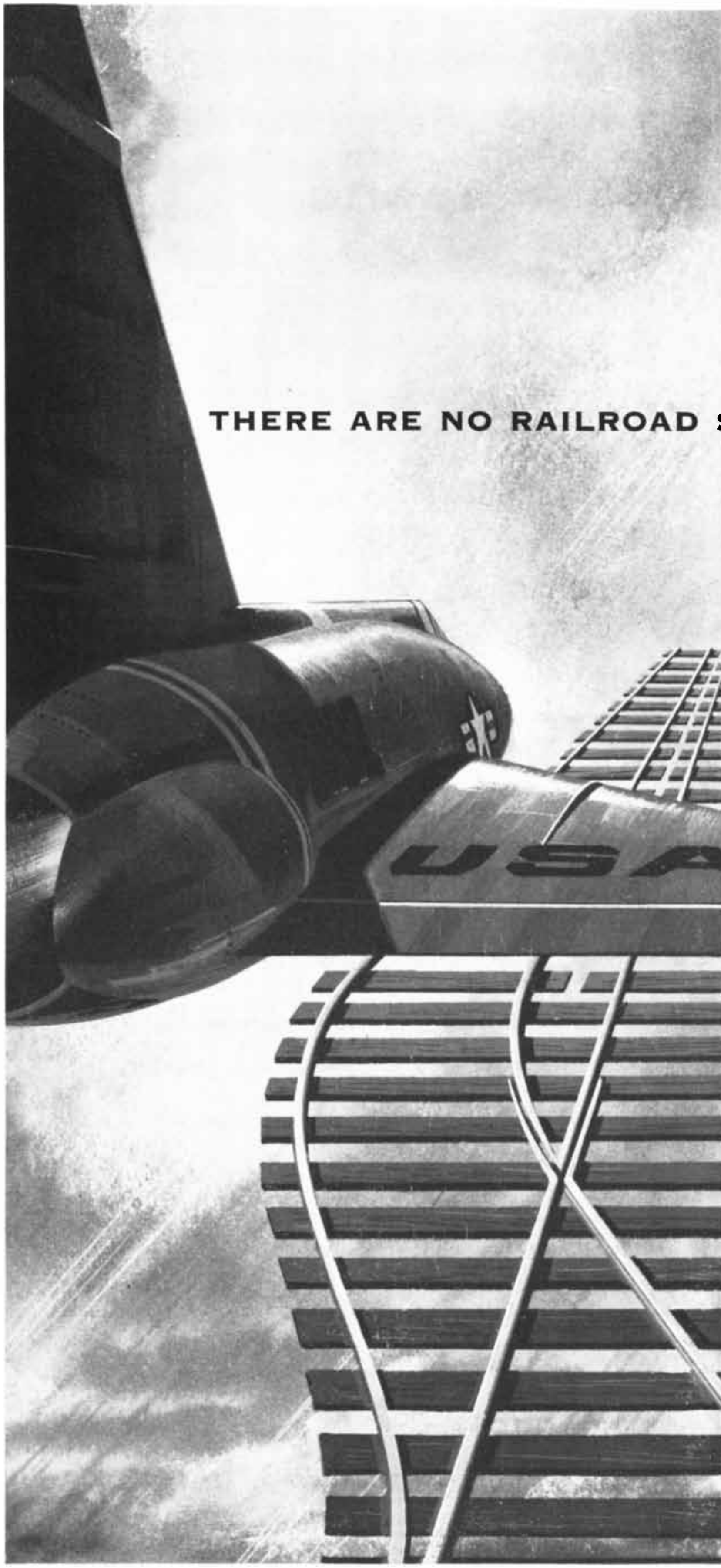

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BOOKS

An experimental investigation of the "attainment" of concepts

by Ernest Nagel

A Study of Thinking, by Jerome S. Bruner, Jacqueline J. Goodnow and George A. Austin. John Wiley & Sons, Inc. ($5.50).

In their waking hours men are constantly deluged by events no two of which possess features that are absolutely alike. The world is nevertheless not a total buzzing, blooming confusion to the human adult, whatever it may be to a newborn infant. The inexhaustible variety of things does not overwhelm us, since we do not attend to all their distinguishable traits. On the contrary, we manage to discover some regularities in the flux of existence and to cope with our environment, only because we treat different things as equivalent by categorizing our experience.

Categorization or classification is a pervasive feature of human thinking, and plays an important role on all levels of cognition. Most of the classifications we make are part of our social heritage, and we learn to identify distinguishable things by using categorizing schemes that have been handed down to us. These schemes become fixed in our language and thus control our normal modes of perception and thought. But there always are areas of experience which fail to exhibit an intelligible order. To make them intelligible, new ways of classification must be devised. Indeed, the development of science is in considerable measure the invention of novel concepts for grouping things which initially appear to be dissimilar. It is because this creative step is both crucial and indispensable that the repeated attempts (such as those of Francis Bacon) at formulating rules of scientific discovery have been uniformly unsuccessful. However, whether we invent a concept for ourselves or simply inherit it, we do not possess effective knowledge of a subject until we learn to recognize individual events as positive or negative instances of the concept. For example, we may understand that a tubercular person is one whose tissues are infected by tubercle bacilli. We would nevertheless not claim for ourselves even elementary knowledge of the subject if we were unable to identify an individual as either tubercular or nontubercular. Moreover, we would probably regard our knowledge as very meager indeed if we could make such identifications only on the basis of a post-mortem examination of tissues. In short, classification requires not only the formation of concepts, but also the "attainment" of concepts: the development of skills for recognizing new instances of concepts.

Two related though distinct questions now emerge. In what manner, and under what circumstances, are concepts formed? By what processes, and under the influence of what factors, are concepts attained? Some information about both of these processes is available, but what we know is still but a small island in the sea of our ignorance. Why has the advance of our knowledge concerning these important matters been so slow, despite the fact that experimental psychology is now almost 80 years old, and despite the promising developments in the experimental study of higher mental processes at the turn of the present century? The answer undoubtedly lies in the fact that these processes are difficult to get at and are not easily analyzed. Most people have had at one time or another what psychologists call the "aha" experience, in which an idea or insight comes to us apparently from nowhere and in an unaccountable manner. In any case, concepts often seem to be attained suddenly, with no noticeable intermediate stages between the time at which a person does not possess a concept and the time in which he does. In consequence, even those trained in introspective methods find it difficult to report anything about their "private" mental processes when achieving concepts. A major problem for the experimenter therefore consists in developing techniques for "externalizing" these "inner" psychological processes, so that they may be objectively described and analyzed.

This is the context of the questions and difficulties in which *A Study of Thinking* belongs. The volume is a publication of the Harvard Cognition Project, and summarizes a five-year program of work on the psychology of concept-attainment. Its aim is to describe "what happens when intelligent human beings seek to sort the environment into significant classes of events," and it has little to say about concept-formation. But it also offers some explanations for the descriptive data, largely in terms of analytical constructs borrowed from information theory and the theory of games. The book is of interest only partly for its experimental findings. Its chief claim to the attention of the general reader is perhaps the fact that it is a study in method: it describes a basic technique for externalizing certain mental processes; it shows how some central notions first developed in the theory of games can be used to analyze data of the psychology of cognition. The first of its three parts supplies the distinctions in terms of which experiments upon the attainment of concepts are designed and analyzed. The second part describes some 20 sets of such experiments performed with Harvard students as subjects. The third part is not related integrally to what precedes it; it is an appendix, largely devoted to the bearing of a theory of categorizing on the study of psycholinguistic phenomena, and includes a discussion of the role of language in patterning thought.

The experiments reported on in this book are intended to be simplified models of the "real-life" situations in which concepts are attained. An example of such a situation mentioned by the authors is the work of a physicist who seeks to identify the substances that will undergo fission upon bombardment with neutrons, and to distinguish them from substances that are not fissionable. It is assumed that the physicist has already formed the concept of fissionable substances. "The essence of his problem is to determine what qualities are associated with fissile and nonfissile substances and eventually to determine which substances will be fissile and which ones nonfissile by means short of neutron bombardment." The problem which faced the authors was to reproduce in a laboratory the essential features of such situations in such a way that the mental processes involved in the attainment of the concept could be externalized and so studied. The technique they devised for doing this is simple. In essence it consists in requiring the experimental subject to announce each of the decisions he makes in the process of attaining an appropriately constructed concept. Since the decisions are public, it is possible to discover what patterns of procedure are embodied in a sequence of such decisions. Moreover, the conditions under which a concept is to be attained can be varied in a number of respects; it then becomes possible to determine both the factors in the situation that influence the procedure of attaining the concept as well as to what degree they do so.

A typical experiment performed by the authors will make their technique clear. A set of cards is constructed so that each card exhibits four attributes and that each attribute may have any one of three "values": the number of figures on a card (either one or two or three); the shape of the figures (either all crosses or all circles or all squares); the color of the figures (either all black or all green or all red); and the number of borders on each card (either one or two or three). The cards are set out before the subject in some perspicuous order. The experimenter now forms out of these attributes a so-called "conjunctive concept," that is, a concept which is the conjunction of one or more of the attributes, such as the concept of cards with red circles or the concept of cards with three borders and green squares. It is explained to the subject that the experimenter has such a concept in mind, and that some of the cards illustrate it while others do not. A positive instance of the concept is then exhibited. The subject is instructed that his task is to discover as efficiently as he can what concept the experimenter has in mind by choosing cards one at a time for testing; he will be told after each choice whether the card is positive or negative. No limit is placed on the number of choices the subject may make, so that he is to continue selecting test cards until he has attained the concept—that is, until the choices of test cards indicate that he has correctly inferred the concept.

What is the best way for the subject to proceed with the experiment? The question invites the consideration of various strategies that may be used and the consequences that follow from the adoption of any one of them. Four such patterns of procedure are distinguished by the authors. One of them, the "strategy of simultaneous scanning," is based on the fact that there are exactly 255 possible conjunctive concepts which can be formed out of the indicated attributes. The strategy consists in using each test card to deduce which of these possibilities are compatible with the information yielded by the card and which must be eliminated. But while this strategy is very effective for attaining the concept, its use (especially without paper and pencil) involves considerable cognitive strain, since it places a great burden on the memory and deductive powers of the subject. Another strategy, "conservative focusing," consists in choosing test cards so that each choice introduces a change in just one attribute exhibited in the positive instance of the concept taken as the "focus." This strategy is based on the consideration that if such a change in the attribute value of the focus yields a positive instance of the concept, the value of the attribute cannot be a factor in the conjunctive concept; on the other hand, if such a change yields a negative instance, the value of attribute changed must be a factor in the concept. Although this strategy is not quite as efficient as simultaneous scanning, its use involves much less cognitive strain. Accordingly there is a "pay-off," associated with each strategy, and the strategies can be compared and evaluated in terms of the consequences which are embodied in the strategies.

Instead of asking which is the best strategy, however, one can ask which strategy, if any, is actually employed by a subject. To answer the question one must analyze the choices of test cards made by a subject, with a view to discovering what pattern is exhibited in the sequence of choices. The occurrence of a certain pattern can then be used to conclude that the subject is following a certain strategy of decision-making. The authors make clear, however, that in imputing a strategy to a subject, they are not imputing to him "a conscious plan for achieving and utilizing information." Only a fraction of the subjects were found to follow an ideal strategy; on the other hand, the rate of adherence to strategies was far in excess of what would be the case if the subjects behaved in a random manner. But the book does not pursue the question how the strategies imputed to subjects come into

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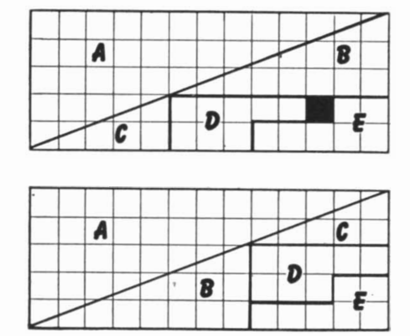

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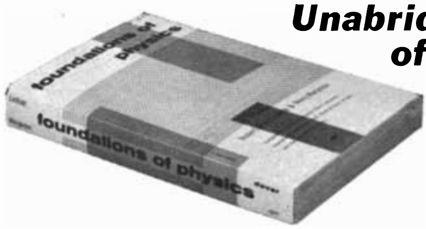

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being or how they are changed—this is left for future research in other branches of psychology.

The experiment described above can be varied in several ways. Instead of operating with conjunctive concepts, disjunctive concepts (*e.g.*, the concept of cards containing either red or square figures) or probabilistic concepts (*e.g.*, the concept of a card which, in a sequence of random drawings, is followed by a card with green figures in 20 per cent of the cases) may be used. Instead of using cards with "abstract" figures such as circles and squares, "thematic" figures may be employed (*e.g.*, human figures differing in sex, age or dress). Instead of displaying the cards in a recognizable order, they may be arranged at random, or test cards may be presented to the subject at random so that he has no control over the card selected for testing. Instead of giving the subject an unlimited number of choices, the number may be limited. Experiments with these and other variations were carried out. The performance of the subjects showed marked differences as the conditions of the experiments were changed. For example, when the number of permitted choices of test cards was small, subjects showed a tendency to substitute for conservative focusing the strategy of "focus gambling"—choosing test cards so that more than one value is changed in the attributes exhibited by the focus card, thereby increasing the risk that the card chosen will not yield relevant information. In general the subjects showed themselves to be flexible, and frequently adjusted their strategies to the demands of the situation with which they were confronted.

It is the emphasis placed upon strategies as the units of analysis which is distinctive of the studies upon which this book is based. The stress is symptomatic of a widespread dissatisfaction with older approaches in psychology, which sought to understand human behavior in terms of individual responses to individual stimuli. The authors of the present book rightly note that the attainment of concepts is a skilled performance, one which involves an ordered sequence of acts, and which cannot be understood when the component acts are isolated from the matrix in which they occur. In their judgment, if current theories of learning are to be adequate to the characteristics of such performances, "the unit of analysis now called the 'response' will have to be broadened considerably to encompass the long, contingent sequence of acts" that constitute the processes of concept-attainment. This is of course a prophecy whose fate only the future can decide. There is no doubt, however, that the use made in this book of the notion of strategy is ingenious and intriguing. The book is a testimony to the value of game theory as a source of promising ideas for experimental psychology, and as a stimulus to the invention of fresh lines of attack on still unresolved problems of that discipline.

It cannot be said, however, that the results of the experiments which this book reports are surprising or that they yield new insights into the nature of our cognitive processes. Surely no one will be amazed to learn that subjects found it more difficult to attain disjunctive concepts than conjunctive ones, or that most subjects tend to avoid strategies that involve considerable cognitive strain. Moreover, it is at least debatable whether the information gathered from the experiments can be legitimately carried over to most real-life situations in which concepts are attained. In the main body of experiments described in this book the concepts employed are explicitly definable in terms of a stated list of attributes with which the subjects are familiar. As a consequence the tasks set for the subjects were essentially problems in the logic of elimination, and involved variants of the procedures stated in John Stuart Mill's 19th-century canons of the experimental method. On the other hand, the task of the real-life physicist mentioned by the authors, who must attain the concept of a fissionable substance, is significantly different. The physicist does not know the list of attributes in terms of which this concept is explicitly definable by way of observable attributes. In short, the tasks set by the experiments illustrate an essentially Baconian conception of empirical inquiry, a conception which the authors certainly know better than to imagine as adequate to the facts. It might be said in rejoinder that manageable experiments inevitably require a simplification of real-life situations. This is undoubtedly true. The fact remains, however, that some experiments (such as those reported in this book) involve grave oversimplifications, so that the relevance of the information garnered from them to the cognitive processes occurring outside the laboratory becomes rather problematical.

In point of fact, the notion of concept-attainment as used in this book covers a variety of things which the authors have not explicitly distinguished. It sometimes means learning to use a concept (such as the concept of red things)

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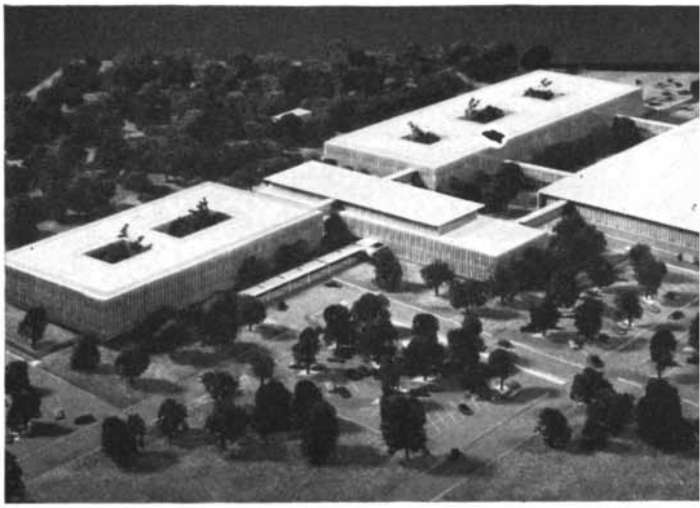

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by way of so-called "ostensive definitions," which associate a certain observable property with a given word or phrase. Sometimes, as in the case of the authors' physicist, it means discovering observable attributes which are not part of the initial connotation of a concept, but which can serve as grounds for reliably inferring the attributes connoted by the concept. Sometimes, as in most of the experiments discussed in the book, it means discovering the attributes that are component parts in the explicit definition of a concept. While there is doubtless something common to these different classes of concept-attainment, there is no *a priori* reason for supposing that the cognitive processes involved in the third class mentioned are typical of the others. Moreover, it is not plausible to assume that most of the concepts we attain, especially in specialized areas of inquiry, are explicitly definable in the way in which the concepts employed in the experiments are definable. How, for example, is the notion of concept-attainment to be defined in this way? There is therefore some reason to suspect that the book does not deal with concept-attainment that is representative of this process in all actual inquiries.

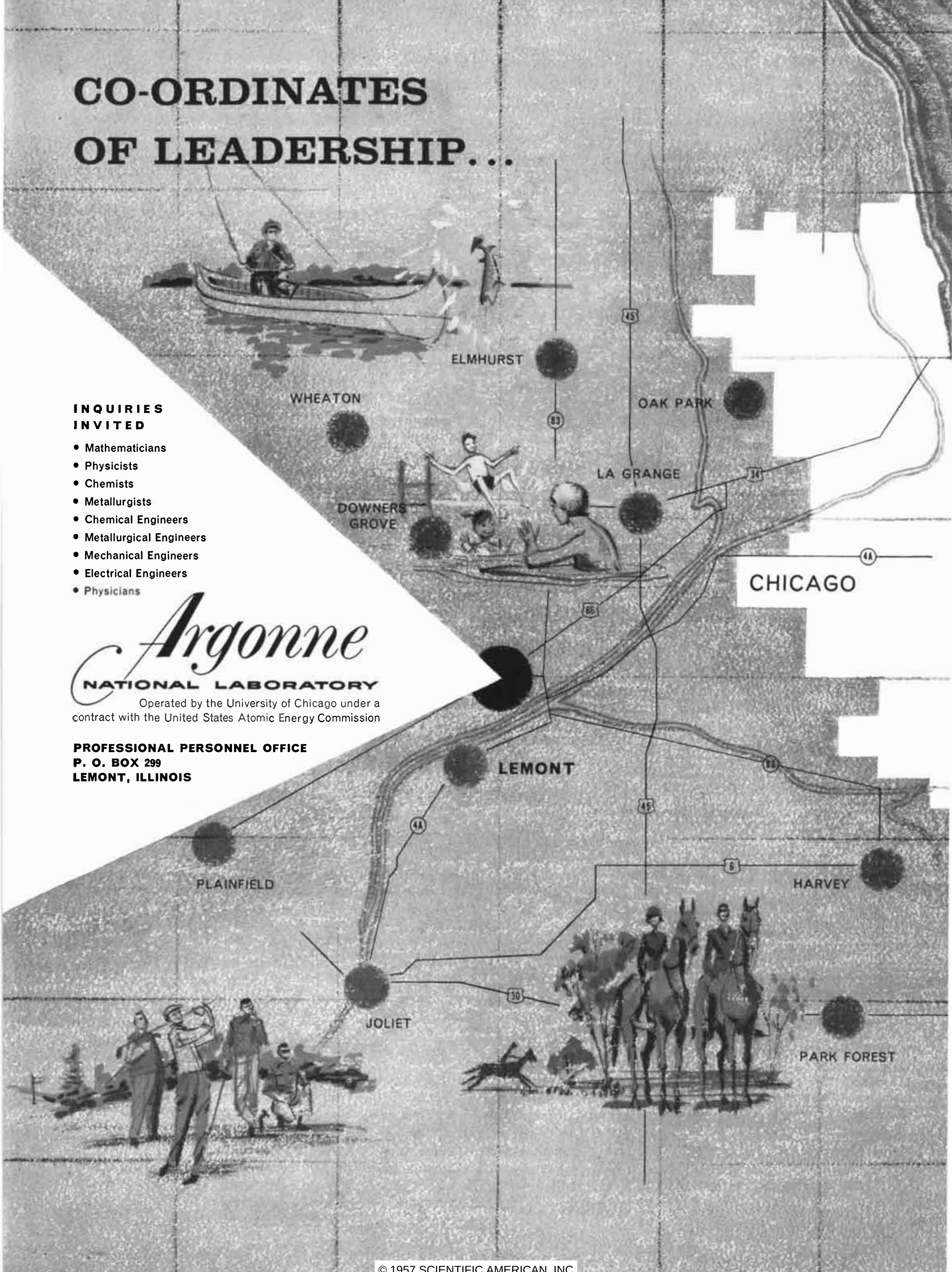
An important point made by the authors themselves casts further doubt on the significance of their experiments. They note that human beings develop certain habits of inference which are highly efficient in the broader contexts of an individual's life, but which may be relatively ineffective in certain special problem-solving situations. As far as the evidence presented in this book goes to show, however, the situations into which the experimental subjects were placed were atypical for them. The subjects apparently had no previous experience in solving problems analogous to those presented in the experiments, and they had no opportunity to work out at leisure effective strategies for coping with these problems. Why then should the performance of such subjects in the experimental situations be taken as evidence for the nature of the cognitive processes involved in concept-attainment in situations more typical for those subjects?

Although the experiments were designed for the study of concept-attainment rather than of concept-formation, it is not entirely clear whether the authors succeeded in completely isolating the former process from the latter. These processes occur rarely in a pure state. Even in the experiments described in the book, a subject must be able to form a concept out of the list of specified attributes before he can hope to attain it. It is not evident from the account given, however, whether, in the case of subjects who failed to attain the concept in the mind of the experimenter, the failure is the consequence of a subject's inability to form the concept, or of the subject's use of a poor strategy.

Few readers of this book will fail to be impressed by the ingenuity and promise of the technique used for externalizing cognitive processes. Nevertheless the technique does not make accessible to observation important moments in the cognition involved in concept-attainment. What, for example, goes into those steps called "decisions" by the subject? When a subject chooses a test card, does he entertain alternative possibilities of choice? If so, through what cognitive processes is the occurrence of such alternatives achieved, and by what procedures is one alternative adopted rather than another? If not, what mental factors do control the choice? Much of importance of concept-attainment may doubtless be discovered through the further use of the technique of externalization described in the book. But it also seems likely that much will remain undisclosed until the technique is made more refined and subtle.

Short Reviews

A History of Technology, Vol. II, edited by Charles Singer, E. J. Holmyard, A. R. Hall and Trevor I. Williams. Oxford University Press ($26.90). Like Volume I of this history, reviewed here in May, 1955, Volume II is a most impressive condensation of an enormous mass of material. The main concern is with technological events between 500 B.C. and 1500 A.D.; the foci of attention are the great Mediterranean civilizations of Greece and Rome and the technologically less understood millennium in Europe, especially western Europe, that followed the fall of western Roman power. Every aspect of the industrial arts is discussed by specialists—it is a tribute both to the editors and the contributors that the quality of the exposition is uniformly high—and a superb collection of hundreds of figures and plates brings the story to life. There are chapters on mining, metallurgy and agricultural implements. Manufactures are covered by papers on food and drink, spinning and weaving and industrial chemistry. The creative urge, the desire to ornament and to make useful things beautiful are brought to light in sections on furniture-making, leather work, ceramics, glass and glazes and fine metalwork. R. H. G. Thomson re-


CO-ORDINATES
OF LEADERSHIP...
INQUIRIES
INVITED
• Mathematicians
• Physicists
• Chemists
• Metallurgists
• Chemical Engineers
• Metallurgical Engineers
• Mechanical Engineers
• Electrical Engineers
• Physicians
Argonne
NATIONAL LABORATORY
Operated by the University of Chicago under a
contract with the United States Atomic Energy Commission
PROFESSIONAL PERSONNEL OFFICE
P. O. BOX 299
LEMONT, ILLINOIS
ELMHURST
WHEATON
OAK PARK
LA GRANGE
DOWNERS
GROVE
CHICAGO
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ports on the skills and limitations of the medieval artisan, Martin S. Briggs on building construction, A. R. Hall on military technology, Bertrand Gille on machines, E. J. Holmyard on alchemical equipment. Transport is a major topic, including surveys of road and land travel, harbors, docks and lighthouses, vehicles and harness and shipbuilding. Two of the noteworthy essays are by R. J. Forbes; they deal with advances in the uses of flowing water, wind and mechanical power as substitutes for man's muscles and animal labor, and with the fascinating subject of hydraulic engineering and sanitation. Open this portly but handsome volume where you will and you will find delightful as well as instructive items. In the Iron Age miners carried their tools in leather kitbags. Inkwells were once made of leather. In classical times rich men wore leather shoes; the poor had to trudge on wooden soles. Gloves were used by early Germanic tribes. The heel first appeared in the 16th century. Samuel Pepys had his leather-covered coach gilded so that it glowed like pure gold in the sunlight. In medieval times legal documents were kept rolled in cylindrical cases; this practice explains the name of Britain's "Master of the Rolls," still a very important legal officer. Folding metal chairs were made in Roman Egypt. It has recently been discovered that iron was used for structural purposes in the Parthenon. The doors of the baths at Pompeii closed automatically to exclude cold drafts and prevent the escape of warm air. Elegant Roman homes had central heating. The inefficient ancient harness used on horses and mules, which throttled the animal when it pulled too hard, had a profound effect on transportation until the 12th century; then the modern type of horsecollar came into use and greatly increased the power available to man. (This invention, it should be noted, was made in China 1,000 years earlier.) It is unlikely that triremes and quinqueremes were three- or five-story vessels, as is often asserted; instead, the terms probably refer to the number of men employed on each oar. Forbes emphasizes the Greek contrast between the liberal arts and the *artes mechanicae,* which precluded efficient cooperation between science and technology. The natural philosopher occasionally had exceptional insights into the working of the world, but he was apt to be too naively empirical, too clumsy to apply his knowledge and too disdainful to wish to do so. Today we think of technology as the child of science, but up to about 1500, as Charles Singer observes, it was more the other way around: technology was the parent of science. It was the Renaissance which began to change this pattern as natural phenomena came to be more and more systematically observed. During most of the period covered by this volume the cultures and civilizations of several peoples of the Far and Middle East were at their highest; the Near East was technologically more advanced than the West, and the Far East more advanced than either. Technological ideas gradually flowed to the west, and finally to Europe. But by 1500 the flow had all but ceased. In the next installment of this magnificent history Europe will appear as the headwater of the stream; a "new and self-conscious science" will make its first impact on a technology becoming progressively industrialized.

LEARNING AND INSTINCT IN ANIMALS, by W. H. Thorpe. Harvard University Press ($10). This masterly work by the director of studies at Jesus College of the University of Cambridge surveys present knowledge in the discipline of ethology—the comparative study of animal behavior—and evaluates the theories of various investigators concerning learning and instinct. The first part of the book treats of general concepts of directiveness and purposiveness in animals, the history of the idea of instinct and of the notion of "releaser and innate releasive mechanisms." The study of so-called "appetitive behavior"—which may be roughly described as a state of agitation or restlessness which is not stilled until a consummatory act, such as the building of a nest, is completed—leads to the suggestion that a certain directiveness steers animal drives and that a feedback mechanism or similar device constantly sharpens perception, shapes the pattern of action and thus acts as a guide to the achievement of a desired objective. Thorpe then considers the various concepts of learning. These include habituation, the relatively permanent waning of a response to an oft-repeated stimulus; associative learning by conditioning and trial and error, as when a guinea pig, say, learns to turn its head in a certain direction at the sound of a buzzer, thereupon being rewarded by a carrot; and the higher achievements of latent and insight learning. The first of these consists of "the association of indifferent stimuli or situations without patent reward"; the second, of the apparently deliberate reorganization of responses as a result of a genuine insight of perception of relations by visual and other sensory appa-

ratus. Another exceptionally interesting aspect of learning is "imprinting." An example of this process—first thought to occur only in birds but later found in fishes, insects and other animals—is the tendency of young geese reared from the egg in isolation to react to their human keepers, or to the first relatively large moving object that they see, by following them as they would their parents. "This need happen for only a few hours (possibly, as Konrad Lorenz showed, only for a few minutes) for the young bird to accept a human as its proper associate and to retain for the rest of its life a tendency to take to human beings as both parent companion and fellow member of the species to which later the sexual behavior will become attached." In the second part of his book Thorpe relates the learning abilities of animals to the degree of development and organization of their instinctive actions and to their behavior in nature. Many hundreds of examples illustrate the knowledge-acquiring capacity of protozoa and lower metazoa, worms and mollusks, insects, fish, amphibians and reptiles, birds and mammals. Digger and hunter wasps, with their marvelous ability to orient themselves in a complex landscape, and to find the way to their several nests even when the landmarks have been deliberately disarranged, stand high in the learning class, as do the social bees. Certain fish show remarkable powers of latent learning and insight not only in their homing habits, but also in solving detour and maze problems, in their play, in recognizing individuals who feed them and in learning to distinguish shapes and colors. Birds are of course star pupils. Thorpe furnishes innumerable instances of their insight learning: house sparrows mastering puzzle boxes, pigeons threading mazes and navigating by the sun, Australian buzzards using stones as tools and tailorbirds using spiderwebs as threads, great tits learning to manipulate strings, jackdaws, ravens and pigeons "thinking and remembering unnamed numbers." This last, by the way, is a feat in which human beings are quite unable to top the birds. Some birds are extraordinarily adept at recognizing individuals of their own and other species. Apparently they even have an esthetic sense: two young wood-pigeons, for example, were visibly dismayed when their keeper appeared one morning wearing a red tie instead of an open-necked shirt. It was quite a while before they forgave him. Thorpe concludes his study by suggesting that the pursuit of ethology promises to cast light on such issues as the distinction between living and nonliving matter, and the explanation of biological phenomena in physical terms.

GOTTFRIED WILHELM VON LEIBNIZ: PHILOSOPHICAL PAPERS AND LETTERS, selected, translated and edited by Leroy E. Loemker. The University of Chicago Press ($12.50). Leibniz, the 17th-century German philosopher, had one of the great minds of history. His thought was both penetrating and spacious, and its range overwhelms the imagination. The introduction to this scholarly work, which contains the most extensive selection from Leibniz's writings available in English, summarizes his activities. He was born in Leipzig in 1646, the son of a professor of moral philosophy. He studied law but soon turned to other pursuits: philosophy, politics, educational reform, science, mathematics, logic, diplomacy. Leibniz, besides being intellectually gifted, was a practical fellow. He always managed to find positions which gave him financial security, afforded him direct access to persons of influence, and left him time to pursue grandiose schemes, cultivate learning, and work in the subject which struck his fancy at the moment. Most of his life he spent as a courtier. He tutored princes and princesses, wrote histories, advised statesmen, kings and emperors. Since he was not only brilliant but also adaptable and conciliatory, he did not lack customers for his services. In his lifetime–he died in 1716–there were nine great wars and as many peace settlements; nimble and realistic, Leibniz was a good man for a small state in the game of power politics to have around. One of his successes, described by Loemker, was helping to elevate the house of Hanover to an imperial electorate and to the throne of England. He had solider achievements. At 20 he published a *Dissertation on the Art of Combinations*, which had to do with the mode of electing the kings of Poland. This question is no longer of crucial concern, but the paper is a landmark in conceiving probability as a branch of logic. He erected a peculiar and intricate metaphysical scheme which showed the influence of René Descartes and Benedict Spinoza, but he differed sharply from them in his definition of substance (he believed in an infinite number of substances which he called monads). He invented the cheery doctrine that this is the best of all possible worlds. He wrote on legal foundations and reforms, the teaching of jurisprudence, theology, ethics, religious unification, physics, psychology, politics, economics and history. He had an extensive correspondence with leading scientists and philosophers, among them Johann Bernoulli, Thomas Hobbes and Christian Huygens. New mechanical principles and discoveries of every kind drew his attention and "few achievements of the day can be named in which he did not have a hand": the discovery of phosphorus and its manufacture as a weapon of war; the development of European porcelain; the use of microscopes in research; Denis Papin's steam engine, for which he proposed a self-regulating mechanism and the re-use of the expanded steam; the principle of the aneroid barometer; machinery for the uniform distribution of power in pumps; improvements in clocks and navigation. Leibniz's greatest contribution was in mathematics. When he went to Paris in 1672 he knew very little about the subject; when he left four years later he had discovered the essential processes of the calculus, independently of Isaac Newton. The issue of priority led to a long, bitter quarrel, not very creditable to either man. Leibniz also invented the notion of mathematical function and was one of the founders of mathematical logic, whose importance he was the first to appreciate. On his death Leibniz left great quantities of unpublished material. He was a difficult writer and his person was not wholly admirable. These circumstances led to his neglect for a long period; only over the last century has the patient work of editors brought to light the magnitude and coherence of his intellectual labors. This book does a service to him and to English-speaking students of science, philosophy and the history of thought.

Notes

Journal of Researches: The Voyage of H.M.S. Beagle, by Charles Darwin. The Heritage Press ($5). An attractive reprint, with engravings by Robert Gibbings and an introduction by Gavin De Beer, of the second edition of Darwin's famous five-year voyage to South America and the Pacific on H.M.S. *Beagle*.

The Historical Background of Chemistry, by Henry M. Leicester. John Wiley & Sons, Inc. ($6). An account of the historical development and interrelations of chemical concepts: Greek scientific thought, Chinese and Arabic alchemy, the transmission of chemistry to the West, the spread of atomistic theories, Lavoisier and the foundations of modern chemistry, the evolution of the theories of organic and inorganic chemistry, physical chemistry in the 19th century, radioactivity and atomic structure, biochemistry.

THE CONCEPT OF NATURE, by Alfred North Whitehead. The University of Michigan Press ($1.35). This paperback in the Ann Arbor Books series presents one of Whitehead's major contributions to the philosophy of science. The work has been out of print for years; it is good to have it back in circulation at an attractive price.

BIBLIOTHECA WALLERIANA, compiled by Hans Sallander. Almquist and Wiksells ($45). In 1950 Dr. Erik Waller, a well-known Swedish surgeon, presented to the University Library of Uppsala his superb collection of ancient medical books, and books on the history of science and medicine. Waller's collection of some 21,000 items is catalogued in two volumes which students of the history of medicine will welcome as an indispensable reference tool.

THE GHETTO, by Louis Wirth. The University of Chicago Press ($1.25). This paperback is a reprint of a classic sociological study which began as an investigation of the ghetto district of Chicago but broadened into the examination of the natural history of a medievally rooted institution of social isolation and its effects upon the development of the American Jew, both in his economic status and in his outlook and personality.

INFINITE SEQUENCES AND SERIES, by Konrad Knopp. Dover Publications, Inc. ($1.75). This little book, translated from the German manuscript by Frederick Bagemihl, is a clear and useful introduction to the theory of infinite series. It is gratifying to have a fresh work from the author, a noted mathematician now professor emeritus at the University of Tübingen.

ARIZONA'S METEORITE CRATER, by H. H. Nininger. American Meteorite Museum ($3.75). The director of the American Meteorite Museum has devoted a large part of his life to studying the immense crater between Winslow and Flagstaff. He describes its history, examines the various theories as to its origin, and pleads for its preservation from "all forms of mutilation and contamination" (it is privately owned) as "one of the world's greatest natural laboratories." Many photographs.

MATHEMATICAL GAMES

Curious figures descended from the Moebius band, which has only one side and one edge

by Martin Gardner

As many readers of this magazine are aware, a Moebius band is a geometrical curiosity which has only one surface and one edge. Such figures are the concern of the branch of mathematics called topology. People who have a casual interest in mathematics may get the idea that a topologist is a mathematical playboy who spends his time making Moebius bands and other diverting topological models. If they were to open any recent textbook of topology, they would be surprised. They would find page after page of symbols, seldom relieved by a picture or diagram. It is true that topology grew out of the consideration of geometrical puzzles, but today it is a jungle of abstract theory. Topologists are suspicious of theorems that must be visualized in order to be understood.

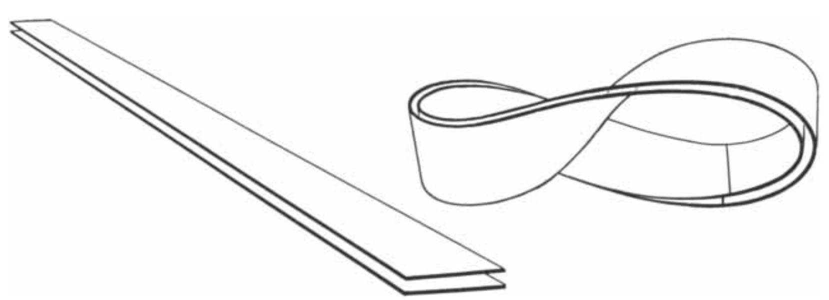
Serious topological studies nonetheless produce a constant flow of weird and amusing models. Consider, for example, the double Moebius band. This is formed by placing two strips of paper together, giving them a single half-twist as if they were one strip, and joining their ends as shown in the illustration at the bottom of this page.

We now have what appears to be two nested Moebius bands. Indeed, you can "prove" that there are two separate bands by putting your finger between the bands and running it all the way around them until you come back to the point at which you started. A bug crawling between the bands could circle them indefinitely, always walking on one strip with the other strip sliding along its back. At no point would he find the "floor" meeting the "ceiling." An intelligent bug would conclude that he was walking between the surfaces of two separate bands.

Suppose, however, that the bug made a mark on the floor, and circled the bands until he reached the mark again. It would find the mark not on the floor but on the ceiling, and it would require a second trip around the bands to find it on the floor again! The bug would need considerable imagination to comprehend that both floor and ceiling were one side of a single strip. What appears to be two nested bands is actually one large band! When you open the model into the large band, you will find it difficult to restore it to its original form.

When the band is in its double form, two separate edges of it run parallel to each other; they circle the model twice. Imagine that these edges are joined and that the band is made of thin rubber. You would then have a tube which could be inflated to make a torus (the topologist's term for the surface of a doughnut). The joined edges would form a closed curve that coiled twice around the torus. This means that a torus can be cut along such a curved line to form the double Moebius band.

The double band is identical, in fact, with a single band that is given four



DOUBLE MOEBIUS BAND is made by placing two strips of paper together (*left*), giving both of them a half twist and joining them as indicated by the straight lines at right.

half-twists before its ends are joined. It is possible to cut a torus into a band with any desired even number of half-twists, but impossible to cut it so as to produce bands with an odd number of such twists. This is because the torus is a two-sided surface and only bands with an even number of half-twists are two-sided. Although two-sided surfaces can be made by cutting one-sided ones. the reverse is not possible. If we wish to obtain one-sided bands (bands with an odd number of half-twists) by cutting a surface without edges, we must resort to cutting a Klein bottle. This remarkable one-sided bottle is described in "Topology," by Albert W. Tucker and Herbert S. Bailey, Jr. [Scientific American, January, 1950].

The simple Moebius band is made by giving a strip one half-twist before joining the ends. Can the band somehow be stretched until this edge is a triangle? The answer is yes. The first man to devise such a model was Bryant Tuckerman, one of the four pioneers in the art of folding flexagons ["Mathematical Games"; December, 1956]. The illustration on this page shows how a piece of paper can be cut, folded and pasted to create Tuckerman's model.

Surfaces may not only have one or two sides; they may also differ topologically in the number and structure of their edges. Such traits cannot be altered by distorting the surface; hence they are called topological invariants. Let us consider surfaces with no more than two edges, and edges that are either simple closed curves or in the form of an ordinary single knot. If the surface has two edges, they may be independent of each other or linked. Within these limits we can list the following 16 kinds of surfaces (excluding edgeless surfaces such as the sphere, the torus and the Klein bottle):

ONE-SIDED, ONE-EDGED

1. Edge is a simple closed curve.
2. Edge is knotted.

TWO-SIDED, ONE-EDGED

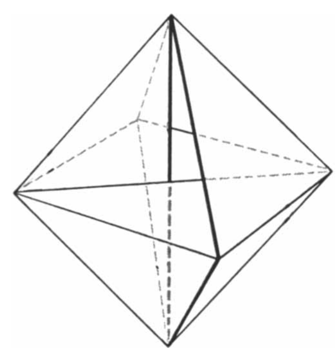
3. Edge is a simple closed curve.
4. Edge is knotted.

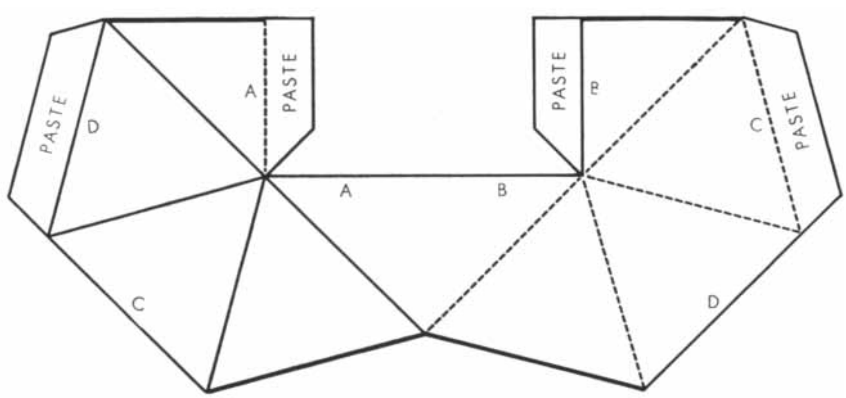
ONE-SIDED, TWO-EDGED

5. Both edges are simple closed curves, unlinked.
6. Both edges are simple closed curves, linked.
7. Both edges are knotted, unlinked.
8. Both edges are knotted. linked.
9. One edge is simple; one knotted, unlinked.
10. One edge is simple; one knotted, linked.

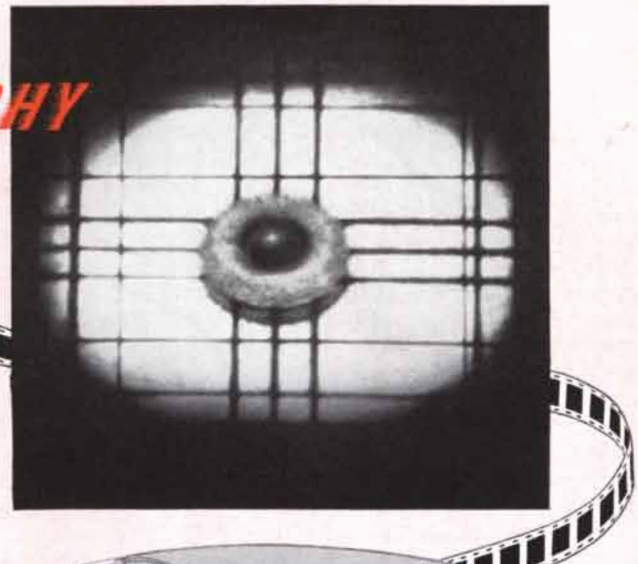
TWO-SIDED, TWO-EDGED

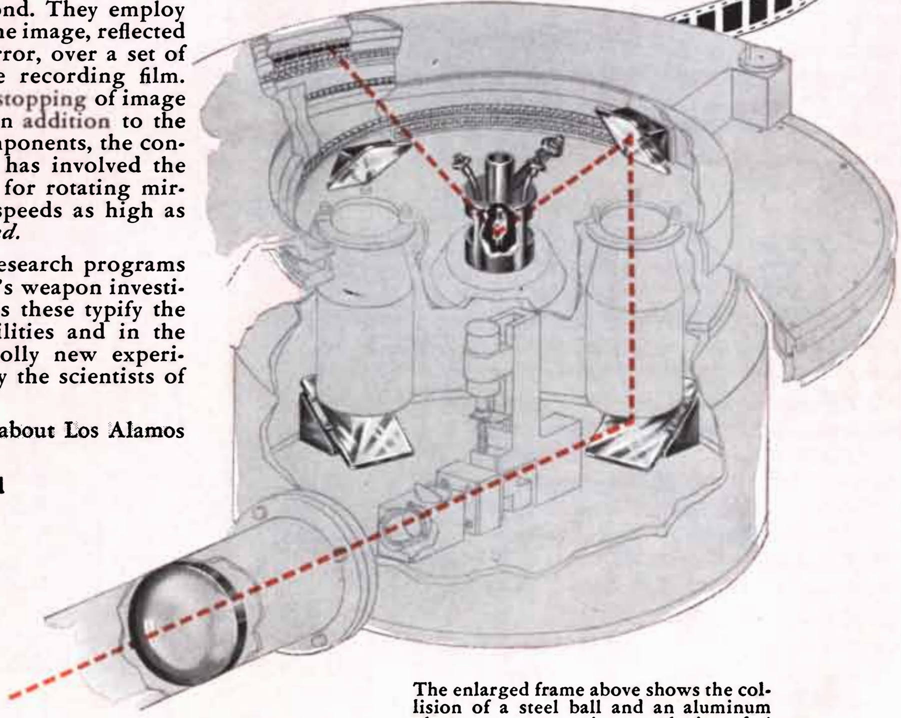
11. Both edges are simple closed





MOEBIUS BAND WITH TRIANGULAR EDGE was devised by Bryant Tuckerman. If the figure at bottom is redrawn, preferably on a larger scale, the polyhedral model at upper right may be assembled as follows. First, cut out the figure. Second, fold it "down" along the solid lines. Third, fold it in the opposite direction along the broken lines. Fourth, by applying paste to the four tabs, join edges A and A, B and B, C and C, and D and D. The heavy lines in the finished polyhedron trace the triangular boundary of the Moebius surface.





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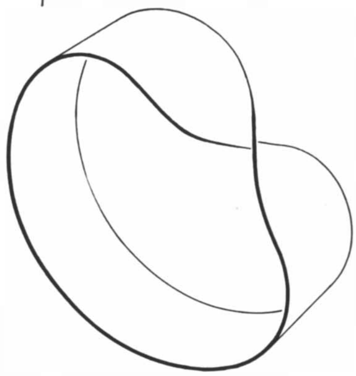

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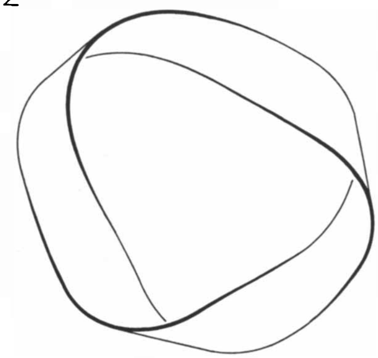

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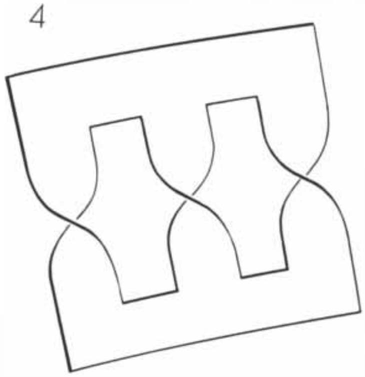

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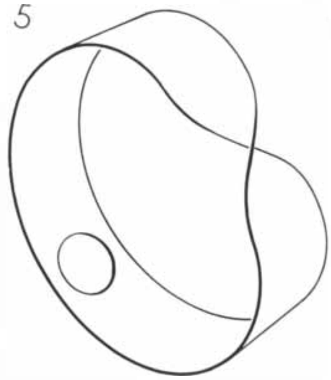

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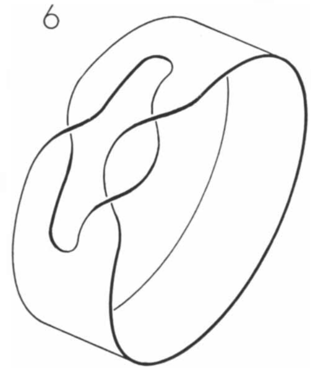

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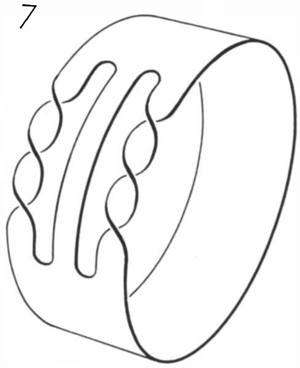

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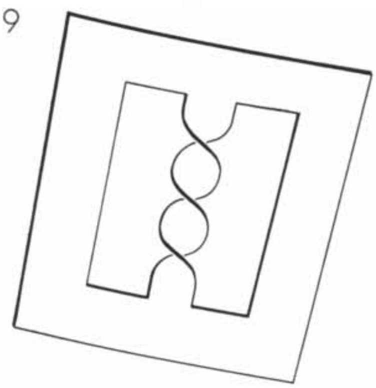

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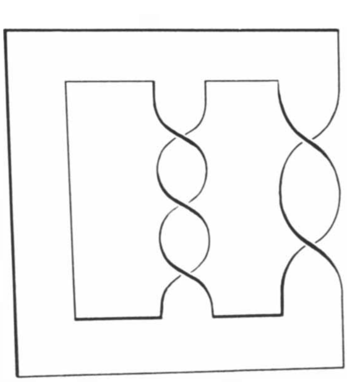

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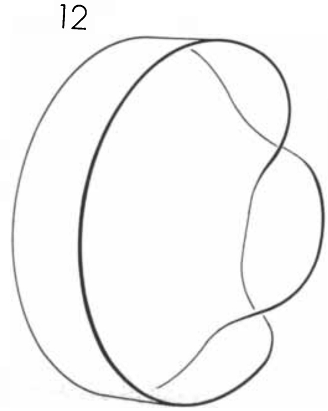


curves, unlinked.

12. Both edges are simple closed curves, linked.
13. Both edges are knotted, unlinked.
14. Both edges are knotted, linked.
15. One edge is simple; one knotted, unlinked.
16. One edge is simple; one knotted, linked.

Paper models are easily constructed to illustrate examples of each of these 16 surfaces. Models for surfaces 1 through 12 are depicted on the opposite page. The reader may enjoy trying to construct models of the remaining four surfaces, drawings of which will appear in this department next month.

When some of these models are cut with scissors in certain ways, the results are startling. As almost everyone who has played with a Moebius band knows, cutting the band in half lengthwise does not produce two separate bands, as one might expect, but one large band. (The large band has four half-twists; thus it can be made into the double Moebius band described earlier.) Not so well known is the fact that if you start the cut a third of the way between one edge and the other, and cut until you return to the starting point, the Moebius band opens into a large band linked with a smaller one.

Cutting surface 12 in half yields two interlocked bands of the same size, each exactly like the original one. Cutting surface 2 in half results in a large band that has a knot in it. This latter stunt was the subject of a booklet that enjoyed a wide sale in Vienna in the 1880s. The booklet revealed the secret of forming a knot in a cloth band without resorting to magical trickery.

In saying that two edges are "linked" we mean linked in the manner of two links in a chain. To separate the links it is necessary to open one link and pass the other through the opening. It is possible, however, to interlock two closed curves in such a manner that in order to separate them it is not necessary to pass one through an opening in the other. The simplest way to do this is shown by the upper curves in the illustration at the top of the next page. These curves can be

TOPOLOGICAL MODELS on the opposite page are 12 of the 16 that can be made from surfaces with no more than two edges, and edges which are a simple closed curve or a single knot. The simple Moebius band is 1.

INTERLOCKED CURVES may be separated without passing one through an opening in the other. The curves at the top may be separated by passing black curve through itself at A.

separated by passing one band through *itself* at point A.

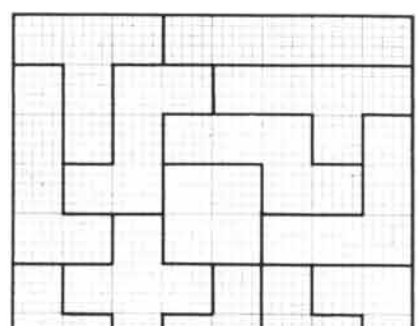
The three closed curves at the bottom of the illustration are also inseparable without being linked. If you remove any one curve, the other two are free; if you link any pair of curves, it frees the third one. This structure, by the way, is topologically identical with the familiar three-ring trademark of a well-known brand of beer. These are called Borromean rings because they formed the coat of arms for the Renaissance Italian family of Borromeo.

A number of readers proposed ingenious alternate solutions to the problem of the logician, one of the brain teasers presented in this department for February. (A logician reaches a fork in the road and wishes to take the branch that leads to a village. Natives in the area either lie all the time or always tell the truth. A native is standing nearby, but the logician does not know whether he is a truth-teller or liar. What single question can the logician ask to learn the correct road?)

The most unusual solution came from H. Janzen of Queens University in Kingston, Ontario. Janzen has devised a question, the answer to which makes clear which road to take regardless of how many roads meet at the intersection! The logician simply points to all roads, including the one he has just traveled, and asks, "Which of these roads do *not* lead to the village?" A truth-telling native naturally points to all roads but one, whereas the liar is forced to indicate the one correct road. (The question cannot be phrased "Which roads lead to the village?" because the liar might lie by pointing to only one incorrect road.)

A large number of readers correctly pointed out that the problem of the commuter, also in this department for February, contained a misstatement (and one that I repeated in April in replying to some letters). Unless you assume that the wife leaves home just in time to meet her husband's five o'clock train, the problem has solutions that range between 50 and 55 minutes for the husband's walking time. These solutions involve either fast driving on the wife's part, or excessive slowness on the husband's part.

The solution to last month's problem of forming a checkerboard with 12 differently shaped pentominoes and one square tetromino is shown below.



LAST MONTH'S PROBLEM of forming a checkerboard with "polyominoes" is solved.

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THE AMATEUR SCIENTIST

About the activities and the trials of amateur rocket experimenters

If, during a weekend drive in the country, you should happen to see a thin trail of white smoke shoot 100 feet into the air, you will find an unusual group of scientific amateurs near the bottom of it. They will be equally proficient in handling explosive chemicals, differential equations, machine tools and irate policemen. In short, they are amateur rocket experimenters. Occasionally they dream of setting foot on the moon, and people who live nearby wish they would—or at least that they would move away! Sometimes the roar of their rocket motors can be heard night and day. But if amateur rocket experimenters are short on local popularity, they are long on enthusiasm and persistence. They have been at it for at least 30 years, and have given rise to nearly all the leading professional rocket workers.

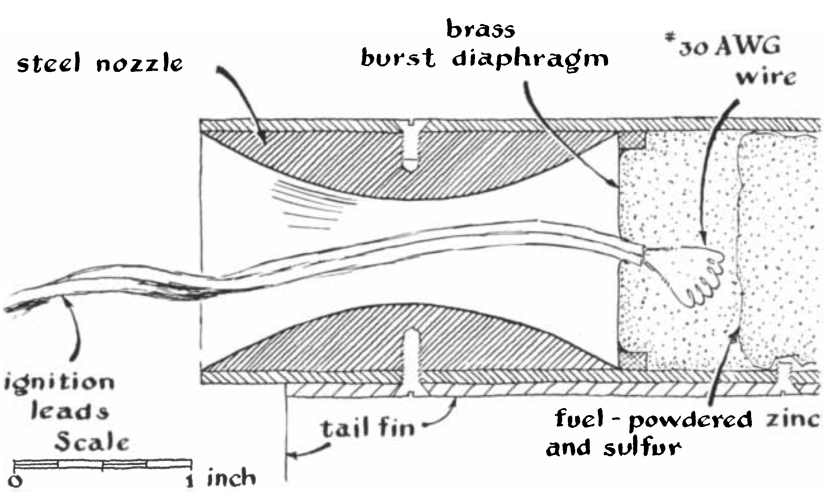
Rocketry is not an avocation for the lone amateur; it requires more in the way of resources than he can usually provide. Rocket experimenters pool their talents and their cash. That they can do so successfully is indicated by the substantial number of amateur rocket groups scattered across the U. S.

Elbert G. Barrett and John H. Granger of the Reaction Missile Research Society, Inc., an amateur group in State College, N.M., write: "Amateur rocket societies give their members an opportunity to participate not only in the theoretical study of rockets and their practical testing, instrumentation, guidance and firing, but also in the many pleasures and satisfactions which come with belonging to a team. The modern hobby was initiated in Germany in 1927, with the formation of a group which included Willy Ley, Max Valier and Johannes Winkler. By 1931 the German amateurs had built a liquid-fuel rocket that could rise to a height of about a mile. Wernher von Braun, Hermann Oberth and many others joined the group; at one time it had nearly 1,000 members. When the Nazis came to power, the society was disbanded and its equipment and experimental results were seized.

"Another pioneer group was the American Interplanetary Society, formed in 1930 by seven men in New York City. The early years of the group were fraught with difficulty, chiefly because of the lack of a permanent proving ground. Upon the completion of a test firing on borrowed (but not always authorized) ground, the group would load its gear into cars and light out for home, often just ahead of the police. But the Society persisted. Finally, through the use of static test stands, as distinguished from flight tests, a rocket engine that performed reliably and consistently was developed by James H. Wyld. He and three other members ultimately succeeded in raising enough money to form what has since become a well-known manufacturing enterprise: Reaction Motors, Inc. Some of their engines have chalked up impressive firsts: they have powered the *Bell X-1*, first plane to pass the sonic barrier, and the Martin Viking rocket, holder of the altitude record for single-stage rockets of 158 miles. In 1933 the American Interplanetary Society changed its name to the American Rocket Society; since 1940 the group has not engaged in experimental work because its members are widely scattered and many of them have become professionals.

"A third pioneer group is the British Interplanetary Society. The day when man will achieve space flight has doubtless been substantially retarded because the law in England forbids laymen to experiment with rockets. The British Society's gifted members have, however, continuously published a fine journal devoted to space flight and allied subjects.

"The outbreak of World War II interrupted the work of all rocket societies. Then, in 1943, George James of Glendale, Calif., founded the Southern California Rocket Society, later renamed the Reaction Research Society. At about the same time the Chicago Rocket Society was organized. These turned out to be vigorous groups, and interest in rocketry has been growing ever since. The Reaction Research Society staged a number of successful mail flights by rocket in an effort to emphasize the peaceful use of the art. The lack of adequate space for testing prevented the Chicago



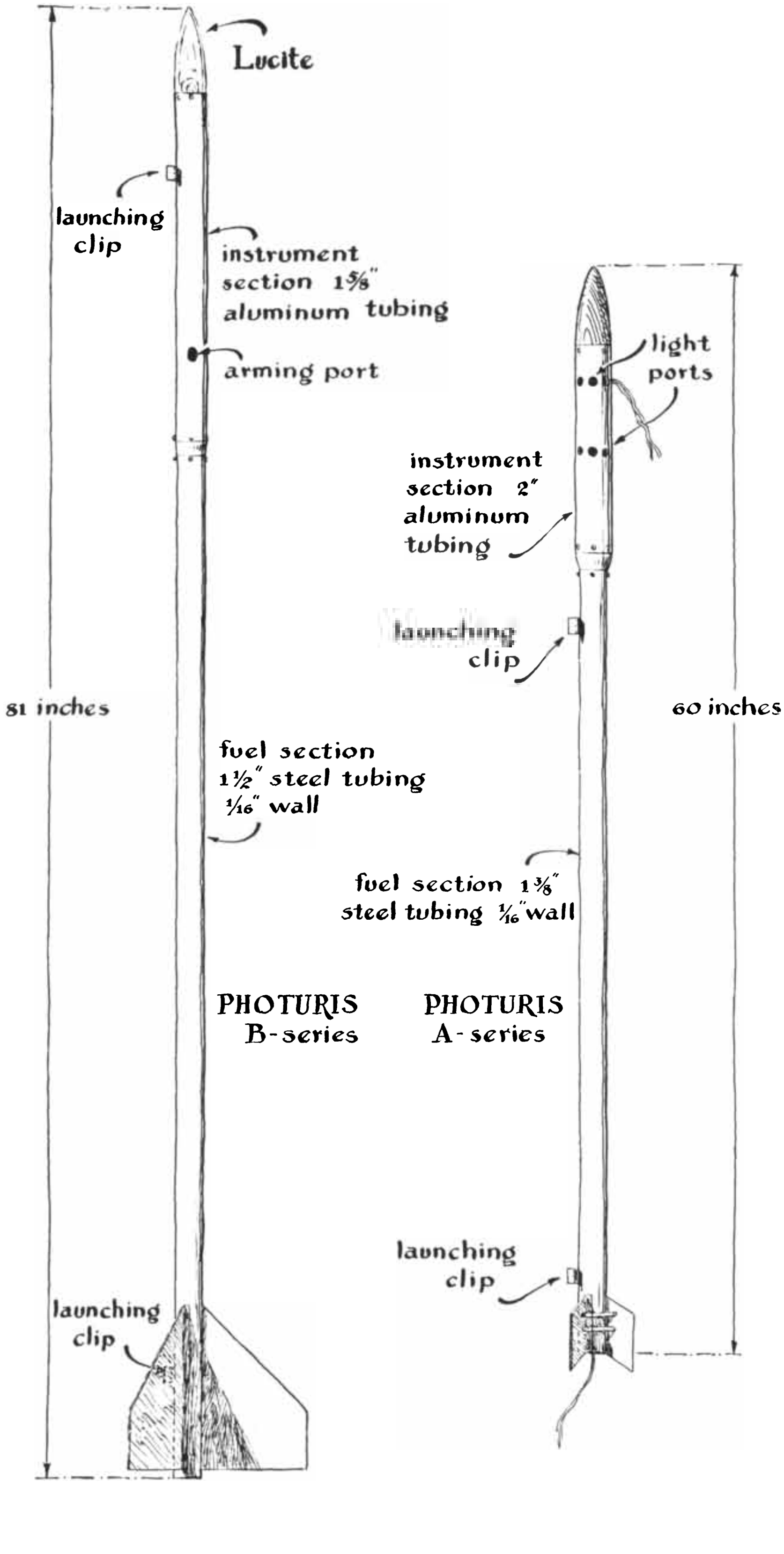
Details of nozzle and ignition system of a rocket built by an amateur group

group from undertaking comparable experiments. Nonetheless an impressive number of ideas and much useful data have come out of its program of theoretical work.

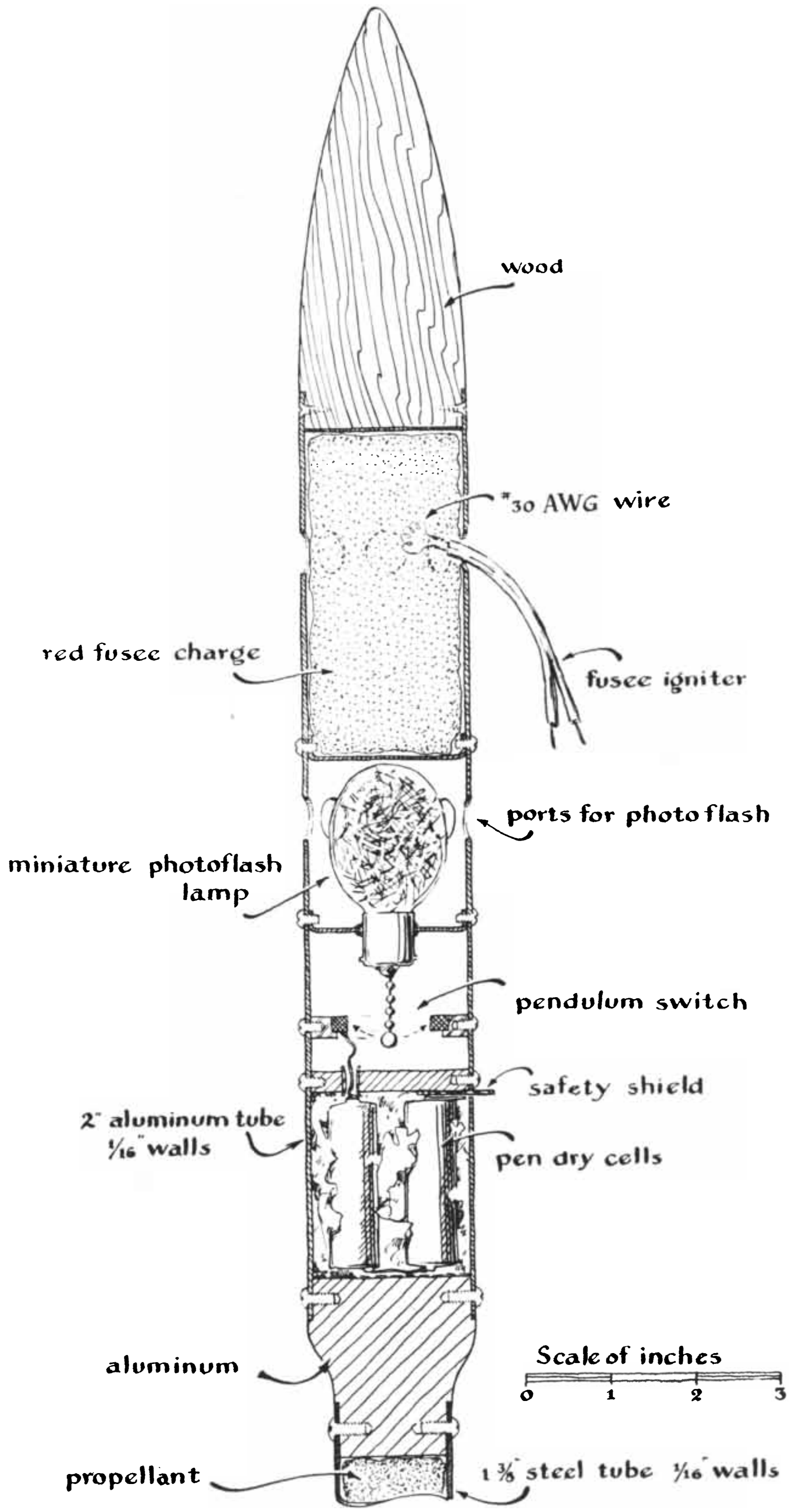
"Representative groups formed since 1943 include the Pacific Rocket Society, the Philadelphia Astronautical Society, the M.I.T. Rocket Research Society, the Intermountain Rocket Society, the Boise Rocket Research Society, the Society for the Advancement of Space Travel and our Reaction Missile Research Society, Inc. All are affiliated with the American Astronautical Federation, formed as a national organization to collect and distribute information and to promote space flight. Numerous other groups are now in existence; it is hoped that a complete roster of rocket societies can soon be compiled." (Any recently formed group may forward its address to this department for listing.)

"Amateur rocketry has a variety of attractions beyond the spectacular but short-lived flight of the rocket. The design and construction of the missile, its launching apparatus and instrumentation pose many intriguing problems. The rocket must be aerodynamically stable both before and after burnout; this problem of stability can be attacked in many ways and invites endless designs and tests. The design of small motors and special propellants can challenge a sophisticated knowledge of mathematics, physics and chemistry. Because of space limitations the instrumentation of small rockets calls for great ingenuity; it should appeal to radio amateurs, particularly those interested in miniaturization. Similarly, amateur photographers always find a ready-made welcome in rocket societies because pictures are needed of take-offs, flight paths, instrumentation records and the apparatus before and after firing. Being a member of a team that coordinates so many fields of interest in carrying a program through to the climax of firing a rocket with instrumentation gives one a feeling of pride in accomplishment with few parallels.

"Members of amateur rocket societies have no illusions that true space flight will be achieved through their efforts. They have neither the funds nor access to the necessary materials. But they can acquire first-hand information concerning the nature of the problems now awaiting solution. By exchanging information and undertaking certain types of experiments beginners can learn the basic facts of rocket flight. Finally, rocket enthusiasts can help enlist public



Rockets with optical and electronic instrumentation built by the group



Instrument section of a "Photuris A" rocket

support for such national efforts as the project to launch artificial satellites of the earth.

"A relatively elementary project undertaken recently by the Reaction Missile Research Society illustrates the sort of experimental work appropriate for beginners and points up some of the tribulations which the amateur rocketeer learns to take in stride and enjoy. The project was conceived by Walter La Fleur, who was then doing graduate work in mathematics at the New Mexico College of Agriculture and Mechanical Arts. The purpose of the project was to record information on the trajectory of a rocket by means of a light source carried in the missile. Incidentally, amateurs enjoy naming their rockets. La Fleur's was to carry a flashing light, so the idea of calling it *Firefly* was proposed. It turned out that another group had used the same name, so we dubbed ours *Photuris,* a classical word for firefly. Our 'A' series was a low-cost program, each missile setting us back about $9. Series 'B' involved electronic instrumentation and each rocket cost $50. In order to record the flight information under the best photographic conditions, all firings were made on moonless nights.

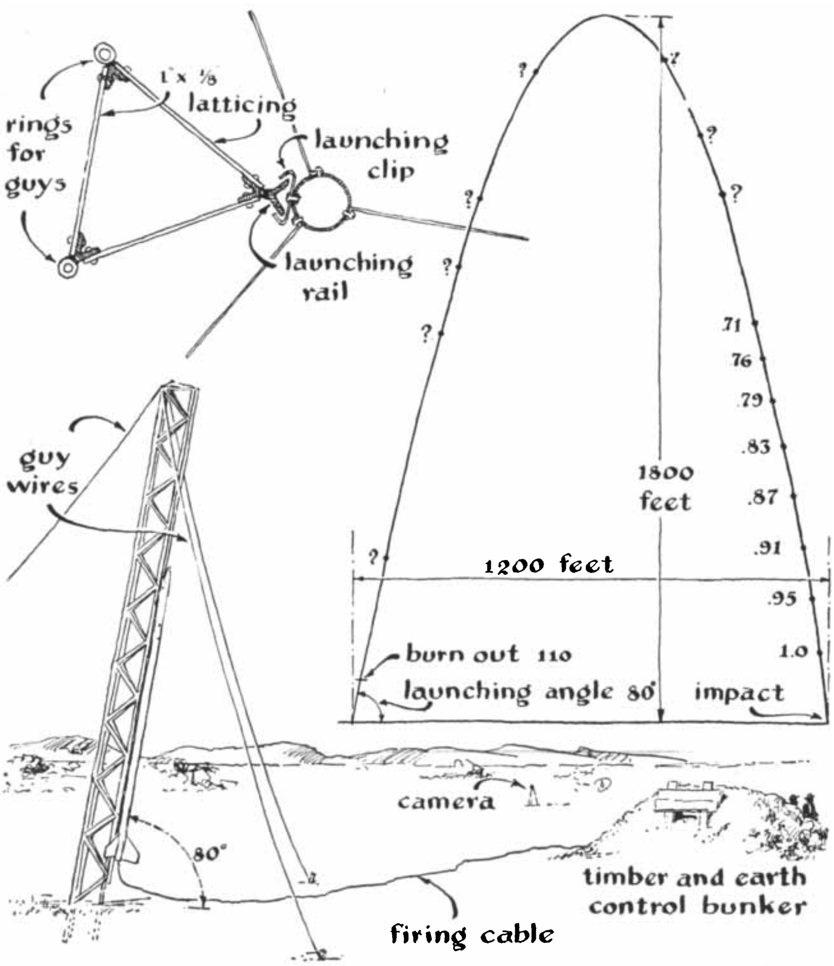
"The *Photuris A* basically consisted of a thin-walled steel tube of 1 1/4 inches inside diameter to which a 2-inch aluminum tube was attached by means of a reduction fitting. The steel section carried the fuel and was fitted with a convergent-divergent nozzle and fins, as shown in Roger Hayward's drawing on page 174. The aluminum tube housed the rocket's instruments and was closed at the top by a wooden nose-cone. A compartment at the top of the instrument section was charged with fusee powder, which burns with a brilliant red light. The powder was ignited electrically by passing a heavy current through a fine Nichrome wire buried in it. The lower compartment of the instrument section was fitted with a miniature photoflash lamp, a pendulum switch and a battery supply. The principle of the switch was being tested as a possible means of releasing a parachute in future missiles. The switch was designed to close when the missile turned over at the top of its trajectory. A record made by the photoflash bulb would prove or disprove the merit of the idea.

"Both the 'A' and 'B' rockets employed zinc dust mixed with powdered sulfur as a propellant. First we thoroughly stirred a mixture of 85 per cent zinc to 15 per cent sulfur. Then we used one of two methods of loading the propellant. In the first method we poured the pow-

der into the nozzle of the steel tube in small amounts, lightly tamping each added amount by jouncing the rocket. In the second method, which is more effective but less convenient, the powder is packaged in small cardboard cylinders, the ends of which are closed with tissue paper. These cartridges, each of which contains the same weight of powder, are loaded into the combustion chamber end to end. The second method has the advantage that every rocket loaded in this way has nearly the same thrust. It has the disadvantage that the nozzle must be removed during loading. In both methods of loading the powder is set off by an electrical ignition unit embedded in the last batch of powder to be added.

"Both 'A' and 'B' rockets were launched from a tower made of angle sections and strap iron. Clips attached near the top and bottom of the missile ride on a launching rail welded to a corner of the tower. The rockets were fired by remote control from an observation bunker located 50 yards from the tower. The bunker was constructed of heavy timbers and covered by several feet of earth; observation slits were cut in the wall facing the tower. All firings were conducted in a rural mountain area. None of the missiles functioned perfectly in every respect; some were downright failures. This is the usual situation in amateur rocketry.

"In the case of *Photuris 1-A* the motor did not function properly. At 'fire' the fuel ignited and burned for about 10 seconds. The rocket left the launcher slowly, climbed about 30 feet, nosed over and struck the ground with the motor still burning. Subsequent inspection disclosed that two hot spots had developed in the combustion chamber, and that about a pound of propellant had failed to burn. Reasons advanced for the malfunctioning included the suggestions that (1) the fuel had not been packed properly, (2) that during transportation to the test area the propellant had moved away from the walls of the chamber, causing erratic burning, (3) that the constituents of the propellant had not been mixed in proper proportion and (4) that the burst diaphragm had not



Launching tower and trajectory of the "Photuris B" rocket

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DIGITAL DATA HANDLING DEVICES	M C	P	M C P	M C P		C	C P		C P	C P			
MISSILE WEAPONS SYSTEMS • RADAR	M W	W	M W X C P	M W X C P	W	M W C	M W C P	W C P	M W X C P	M W X C P			
INERTIAL NAVIGATION			W C P	W C P		W C	W C P		W C P	W C P			
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MISSILE WEAPONS SYSTEMS—Planning and Design—Radar—Fire Control—Servomechanisms—Computers	C M	W C M X	W C M X	W C M X	W C M X	W C M X	W C M X	W C M X	W C M X	W C M X			
AVIATION ELECTRONICS—Radar—Computers—Servomechanisms—Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Automation—Transistorization—Infrared—Airborne TV	W C	W C X	W C X	W C X	W C X	W C X	W C X	W C X	W C X	W C X			
RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays	M C	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X			
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GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Ceramic to Metal Sealing—UHF and VHF—Super Power		L	L	L	L	L	L	L	L	L	L	L	
RECEIVING TUBES—Tube Design—Test and Application Engineering—Chemical and Physical Development—Methods and Process Engineering		H	H	H		H	H		H	H		H	H
MICROWAVE TUBES—Tube Development and Manufacture (Traveling Wave—Backward Wave—Magnetron)	H	H	H	H		H	H		H	H		H	H
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RADAR—Airborne—Surface—Shipboard—Sonar—Fire Control	F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	Z F S			
COMMUNICATIONS—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation	F	F S	F S	F S	F S	F S	F S	F S	F S	F S			
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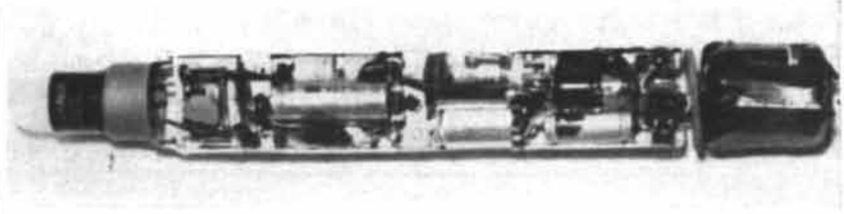


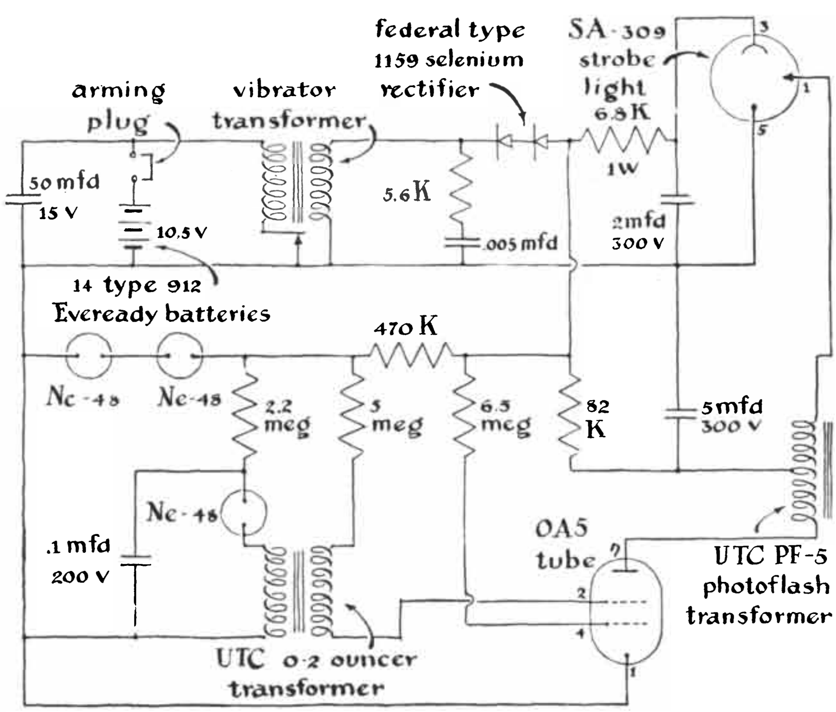
Strobe-light assembly of the "Photuris B"

been strong enough. The burst diaphragm temporarily closes the combustion chamber so that pressure can build up within it. The diaphragm thus establishes the rate at which the propellant burns. If the diaphragm bursts too soon, the burning rate will be low at the outset and the rocket will not rise from the launcher promptly. Because the tail fins of the rocket will not stabilize it effectively at low speed, the rocket will thus be aerodynamically unstable during the early part of its flight. The next morning we ran two static tests which proved that the burst diaphragm had in fact been at fault. A thin diaphragm employed in the first static test resulted in a performance identical with that of the previous night: slow burning and a remainder of unburned fuel. A heavier diaphragm used in the second static test resulted in perfect burning.

"*Photuris 1-A* not only had motor trouble; its instrumentation section also behaved badly. The signal flare did not ignite properly, the lower end of the wooden nose-cone burned away (although supposedly protected by a layer of asbestos insulation) and the ports provided for flare exhaust appeared to be too small. The pendulum switch apparently worked. Two observers reported seeing a flash as the missile turned over at the top of its trajectory.

"Following our tests *Photuris 2-A* was fitted with a stronger burst diaphragm. A low-current relay system was installed to improve the ignition of the signal flare. The flare section was provided with larger exhaust ports, and both the top and bottom of the flare compartment were fireproofed with a thick layer of plaster of Paris.

"The time required for these changes, other activities of the Society and unfavorable weather delayed the next test for about two months. Finally the big night came and we threw the switch. The motor refused to fire. Investigation revealed that the propellant in contact with the ignition filament had fused into hard pellets. The combustion chamber



Wiring diagram of the strobe-light assembly

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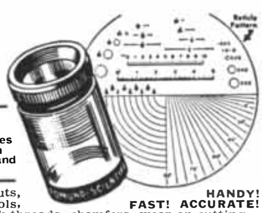

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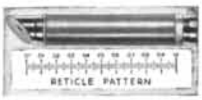

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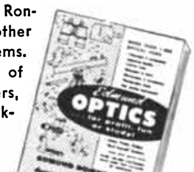

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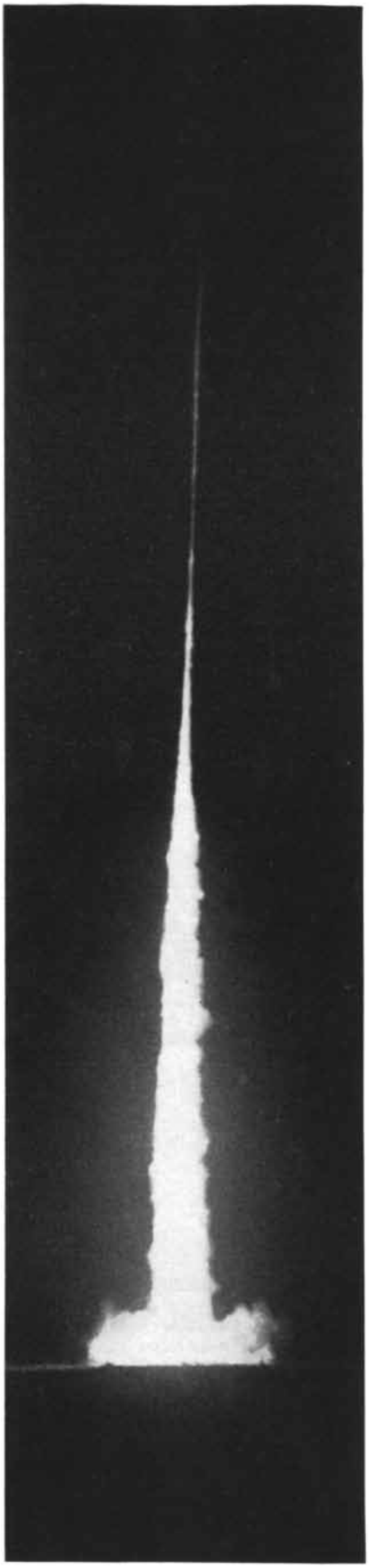

Take-off of "Photuris B"

was emptied, repacked and fitted with a new ignition element. At the second firing the burst diaphragm ruptured and released a short tongue of flame. The missile did not move from the launcher. Suddenly the wall of the combustion chamber near the exhaust nozzle became red hot and the red area moved slowly toward the nose of the rocket. Subsequent chemical analysis of residue within the combustion chamber disclosed an excess of zinc in the propellant. We changed the fuel mixture to 75 per cent zinc and 25 per cent sulfur.

"*Photuris 3-A* was fired successfully one week later. The instrumentation was the same as that in previous tests. We did not, however, attain our objectives. The flare went out during acceleration. doubtless because its powder had not been properly mixed. The flash bulb failed to operate when the rocket turned over; a subsequent check showed that its supposedly 'new' batteries were dead. As a final contribution to our dismay the rocket shed its fins after three quarters of a second at an altitude of about 75 feet! The total burning time was about one second. The main body of the missile landed 300 feet short and north of the predicted impact area a quarter of a mile away. The divergent section of the exhaust nozzle was badly eroded.

"Despite these failures the group felt it had acquired enough experience with zinc-sulfur propellant to risk the construction of a larger missile with more elaborate instrumentation. Accordingly we began to work on the first of the *Photuris B* missiles. The propulsion section was made of steel tubing 1/16 inch thick, 57 inches long, and with an inside diameter of 1 3/8 inches. It was equipped with three parallelogram-shaped fins with a 60-degree angle of sweepback. The rocket weighed 8.75 pounds empty and 15.4 pounds fueled, a mass ratio (empty weight to fueled weight) of 1:1.8. The fuel mixture was 75 per cent zinc dust and 25 per cent sulfur. The exhaust nozzle was a 30 degree convergent-divergent double cone of steel.

"The instrumentation consisted of a high-brilliancy xenon strobe lamp, a power supply and an associated electronic timing-circuit designed to trigger the lamp at a rate of five flashes per second. Photographs of the flashes, which were bright enough to record on film from a distance of three quarters of a mile, were meant to chart not only the flight path but also to enable us to compute the missile's velocity, its total flight time, its acceleration at any point on its trajectory and so on.

"Providing a direct-current source of 300 volts and .008 amperes for the lamp in the small space available turned out to be a major headache. Because batteries of the desired voltage and current rating were not available, we decided to use flashlight batteries and step up their voltage by a vibrator power-supply of the type used in automobile radios. A series of tests were first run to ascertain if the flashlight batteries could deliver enough power to drive the lamp and associated circuitry for the estimated flight time. A large number of three-minute, high-current tests were run on four brands of flashlight batteries available in local stores. We learned in these tests that although the small batteries used in pen-sized flashlights have about a 20th the volume of the largest flashlight batteries (size D), they deliver half as much energy. Another interesting fact came out of the tests: Inferior cells always show a characteristic drop in voltage during the first 10 seconds following the application of a heavy load. As a result we set up a standard testing procedure which required that all cells to be used in the missile deliver voltage within prescribed limits during a 10-second test interval. As finally assembled, the battery consisted of 14 size-912 cells wired in series parallel. It delivered 10.5 volts and occupied 1 3/4 vertical inches of the instrument section.

"The timing circuit consisted of a 2.2-megohm resistor through which a .1-microfarad capacitor was alternately charged by the power supply and discharged by an NE 48 gas-diode tube. Because the supply voltage tended to vary beyond tolerable limits, a voltage-regulating circuit was added. This consisted of two NE 48 gas diodes in series with a 470,000-ohm resistor [*see circuit diagram on page 180*]. The timing circuit worked well and continued to function even when the voltage dropped below the value at which the strobe lamp would fire.

"The problem of triggering the strobe lamp was initially difficult but was finally solved by the use of a trigger tube of the OA type which actuated a photoflash trigger transformer. The trigger tube was in turn triggered by the timing circuit through a transformer of the microphone-to-grid type.

"A hollowed block of clear plastic was cast and machined to size to serve both as the nose-cone of the missile and the housing of the strobe lamp, an arrangement which afforded an unobstructed view of the lamp. The circuit components were mounted in a cylindrical

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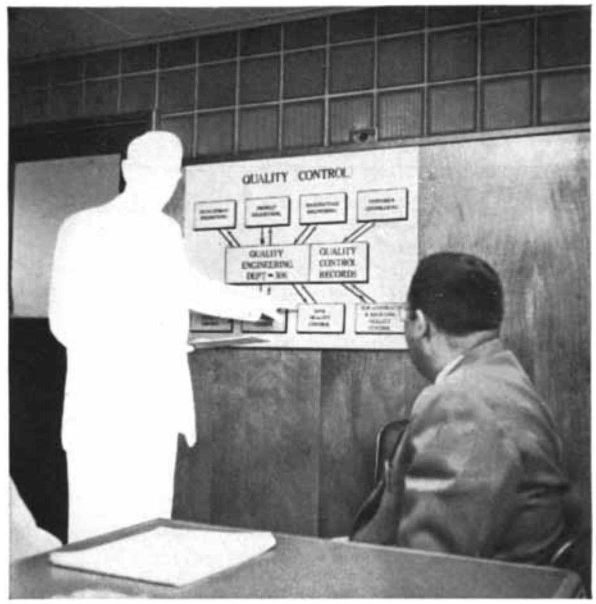

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chassis which fit snugly inside the nosecone.

"The circuit was switched on by inserting a small short-circuiting plug into a port in the instrument section. This connected the plus side of the battery to the body of the missile (which acted as a common ground return for the various circuit components). Bench tests of the circuit proved that the lamp would operate reliably for three minutes.

"The gadget behaved normally—that is, it refused to work when installed in the missile. The difficulty stemmed from the vibrator assembly in the power-supply unit. The reeds of the vibrator were mounted on the side of the transformer, which was attached to the body of the missile. Stresses set up when the transformer was screwed into place disturbed the contact adjustment and function of the reeds. It was apparently necessary to readjust the contacts following the assembly of the missile. Because this problem had not been foreseen, the design of the missile had made no provision for access to the reeds. To correct this shortcoming would have meant rebuilding the rocket, so we decided to settle for an approximate adjustment and proceed with the firing.

"The rocket was launched at the same angle as that of the *Photuris A* series: 88 degrees with respect to the horizontal. The missile reached an altitude of 1,800 feet and landed squarely at the predicted point of impact 1,200 feet away. The motor functioned perfectly [*see photograph on page 182*].

"The trajectory was photographed from a distance of about a third of a mile by a special camera placed at right angles to the flight path. Because the missile passed out of the camera's field, we lost the top part of the trajectory. The missing section of the trajectory was extrapolated from the section that had been photographed, and is shown in the illustration on page 178.

"The strobe lamp did not operate during the first part of the flight, doubtless because of the effects of acceleration on the vibrator assembly, but worked well during the last part. The photograph did not come up to expectations; images of the flashes on the plate, although quite definite once located, were tiny and hard to find.

"The instrument section was destroyed so completely on impact that not a single component could be salvaged. Thus the group decided, for reasons of economy, to delay additional firings pending the development of an adequate parachute system. In the meantime the idea has been advanced of installing a continuous light source in the missile and providing timing by means of a rotary shutter in front of the camera.

"More advanced projects currently under way include the development of a nozzleless, finless missile of high mass ratio, a device to measure range by short-wave radio and a data-recording system. The mass ratios of conventional rockets rarely exceed three to one. The projected missile will have a mass ratio of nine to one. A small cone at the tail of the rocket will replace the conventional fins. Results of wind-tunnel tests on pilot models indicate that a cone should provide better stability than fins.

"A number of rocket societies are investigating both solid and liquid propellants. Our group, however, prefers to concentrate on instrumentation. Liquid fuels are challenging and have spectacular performance, but they are costly. Some of them, like hydrogen peroxide and fuming nitric acid, can get out of hand. Amateurs without experience in rocketry will find excitement enough in the zinc-sulfur mix to outlast their first year in the hobby. In contrast with black gunpowder and other solid propellants, the zinc-sulfur fuel can be used with relative safety even in large rockets. Its burning rate is high—on the order of five linear feet per second regardless of tube diameter. Its density is also high, yet danger from explosive pressures is low. Our society purchases Zinc Dust, Technical Grade, from the American Smelting and Refining Company, P. O. Box 487, Sand Springs, Okla. We do not specify grain size. The current price is $18.25 per 100 pounds. Prices quoted by chemical supply houses usually run somewhat higher, doubtless because of refining costs and certified purity. Flowers-of-sulfur is inexpensive and available locally in most communities from hardware stores and dealers in farm and garden supplies.

"Should you feel the urge to take up rocketry as a hobby, you will be well advised either to join with others in your community who are similarly inclined, or become a member of an established group. Few individuals have the time and skills required for the design and construction of a successful, well-instrumented rocket, and none can be in enough places at once to fire and adequately observe the performance of one. Even if he could, he would be cheating himself of the rich satisfactions which come only through participation in a group project."

A list of rocket societies can be obtained by forwarding a stamped, self-addressed envelope to this department.

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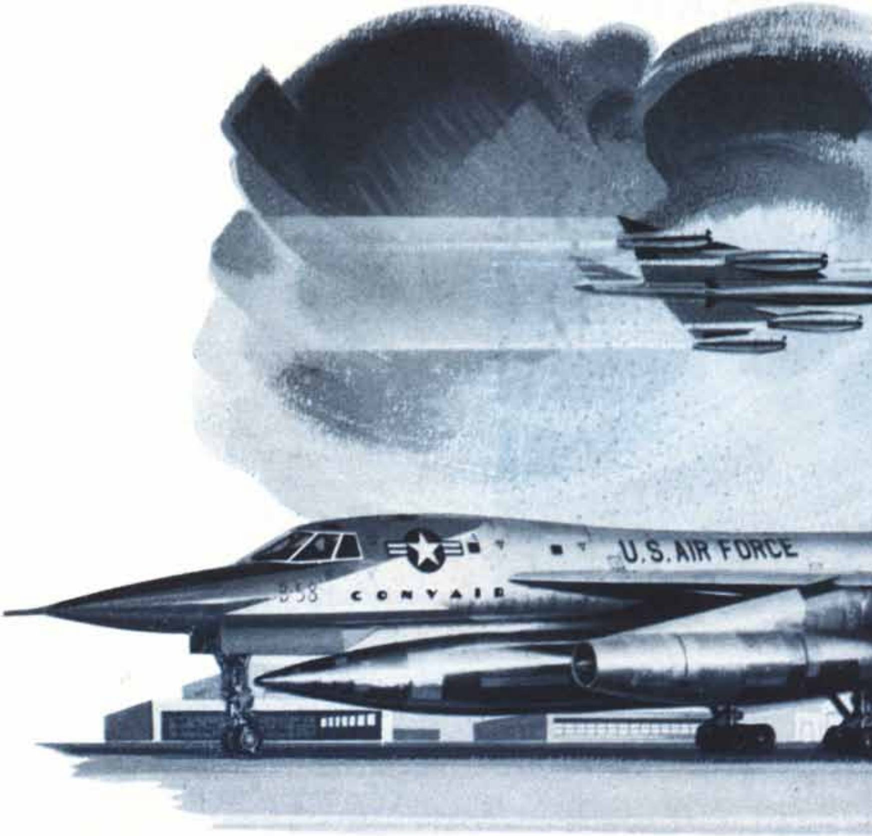

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