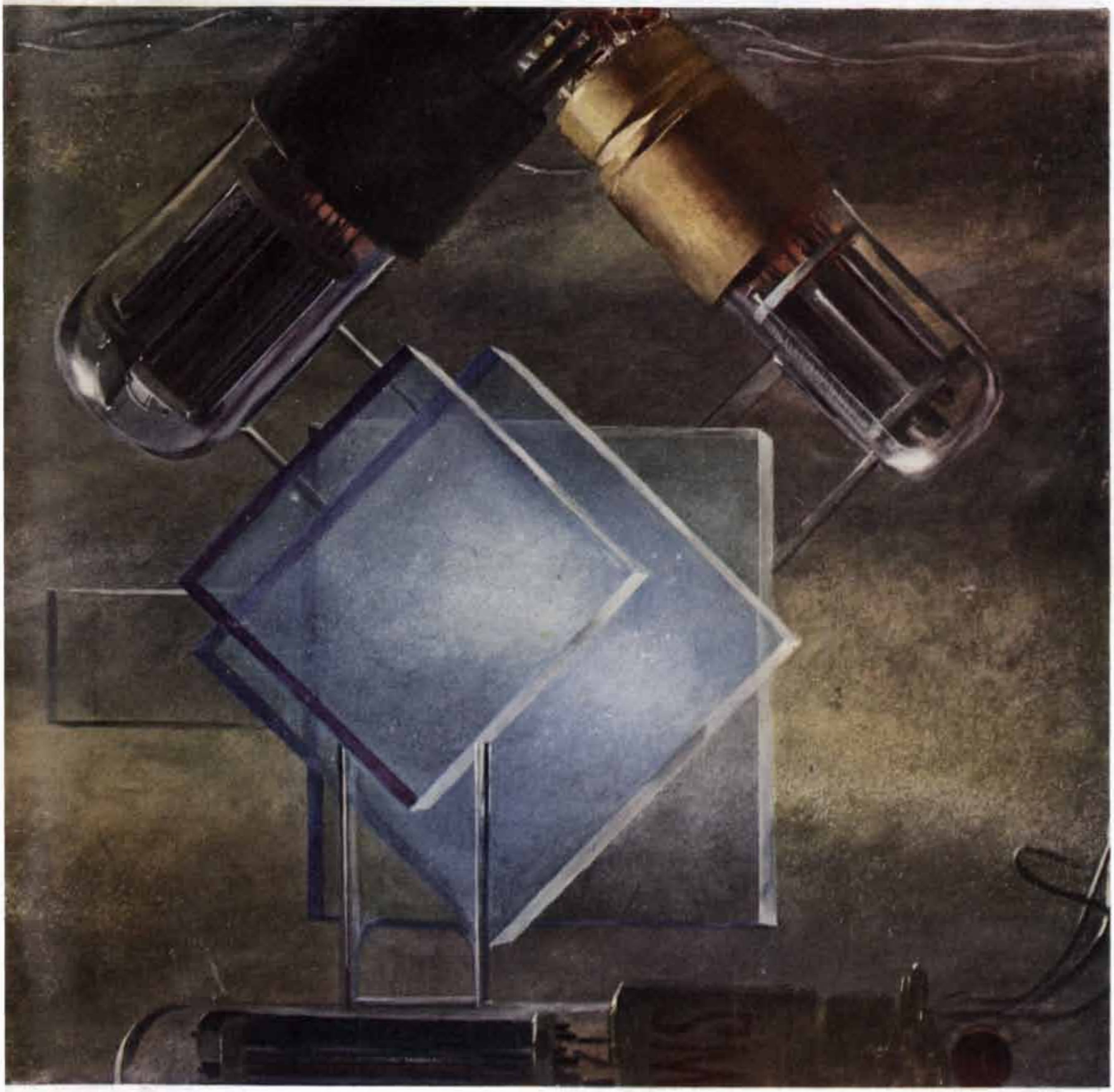
SCIENTIFIC AMERICAN



SCINTILLATION COUNTERS

FIFTY CENTS
SEVENTY-FIVE CENTS OUTSIDE THE AMERICAS

November 1953

What in the world are silicones?

These astounding chemicals—born of sand and oil—hate water, laugh at heat and cold, and are doing remarkable things for you and industry

SILICONES are the fabulous offspring of an unusual chemical marriage between sand and oil. Sand, the basic material for glass, gives silicones some of the best features of glass. Oil, source of many plastics, gives silicones some of the special qualities that have made plastics so useful to all of us.

WIPE ON . . . WIPE OFF—Silicones are the secret of the new, long-lasting automobile and furniture polishes that you simply wipe on and wipe off. Another silicone forms a water-tight bond between tough glass fibers and plastics that go into radar domes for airplanes, boat hulls, even washing machine parts.

WHEN APPLIED TO MASONRY WALLS, silicones are at their amazing best. A one-way street for water, they keep rainwater from penetrating, yet let inside moisture out!

THEY LAUGH AT HEAT AND COLD—Heat-resistant silicone insulation protects electric motors at high temperatures. Yet silicone insulation on jet plane wiring remains flexible, even in the brutal cold of the stratosphere. And silicone oils and greases withstand both arctic cold and tropic heat!

SILICONES AND THE FUTURE—Even the scientists don't know all the answers about silicones. But they do know there is an exciting future ahead for them. The people of Union Carbide, who pioneered in many of the special silicones now used by industry, are helping to bring that future closer to all of us.

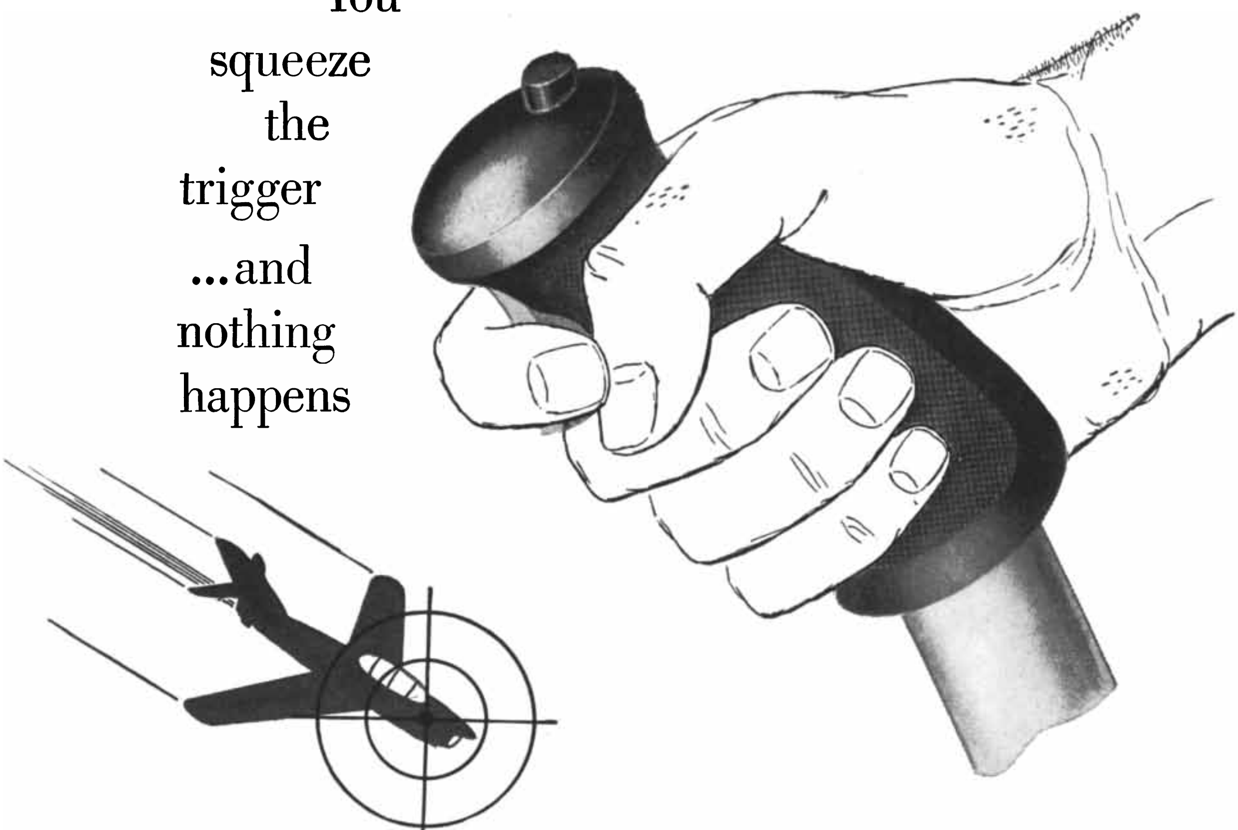
FREE: *Learn more about the interesting things you use every day. Write for the illustrated booklet "Products and Processes" which tells how science and industry use the ALLOYS, CARBONS, CHEMICALS, GASES, and PLASTICS made by Union Carbide. Ask for booklet G.*

UNION CARBIDE
AND CARBON CORPORATION
30 EAST 42ND STREET UCC NEW YORK 17, N. Y.

UCC's Trade-marked Products of Alloys, Carbons, Chemicals, Gases, and Plastics include

LINDE Silicones • DYNEL Textile Fibers • BAKELITE, KRENE, and VINYLITE Plastics • PRESTONE and TREK Anti-Freezes
PREST-O-LITE Acetylene • LINDE Oxygen • ELECTROMET Alloys and Metals • HAYNES STELLITE Alloys
SYNTHETIC ORGANIC CHEMICALS • EVEREADY Flashlights and Batteries • NATIONAL Carbons • UNION Carbide • PYROFAX Gas

You squeeze the trigger ...and nothing happens



A "RESISTOR" burned out! The guns won't work! Yes, sixteen cents worth of wire wrapped around a poor ceramic core can disrupt the operation of a million dollar jet plane. Seems incredible . . . yet the tiny heart of *this* and most other electrical systems is the resistor.

Why did it burn out? One common reason for resistor failure lies with the materials used in manufacturing the core. If the ceramic body isn't of proper crystalline structure, it can cause a serious variation in the physical and chemical property, resulting in unstable electrical performance.

To maintain an accurate check on the properties of materials used in their resistors, technicians of Ward Leonard Electric Co. – nation's foremost maker of resistors–turned to equipment engineered by North American Philips, a leader in electronic research.

NORELCO X-ray Diffraction is the answer

The characteristics of materials can be determined by their atomic structure. Analysis of ceramic substances by non-destructive NORELCO X-ray Diffraction *prior to processing* enables Ward Leonard technicians to predict their suitability. It takes less than two hours, whereas ordinary chemical methods require a week or more.

NORELCO serves science and industry

Throughout all phases of industry, manufacturers find a multitude of economical uses for NORELCO X-ray Diffraction. It has profitable applications in research, new product development and production control.

Doubtless you will find the precision manufacture, creative engineering, and imaginative thinking of NORELCO useful in your field.

NORELCO products include: Industrial Radiographic Equipment, Electron Microscopes, Research and Control Instruments, Metallurgical Products, Diamond Dies, Electronic Tubes, Precision Timing Motors and Relays.

Non-destructive NORELCO X-ray Diffraction can provide invaluable aid to your organization. The technical staff of North American Philips Application Laboratories is available for free consultation. Write also for booklet "Three Powerful X-ray Tools."

Many Users, Many Uses

California Institute of Technology • Dowell Incorporated • Gulf Research & Development Company • Kaiser Steel Corporation • Arthur D. Little Inc. • Monsanto Chemical Company • North American Aviation, Inc. • Pacific Coast Borax Co. • Phillips Petroleum Company • Rutgers University, The State University of New Jersey • Sinclair Refining Company • Sprague Electric Company • Standard Oil Company (Indiana) • State of Nebraska, Department of Roads and Irrigation

Norelco

Serving Science and Industry

NORTH AMERICAN PHILIPS COMPANY, INC.

• Dept. IH-11—100 East 42nd Street, New York 17, N. Y.

In Canada: Rogers Majestic Electronics Ltd., 11-19 Brentcliffe Road, Leaside, Toronto 17, Ontario

LETTERS

Sirs:

The article "Is Man Alone in Space?", by Loren C. Eiseley, in the July *Scientific American* recalls one with a similar title written by myself ("Are We Alone in the Universe?", *Scientific Monthly*, August, 1939). On the surface our conclusions are antithetical, though much of the difference is in point of view rather than substance. However, a little substance remains, and I should like to comment on that.

My own article concludes: "Somewhere in space are many, many fellow travelers on the brief but hopeful trek of life." I definitely did not say "fellow humans." Of course by definition human life is the kind developed on this one planet, and probably it hasn't even occurred to any except a few scientifically innocent souls that a replica of a particular John Smith hunts and fishes on some other globe. For that matter, he is absolutely unique even here. I realize that this stretches the point finer than author Eiseley intended, his point being, I take it, that maybe (or probably) we are not being even approximately duplicated elsewhere. Searching for his key sentence, I find: "It is not my contention that in the long cycles to come some of man's traits, even to an advanced brain, may not emerge once more in other living forms."

Then why carp at all? Well, for one thing, I don't like that "to come," even

Scientific American. November, 1953; Vol. 189, No. 5. Published monthly by Scientific American, Inc., 2 West 45th Street, New York 36, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

Editorial correspondence should be addressed to The Editors, Scientific American, 2 West 45th Street, New York 36, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Martin M. Davidson, Advertising Manager, Scientific American, 2 West 45th Street, New York 36, N. Y.

Subscription correspondence should be addressed to Circulation Manager, Scientific American, 2 West 45th Street, New York 36, N. Y.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.

Subscription rates for U.S.A. and possessions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $10; 3 years, $14. All other countries: 1 year, $8; 2 years, $12; 3 years, $16.

A REPORT FROM THE LABORATORIES OF REMINGTON RAND ON

ELECTRONIC DEVELOPMENTS FOR BUSINESS AND SCIENCE

Much of the popular talk about "giant brains" has actually obscured the work which electronic computing systems *are doing now* . . . to answer the pressing problems of business record keeping and control as well as scientific and mathematical computations.

An electronic computer system can process a large volume of data faster and more economically than any other method. Only one operation is required for a complicated program of computing, selecting and filing information. Routine decisions can be made automatically on the basis of instructions given the system. Exceptional conditions requiring management attention can be automatically signaled.

Remington Rand presents here some practical electronic devices which may be applied profitably today by business and science:

High-speed tallying

This Fac-tronic storage system is a new Remington Rand development. For John Plain & Co., a large wholesale mail order firm, it produces up-to-the-minute inventory analysis by item under the most demanding conditions of seasonal and shifting demand. Just ten order clerks—working at 10-key input systems to a magnetic drum memory—can provide accurate tallies of orders for 12,000 different items; make available complete tallies each day or anytime needed; and accommodate approximately 80,000 order lines per day.

Punched-card computers

New standards of speed and simplicity in punched-card procedures have been set by our new Punched-Card Electronic Computer. This system eliminates many time-consuming operations on other machines . . . produces *complete* cards which are ready for *immediate* tabulation of records and reports.

Big electronic computers

Remington Rand offers two distinct families of big computing systems: 1) The UNIVAC all-purpose system is designed primarily for business record keeping; 2) the ERA 1101, 1102 and 1103 general purpose systems are designed for scientific or mathematical computations.

Solving problems *today!*

Right now, electronic systems are working economically on such practical tasks as—billing and accounting, statistical reports and forecasts, planning studies and scheduling, production and inventory control, payroll and cost accounting records, pricing analyses, engineering design and many data-reduction applications.

Outstanding UNIVAC features are: processing of alphabetical as well as numerical data without special coding and decoding operations; high speed in sorting, collating, and filing as well as computing and decision making; tremendous speed of input and output by magnetic tapes; and built-in circuits for *automatic self-checking,* unique among large-scale data-handling systems.

ERA systems have an enviable record for high-speed solutions to complicated mathematical problems such as data reduction, systems simulation, planning studies, and control in real time. The new ERA 1103 provides very high internal speed, large storage capacity, and flexibility to surpass other systems of the same character. The 1103 also provides versatility of input and output—by teletype tape, magnetic tape, punched cards (80 or 90 columns), line printer, electric typewriter, and oscilloscope.

Custom-made systems

Air traffic control is just one example of the many special purpose electronic computer systems created by Remington Rand. This high-speed system receives via teletype such flight facts as: departure time, destination, route, fuel load, payload, and other pertinent data. In less than half a second, the system electronically compares the facts on each flight with as many as 2,000 flight plans it has stored in its magnetic-drum memory. It then revises, cancels, or brings the information up to date according to current conditions. The system completes the process by teletyping the required results back to the sending station . . . without human handling.

System designing

Remington Rand specialists analyze *your* needs in scheduling, process control, machine control, inventory control, data reduction, automatic filing, or other problems. A system may be created for you from standardized "building block" components, or we can make components to meet your needs.

Computing services

Through two electronic-computing centers, Remington Rand offers you the advantages of the UNIVAC and the ERA systems on a service-bureau basis. The centers have solved problems of such diverse types as complex accounting and record keeping, involved statistical and personnel studies, and cross-indexing of complex catalogs, books, and timetables.

One of the recent jobs handled by the UNIVAC center was a study of seasonal sales patterns and advertising timing. The Bureau of Advertising wanted a projection of 1954 monthly buying trends for 28 specific lines of merchandise in stores across the nation. To do the calculations on this series of 336 trend lines with desk calculators would have taken about 200 man-hours. The UNIVAC computer made all the calculations in just 3 and ½ minutes.

Let us show you how to save time and money on one-time jobs, deadline jobs, unusual jobs, and even routine jobs.

Management seminars

Through seminars and training courses, Remington Rand will help you learn how to apply electronic methods to your needs. In this way your organization can determine for itself the computer system needed—and the economic considerations involved—including choice between our rental or purchase plans. Remington Rand will also train your employees to operate the system efficiently. For more information, write to Remington Rand Inc., Electronic Computer Dept., Room 1417, 315 Fourth Avenue, New York 10, New York.

in a "speculation." Are we, in our off-center, frustratingly isolated position in one galaxy among millions, likely to be the smartest creatures extant at this moment? Isn't it more likely that space ships (with dissimilar pilots, of course) flood the crowded cosmic ways of many a globular cluster, heading for target planets with heavily jeweled skies and handy neighbors?

"No," says author Eiseley, "there hasn't been enough time." But this shortage of time is an anomaly that has come upon the scene only recently; and it seems far out of line with other facts of observation and the "feel" of an orderly universe. Besides, *a priori* absurdities in science have a way of clearing up. For example, the conclusion that our galaxy is much bigger than all others seemed unlikely on the face of it; but there it was, according to the evidence, until about a year ago, and then there it wasn't—at least, not so much. The simple truth as it now comes out is that the distances to other galaxies have been underrated. Incidentally and significantly, this 1952 finding pushed back the time of the hypothetical "galactic explosion" of two billion B.C.—now four billion—and gave a further lift to our sense of the fitness of things.

The galaxies which lie in the tremendous and yet limited field of view of earth's telescopes are in apparently different life-cycle stages, as are their stars. The evidence for a common spewing out from a primordial "monobloc," strong as it is, is not conclusive as yet, and alternative explanations of the strange effect, such as that afforded by the "tired light" theory, are not out of the picture. In any case, the galaxies might have come through the "monobloc crisis" unscathed from a previous state. Nor are we obliged to assume that all life everywhere started after this uncertain event. Thus it seems to me to be a very poor bet that we of the planet Earth are the current intellectual champions of creation. (However, the thought is not too unpleasant, at that.) Thanks anyway for an interesting article.

R. S. UNDERWOOD

Lubbock, Tex.

Sirs:

Your article "Archaeology and the Earliest Art" [SCIENTIFIC AMERICAN, August] causes me to ask the following question: Why did Picasso paint "Young Girl at the Mirror"?

One of the questions which the author

proposes to answer in his article is why the cave pictures were made. As an instrument to solve his problem the author uses the hypothesis that every form of art reflects the culture of the people who created it. The author rejects the possibility that the artists drew these pictures merely for the sake of expressing themselves. It sounds very plausible that primitive peoples in general do not and did not draw to create an expressive picture, but the same thing can also be said of more modern peoples. The great paintings which hang in the museums seem to me to be more a reflection of the personality of the individual artist than the culture of his people. Commercial art or pictorial advertisements, on the other hand, are without a doubt almost completely representative of cultural influence.

The prehistoric artist who drew the cover of your August issue may have been advertising buffalo for sale, but it seems more likely that he was an outstanding personality of his time striving for self-expression.

Great geniuses in the history of art have probably influenced succeeding cultures more than they have been influenced by their own. The introduction of something distinctly new is almost a trademark of outstanding artistry in any field. If we attempted to evaluate Picasso only insofar as he is representative of his culture, we would get a distorted picture of both the artist and his culture.

ALBERT ROWE

Pittsfield, Mass.

Sirs:

Permit one who appreciates the quality of your journal, and one genuinely interested in the early history of electricity, to congratulate the Rollers, father and son, upon their article about Francis Hauksbee in your August issue.

However, I feel I must remonstrate against the practice so often indulged in by biographers, namely that of maximizing the hero of the play by minimizing the supporting cast, in this case those upon whom the Hauksbee advance was built. The authors make this statement about von Guericke and his sulfur ball which was electrified frictionally by rotation:

"Thus he did not devise it as an electrical generator or use it for investigating electricity. Moreover, his device and the experiments with it seemed to have been unknown to electrical experimenters in England and France until nearly three

Presenting some outstanding "portraits" from

THE **LYCOMING** GALLERY OF FAMOUS AMERICAN PRODUCTS

. . . featuring Lycoming's contributions to these products as seen through the eyes of Boris Artzybasheff, one of America's great contemporary illustrators.

Look closely—one of these achievements for America's industrial and military leaders may indicate how Lycoming can solve *your* metal-working problem.

See how these "portraits" help interpret Lycoming's abilities. See why you can depend on Lycoming's versatility of skills, extensive facilities, and well-rounded experience to meet your most rigid metal-working requirements.

Whatever your problem—whether you need creative engineering for "just an idea" or precision or volume production of a finished product—"Look to Lycoming!"

For a more complete story on Lycoming's varied abilities and facilities, write—on your company letterhead—for the interesting, illustrated booklet "Let's Look at [illegible]"

Presenting some of America's leaders who

LOOK TO LYCOMING

AERO DESIGN AND ENGINEERING COMPANY
AMERICAN CAR AND FOUNDRY COMPANY
AIR MATERIEL COMMAND
BEECH AIRCRAFT CORPORATION
BENDIX AVIATION CORPORATION
CESSNA AIRCRAFT CORPORATION
THE CLEVELAND PNEUMATIC TOOL COMPANY
DOMAN HELICOPTERS, INC.
FOOD MACHINERY & CHEMICAL CORPORATION
FORD MOTOR COMPANY
GENERAL ELECTRIC COMPANY
GENERAL MOTORS CORPORATION—CHEVROLET-AVIATION ENGINE DIVISION, DETROIT TRANSMISSION DIVISION
INTERNATIONAL BUSINESS MACHINES CORPORATION
KAMAN HELICOPTER CORPORATION
NAVY BUREAU OF AERONAUTICS
NEW IDEA FARM EQUIPMENT COMPANY
PIASECKI HELICOPTER CORPORATION
PIPER AIRCRAFT CORPORATION
PRATT & WHITNEY AIRCRAFT
RYAN AERONAUTICAL CORPORATION
SYLVANIA ELECTRIC PRODUCTS, INC.
THOMPSON PRODUCTS, INCORPORATED
U.S. ARMY ORDNANCE
WESTINGHOUSE ELECTRIC CORPORATION
WRIGHT AERONAUTICAL DIVISION, CURTISS-WRIGHT CORPORATION

"Sinews" to give cars "go"

For vital automotive parts—precision-machined components that can "take it," year after year, leading *automobile manufacturers like* FORD, *have long looked to Lycoming.*

"Blasts" for jets

To precision-produce tough, unfailing major components that put the "blast" in its superb J-47 jet engine—GENERAL ELECTRIC *looks to Lycoming.*

How a helicopter hangs by its "elbows"

For flexible "elbows"—rotor assemblies that control the amazing maneuvers of its H-21 "Work-Horse" Helicopter—PIASECKI *looks to Lycoming* for precision production.

New "ticker" for tanks

For a dependable tank "heart"—500 horsepower's worth of rugged, air-cooled engine—U. S. ARMY ORDNANCE *looks to Lycoming*, pioneer in the air-cooled engine field.

How a jet engine runs on its "nerves"

To produce the auxiliary "nerve center" for its J-40 jet engine—a complex gearbox that transmits power to vital accessories—WESTINGHOUSE *looks to Lycoming.*

"Air horses" for lifesaving over the sea

To help swell the production of the mighty Wright-Cyclone engine—dependable "horses" for air-sea rescue work—CURTISS-WRIGHT *and the* U. S. AIR FORCE *look to Lycoming.*

FOR RESEARCH • FOR PRECISION PRODUCTION

LOOK TO **LYCOMING**

Lycoming-Spencer Division, Williamsport, Pa. AVCO Bridgeport-Lycoming Division, Stratford, Conn.

AIR-COOLED ENGINES FOR AIRCRAFT AND INDUSTRIAL USES • PRECISION-AND-VOLUME MACHINE PARTS • GRAY-IRON CASTINGS • STEEL-PLATE FABRICATION decades after Hauksbee had published his work."

In view of the recognition accorded the electrical experiments of von Guericke by many authorities, his building of the sulfur ball to simulate the earth for the purpose of testing his conception that electrical attraction might be the explanation of gravity in contrast to Gilbert's assumption of magnetism, his demonstration of electrical repulsion, of conduction along a string, observation of the discharging power of points, the dissipation of charge by flame, the observance of the weak light accompanying electrification—surely these are electrical discoveries of a fundamental character. Nor can there be sustained the authors' assumption that von Guericke's experiments remained unknown. His book of 1672 was reviewed in *Philosophical Transactions of the Royal Society*, of which Hauksbee was Curator of Experiments. Boyle had built upon von Guericke's air pump and it was upon this that Hauksbee built in turn. As to the rotating type of generator, Newton is credited with having suggested the substitution for the sulfur ball of a glass ball, the kind of vessel that Hauksbee evacuated.

Altogether the hero of this play appears to have been overdone, but he is a long-forgotten one deserving of being recalled, and the play itself is nicely presented.

LLOYD ESPENSCHIED

Bell Telephone Laboratories
New York, N. Y.

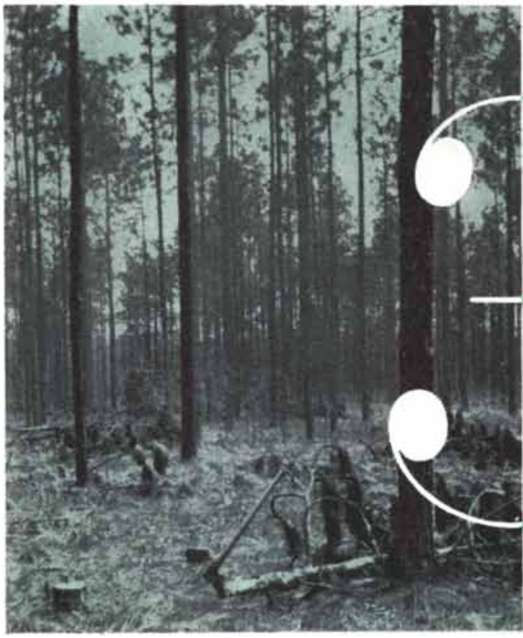
Sirs:

As a careful reader of Cecilia Payne-Gaposchkin's published work, I feel that I must call attention to an incorrect statement in her article "Why Do Galaxies Have a Spiral Form?" [SCIENTIFIC AMERICAN, September]. The statement is: "only this year . . . certain observations . . . doubled all stellar distances."

Mrs. Payne-Gaposchkin will be the first to assert that this is incorrect. While it is true that certain observations have doubled the distances of most galaxies outside our own, it is certainly not true that these observations have doubled the distances of stars within our galaxy. The error was due to an oversight in the final correction of the article.

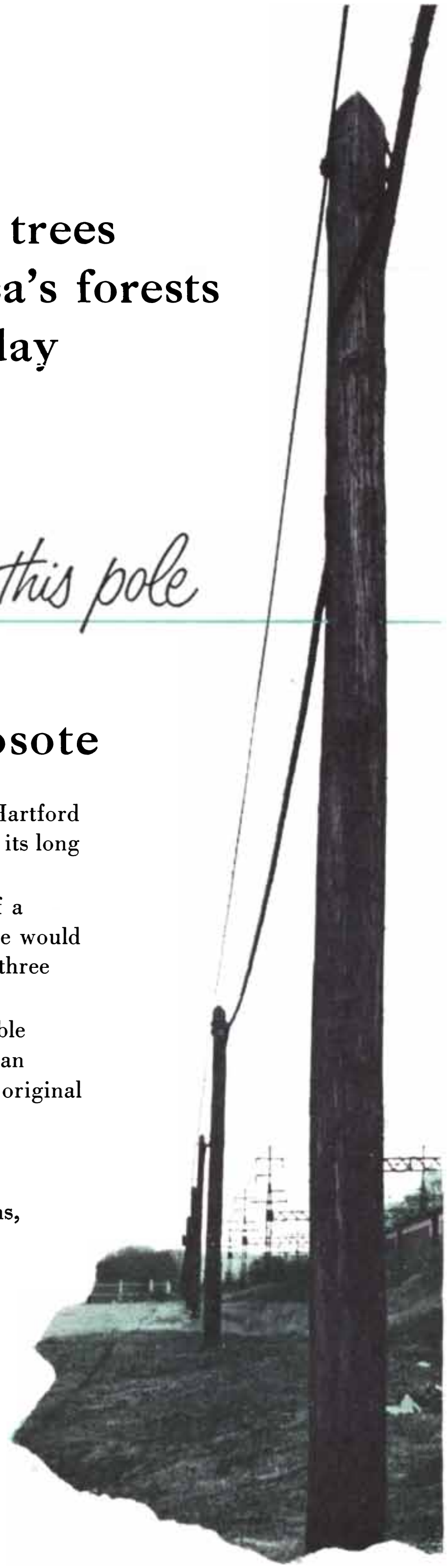
CECILIA PAYNE-GAPOSCHKIN

Harvard College Observatory
Cambridge, Mass.



3 more trees in America's forests today

because this pole



was pressure-treated in 1918 with Creosote

It stands along the right-of-way of The New York, New Haven and Hartford Railroad Company at Milford, Conn. It's been there for 35 years, and owes its long service life to pressure-treatment with Creosote before installation.

Before railroads began using poles treated with Creosote, the average life of a yellow pine pole like this was about 10 years. Under those conditions, this pole would have been replaced three times since its installation. And there would have been three less trees numbered among America's natural resources.

Apply this figure to the 3029 poles that carry this railroad communication cable through New York and Connecticut and it's a sizable saving in timber . . . and an equally impressive economy in maintenance costs. (Incidentally, 98.7% of the original 3029 poles in this line are still in service.)

Pressure-treatment with Creosote is the most thoroughly proved of all wood preserving methods. It is used to extend the life of utility poles and crossarms, railroad ties, construction and mine timbers, piers and other marine installations, fence posts and pole barns. The wood preserving industry is currently using Creosote at a rate of more than 200 million gallons a year.

● ***United States Steel is a major supplier of Creosote to railroads and independent wood preserving companies. U·S·S Creosote is produced in a continuous processing operation in America's largest tar distilling plant.***

If you use wood for any of the purposes mentioned above, take advantage of economies of pressure-treatment with U·S·S Creosote. Specify it to your treater. For further information, contact our nearest Coal Chemical Sales Office or write directly to United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pa.

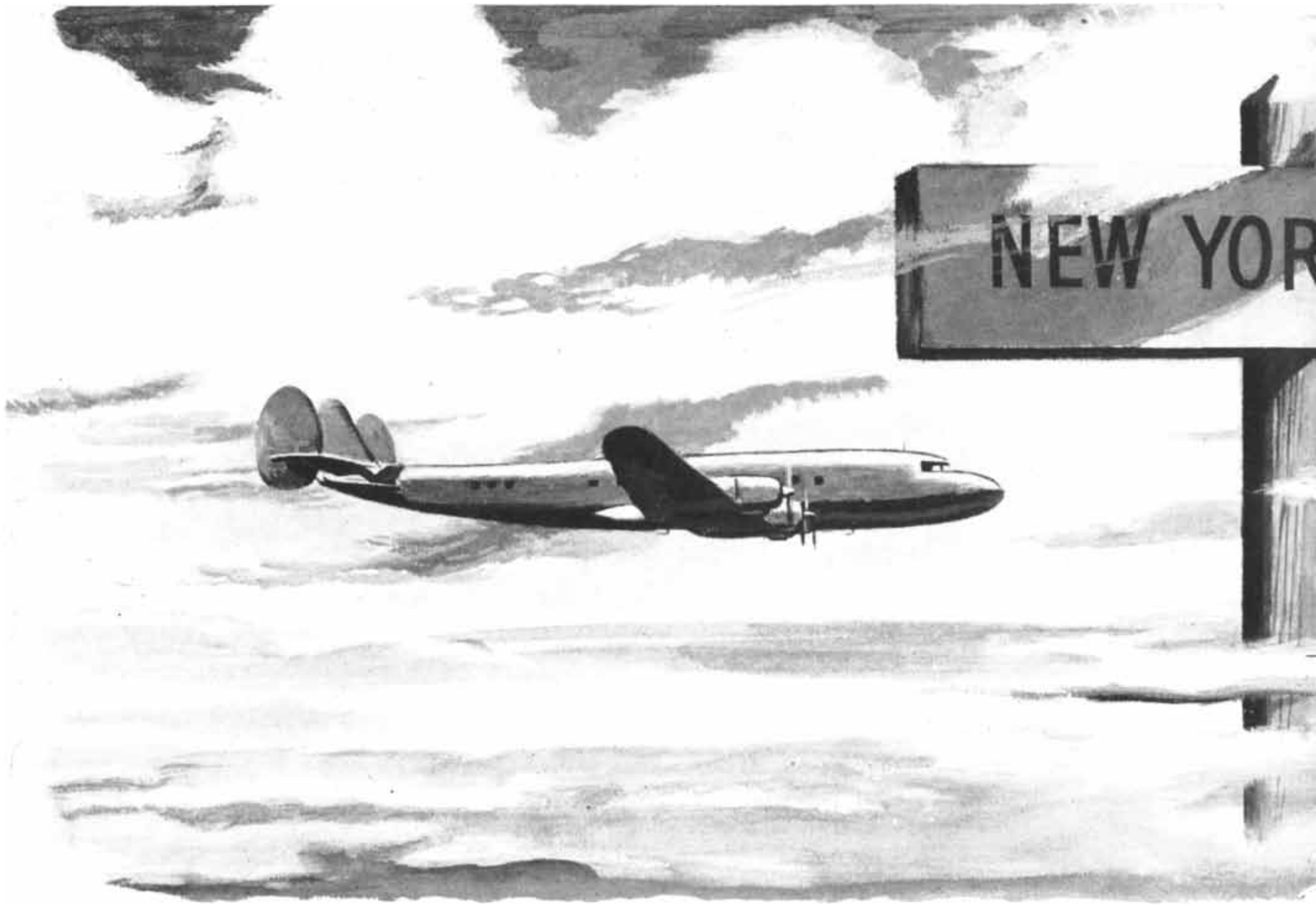
U·S·S CREOSOTE

Creosote—***the proved preservative that makes wood last longest***

USS TRADE MARK

3-2086

UNITED STATES STEEL



Ever see a Milepost in

Wherever planes fly, Bendix devices contribute to their efficient operation. The human pilot's task is eased by Automatic Pilots which fly planes accurately; by "Glide Path" Controls and GCA (radar) that help him land in bad weather; by Omni-Mag that points his course; by Radio for instant ground communications and by scores of other products that make flying safer and more economical.

Newest member of the family is Bendix DME—distance measuring equipment that constantly indicates how many miles the plane is from its airport. Especially valuable in adverse weather, DME helps pilots immeasurably, eliminates "estimating", increases the safety factor, effects operational savings.*

Though we design and manufacture hundreds of products for the aviation and automobile industries, Bendix Aviation Corporation must be classified also under a score or more of other type business categories, some of which can be gleaned from the partial listing of divisions and products at the right.

The nature of Bendix is what might be called planned diversity. Our forte is an abundance of technical talent—an engineering and research staff of over 6000—coupled with a 25-division manufacturing organization experienced in

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

NOVEMBER, 1903: "Mr. O. Chanute, than whom there is probably no greater authority living on soaring flight, says that he has just returned from witnessing this season's gliding experiments of the Brothers Wright, and that 'they have made a very considerable advance since last year, and now glide at angles of 6 deg. to 7 deg., sustaining 125 to 160 pounds per net horse power. Wright is now doing nearly as well as the vulture, is not far from soaring flight, and I am changing my views as to the advisability of applying a motor.' "

"Peter Lebedew, the Russian physicist who has recently succeeded in measuring the pressure of light, describes his experiment in the Astrophysical Journal. A torsion thread hangs in a highly exhausted bell jar and carries a vertical glass rod. Thin disks of 5 millimeters diameter, of the metal to be investigated, are attached to this rod at a distance of 10 millimeters from its axis. If the radiation from an arc lamp is concentrated on one of the disks the incident radiation will exert a pressure upon it, and it will retire until the pressure due to radiation is balanced by the torsion of the glass thread; the angle of torsion is measured by a mirror and scale as for a galvanometer. This observation permits the determination of the absolute magnitude of the pressure (in dynes) if the directing force of the torsion thread is measured in absolute units by one of the well-known methods."

"The Swedish Academy of Sciences, which awards the Nobel prizes, has decided that the recipients for this year shall be as follows: in literature, Henrik Ibsen and Bjornstjerne Bjornson; physics, Signor Marconi; and medicine, Dr. Finsen."

"With the lamentable failure of Prof. Langley's aerodrome and the accident which befell Dr. Greth still fresh in the public mind, one cannot help but admire the courage which Santos-Dumont has displayed in navigating the ten airships

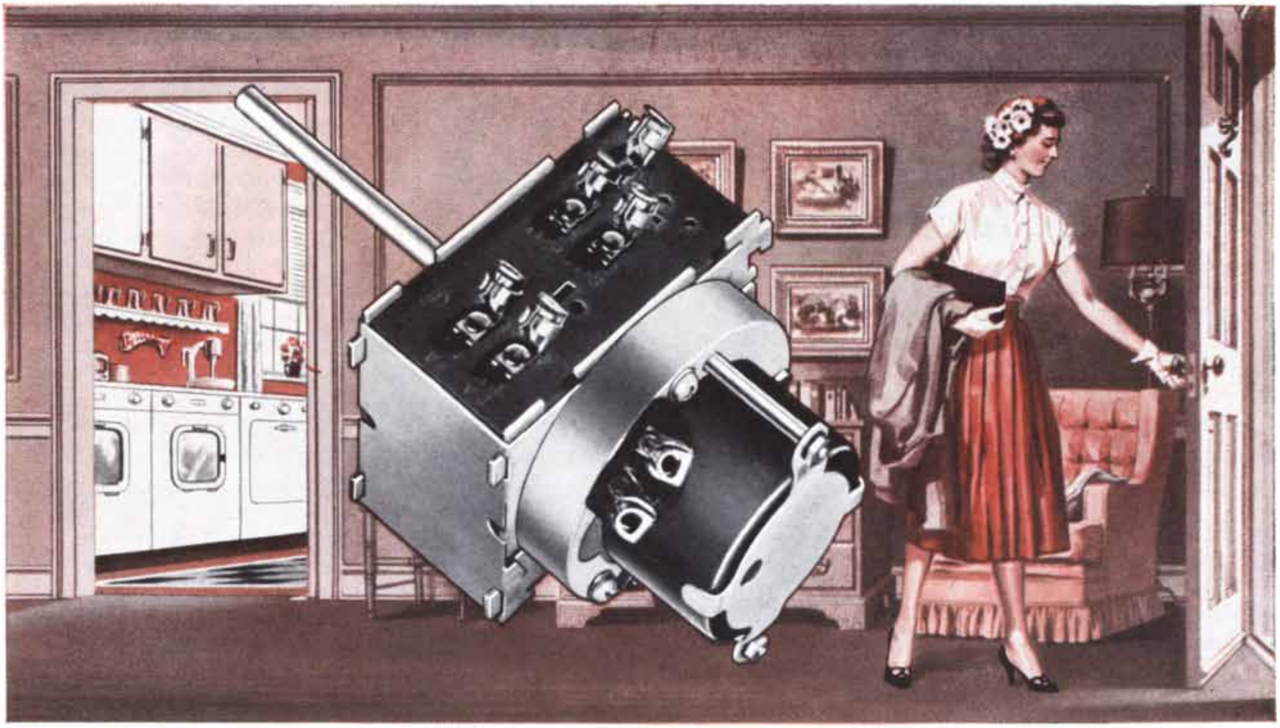
which he has thus far constructed. Severo and De Bradsky, in machines that differed not radically from his, both lost their lives. Still, he persists in adhering to his design with a pertinacity that shows he has the courage of his convictions."

"Dr. Niels R. Finsen is the director of the five new buildings in Copenhagen known as 'Finsen's Medicinske Lysinstitut,' which was founded by the Danish government. Since 1890 Finsen has devoted himself to work on phototherapy or the therapeutic influence of the various rays of the solar spectrum. His first great result was the red-light treatment for small-pox, which is now being used all over the world with splendid results. The result of the red-light treatment is that suppuration is usually abolished. Scars are extremely rare, and the duration of the disease is shortened."

"The British authorities in Uganda are making great efforts to discover the source of the terrible 'sleeping sickness' which periodically decimates the natives of that territory and other parts of Africa, and, if possible, to find a means of preventing its spread. In May last year the Royal Society dispatched a commission to Entebbe, Uganda, for the purpose of investigating the disease. Its studies showed that the disease is caused by a minute parasite in the blood, which could not be conveyed from man to man. Consequently suspicion fell upon the tse-tse fly, a species of which, similar to the one prevalent in Zululand, was found abundant in Uganda. Experiments are now in progress to settle whether the Uganda tse-tse carries in its blood the identical parasite which is peculiar to the disease, and whether it can pass it to an animal. One rather tentative experiment seems to show this, and it is expected that the truth or falsity of the theory will soon be determined."

SCIENTIFIC AMERICAN

NOVEMBER, 1853: "It has been lately discovered that heat, as well as light, is susceptible of polarization; and, as it is governed in its reflection and refraction by the same laws which govern the similar phenomena of light, it becomes necessary for those who adopt the undulatory theory of light to apply a similar explanation to the phenomena of



Picture of the Smartest Helper a Housewife Ever Had...

THE problem of how to free the housewife from tiring, time-consuming chores in laundry and kitchen hinged for a long time on development of a device to control automatic washers, dryers and dishwashers.

Mallory came up with a timer switch smart enough . . . small enough . . . and tough enough to mastermind the operation of automatic appliances and give the housewife time for other things in and out of the house.

There is masterminding aplenty in millions of homes today as the Mallory Timer Switch turns water on and off . . . activates spinners, agitators or fans . . . regulates heat in drying units—all on a precise, predetermined schedule.

The Mallory product line-up is full of family "helpers". To mention a few: the vibrator power supply in car radios . . . vital parts in TV sets . . . TV tuners, including the Mallory UHF Converter . . . contacts in thermostats and everywhere else that electrical circuits must be made and broken.

In the fields of electronics, electrochemistry and metallurgy, manufacturers count on Mallory precision components and specialized knowledge to hold down costs . . . solve problems . . . develop designs . . . improve products.

P. R. MALLORY & CO. Inc.
MALLORY

SERVING INDUSTRY WITH THESE PRODUCTS:

Electromechanical • *Resistors, Switches, Television Tuners, Vibrators*
Electrochemical • *Capacitors, Rectifiers, Mercury Batteries*
Metallurgical • *Contacts, Special Metals and Ceramics, Welding Materials*

P. R. MALLORY & CO., Inc. INDIANAPOLIS 6, INDIANA heat. Hence, we are now taught that heat, as well as light, is produced by the vibrations of an elastic medium.

"But it has also been shown that electricity is likewise capable of polarization; so, in order to be consistent, the undulatory hypothesis must also be applied to this. If this be done, one of two assumptions must be made, either there are diffused throughout all space three elastic media, each capable of vibrating at widely different rates of frequency and intensity, or there is one medium, capable of producing, by its vibrations, results as totally distinct as are those of light, heat and electricity. We think no one will propose an assumption so labored as the latter, and we shall therefore consider the former as the one necessarily adopted by those embracing the hypothesis in question.

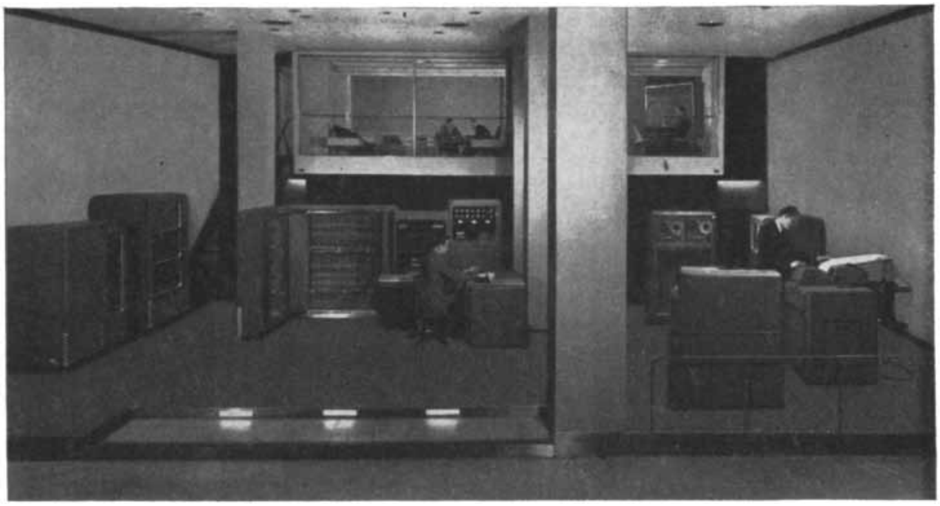
"The doctrine of latent heat is established not from theoretical considerations but from accurate and indisputable experiments. In this manner it has been determined that any body in passing from the solid to the fluid state combines with a certain definite quantity of caloric, which remains in combination with it so long as it is in the fluid state, but is set free when it again becomes a solid. Let it be remembered this is not theory but *fact*. It is therefore possible, according to the theory of undulations, for the *vibrations* of an elastic medium to combine with matter, remain in this state of combination for years or centuries, and then to be again set free in an active state!

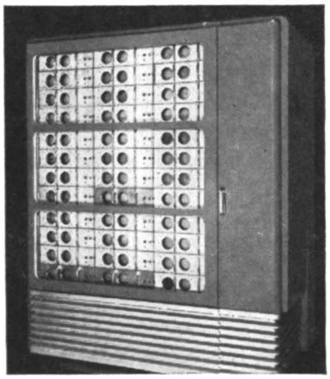
"But this is not all. The vibrations of an elastic fluid can only act on a solid body by generating corresponding vibrations in that body. The change of state from the solid to the fluid must then be an actual shaking to pieces of the particles of the solid body! This borders closely on the ridiculous, but it is certainly a fair inference from the theory under consideration. And why should so powerful a vibration not become manifested in some other way? Why, for instance, is it not communicated to the air and revealed to us by sound? If it be said that the vibrations are so frequent that they cannot be caught by the air, we shall reply that the experiment has taught us that bodies have but one tone, and are incapable of vibrating in any other. If it be said the air vibrates, but produces heat instead of sound by these vibrations, then we have found an elastic medium capable of producing two different classes of phenomena by its vibrations, and, by the same mode of argument, the phenomena of all the imponderable agents!"

This is the latest in electronic "brains"

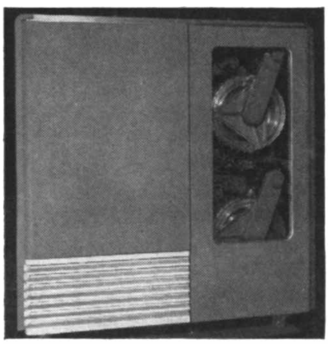
It's IBM's electronic calculator. It performs such mathematical feats as solving, in a few minutes, equations useful in aircraft wing design, which require some eight-million calculating steps. Such equations would take an expert working with a desk calculator seven years to solve.

The heart of this "brain"—comprising banks of cathode ray tubes through which all information to and from all other components must pass—is protected from stray electrostatic charges by PYREX brand EC electrically conducting glass. The magnetic drum unit "memory device" is protected in the same manner.





The 72 cathode ray tubes in the Storage Unit (pictured above) store 20,480 digits in the form of electronic charges, ready for delivery to other parts of the machine in 12/1,000,000 of a second.



The two drums in the Magnetic Drum Storage Unit (pictured above) store as many as 81,920 digits as magnetized spots on the drum faces. Each digit can be recalled for processing in an average of 40/1,000 of a second.

The PYREX *brand EC glass window panels in these extremely sensitive "memory" devices permit the operators to see that everything inside is working properly and they ward off outside electrostatic charges which would disrupt operation.*

How EC glass solved a problem for this electronic "brain"

Protection of IBM's electronic calculator from straying electrostatic charges became a design problem because operators had to see that everything was working properly *inside* certain units.

Metal would protect; but you can't see through it. Ordinary glass lets you see, but it doesn't protect.

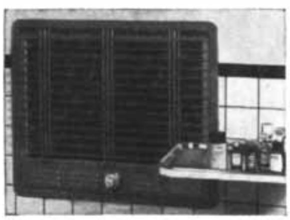
The IBM engineers solved the puzzle by using Corning's EC glass for cabinet window panels.

EC glass is a PYREX brand glass with a thin transparent electrically conducting coating permanently bonded to one surface. It carries electrostatic charges away just as metal does.

This remarkable material has many other uses—For example, EC glass is excellent for home heating units. Simply switching an electric current through the EC coating makes it a heating element that gives out an evenly distributed flood of radiant energy. It's finding increasing use in industrial heating and drying operations, too, especially where an *even* distribution of heat is desirable.

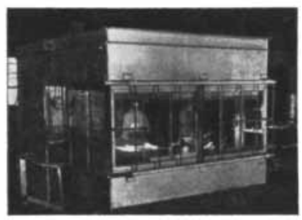
The EC coating is also an efficient reflector of infrared heat rays. So you find EC glass panels used as shields for people working near sources of intense heat, in steel mills, for instance, and movie or TV studios.

The immense possibilities of PYREX brand EC glass have scarcely been scratched. If it interests you, Corning engineers will be glad to talk with you about it and any application you may have in mind. There's a more complete story in the June-July, 1953, issue of the "Corning GLASSMAKER." We'll be glad to send you a copy.



Wall-mounted Berko EC heater in doctor's office.

EC radiant panels drying lacquer on plastic sheets.



EC panels protect shear pulpit operator in steel mill hot spot.

PYREX

CORNING GLASS WORKS
CORNING, NEW YORK

Corning means research in Glass

CORNING GLASS WORKS, 610 Crystal St., Corning, N. Y.
Please send me a copy of "Corning GLASSMAKER," June-July, 1953 issue.

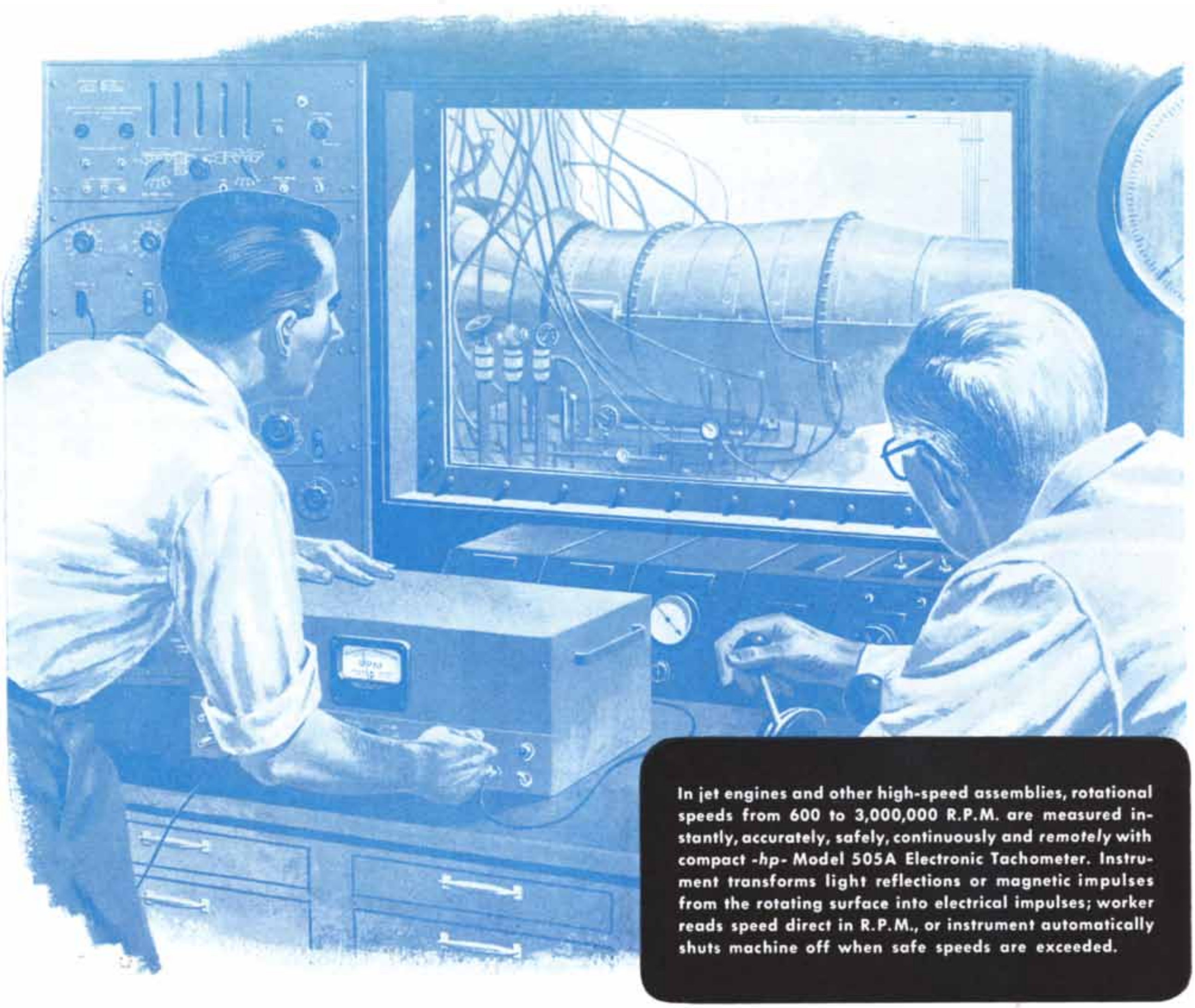
Name..........
Title..........
Company..........
Address..........
City.......... Zone.......... State..........

THE AUTHORS

JOANNE STARR MALKUS ("Trade Winds") decided to become a student of the weather when, as an undergraduate at the University of Chicago, she took up amateur flying. This necessitated a short course in meteorology, a subject which so excited her, "especially the parts concerning the growth of clouds," that she took a B.S., an M.S. and a Ph.D. in the subject. After the war, in which she served as a forecaster at the Chicago Weather Bureau and as an instructor of student weather officers, Dr. Malkus joined the physics department of the Illinois Institute of Technology. There she became assistant professor of physics and meteorology, introduced a course in meteorology for engineers and conducted a project on cumulus cloud dynamics for the Office of Naval Research. In 1951 she moved to the Woods Hole Oceanographic Institution, where she now holds the position of marine meteorologist. During a visit to England she met P. A. Sheppard, chairman of the meteorology department at Imperial College. He also had his eye on the trade winds and urged on her a Woods Hole-Imperial College expedition. Woods Hole, which had acquired a PBY seaplane, assigned it to Dr. Malkus in March and April of 1953 for flights in the trade-wind region. Her present article is based largely on data obtained on that trip. Dr. Malkus is married to Willem V. R. Malkus, theoretical physicist and oceanographer at Woods Hole. They have two sons.

GEORGE B. COLLINS ("Scintillation Counters") is in charge of the Cosmotron at Brookhaven National Laboratory on Long Island. His educational background is unusual in that he never acquired a B.S. or an M.S. degree but received a Ph.D. from M.I.T. His first job after obtaining his degree in 1931 was as instructor in physics at the University of Notre Dame. While there he helped to build one of the first electrostatic generators. It operated at 1.8 million volts, a respectable figure in those days, and showed that electrons could produce nuclear disintegrations. Collins and his associates also used it to investigate Cerenkov radiation. During the war Collins was in charge of a group at the Radiation Laboratory of M.I.T. whose job was to adapt British inventions in the radar field to the systems being developed in the U. S. After the war he was appointed

Your business *is* in the Age of Electronics



In jet engines and other high-speed assemblies, rotational speeds from 600 to 3,000,000 R.P.M. are measured instantly, accurately, safely, continuously and *remotely* with compact *-hp-* Model 505A Electronic Tachometer. Instrument transforms light reflections or magnetic impulses from the rotating surface into electrical impulses; worker reads speed direct in R.P.M., or instrument automatically shuts machine off when safe speeds are exceeded.

On your production line, as in research, electronic tests may save time and money

Overspeed control and accurate determination of R. P. M. are two of many functions industry now performs efficiently with electronic test instruments.

Manufacturers of turbines, engines, motors, centrifuges and other high-speed assemblies use electronic instruments for fast, accurate speed and speed-control checks—on the production line as well as in the laboratory. Non-technical production workers can obtain reliable data day after day with these easy-to-use, direct-reading instruments. And, in the hands of your engineers, the same equipment often supplies research information not otherwise obtainable.

Hewlett-Packard is a pioneer and world leader in electronic test instruments—basic measuring tools used in R.P.M. measurements and many other manufacturing, research, communications and military applications. Each application differs; *-hp-* factory-trained engineers can tell quickly which of our 200 different instruments can help you. Write today, outlining your problem. Our nearest field engineer will call soon to discuss it with you at no obligation.

ELECTRONIC MEASURING INSTRUMENTS

HEWLETT-PACKARD COMPANY

2407-S PAGE MILL ROAD • PALO ALTO, CALIFORNIA chairman of the physics department of the University of Rochester. The University was then building its 240-million-volt synchro-cyclotron, and the need for counters that could operate in the intense pulsed beam of this machine led Collins to explore the capacities of scintillation counters. He moved to Brookhaven in 1950.

STUART PIGGOTT ("A Forgotten Empire of Antiquity") became interested in the prehistoric sites of India during World War II. Because of his archaeological background, the British Army had assigned him to intelligence and had sent him to Delhi as an aerial-photograph interpreter. In his spare time there he looked into Indian prehistory, "largely as an escape from war, but also because I saw it was in a muddle which might be sorted out by the application of methods learned in England." Piggott holds the chair of Prehistoric Archaeology at the University of Edinburgh. His main field of study now is Western Europe in the Second Millennium B.C., but he still keeps "an affectionate eye on the Orient." He is 43 years old and married to a fellow archaeologist. In addition to several books in his own field, he has published "the inevitable slim volume" of war poems.

LAWRENCE P. LESSING ("The Gas Turbine") joined the Board of Editors of SCIENTIFIC AMERICAN early this year. He is a journalist who has specialized in technology and has written articles on high-speed chemistry and on hydrazine for recent issues of the magazine (May and July, 1953).

JEAN PIAGET ("How Children Form Mathematical Concepts") is professor of psychology at the University of Geneva and co-director of the Institut J. J. Rousseau, affiliated with that University. He was born in Switzerland in 1896. By the age of 15 he was contributing to journals of zoology, both Swiss and foreign. These articles elicited offers of positions and engaged him in correspondence with "colleagues" who did not know they were dealing with a schoolboy. Piaget's studies soon convinced him that, at every level from the cell to society, life could be understood only in terms of "totalities" or "structures-of-the-whole." He believed this was particularly true of the intellectual processes, and he therefore turned to psychology. His interest in children, with whom he has worked for the past 30 years, began at the Sorbonne, where he was associated with Théodore Simon, co-author

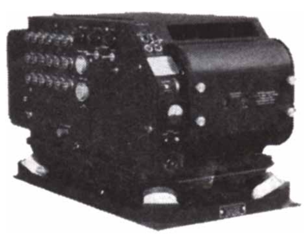
Sir Isaac did it this way...

Deceleration, momentum and gravity intrigued Sir Isaac Newton in 1660, but he lacked today's scientific instrumentation and therefore had to carry out his experiments on a basis of guesswork.

The Air Force does it this way...

Deceleration forces are a major problem in high-speed flight. To study human resistance to high crash forces and the strength of aircraft components and safety equipment, the U. S. Air Force conducted 233 tests. Crash belts, seats, and even volunteer personnel were fitted with strain gages and propelled at high speeds on a rocket-powered sled, stopping with crash-impacts up to 45 times the force of gravity. Electric signals from the strain gages were telemetered to a Consolidated dynamic recording system where stress, strain and displacement data were all measured and recorded simultaneously, making clear, permanent records for future reference and study.

You can profit by their experience this way...



Progress and profit are closely tied to process control, product development and improvement. Thousands of industries as well as the military conduct performance evaluation through dynamic testing. Consolidated produces high-precision analog-data-processing instruments such as the Recording Oscillograph, left, to record static and dynamic data; analytical and control instruments of the mass spectrometer type for analysis, process monitoring and control; digital data-processing devices such as electronic converters and computers. Perhaps our long experience in the instrumentation field can help you improve your product or process, and thus increase your profit. We would like to discuss this possibility with you.

Consolidated Engineering
CORPORATION

300 North Sierra Madre Villa, Pasadena 15, California

Sales and Service through **CEC INSTRUMENTS, INC.,** *a subsidiary with offices in: Pasadena, New York, Chicago, Washington, D. C., Philadelphia, Dallas.*

ANALYTICAL INSTRUMENTS
FOR SCIENCE AND INDUSTRY

of the Binet-Simon test. In the U. S. Piaget is known for a series of books on the development of thought and reasoning in the young. The most recent of these, a synthesis of his present thinking on the subject, is *The Origins of Intelligence in Children* (1952). In addition to his research, teaching and voluminous writing (he has published 22 books and innumerable articles), Piaget has been at various times Director of the International Office of Education, president of the Swiss Society of Psychology and co-editor of the *Revue Suisse de Psychologie*. He is a member of the Executive Council of UNESCO. Piaget is married and has three children.

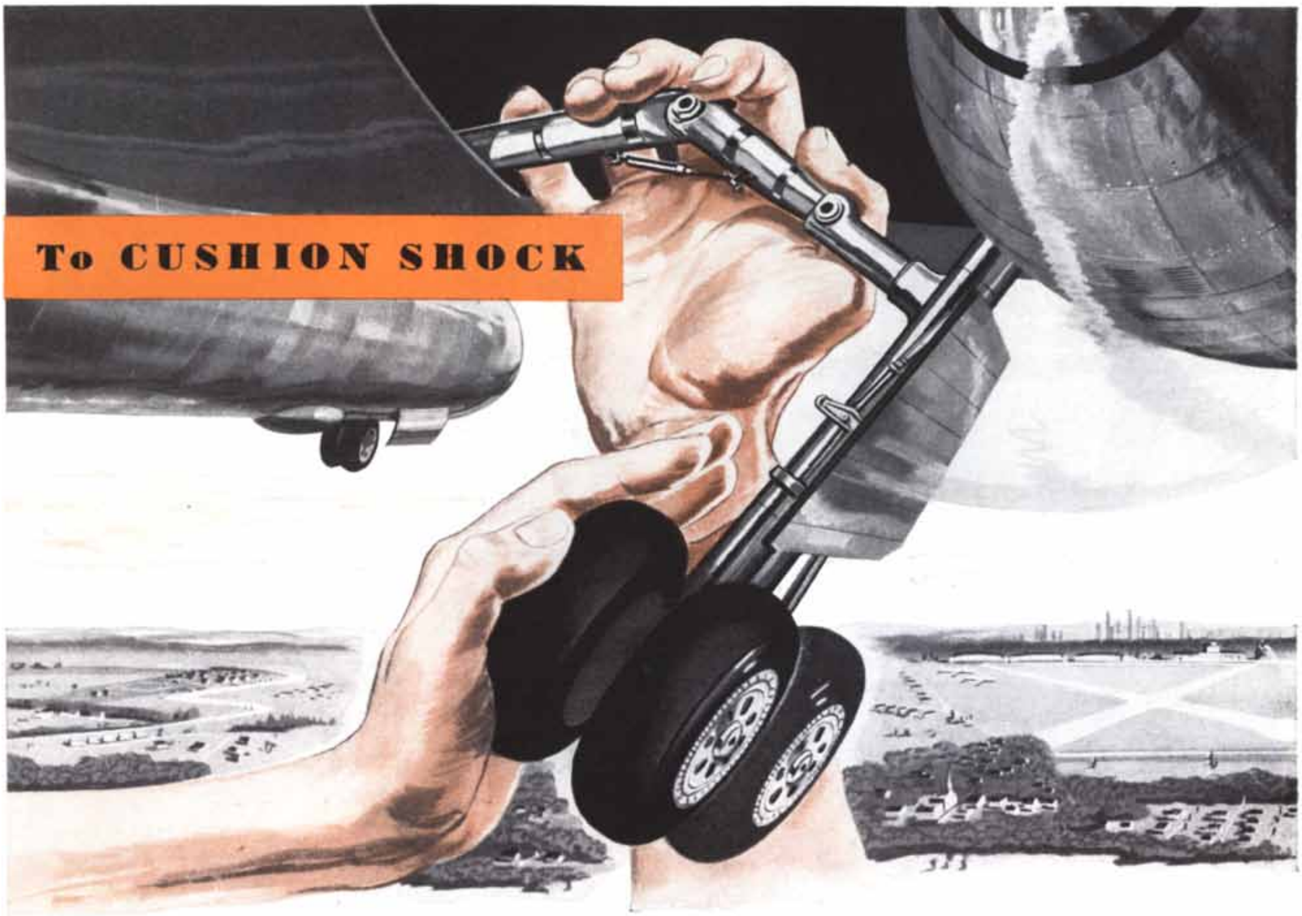
EUGENE I. RABINOWITCH ("Progress in Photosynthesis") became a botanist after having been trained (at Berlin, Göttingen, Copenhagen, London and M.I.T.) in biochemistry and physics. This diverse background fitted him particularly for studying photosynthesis, which breaks down into a series of biochemical and physical problems, and he is recognized today as one of the leading authorities on the subject. During the war Rabinowitch was on the staff of the Manhattan District. He is one of the founders of the *Bulletin of the Atomic Scientists* and has been its editor from the beginning. Born in St. Petersburg (Leningrad) in 1901, he came to the U. S. from England in 1939 and is now research professor in the department of botany at the University of Illinois. Rabinowitch contributed a general survey of research in photosynthesis to the August, 1948, issue of SCIENTIFIC AMERICAN. His present article brings the story of the work in this active but baffling field up to date.

PIETER KORRINGA ("Oysters"), a biologist on the staff of the Dutch Institute for Fishery Investigations, directs his government's assistance to the Dutch oyster industry. Korringa's interest in marine life dates from boyhood shell-collecting expeditions along the Dutch beaches; he was born in 1913 in the seacoast town of Heemstede. He took degrees in zoology and botany at Amsterdam University and was working in the laboratories of Royal Dutch Shell in 1937 when the Dutch Government asked him to assist in a fight against two plagues that threatened to wipe out the oyster fisheries—the American slipper limpet, an oyster parasite, and the so-called shell disease. Thanks largely to Korringa's efforts, ways have been found to control the limpet and the shell disease. His many technical and practical suggestions

have contributed to making the Dutch oyster beds the most profitable land per acre of any in Holland. Biologists and oystermen from other countries are frequent visitors to the Institute's research station at Bergen op Zoom. Korringa recently returned from a trip to South Africa, where he inspected the new oyster industry and gave advice on problems that have arisen there. Korringa's present worry is that the Dutch oyster fisheries may be destroyed by a tremendous conservation project now being considered by his government as the result of last winter's disastrous floods. The Government proposes to turn many of Holland's deep estuaries into fresh-water lakes, and some of those marked for enclosure from the sea contain the best of the oyster beds.

SIR EDMUND WHITTAKER ("G. F. FitzGerald") was born in Lancashire, England, in 1873. In his 81st year he is still active; the second volume of his *History of the Theories of Aether and Electricity* has just appeared. Whittaker not only is an eminent mathematician but has been associated with a remarkable galaxy of great modern scientists. He knew FitzGerald; he studied mathematics at Cambridge under Arthur Cayley and Sir George Stokes; as a Fellow of Trinity College he worked with A. N. Whitehead, Bertrand Russell, Sir J. J. Thomson and Lord Rutherford; among his students over the years were G. H. Hardy, Sir James Jeans, Sir Arthur Eddington, H. W. Turnbull and Sir Geoffrey Taylor. In 1906 Whittaker was appointed Royal Astronomer of Ireland. His most famous pupil there was Eamon de Valera, then a promising young mathematician. When Whittaker left Ireland for the chair of mathematics at the University of Edinburgh, de Valera wrote him that his greatest ambition was to translate Whittaker's *Modern Analysis* and *Analytical Dynamics* into the Celtic language. Whittaker wrote an article on mathematics in the 20th century for the September, 1950, issue of SCIENTIFIC AMERICAN and has reviewed several books for this magazine. Outside of mathematics and physics his activities have been chiefly in the fields of religion and philosophy. He is a Catholic and has devoted considerable attention to the relation between science and theology.

JAMES R. NEWMAN, who reviews *The Life and Work of Sigmund Freud* by Ernest Jones in this issue, is a member of the Board of Editors of SCIENTIFIC AMERICAN and the editor of our book review department.



Gentle restraint on a 3-ton knee

keeps a shock absorber from being shocked

It is easy for the big 6600-pound landing gear we build for the B-36 bomber to absorb the impact of the 180-ton aircraft as it lands at 100 miles an hour.

Unfolding the gear for a landing is eased by a small shock absorber which gently cushions the knee of the big shock absorber (aircraft landing gears are just *big* shock absorbers). This restrains the knee from "slamming home" (as engineers term it) when it locks.

If you are plagued by severe shock in machines or apparatus you build, or if tiny flutter in your device tends to build up into large destructive waves, it will pay you to talk with us. Some vibration and impact problems are so complex that they require shock absorbers to cushion the shock absorber. But we believe no impact problem is so complex that it can't be solved. Write for descriptive booklet D-11.

Cleveland Pneumatic
Tool Company CLEVELAND 5, OHIO

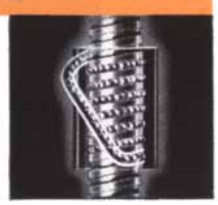
Department D-11

BALL-SCREW ACTUATORS • AUTOMOTIVE SHOP EQUIPMENT
AIR-OIL IMPACT ABSORBERS

World's Largest Manufacturer of Aircraft Landing Gears

To MOVE with less EFFORT

Combining the screw with balls makes Cleveland Pneumatic's patented ball-screw actuator drive with as little as 10% friction . . . compared to as much as 50% for ordinary screw drives. You can cut the weight of a drive system, reduce its space, lessen its cumbersomeness, increase its control accuracy, and provide pin-point positioning. Let our engineers work out your ideas for our ball-screw actuators.



THE COVER

The painting on the cover is a fanciful still life of scintillation counters (*page 36*). Each counter consists of a rectangular piece of plastic and a photomultiplier tube. Between the two is a short plastic "light pipe." Here the plastic flashes at the passage of a high-energy particle. Normally the apparatus would be sealed up to keep out stray light.

THE ILLUSTRATIONS

Cover painting by Stanley Meltzoff

Page	Source
31	Woods Hole Oceanographic Institution
32-33	Bunji Tagawa
34	Woods Hole Oceanographic Institution
35	Woods Hole Oceanographic Institution (*top*), Bunji Tagawa
36	Brookhaven National Laboratory
37	James Egleson
38	Brookhaven National Laboratory
39	James Egleson
40-41	Brookhaven National Laboratory
42-43	Copyright, Department of Archaeology, Government of India
43-44	Eric Mose
45-47	Copyright, Department of Archaeology, Government of India
65	Pratt & Whitney Aircraft
66-67	Irving Geis
69	Irving Geis (*top*), General Electric Company
70	General Electric Company (*top*), Irving Geis (*middle*), Bituminous Coal Research, Inc.
72	Boeing Airplane Company
74-78	Bernarda Bryson
87	B. Havinga (*top*), H. F. Prytherch (*bottom*)
88	International News Photos
89	H. F. Prytherch
94	Eric Mose
113-118	Roger Hayward

Dividends in Mileage and Power through TRICRESYL PHOSPHATE made by Celanese

Something extra has been added to Shell Premium Gasoline! It's TCP†—Shell's trade name for a new gasoline additive blended into Shell Premium Gasoline to prevent spark plug fouling and pre-ignition, and to give you up to 15% more power . . . extra mileage, too. New Conoco Super Gasoline with TCP† makes this great gasoline development available coast to coast.

Among other things, TCP contains tricresyl phosphate—a Celanese-developed chemical which is improving products and performance for many American industries. Celanese* Tricresyl Phosphate is an oil additive or high speed lubricant—its high film strength and non-oxidizing qualities provide a superior film cushion for moving parts. As a non-flammable hydraulic fluid, Celanese Tricresyl Phosphate reduces the hazards of fires due to line breaks, and contributes to plant safety and personnel morale.

This versatile chemical—sold under the trademarks, Lindol* and Celluflex*—is also an important plasticizer for vinyls and other plastics where it reduces the natural flammability of these materials. In the new polyester resins, it is used as a carrier for peroxide catalysts.

The growing importance of tricresyl phosphate to the automotive and plastics industries is typical of the basic contribution to American industry being made today by Celanese organic chemicals.

Celanese Corporation of America, Chemical Division, Dept. 582-K, 180 Madison Avenue, New York 16, N. Y.

†Trade Mark owned and Pat. App. for by Shell Oil Company

Celanese* CHEMICALS

*Reg. U. S. Pat. Off.

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR NOVEMBER, 1953 VOL. 189, NO. 5

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN
NOVEMBER, 1953 VOL. 189, NO. 5

Trade-Wind Clouds

The easterlies that blow across the subtropical oceans contain cumuli which act as fuel pumps for the atmospheric heat engine. They are studied by the simple stratagem of flying through them

by Joanne Starr Malkus

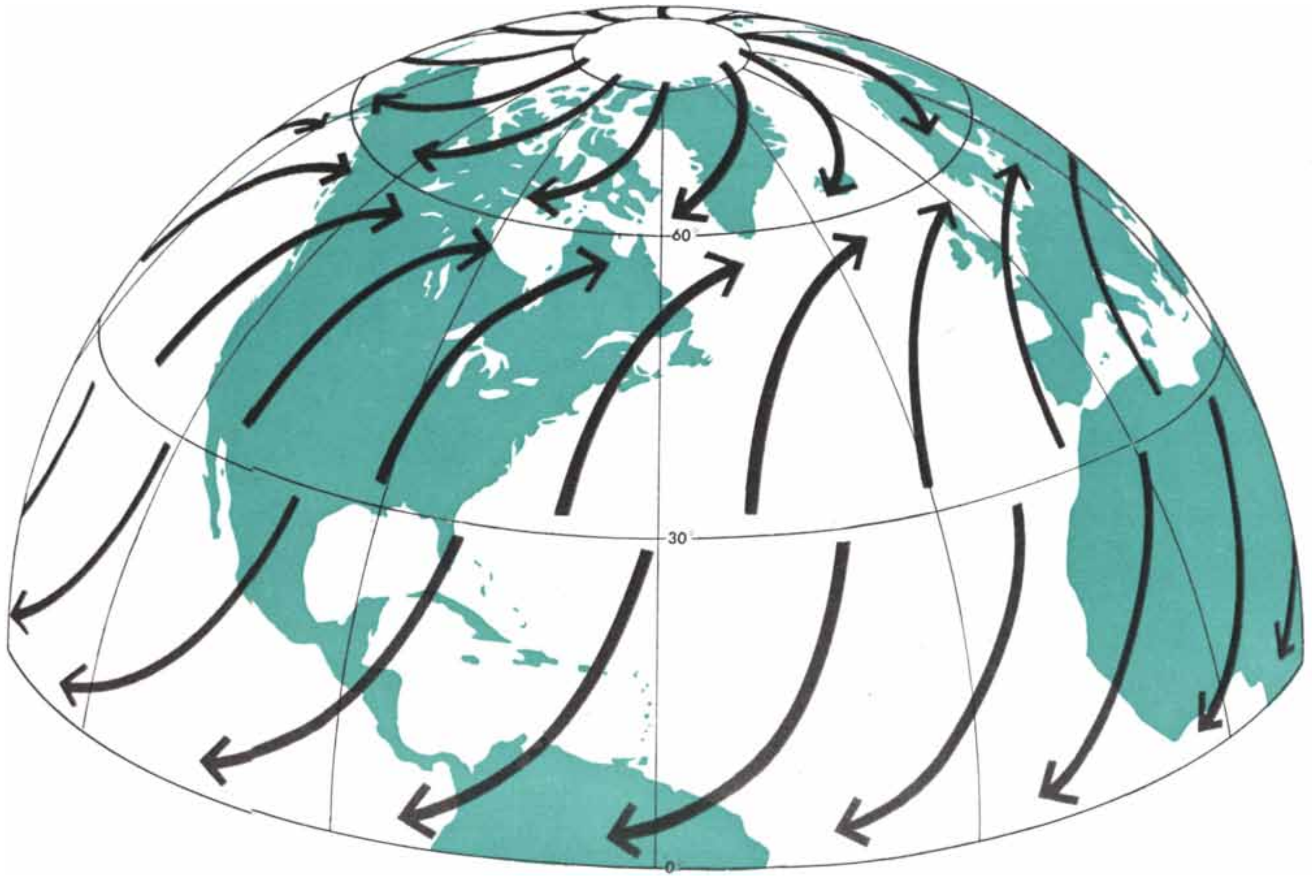
The cottony cumulus cloud that everyone likes to watch crossing the sky on a sunny summer day is not only the prettiest but also probably the most important cloud form known to man. From cumulus clouds grow mighty thunderstorms. Cumulus clouds supply much of our rain. More than that, these innocuous-looking puffs, building day and night over vast areas of the subtropical oceans, play a critical role in the operation of the great heat engine that is our atmosphere.

The energy put out by that engine is fantastic. A single hurricane during its brief lifetime uses up and dissipates more energy than that of 30,000 atomic bombs. And a hurricane is only a very small dimple on the face of the atmosphere compared to the huge cyclonic storms and the jet stream of the high altitudes [see "The Jet Stream," by Jerome Namias; SCIENTIFIC AMERICAN, October, 1952].

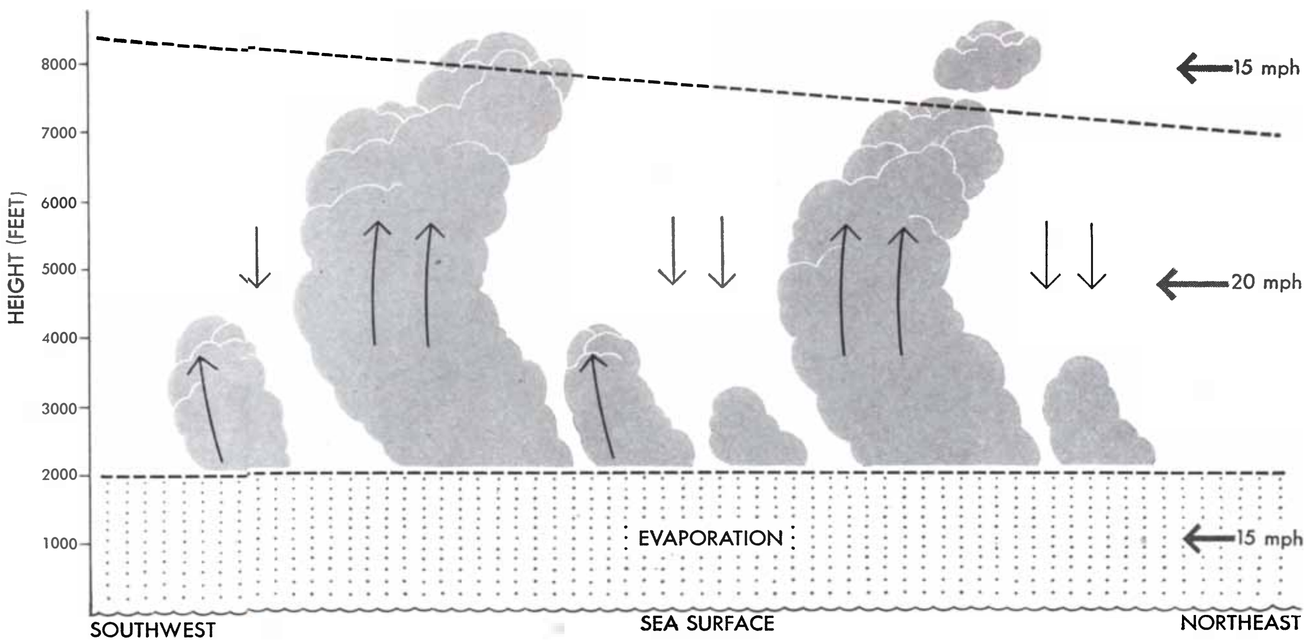
Where does all that energy come from, and how is it transported? We have begun to learn in the last few years that the trade-wind cumulus clouds originating in the earth's subtropical regions are important feeders of the energy.

It has long been known that nearly all the energy for driving the earth's wind systems is supplied to the air by the sun-warmed tropical oceans. During World War II new studies of these regions were made. The most important were two Navy-sponsored investigations: one of trade-wind clouds and heat and moisture rise in the Caribbean area, made by

CUMULUS CLOUDS over the Caribbean are softer in outline and more elongated than those of higher latitudes. On the average they begin at 2,000 feet, below which is a turbulent zone. They rise to about 7,000 feet, above which is a stable inversion layer.



SURFACE WINDS of the Northern Hemisphere usually blow in the directions indicated by the arrows. In the high latitudes the winds are from the east; in the middle latitudes they are from the west. In the lower latitudes are the easterly trade winds.



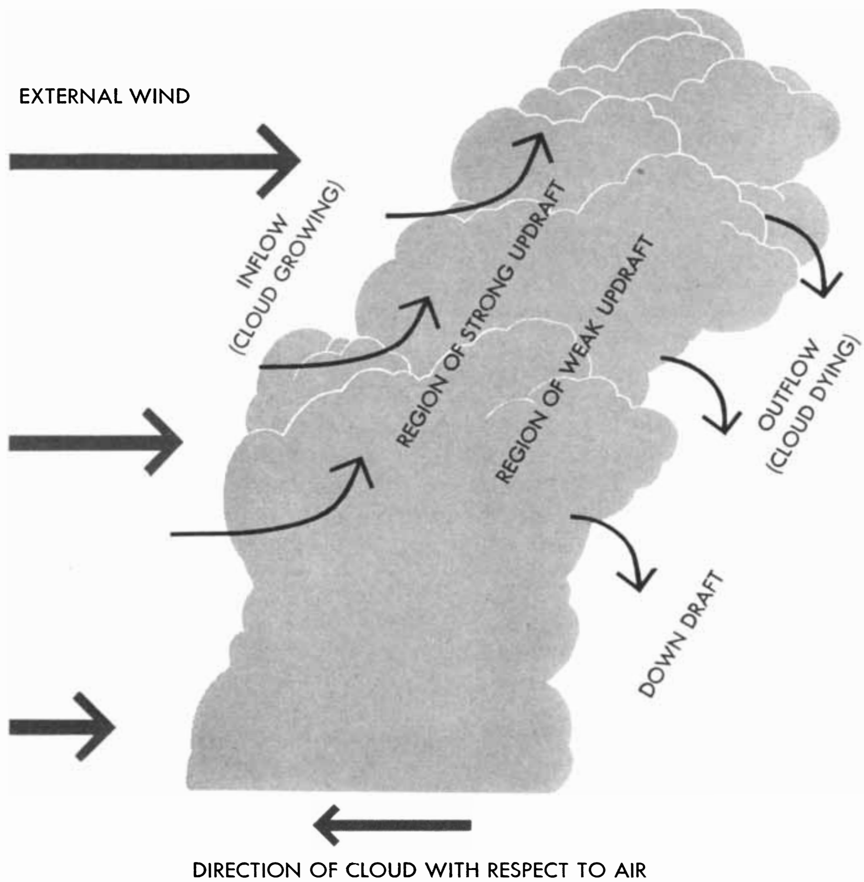
CROSS SECTION of the lower atmosphere along the path of the trade wind depicts the development of cumulus clouds. The heavy arrows at the right show the velocity of the wind at three levels. Above the dotted line at top is a layer of dry, stable, sinking air.

Woods Hole Oceanographic Institution scientists led by Jeffries Wyman and Alfred H. Woodcock, and the other of disturbances in the trade-wind current and the growth of tropical hurricanes in the Pacific, a study christened Tyrena (TYphoon REsearch NAvy). The latter was carried out in the Pacific from an island station and a chain of weather ships strung out along the path of the trade-wind air from northeast to southwest. The data collected were later analyzed by Herbert Riehl and several collaborators at the University of Chicago.

The results from Tyrena and from the Caribbean expedition, combined with earlier findings, provide the beginnings of a coherent picture of the trade-wind atmosphere, its internal mechanisms and its role in large-scale transport processes. Part of this picture is sketched in the bottom diagram on the opposite page.

The energy that powers the atmospheric engine comes mainly from the evaporation of surface water in tropical seas by the sun. This energy is stored in the form of latent heat in the water vapor. The invisible vapor is carried up, some of it to high levels, and then is borne by the trade winds for great distances. When the vapor recondenses into liquid drops, which form clouds and eventually rain, the energy is released again as heat. We are concerned here with how the water vapor is transported up to high levels in the trade-wind atmosphere. Its trip from there to the nontropical regions of the world and its conversion into the kinetic energy of winds—processes which are still largely unexplained—lie beyond the scope of this article. Our concern is with the primary fuel pump of the atmospheric engine.

In the first few hundred feet above the surface of the sea the water vapor is mixed through the air by turbulent eddies formed by the wind blowing over the rough waves—almost as the cream is mixed through your coffee when you stir it. But to carry the vapor higher another process must take over. This is where the trade-wind clouds enter the picture. The clouds transport the vapor up for several thousand feet; they may be thought of as warm, moist chimneys of rising air which day and night are pumping vast quantities of moisture aloft. The cloud-forming layer of the atmosphere extends on the average from about 2,000 feet up to 7,000 feet elevation [*see diagram on opposite page*]. At its top is a stable stratum of air called the trade inversion [*indicated by the uppermost dashed line in the drawing*]. This inversion, which



SUGGESTED OPERATION of a cumulus cloud in a wind that increases speed with altitude is shown in this cross section. The cloud moves from left to right more slowly than the wind.

marks the beginning of a deep layer of much drier air, may be imagined as a kind of lid hindering higher growth of the clouds. A few clouds with exceptionally strong updrafts do penetrate a little way into the inversion layer, but their tops then are cut off and evaporate.

Can the energy pumped upward in this manner possibly be enough to fuel all the mighty global wind systems? It can indeed. A group of trade cumulus clouds covering 50 per cent of a one-half square mile area can easily carry upward as much latent energy in water vapor as would be provided by a 1,000-pound bomb of TNT exploding every minute! Summed up over all the tropical oceanic areas normally covered by trade cumulus, this energy supply is some 40 to 50 times as great as the rate at which the wind systems of the globe actually use up kinetic energy. The atmosphere is really an inefficient heat engine: most of the energy released by its water-vapor fuel does not go into winds but is lost by reradiation into space.

The whole affair bristles with questions. Why, even on stormy days, do cumulus clouds congregate in relatively small clusters, leaving large clear areas between them? What causes clouds to start growing in the first place, and what fuel keeps them running? Why do they usually start at a height of about 2,000 feet? Just how do clouds carry moisture upward? Perhaps we can answer these questions by finding the answer to a more basic question which underlies them all: Why does the average trade-wind cloud cease growing far below the level of the trade inversion? Few clouds grow tall enough to penetrate the inversion. What factors determine which ones will be able to do so?

Classical meteorological reasoning treated cumulus clouds as isolated air parcels, rising without interference from the surrounding air. If this were true, the trade-wind clouds should build up to the inversion ceiling much more often than they actually do. Some braking mechanism, involving the surrounding air, must be in operation. Analyzing the Caribbean expedition's measurements of temperature and water-vapor conditions inside trade clouds and in their nearby environments, Henry Stommel of the Woods Hole Oceanographic Institution showed that the clouds must be continually mixing with the air outside them. He suggested that as a growing cumulus cloud rises, it "entrains" (draws into itself) air from the outside. The air drawn in is generally far drier than that in the cloud. Since the driving force of a cloud is the heat released by condensation of water vapor, the influx of drier air may choke off the energy supply for its updrafts and weaken or kill the cloud.

The meteorology group at Woods Hole has constructed a tentative model of cumulus cloud structure and behavior, based on the entrainment idea [*see diagram on the preceding page*]. This cloud is assumed to be embedded in a wind current whose velocity increases with elevation. The difference in speed of the winds at the lower and upper levels gives the cloud a noticeable slant (which can be seen in photographs of actual clouds). Air is entrained on the windward side of the cloud and flows out on the downwind side. The upper part of the cloud is not moving as fast downwind as the wind itself, because the air composing it has risen from the slower-traveling lower levels. Thus the cloud, growing on its windward side and decaying on the other side, may be thought of as moving upwind, in effect. When the wind decreases with elevation, the situation is reversed; then the cloud grows on the downwind side.

In short, we no longer conceive of a cumulus cloud as an object drifting passively with the air currents, like a toy balloon or the tumbling tumbleweed, but as a dynamic process—a body balanced by rapid growth and equally rapid destruction.

Some parts of this model have received qualitative confirmation from recent studies of clouds in the Atlantic Ocean at middle latitudes, some of them near Woods Hole. In several cases the upper part of a cloud has been observed moving in a direction at an angle as much as 45 degrees from the wind direction, where the wind has turned with height. Quantitative checks of the theory also have been made. The relation between the slant, the magnitude of entrainment, the horizontal speed and the vertical velocity of the updrafts has been found to agree with the theory.

It is important to know the speed of the updrafts, because this is a significant factor in the influx of energy into the general circulation and in the development of precipitation, and it is a critical test in evaluating theories. The classical theory predicted that updrafts in ordinary trade-wind cumulus clouds would rise at the rate of about 40 or 50 feet per second, while the model based on the entrainment idea predicts that the speed usually should be only about eight to 12 feet per second.

In 1952 the Woods Hole Oceanographic Institution began to make detailed measurements of updrafts and other conditions in trade cumulus clouds. It borrowed a PBY-6A aircraft from the Navy and fitted it out as a meteorological tool. The most important measurements needed were the temperature and moisture content of a cloud and its surroundings, the structure of the turbulence inside the cloud, the vertical drafts and their distribution, the wind at various levels outside the cloud and how much the cloud tower slopes or slants. The latter was measured by means of aerial photographs, and many of the other measurements were obtained with little difficulty. But the measurement of draft speeds inside the clouds is an extremely tricky problem, for the observations must be made from a moving aircraft. After considerable study of the lift characteristics and aerodynamics of the PBY, a technique for draft determination, based essentially upon accelerometers, was worked out.

Two studies have been made in the Caribbean area with this aircraft—the first in June, 1952, near San Juan, Puerto Rico, and the second in March and April, 1953, near the small West Indian island of Anegada. In the second investigation a group of British meteorologists from the Imperial College in London collaborated with the Woods Hole group. The results of this year's expedition cannot yet be reported, as the analysis of the data in this type of investigation is a formidable labor, taking considerable time. But some extremely interesting results have already come from the 1952 investigation.

To photograph a cloud and make the desired measurements observers flew through the cloud five or six times in rapid succession at different levels. The photographs were made with a motion picture camera operated from the nose of the aircraft, thus recording the point at which the cloud was entered. A picture of the profile of a typical trade cumulus cloud, in the plane of the wind, is shown here on the opposite page. Below this photograph is a chart summarizing the draft, temperature and water-vapor conditions through the cloud and in its immediate vicinity.

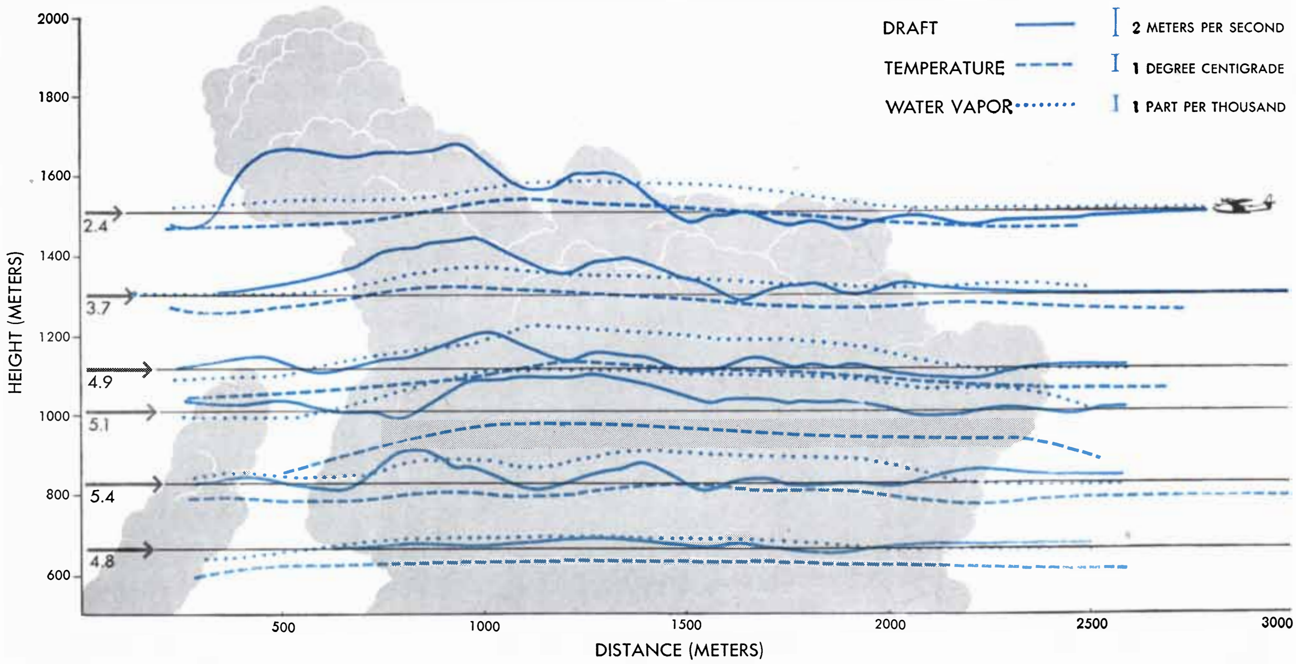
Calculations so far completed strikingly verify the model of the trade cumulus that was worked out at Woods Hole. The temperatures, slopes, and drafts observed in clouds agree closely with the predictions. We shall need many more than the two clouds so far analyzed to place the model on firm footing, but the meshing into a consistent picture of so many independent measurements is not likely to be coincidental.

The two expeditions had other objectives besides testing the steady-state model of a full-grown cloud. It is hoped that the data collected will offer clues as to how clouds are formed in the first place and how small clouds grow into big ones—in other words, the life history of a cumulus cloud.

One of the clues provided by the 1952 investigation is that clouds formed over the Caribbean have no well-defined "roots," that is, columns of unsaturated or warm air rising from deep in the layer of air under the cloud. On the contrary, the clouds seemed to arise from random bunches of air, or eddies, that had reached the condensation level. The PBY photographed a group of small cloudlets which apparently had been formed in this manner. Later it got several series of photographs which showed small clouds combining into very large ones, which were then able to grow to great heights. When it flew through an isolated cumulus, the cloud often evaporated, disappointingly enough, before the run through it was finished. But when the cloud was one of a cluster of four or five close together, the clouds lasted beautifully despite invasion by the aircraft, and some even grew to thunderhead proportions. Large clouds were almost invariably full of clear spaces—holes through which we could see the ocean—at their lower levels, and these breaks suggest that a large cloud is actually a family or cluster of smaller ones, which may once have been independent.

Cloud study, like most other fields in meteorology, is still very young. The specific problem of the role that trade-wind clouds play in the large-scale circulation of the atmosphere is only a small part of the total picture: it is a little like trying to find out how an automobile engine runs by examining one part of the fuel pump. But the investigation has been illuminating, for it has shown that a cloud is a microcosm of the same turbulent mixing processes which operate on a grander scale not only in the atmosphere but also in the oceans, in the earth's interior and even in the formation of planetary systems and galaxies.

CUMULUS CLOUD in this photograph was studied by the group in the PBY in June, 1952. The cloud had formed over the ocean about 20 miles from St. Croix in the Virgin Islands. Here it is in a stage of vigorous growth. The wind blows from left to right.



SAME CLOUD is diagrammed after the plane had flown through it six times (*horizontal black lines*). The red lines that follow the black indicate variations in draft, temperature and water vapor. The numbers below arrows at left show wind in meters per second.

SCINTILLATION COUNTERS

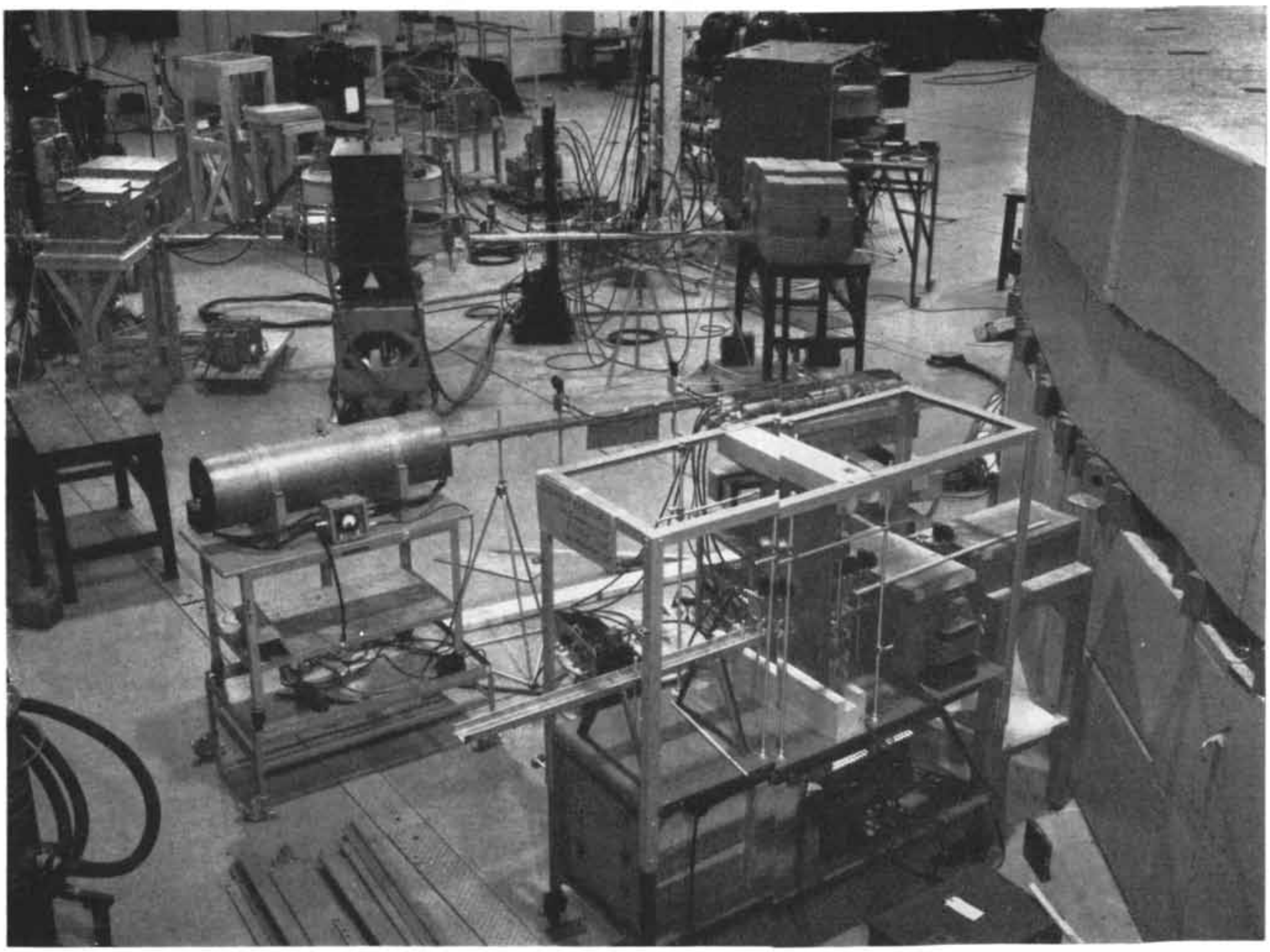
When certain substances are hit by a ray or particle, they emit light. Joined to a device which amplifies the flash, they make an instrument of great versatility and large importance to the progress of physics

by George B. Collins

Physicists interested in atoms and the particles in atoms can never hope to see the objects of their study. They must therefore resort to ingenious schemes to bring these invisible particles within the range of human detection by some indirect means. The entire structure of nuclear physics rests upon the four or five devices that have been created to do this.

Five years ago a new method of detection was invented by H. Kallman, then of the Kaiser Wilhelm Institute. He combined two pieces of equipment, a scintillating crystal and a photomultiplier tube, to make the "scintillation counter." Today it is one of the most useful instruments in the nuclear physics laboratory, and in research work is largely supplanting the famous Geiger counter.

All radiation detectors are based on the same phenomenon: a rapidly moving charged particle passing through matter leaves behind it a trail of ions.



SCINTILLATION COUNTERS are the small black objects in this photograph of the experimental area outside the Cosmotron, the two-billion-electron-volt accelerator at Brookhaven National Laboratory. On the apparatus in the center are three such counters in a row. The shielding of the Cosmotron is at the right. Various experiments are set up in front of ports in the shielding.

These are detectable in various ways. In a gas the trail of ions can trigger an electric current, as in the Geiger counter, or serve as condensation nuclei for a vapor, as in the cloud chamber. In a photographic emulsion the ions produced by the particle cause silver grains to develop, thus creating a succession of black dots which mark the path of the particle. In the scintillation counter the particle passes through certain transparent solids or liquids and causes them to emit a little splash of visible light. The phenomenon is familiar to everyone in the form of the luminous watch dial.

Scintillation has been known for many years. It was, in fact, the means of detection in one of the greatest of the early atomic experiments: Ernest Rutherford's demonstration that the atom has a nucleus. Rutherford observed the path of charged helium nuclei (alpha particles) as they passed through thin metal foils. From the way in which the particles were deflected he was able to show that an atom must consist of a diffuse outer region and a small, dense core. To discover the direction of scattering, he placed a zinc sulfide screen behind the foil. Each particle that hit this screen produced a little flash of light. With great patience Rutherford sat in his darkened laboratory and counted the scintillations. The relative numbers striking at different points established a scattering pattern such as could only have been produced by collisions of the particles with a dense atomic core. A few years later Rutherford used zinc sulfide scintillation in another historic experiment, when he bombarded nitrogen with alpha particles and achieved the first artificial transmutation of elements.

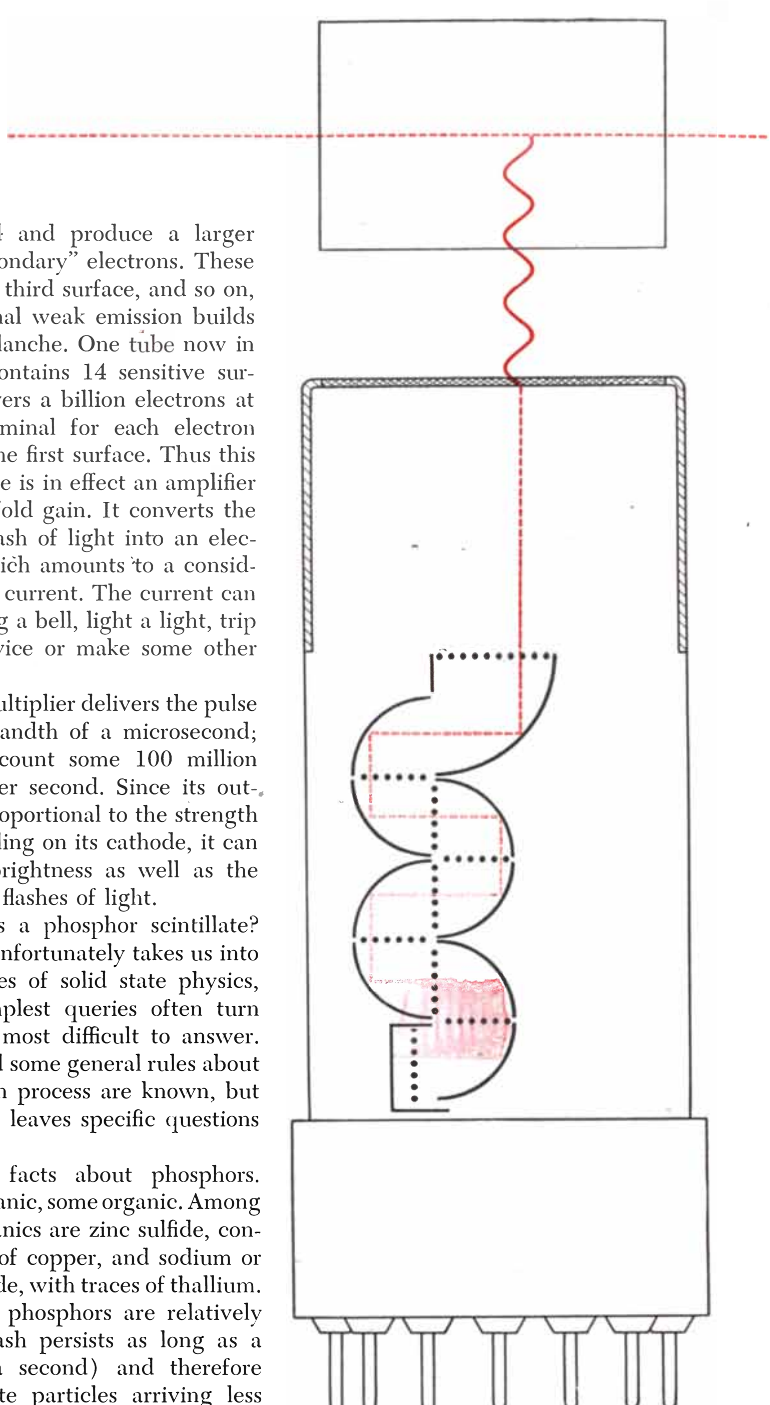
Scintillation counting by eye is too tedious and too subject to error. It fell into disuse in most laboratories. Its renaissance as an experimental tool awaited a substitute for the human eye as a detector of the flashes of light. The substitute that turned up was the photomultiplier tube, a modification of the familiar photoelectric cell. The photomultiplier is not only more reliable and far faster than the human eye but also an extremely sensitive detector of light.

A piece of scintillating material (*i.e.*, a phosphor) is placed against a photomultiplier tube. A charged particle passing through the scintillator produces a little flash of light. The photomultiplier first converts this flash into a small burst of electrons. The tube has a series of electron-emitting surfaces. Light striking the first surface releases electrons which hit the second and produce a larger shower of "secondary" electrons. These in turn strike a third surface, and so on, until the original weak emission builds up into an avalanche. One tube now in common use contains 14 sensitive surfaces and delivers a billion electrons at the output terminal for each electron emitted from the first surface. Thus this remarkable tube is in effect an amplifier with a billion-fold gain. It converts the tiny original flash of light into an electrical pulse which amounts to a considerable surge of current. The current can be made to ring a bell, light a light, trip a counting device or make some other record.

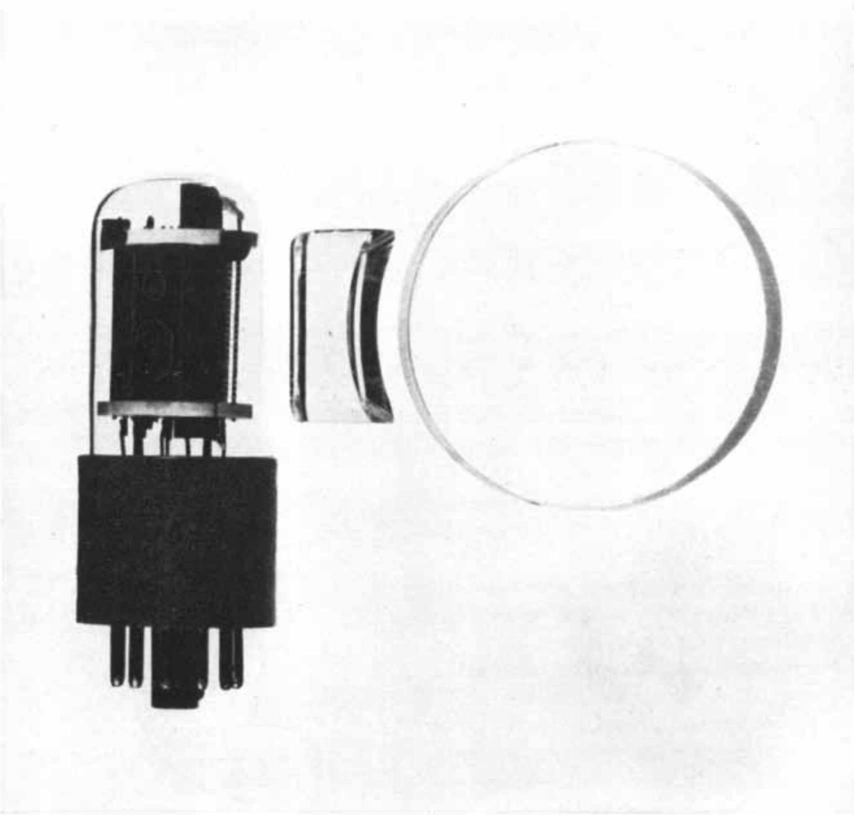
The photomultiplier delivers the pulse within a thousandth of a microsecond; hence it can count some 100 million scintillations per second. Since its output signal is proportional to the strength of the light falling on its cathode, it can measure the brightness as well as the number of the flashes of light.

What makes a phosphor scintillate? The question unfortunately takes us into the complexities of solid state physics, where the simplest queries often turn out to be the most difficult to answer. Many facts and some general rules about the scintillation process are known, but the theory still leaves specific questions unanswered.

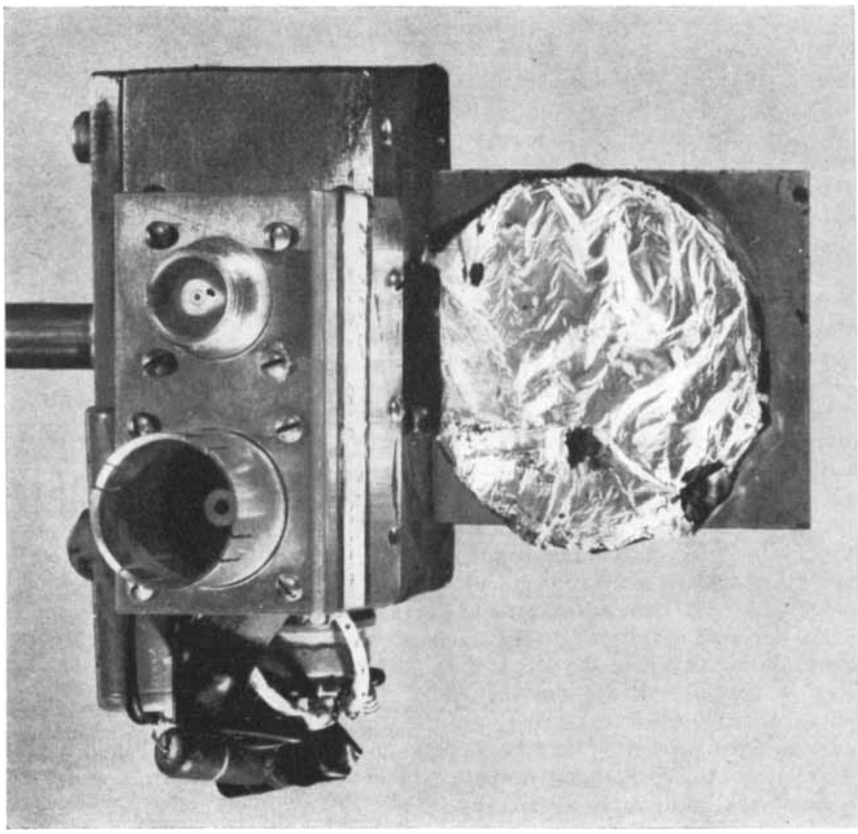
First some facts about phosphors. Some are inorganic, some organic. Among the best inorganics are zinc sulfide, containing traces of copper, and sodium or potassium iodide, with traces of thallium. The inorganic phosphors are relatively slow (each flash persists as long as a millionth of a second) and therefore cannot separate particles arriving less than a microsecond apart. But they have the valuable property that the amount of light they emit is proportional to the energy lost by the exciting particle. Thus they can give more information about the particle than the simple fact that it has passed. Of the organic phosphors, the aromatic, or ring, compounds have proved to be the best scintillators. Among the most commonly used are anthracene, stilbene and terphenyl. They are fast (their light decays in a few billionths of a second) but do not give as good an indication



PRINCIPLE of the counter is illustrated by the entry of a particle (*red dotted line at top*) into a scintillating crystal. The crystal emits a flash of light (*red wavy line*) which falls upon the photosensitive surface of a photomultiplier tube. The surface gives off electrons (*red dotted line inside tube*) which are focused on the first of a series of metal plates. As the electrons fall on each plate they are multiplied until at the bottom there are a million or more for every one emitted by the photosensitive surface. This current is finally used to actuate some recording device, usually by way of an amplifier.



PLASTIC DISK is the scintillating material in this counter made at Brookhaven. The photomultiplier tube is at the left. Between the disk and the tube is a plastic "light pipe."



SAME COUNTER is assembled in its housing. The scintillating substance, the light pipe, if any, and the photomultiplier tube are covered up in order to keep out extraneous light.

of particle energy as inorganic crystals.

Liquid scintillators (*e.g.*, a solution of a few per cent of n-terphenyl in the inert solvent xylene) are very useful, because they are the fastest of all and can be formed in any size or shape simply by pouring them into an appropriate vessel. Plastic scintillators, an example of which is pictured on the cover, are variations of the liquid type. Here the active organic substance is dissolved in the liquid plastic before it is solidified.

A charged particle moving through matter interacts with its atoms and loses some of its energy to them. Thus it travels more slowly coming out than going in. In most substances the energy acquired by the atoms is quickly dissipated as heat. The phosphors, however, convert some of the energy into light. The absorbed energy raises a molecule or a small region of the solid to an "excited state," from which it will fall to the ground state again fairly quickly. The trick is to have this transition take place by the emission of light rather than by a process whereby the energy is lost as heat.

In inorganic phosphors impurities are deliberately introduced for this purpose (*e.g.*, the thallium in a sodium iodide phosphor). The resulting irregularities in the crystal seem to trap a large fraction of the energy from a charged particle and emit it in the form of light. In a zinc sulfide crystal with a little silver impurity something like half of the energy lost by an alpha particle passing through the crystal appears as light, although the silver makes up only about 1 per cent of the material. How this is accomplished is not understood.

The same process seems to occur in organic phosphors. The mechanism can be demonstrated by a simple experiment. The organic liquid xylene is a poor scintillator. But when a small amount of n-terphenyl is added, the solution scintillates strongly. The light given off is characteristic not of xylene but of n-terphenyl. We know that the latter material does not itself absorb all the energy from a passing particle, because there are not enough of its molecules in the solution to do so. Nevertheless, it gives out all the light. We conclude that the xylene catches the energy and passes it to the n-terphenyl.

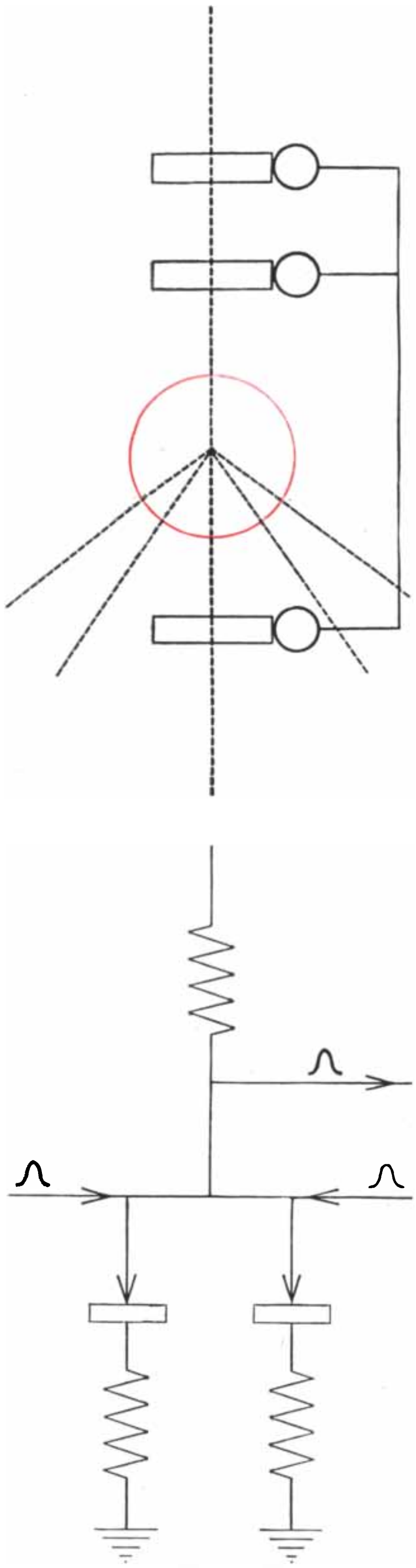
This, in somewhat simplified terms, is about all we understand of the process. The theory does not tell us what substances will be good scintillators or what combinations will perform best. Our working knowledge has come almost solely from trial and error. Physicists ransacked the chemists' shelves for substances that could be tested as scintillators. They looked for materials that turn a large fraction of the absorbed energy into light, that emit in the blue or near ultraviolet (photomultipliers respond best to these wavelengths) and that can be had in large, clear pieces. From the thousands of substances tried (the search still goes on) they have obtained a long list of phosphors, whose varied scintillation characteristics suit them to different applications.

Versatility is one of the qualities that make the scintillation counters so useful. There are scintillators smaller than a pinhead. A counter recently built at the Los Alamos Scientific Laboratory of the University of California has a volume of 10.7 cubic feet and uses 90 photomultiplier tubes around the tank of scintillating liquid to pick up the light [*see "Science and the Citizen" page 50*]. Scintillators can be molded into any shape that the experimental setup requires. They are almost unaffected by outside conditions and can be operated in strong electric or magnetic fields and over a wide temperature range. They are easy for the experimenter to build and use, for many of the difficult electronic problems have been solved by the manufacturer of the photomultiplier tube. These tubes give so large an output that they can be fed into relatively simple detecting circuits. With the proper choice of phospor, scintillation counters can record a series of events that follow each other at intervals measured in billionths of a second.

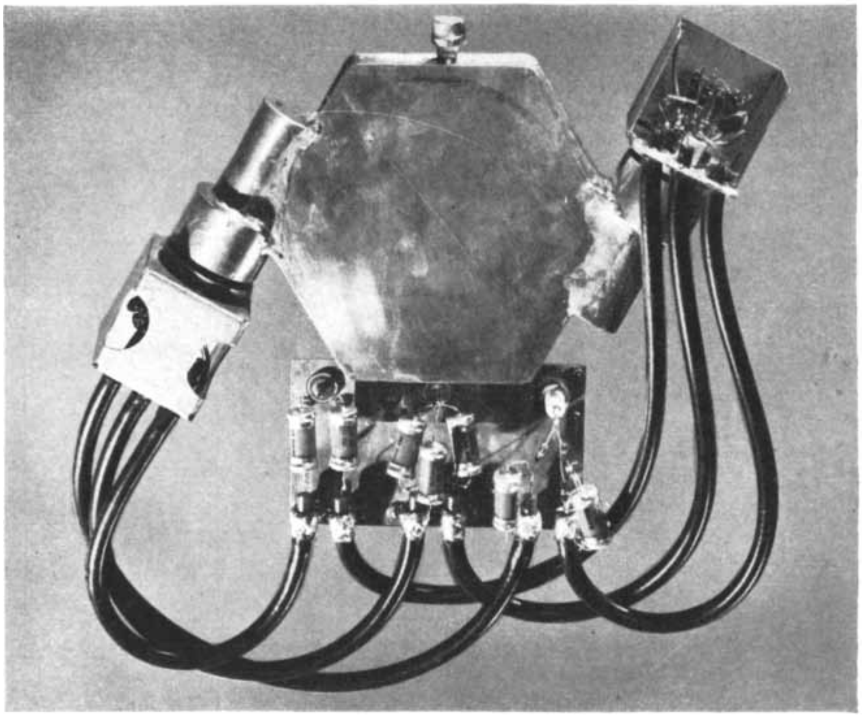
The Geiger counter is inferior to the scintillator type in several respects: its size and shape are not nearly so flexible; strong external fields disturb it; it is slow, detecting only events several thousandths of a second apart. Consequently it is practically useless in one of the most active fields of current research—experiments with high-energy accelerators. Indeed, it is fortunate that the scintillation counter came along when it did, because it is what made those experiments possible. The new accelerators produce their high-speed particles in short bursts, separated by long periods of inactivity. The Cosmotron at Brookhaven National Laboratory, for example, gives a burst of protons every five seconds, each lasting about a hundredth of a second. To learn what the projectiles do when they strike a target one must be able to detect a large number of happenings during an active period. A Geiger counter could pick up perhaps 10 counts during a cycle, and many of these would be from random radiation. An n-terphenyl scintillator can count millions of separate particles each time the machine goes into action; thus it collects data about a million times faster than a Geiger counter. Finally, scintillators give information about the energy of particles, whereas the Geiger counter can only count them.

One of the most important products of the Cosmotron is pi mesons—the particles thought to play a key role in holding the nucleus of the atom together. They are detected by an experiment much like Rutherford's. The experimental setup is shown in the diagram at the right. A beam of mesons passes through a pair of scintillation counters, then through a hydrogen-containing substance such as paraffin. The protons (hydrogen nuclei) scatter away some of the mesons in the beam. Finally the mesons that are not scattered are recorded in a third counter. This array is necessary to insure that only the desired events are counted. A single counter responds to all the random radiation flying around the laboratory. But the pair of scintillators through which the beam passes selects for counting only the mesons in this beam. It is hooked up in what is known as "twofold coincidence." This means that the electric output pulses from the two counters are fed into a circuit which puts out a pulse of its own, but only when it receives pulses from the two scintillators at exactly the same time. The path of the output from the second counter is slightly shorter, to compensate for the time required by the meson to pass from the first counter to the second. The two counters are lined up in the direction of the meson beam and yield a coincidence pulse when a high-energy meson passes through both. The output of the third counter is combined with the coincidence pulse from the first pair in a threefold coincidence. Here only particles that pass through all three scintillators are counted. By comparing the threefold count with the twofold, one can tell what fraction of the mesons was scattered by the protons.

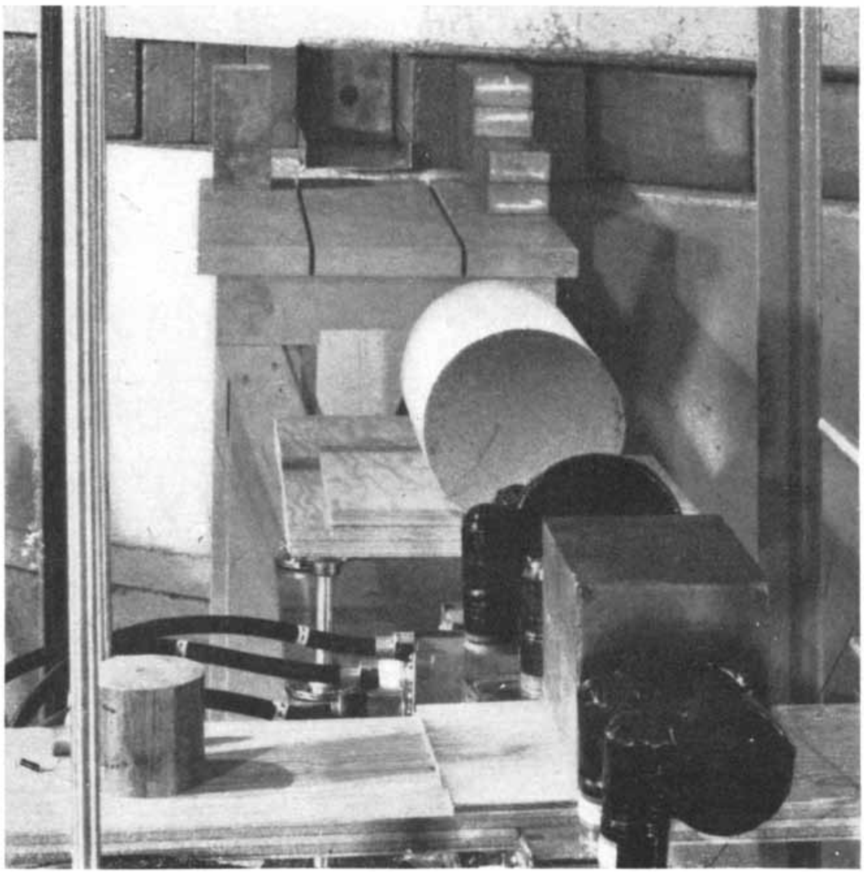
Often an experimenter deals with a mixed beam, say of protons and mesons, and wants to count only one kind. The fast scintillation counter and the coincidence circuit make this possible. The beam is bent in a magnetic field and two counters are lined up along a specific bending angle. At this angle there will be particles of both kinds, but their speeds will be different, for the heavier proton must travel more slowly if it is bent at the same angle. By adjusting the length of the delay line that feeds the first counter



EXPERIMENT to measure the scattering of pi mesons (*dotted lines*) by the protons of hydrogen (*red circle*) involves counters linked in a threefold coincidence circuit. A twofold coincidence circuit is depicted at the bottom. Output pulse (*small curve at the upper right*) occurs only when input pulses (*left and right*) are simultaneous.



LIQUID scintillating material is contained in a flat metal vessel with a stopper at the top. At opposite sides of the vessel are two photomultiplier tubes. They are wired together in a circuit in order to amplify the signal from a scintillation of low energy.



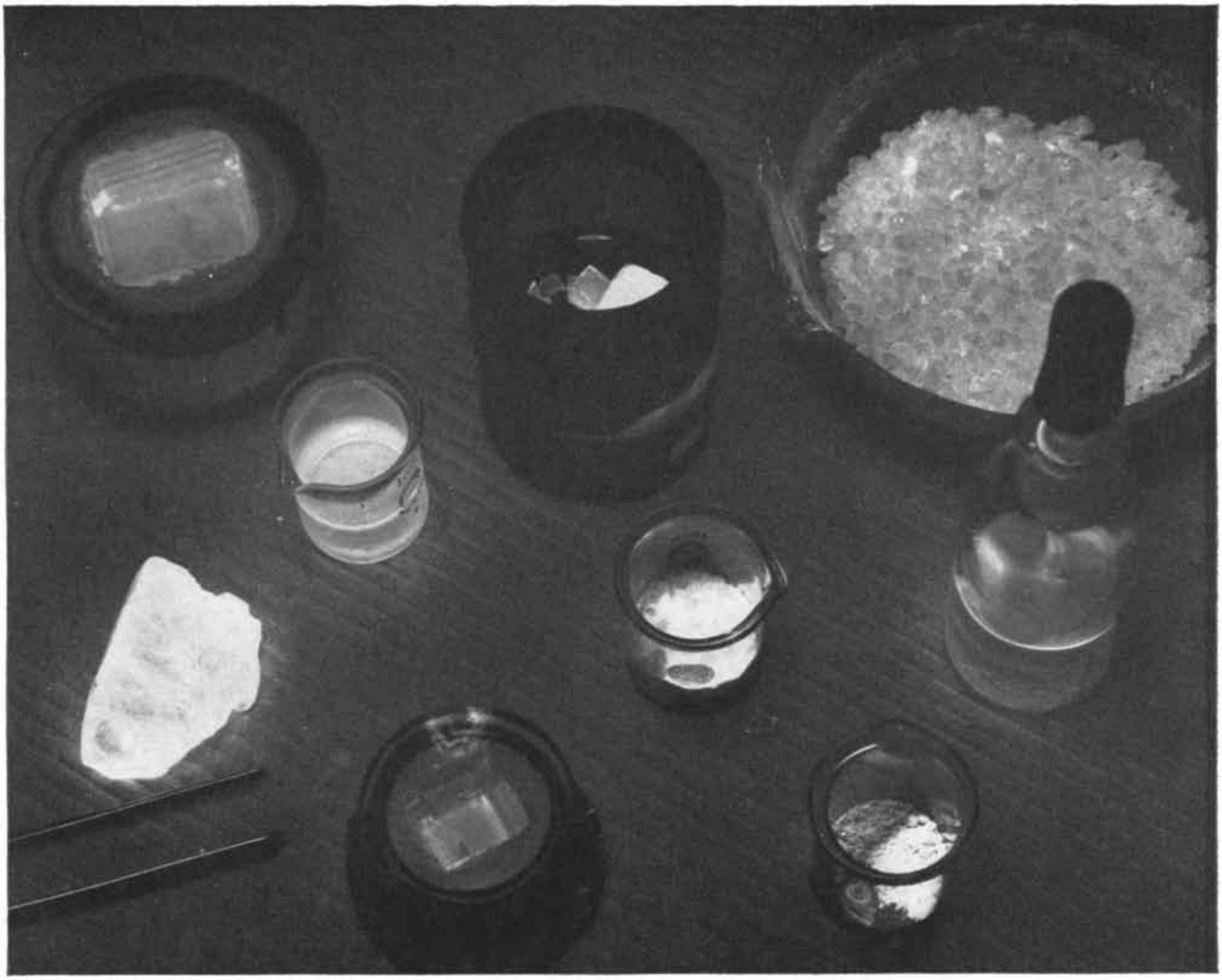
INTERACTION of neutrons with nuclei is studied with counters outside the Cosmotron. Neutrons come out of the hole at top and produce protons in a cylinder of paraffin. The protons are detected by two pairs of counters. Block of lead filters out low-energy particles.

pulse into the coincidence circuit one can select for counting either the fast mesons or the slower protons. The time delays are measured in billionths of a second, and only a fast instrument such as the scintillation counter can do this job.

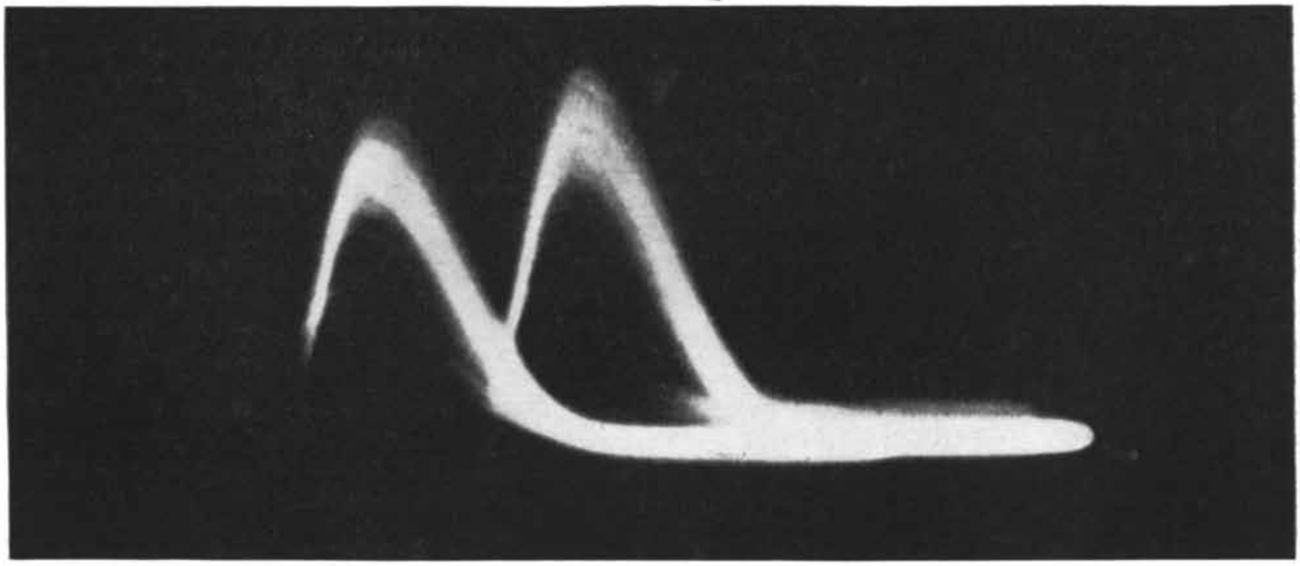
An important problem facing experimental physics today is to determine the energy levels in atomic nuclei. One way to do it is to make an atom artificially radioactive and to observe the energy spectrum of the gamma rays it emits. Before scintillation counters this was a difficult and lengthy task which required very complex instruments. Now one can run a spectral analysis in minutes. A gamma ray activates a scintillation counter indirectly by liberating an electron within the crystal, which in turn produces the flash of light. The gamma ray's energy determines the energy of the electron. To take a spectrum one uses an inorganic scintillator, making the crystal large enough so that most of the electrons do not escape but come to rest within it. Thus all their energy is extracted, and the amount of light produced is an accurate index to this energy. The photomultiplier output, which is proportional to the amount of light, is fed into an oscilloscope, where it shows up as a hump in the horizontal trace [*see photograph at bottom of opposite page*]. Counts of different energies reveal themselves as humps of different height, so the whole spectrum can be read directly off the face of the tube.

Scintillation counters are now being manufactured commercially and are finding applications in many fields. Geologists and uranium prospectors use them in searching for radioactive deposits; a scintillator detects gamma rays much more efficiently than a Geiger counter can. The instrument is easily portable. Airplanes have towed scintillation counters to survey large areas from the air. For detecting radiation hazards, in medical and biological tracer work and in other applications where a sensitive and rapid response to radiation is needed, scintillation counters are being used more and more. But it is the nuclear physicist who most appreciates the value of scintillation counters.

In the four years since this useful device was developed in its present convenient form, it has already won remarkably wide acceptance. The instrument is still being improved and new types are being devised. It seems safe to say that the scintillation counter will soon exceed in usefulness that tried and true detector of radioactivity, the Geiger counter.



GLOWING OBJECTS are crystals and liquids being tested by ultraviolet for scintillation counter purposes. If a substance does not fluoresce under ultraviolet, it will not scintillate. If it does fluoresce, it may scintillate. Sometimes the fluorescence is very faint; in the tall vessel at the top the fluorescence of a crystal has been intensified by chilling it through immersion in liquid nitrogen.



ENERGY LEVELS of two atomic nuclei are depicted by traces on the face of an oscilloscope hooked up to a scintillation counter. The height of the peak at left represents the energy of gamma rays emitted by the nuclei of radioactive cobalt 60; the peak at the right, the slightly higher energy of gamma rays from antimony 122. The two peaks were photographed together by time exposure.

RUINS OF MOHENJO-DARO, one of the twin capitals of the Harappa Civilization, are partly revealed by excavation. Covering about a square mile, the city was divided by streets into 12 huge blocks 1,200 by 800 feet. It had a population of perhaps 20,000.

A Forgotten Empire of Antiquity

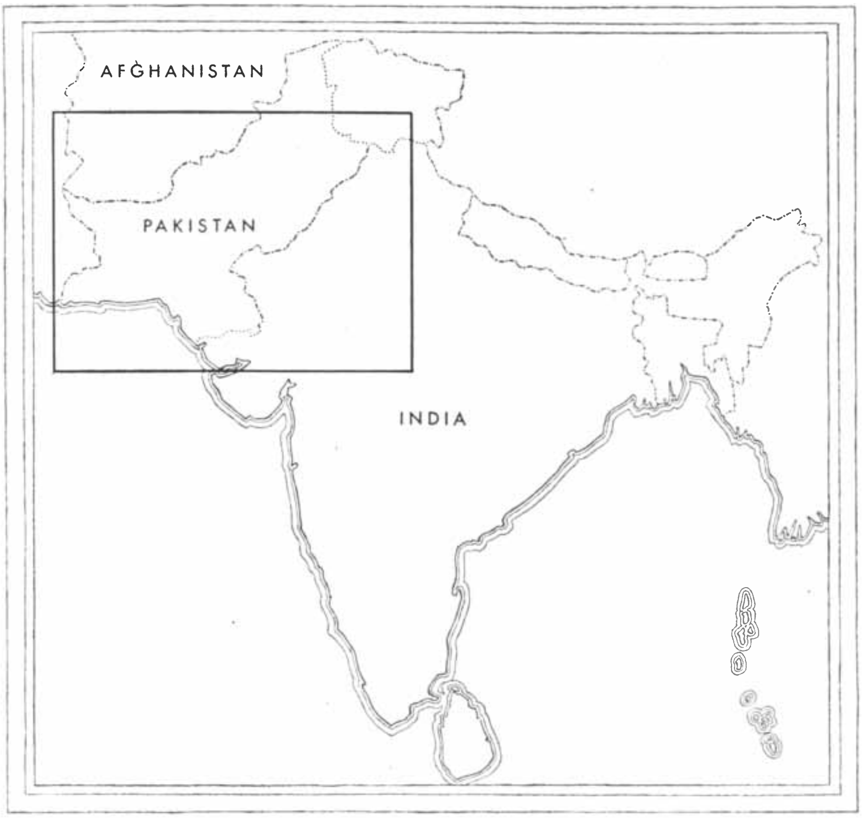
At the time of the first civilizations in Egypt and Mesopotamia a much larger one flourished in western India. It achieved great works, and then curiously did not change for a thousand years

by Stuart Piggott

When we think of the birthplace of civilization, we are apt to think only of Babylonia and Egypt. It was in the valleys of the Tigris-Euphrates and of the Nile, the archaeologists say, that agriculture began and mankind built the first villages, the first cities and the first kingdoms—Sumer and Egypt. Few people realize that there was a third great kingdom which rose and flourished side by side with them at the same time. This nameless and forgotten empire of antiquity, occupying the Indus Valley in western India, was far larger and more tightly ruled than Sumer or Egypt. It is nameless, and much less known than the other two, only because its language has not yet been deciphered and the remains of its writings cannot be read. Archaeologists hope that the code may some day be broken, as the hieroglyphics of ancient Egypt were deciphered, by discovery of a bilingual inscription—a Rosetta Stone of the Indus Valley. Until that momentous event, the story of this ancient Indian civilization must remain as incomplete as a silent picture. But the archaeological evidence tells enough to enable us to compare this culture with the more fully documented civilizations of Sumer and Egypt.

The study is a vital and exciting one, for it concerns the history of human ideas. Here in western Asia there rose three parallel but separate civilizations. In all three, technology followed much the same sequence: the invention of writing (that "incidental by-product of a strong sense of private property," as the U. S. archaeologist Ephraim Speiser so pleasantly put it), the development of skill in working bronze and precious metals, the evolution of architecture from mud huts to palaces, the growth of transport and trade and the rise of centralized government. Yet while the technological development of the three empires was nearly identical, their intellectual concepts and forms of society were very different. With respect to the peoples of Sumer and Egypt, we can read their differences of thought in their literature, and in the Indus Valley we can read it in the archaeological record

HOUSES OF MOHENJO-DARO were made of standardized bricks that had been baked rather than sun-dried. When the city was flooded, it was rebuilt in exactly the same plan.



LOCATION of the area in the map on the opposite page is amplified here. The remains of the Harappa Civilization are found principally in the Punjab and Sind regions of Pakistan.

of the people's way of life. For the Indus civilization had a unique individuality of its own, already marked with some of the features of what was to become the characteristic Hindu culture of historic India. The comparative study of these three earliest civilizations shows how varied were the intellectual means whereby mankind found ways to create and maintain a stable society.

Archaeologists have named the Indus kingdom the Harappa Civilization, after a modern village which stands on the site of one of the great ancient towns. The Harappa Civilization had developed from a peasant to an urban culture by about 2500 B.C., and it endured for at least a thousand years before it was destroyed by invaders. It was a nation based on cities, towns and villages, with a Bronze Age technology and a central government strong enough to keep the peace and organize the economy for the common welfare.

Like the other ancient civilizations, it was centered on a river system—that of the Indus and its tributaries. But it was enormously larger, at least seven times bigger in area than the kingdom of Sumer. Two great cities and some 60 to 70 towns, villages and trading posts have already been unearthed, and more are likely to reward diggers in the future. The Harappa empire apparently covered a triangle stretching from a 600-mile seaboard at the base to an apex in the Himalayan foothills nearly 1,000 miles away. Its two cities stood like twin capitals 400 miles apart on the river system; they were at the sites now occupied by Mohenjo-Daro (the Mounds of the Dead) on the Indus and Harappa on the Ravi tributary. The cities were roughly square, and probably each about one square mile in area. We can only guess at their population: probably the cities had some 20,000 inhabitants each and the empire as a whole a population of at least 70,000 to 100,000.

The cities and towns show every evidence of a culture at least as far advanced as that of the neighboring civilizations to the west. Though they had no stone palaces, their buildings were of brick, which, in response to the climate of monsoon rains, was baked hard in the modern manner, instead of being sun-dried as elsewhere in the ancient East. The Harappa people did metalwork in copper and bronze, created jewelry of gold and semiprecious stones, wove cotton cloth, made pottery, used wheeled vehicles and were widely literate.

Even a superficial survey of the material culture of the Harappa Civilization shows that we are not dealing with a loose confederacy of city-states, each with its local customs, but with a highly organized kingdom directed by a strong central government according to a carefully planned scheme. The two major cities are very much alike and appear to have spoken with a single voice. Throughout the area there was a remarkable uniformity of products: pottery was mass-produced and the baked bricks were of standard sizes. Indeed, the weights and measures of the Harappa empire seem to have been regulated to a degree of accuracy unknown elsewhere in the ancient world.

There is little archaeological evidence as to the origins of the Harappa Civilization; we know it only as a fully developed empire. Probably its beginnings stemmed from the region to the northwest some time in the Fourth Millennium B.C. But its development was entirely independent, and even at its height the Harappa kingdom had only sporadic and small-scale trading contacts with Sumer and none at all with the Egyptian empire.

The most remarkable fact about the known history of the Harappa Civilization is its stability and conservatism. For a thousand years, from its arrival at a state of maturity about 2500 B.C., there was almost no significant change, as far as the archaeological record shows. Through all those centuries the culture stood still in an arrested state of development: its script, its pottery, its architecture, its sculpture and seal-engraving, its curiously primitive metal tools—all these remained the same. There are no signs of disturbance by dynastic change or warfare. From time to time the town at Mohenjo-Daro was destroyed by floods, and after each inundation the city was rebuilt exactly as before, even to the same line for the house fronts along the streets. Such immemorial conservatism, such unwavering continuity of tradition, is unparalleled elsewhere in the ancient world, even in Egypt.

When the end did come, it came quickly, and to a people unprepared to defend their long-established civilization against attack from outside. Though the two great cities boasted walled citadels, we find there no sign of weapons such as might equip an army and no evidence of military battles or resistance. Somewhere around 1500 B.C. warrior bands from the west simply overran the kingdom. The urban civilization of the

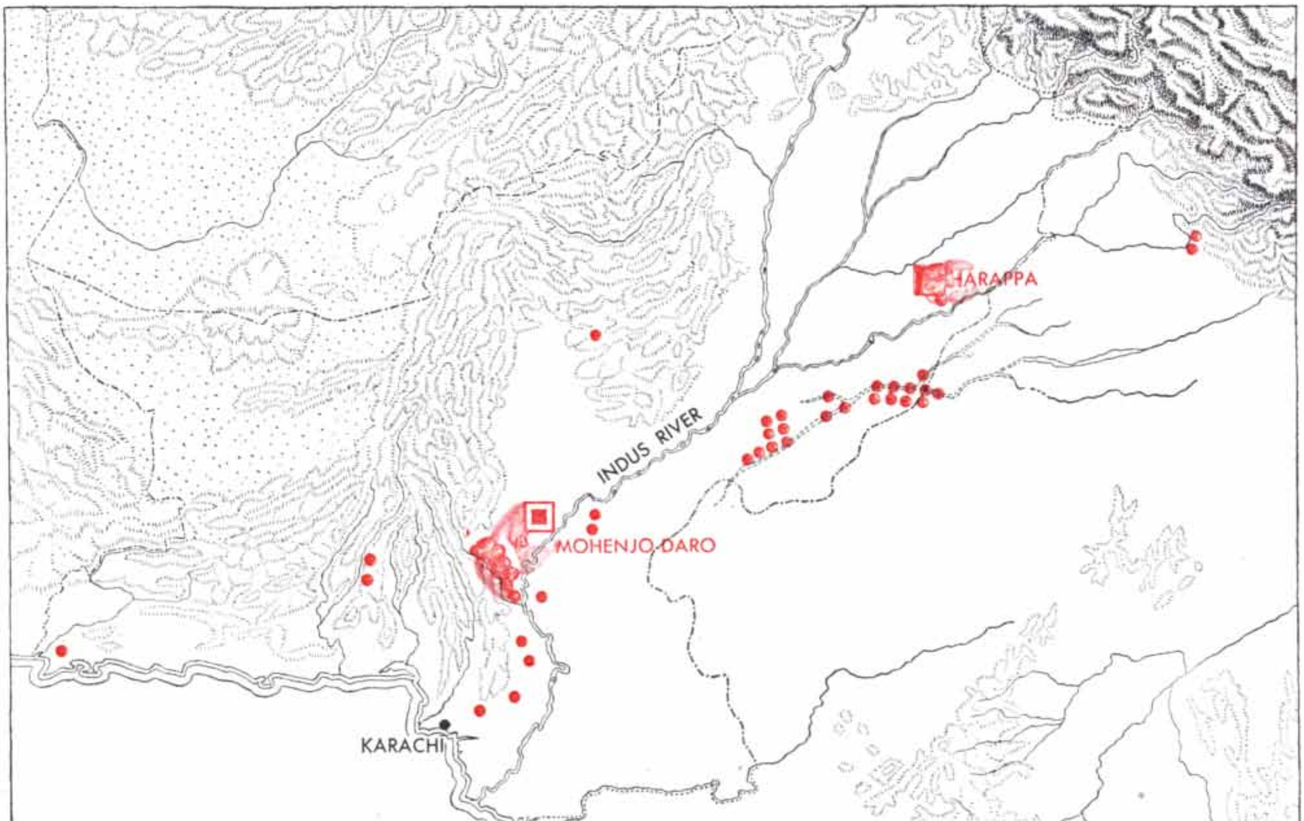
Harappa world ended and was replaced by scattered barbarian farmsteads.

What were the distinctive qualities of this enduring but fragile civilization? For one thing, their writing was unusual for the ancient world. It consisted of a stiff hieroglyphic script with a total of about 400 characters, nearly half of which were variants on a basic 250 or so. This relatively small number of signs in a non-alphabetic language implies an advanced stage in the craft of writing—the earliest writing in Sumer, for instance, had 2,000 signs. The samples of Harappa writing that have been found are mainly engraved stone seals which, as elsewhere in the ancient world, seem to have been used to identify personal property. The Harappa script was pictographic (apparently there was no cursive form), and the longest inscriptions discovered do not exceed 20 characters. Thus even when the Harappa writings are deciphered, they will not give us a lost literature. But to know to what language group they can be assigned will be of great importance.

The Harappa scale of weights was curious and without parallel. The unit was equivalent to 13.64 grams (a little less than half an ounce). But the scale defining multiples of the unit was calculated in a peculiar way: the unit itself was the ratio 16, and at the lower end of the scale the multiples were binary (doubling each time), while the heavier weights were reckoned in decimal multiples. Thus the weights ran in the ratio 1, 2, 8/3, 4, 8, 16, 32, 64, 160, 200, 320, 640 and so on. Fractions of a unit were expressed in thirds. This sequence has been deduced from a number of cubical stone weights found at sites in the Harappa kingdom. Unlike other peoples of antiquity, the Harappans seem to have stuck to their weight system with considerable precision, and the enforcement of the standard over so wide an area suggests careful control and inspection.

The Harappa people also used exact linear measurements. They had two units—a foot of 13.2 inches and a cubit of 20.62 inches. Investigators have found actual Harappa rules, engraved on shell and on bronze, and by check measurements on buildings have ascertained that the units were accurately followed. The Harappa foot and cubit units were the same as those used in other empires of the ancient Orient, which suggests that they came from a common source.

The centralization of authority which the uniformity of weights and measures and of mass-produced products in the Harappa empire bespeaks is even more insistently expressed in the cities themselves. At Mohenjo-Daro enough has been recovered of the town plan to show that it was conceived and laid out as a conscious civic creation from the start; the city was not the rabbit warren typical of the ancient (and much of the modern) Orient. A grid of streets, some of them 30 feet wide, divided the square city into 12 major blocks. Each measured some 1,200 by 800 feet (roughly six times the size of a typical block in New York City). The houses were set closely together, and on the street side they presented blank walls without any architectural embellishment except their doorways. In back they faced interior



SITES at which the remains of the Harappa Civilization have been found are in red. The twin capitals of the kingdom were near its opposite ends. With Mohenjo-Daro on the Indus and Harappa on its tributary the Ravi, the cities were linked by a 400-mile waterway.

GRAVE at Harappa contained traces of a reed shroud and wooden coffin, customs characteristic of Sumer. There is little evidence, however, of contact between the two civilizations.

PLATFORM of bricks at Harappa is where workers stood while they pounded grain. In the section of earth above the center of the platform are traces of the wooden grain mortar.

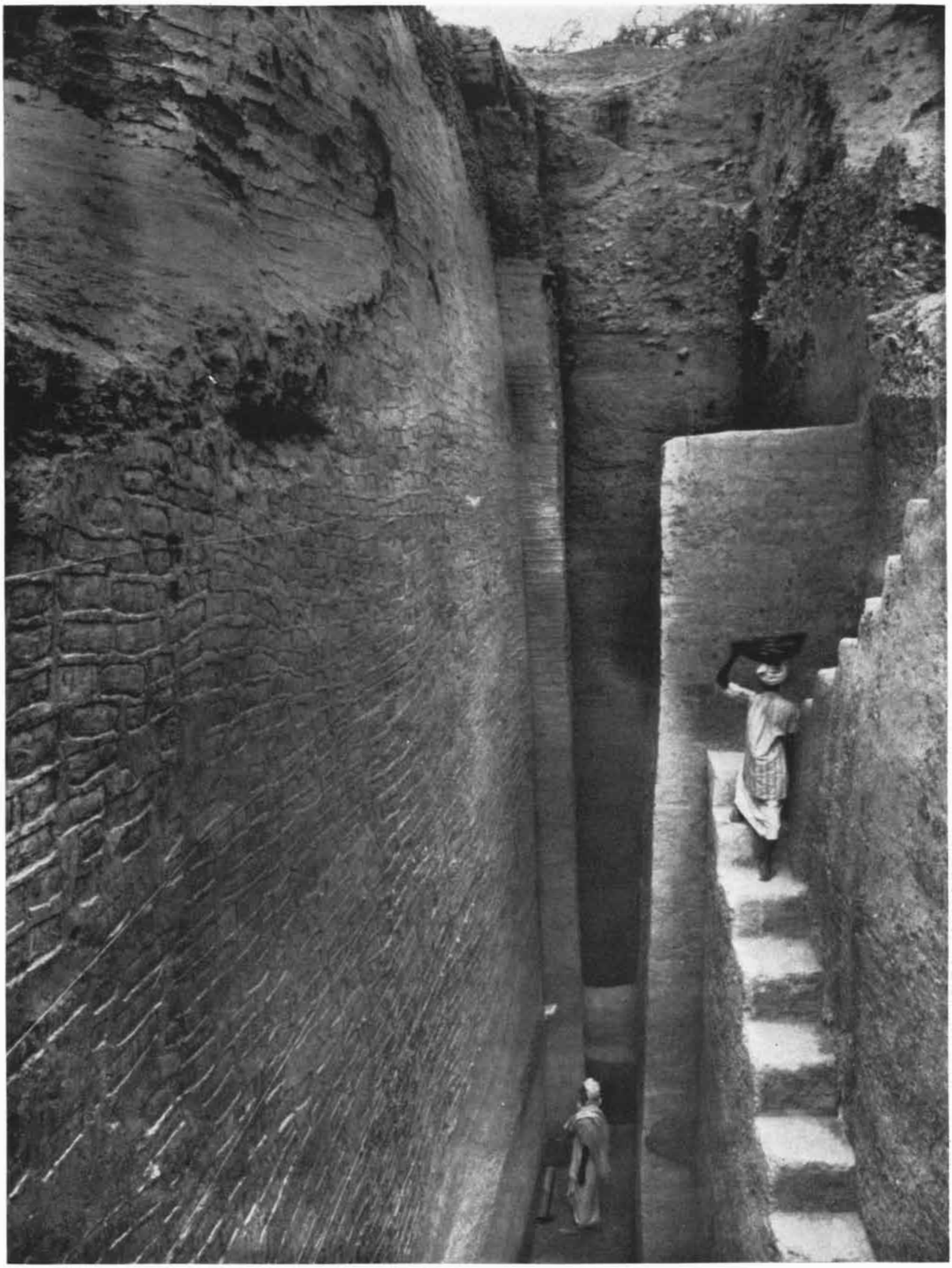
courtyards and were separated by lanes and alleyways. The dwellings were extremely well built of fired brick, and their walls seem to have been plastered and painted inside and out. They had bathrooms with paved floors, and drains leading to a main sewer system beneath the streets, where manholes covered by large tiles gave access for cleaning. In the walls were rubbish chutes opening into brick bins. The whole system shows a concern for sanitation and cleanliness, and a civic organization to that end, unique in oriental antiquity.

The houses generally did not vary greatly in size, suggesting no more inequalities in wealth than one would expect to find in a middle-class population of shopkeepers, craftsmen and merchants. But in both major cities there were separate blocks of two-room cottages which apparently were the quarters of manual workers—a supposition which is reinforced by the fact that at Harappa this housing stood hard by a group of circular corn-grinding platforms and a great communal granary.

The dominant feature of each city was its citadel, a massive rectangular platform at least 50 feet high. At Mohenjo-Daro this structure appears to have occupied one of the central blocks on the western side of the grid. The citadel at Harappa seems to have been similarly placed, but its position is less certain because the city is much less well preserved than its twin and has been badly plundered for its brick. The citadel platforms were built of mud brick with walls of burnt brick. Terraced ways led up to their gates, and the citadels were topped by rectangular bastions and angle-towers.

At Mohenjo-Daro the granary was within the citadel walls; there are still remnants of the loading platforms built to handle the grain. Of the buildings that stood on the citadel platform the most remarkable was an open bath about 8 feet deep and 40 feet long by 24 feet wide. The bath was surrounded by a veranda and changing-rooms and had steps leading down into it. Near it was a large building with a cloistered court and a pillared hall some 80 feet square. There was also a building, possibly a temple, which unfortunately is now almost obliterated by a Buddhist monastery later built on the site. And there were buildings similar in plan to the dwellings of the town. But none of the structures in the citadel could be interpreted as a palace.

These citadels, with their monumen-



WALL is excavated by Indian workers at Harappa. It is the side of a platform 1,200 by 600 feet that rose some 30 feet above the city. On top of the platform was a citadel of public buildings. At Mohenjo-Daro, which has much the same plan, there is a similar structure.

POTTERY from Harappa is red with black designs. Most pottery from Harappa, however, is of a plain, mass-produced variety which did not change during the history of the city.

FIGURINES from Harappa are made of clay. Mostly representing women, they were either private deities or toys. No large statues have been found in either Mohenjo-Daro or Harappa.

tal walls, gateways, approach ramps and special buildings, must have been the seats of the centralized power of the Harappa Civilization. What was the source of the rulers' extraordinary authority? Clearly it was not primarily the force of arms, for no sign of any distinctively military equipment has been found in the kingdom. One can guess that their authority was spiritual. The conservative uniformity of the culture and the peaceful coexistence of the two major cities suggest that the kingdom was ruled by men who were priests before they were kings. The art and architecture of the Harappa Civilization look very much like precursors of the Hindu culture: nothing could be more characteristic of a Hindu sacred site than the great bath or "tank" at Mohenjo-Daro. On an engraved seal found in the same city is a figure which is easily recognizable as the prototype of Siva, one of the Hindu divinities. There are a hundred similar indications. All the archaeological evidence suggests that the Harappa polity was a theocracy ruled by priest-kings from sacred citadels, as Tibet is ruled today from the Potala at Lhasa and from Shigatse.

With ancient Egypt and Babylonia, the Harappa Civilization in India takes its place as the third area where urban civilization was born in the Old World. Like the others, it was based on a common stock of peasant skills acquired in little corn-growing, cattle-breeding communities, such as had grown up during the fifth and fourth millennia B.C. in many regions between the Nile and the Indus. But the Harappa people, like those of Egypt and Sumer, worked out their own distinctive and arresting variant of an urban civilization.

The very qualities that enabled the Harappa Civilization to endure unchanged for a thousand years apparently were responsible for its quick collapse at the end. Its peaceful, delicately adjusted economy could not survive an invasion. The invaders probably were the Indo-European tribes (the originators of the languages which were to become Sanskrit and Iranian) who began to migrate eastward from the western rim of Asia soon after 2000 B.C. These horse-driving squires and cattle drovers trampled out the Harappa culture, and a Dark Age of comparative barbarism ensued. But the Harappa Civilization was not completely extinguished, and from the new mixture of peoples and ideas came the traditions which molded historic Hinduism.

Kodak reports to laboratories on:

our answer to requests for extra-sensitive film or plates . . . a new way to track down organic chemicals . . . three recent publications on color photography, scientific photography, and industrial radiography

Sensitivity

Currently, *Kodak Tri-X Panchromatic Film* is our "fastest" regular product. Excellent stuff it is too, with an Exposure Index of 160, beautiful tone characteristics, and very little granularity for all that speed. It has the important virtue, also, of quick availability from the shelves of any dealer who carries a general line of Kodak products.

Now, what if *Tri-X Pan Film* still isn't sensitive enough for some extraordinary problem that confronts you?

We have two different answers, depending on whether the exposure is 1) taking too many hours or 2) too many seconds, milliseconds, or microseconds. For Case 1, there are *Kodak Spectroscopic Plates and Films* of Type 103a. For Case 2, we take Type I emulsion and give it Class D sensitization, which extends in strength from 4600 A to 6200 A. Case 1 is chiefly of interest to astronomers, who know all about it. Case 2 occurs more frequently. *If* it has come up in your laboratory, *if* you can wait until our Research Laboratories can coat Type I-D emulsion on plates or film for you, and *if* you are willing to put up with a little less uniformity, and a little poorer pictorial quality and granularity than *Tri-X Pan* provides, we can give you approximately a 3 to 1 advantage in sensitivity over the latter product under comparable conditions. Better check first, though, to make sure there isn't some way you can use *Tri-X Pan Film.*

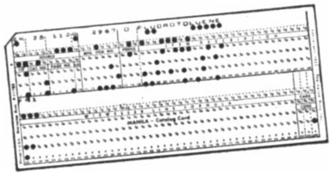
You can order Type I-D *plates and films through your Kodak Industrial Dealer. (Address on request from Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.) We'll even be glad to coat the emulsion for you on 16mm and 35mm movie film, but we'll have to ask you to take at least 10 100-foot rolls of the 16mm or 5 of the 35mm. The 16mm is priced at $4.98 per roll, and the 35mm at $8.25 per roll, both on daylight-loading flanged spools. On cores for darkroom loading, they are priced at $4.37 and $7.50 for 16mm and 35mm, respectively.*

Fine needles, fine haystack...

o-Benzoic Sulfimide (Eastman 38) is a white powder melting at 224-226 C and slightly soluble in water, chloroform, alcohol, and ether. The compound is of importance in commerce as "insoluble saccharine."

2-Aminobenzothiazole (Eastman 3940) is nearly white crystals, melting at 129-131 C, slightly soluble in water, quite soluble in chloroform, alcohol, and ether. It is used as an intermediate in the manufacture of certain photographic chemicals.

One of our senior chemists, who knows the Eastman catalog about as well as he knows his children's names and ages, got to brooding recently that given one of these compounds, even *he* wouldn't have been able to name the other right off as one of its nearest relatives in our list. (Both consist of a C_3NS heterocycle fused to a carbocycle.) His unease about the difficulty in picking up such relationships among his own merchandise pricked him to spend a good many hours at home making up a deck of cards coded for each compound, that could be shuffled in various ways.



We now learn that another chemist, who works not for us but for Remington Rand, has done the job by punched cards. We ourselves have encoded a fair amount of chemical data on punched cards, but this chemist has done it by the new Wiswesser notation for every Eastman Organic Chemical having a known structure. Thus electromechanical brains, such as are ensconced in many large organizations, can fill in their idle moments by discovering all sorts of important relationships among the more than 3500 organic compounds available from a single, completely dependable source—namely, us.

If you want to know more about what this man has done, or if you want to purchase our catalog in punched card form, write Remington Rand Inc., 315 Fourth Avenue, New York 10, N. Y. In its conventional book form, the catalog remains free of charge. If you need a copy, write to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

Three books

These three fellows of ours are smiling for the photographer in celebration of the publication of their book, "Principles of Color Photography." In the book they don't smile at all. Soberly and with an abundance of illustrations, Messrs. Ralph M. Evans, W. T. Hanson, Jr., and W. Lyle Brewer (pictured r. to l. in that order) present the theory behind visual and photographic sensitometry, analyze the methods of obtaining colorant images, and tell how they are combined to give color processes. It's sold by Kodak dealers for $11, and no inventor of new systems of color photography should be without a copy.

No user, or prospective user, of the photographic emulsion as a scientific instrumentality should be without a copy of "Kodak Photographic Plates for Scientific and Technical Use." Besides giving the detailed information implied by the title, it contains just about the most concise précis of the scientific theory of photography to be found. The new edition has been extensively revised. Kodak dealers sell it for 50¢.

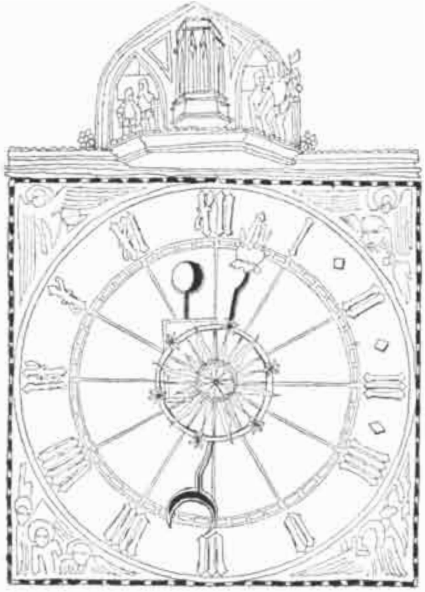
Still lower on the price scale, namely free, is another newly revised booklet, "Kodak Materials and Accessories for Industrial Radiography." This one tells how to pick the best type of film for any non-medical job involving exposure to x-rays and describes various devices to make life more pleasant in the x-ray laboratory. You can get a copy by writing Eastman Kodak Company, X-ray Division, Rochester 4, N. Y.

Prices include Federal Tax where applicable and are subject to change without notice.

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*

Kodak
TRADE-MARK

SCIENCE AND



Neutrino Found?

Physics possibly has reached another milestone: detection of the mysterious particle known as the neutrino. Ever since Wolfgang Pauli of Zurich suggested the neutrino in 1933, physicists have been somewhat unhappy about the particle. They need it to preserve the laws of conservation of energy and of quantum spin in the atomic nucleus, but up to now the only evidence of its existence has been the set of phenomena it was invented to explain. Having no charge and almost no mass, the neutrino seems undetectable by any conceivable instrument. Two workers at the Los Alamos Scientific Laboratory now think, however, that they have "probably" detected a reaction involving neutrinos. F. Reines and C. L. Cowan, Jr., report their work in a letter to appear shortly in *The Physical Review*.

Neutrinos supposedly are produced when a neutron decays into a proton and an electron. Reines and Cowan use the reverse reaction: the capture of a neutrino by a proton, which yields a neutron and a positron. They detect this reaction by the successive flashes it causes in a scintillating liquid. The first flash comes from the positron; the second, a predictable time later, when the neutron is absorbed by cadmium in the scintillator with an emission of gamma rays. Reines and Cowan calculated the neutrino spectrum that should emerge from the Hanford atomic pile and found that by building an enormous scintillator and an appropriate delayed coincidence circuit (*see page 36*) they should be able to capture and record one such event every three to 10 minutes.

An event so infrequent of course is very difficult to distinguish from the background of other radiations around an atomic pile, even with the selective coincidence circuit. By elaborate shielding and electronic circuitry Reines and Cowan succeeded in screening down the "background" count to about 2.15 per minute. Then, running the counter with the pile power alternately off and on, they found the count 2.5 per minute when the pile was on. This gain they attribute to neutrinos. The neutrino frequency count, if indeed the difference is due to neutrinos, is somewhat higher than they had predicted. Other physicists are very interested in the experiment, but they, as well as Reines and Cowan, are reserving judgment pending "further confirmatory work."

The Military and the AEC

Atomic energy, which was taken out of the Army's hands and turned over to civilian control under the Atomic Energy Commission by Congress in 1946, seems to be reverting to military control. Rear Admiral Lewis L. Strauss, U.S.N.R., was recently appointed chairman of the AEC. Last month Admiral Strauss announced the appointment of Major General Kenneth D. Nichols, U.S.A., as general manager of the Commission. General Nichols succeeds Marion W. Boyer, who is returning to private business.

General Nichols has been the Army's chief of research and development. With the Manhattan District during the war, he was in charge of building and operating all plants used in producing plutonium and uranium-235. The General graduated from West Point in 1929.

Science Budget

The figures on Federal appropriations for scientific research and development in the fiscal year 1954-1955, as assembled by the National Science Foundation, show that the new Republican Congress (1) appropriated about the same total amount as the Democratic Congress in the preceding year, (2) reduced some allowances for basic research, and (3) increased the funds for military research.

The research total for all government agencies is $2,074,235,000, some $100 million less than last year. The lion's share is allocated to the Defense Department, which gets $1,556 million. While this is some $100 million less than last year, part of the previous appropriation was for construction of laboratories; for the actual conduct of research and development the allowance this year is larger than last. The National Science Foundation says, however, that probably not all the money will be spent. If cuts are made, they are likely to fall much more heavily on the basic research allocation than on applications of more immediate military value. In 1953 the Defense Department spent about $31 million on basic research.

The Department of Agriculture gets $67.8 million, a $10 million increase; the Department of Health, Education and Welfare has $63 million, a $4 million decrease over-all but a gain of $10 million for actual operations; the Atomic Energy Commission receives $239.3 million, a $7 million cut; the National Advisory Committee for Aeronautics gets $73 million, down $5 million; the National Science Foundation has $8 million, up more than $3 million. The Department of Commerce was cut from $23.3 million to $16.6 million. Curtailment was in the Bureau of the Census and the National Bureau of Standards.

The heaviest blow of the economy axe fell on the work of the Bureau of Standards. Its research funds were reduced from $6.75 million to $5 million, which will mean drastic reduction of some of its important basic studies. The Bureau's atomic physics section, which has been making precise measurements of atomic masses, is wiped out. Its activities in solid state physics are severely reduced. Its work on refinements of length and temperature measurements is slowed down. Also hit are its programs in spectroscopy, nuclear data, numerical analysis, surface chemistry and calibration of instruments for industry. More than 100 of the Bureau's professional staff of about 2,500 will be dismissed immediately, and several hundred more will lose their jobs later because the research that the Bureau has done for other Federal agencies also is to be curtailed.

In the anticipated reduction of basic research sponsored by the Defense Department, social science will probably be hit harder than physical or biological. A major economic study that has been supported by the Air Force, for example, is being dropped before its completion, although budgeted funds are available. This is an input-output analysis of the impact of defense mobilization on the economy. It would have been the first large-scale application of a new theoretical technique which has excited wide interest among economists.

Fuel from the Sun

The world's usable reserves of fossil fuels will be gone in 70 years, and radioactive fuels will last no more than 175 years beyond that point, according to Palmer Putnam, consultant for the Atomic Energy Commission. The calculation is based on the premise that world population and per capita power consumption will continue to rise at their present rates. "Usable" fuel means fuel that will produce power at no more than twice present prices; beyond that point, Putnam believes, the economy would slow down.

He announced his estimate at a recent symposium on solar energy sponsored by the National Science Foundation and the University of Wisconsin. Direct capture of the sun's heat by various focusing devices has proved satisfactory in limited applications, the symposium was told. A solar cookstove is being sold widely in India. But scientists doubt that focusing engines will ever attain a high enough efficiency for large-scale use.

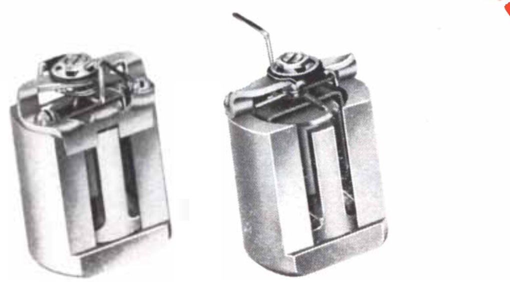
Farrington Daniels, president of the American Chemical Society and host to the symposium, suggested a chemical approach. Since sunlight yields many more energy quanta in photochemical reactions than in heat, he believes that the answer lies in finding a substance which will react chemically under sunlight and which can later be made to revert to its former state, giving up the absorbed energy as heat. A start along this line has been made by Lawrence J. Heidt of M.I.T., who has discovered a way to decompose water into hydrogen and oxygen under the action of sunlight.

Test-Tube Cold

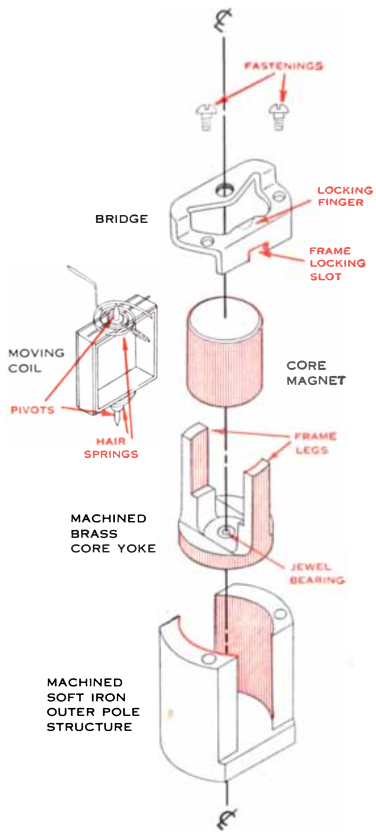
The virus of the common cold, one of the last of the familiar disease agents to resist transfer to experimental animals and laboratory cultures, is now being grown in a test tube. This important advance on the road to a cure was announced in *The Lancet* by Christopher Howard Andrewes, director of the Common Cold Research Unit at Salisbury, England.

Ever since it was set up seven years ago, the Salisbury unit has been looking marion

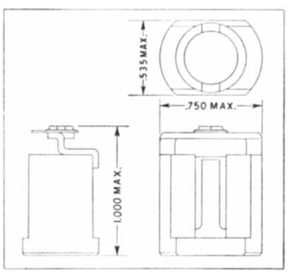
advancement in instrument design



TWO VIEWS SHOWING COAXIAL MECHANISM
ACTUAL SIZE



EXPLODED DIAGRAM SHOWING
INTERLOCKING CONSTRUCTION

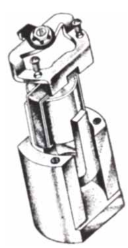


COAXIAL METER MECHANISM DESIGN*
OPENS NEW FIELDS OF APPLICATION

A new Marion concept in the mechanical design of the moving coil galvanometer magnetic system has resulted in a "miniature" movement with performance characteristics and durability exceeding existing ruggedized or regular panel instruments of far greater size and weight. The Marion "Coaxial" assembly provides a magnetic field of great strength, uniformity and stability which is self-shielded. Ruggedness and stability are inherent in the basic simplicity of the design. The small size and weight make practical the application of the moving coil mechanism as a component of a great many electrical or electronic instruments or other products. This is especially pertinent in aircraft instruments where size and weight are of critical importance, yet no compromise can be made with performance and durability.

The new assembly (see exploded diagram) consists essentially of a soft iron outer pole structure, a non-magnetic yoke and a magnetized core of such diameters that the yoke fits snugly in the pole structure and the core within the yoke. The assembly is locked by attaching the bridge to the pole structure by means of two screws—the only fastenings in the entire assembly. A locking finger on the bridge holds the core and the frame in position. Rotation of the core yoke is prevented by the slot in the bridge flange which engages one of the legs of the frame. The moving coil is contained by its pivots, and bearings located in the bridge and the base of the frame.

The basic design in which all critical dimensions are machined from a common center (the bearing axis) gives far more precise and uniform alignment than is possible with stamped assemblies. The interlocked assembly assures maintenance of these close tolerances and affords far greater rigidity and strength than is available in conventional mechanisms, particularly when mass is considered.



MECHANISMS BY MARION

The Marion "Coaxial" mechanism has many applications, not only in indicating instruments, but also as a component of equipment utilizing the moving coil galvanometer principle. It is one of a number of Mechanisms by Marion that extend the field of application of moving coil galvanometers where previously size, weight or performance characteristics prevented their use.

Marion Electrical Instrument Company, 416 Canal Street, Manchester, N. H.

*Patents Pending

marion meters

Reg. U. S. Pat. Off.

MANUFACTURERS OF RUGGEDIZED AND "REGULAR" METERS AND RELATED PRODUCTS for some host, other than the human nose and throat, in which to grow and study the virus. In the absence of that substitute, they have carried on experiments with human volunteers ["The Common Cold," by Christopher Andrewes; Scientific American, February, 1951].

After John F. Enders, of Boston's Children's Hospital, succeeded in growing the poliomyelitis virus in a culture made from human embryo tissue, the workers at Salisbury tested the cold virus in a culture of human embryo lung tissue. They have now obtained what they feel sure is evidence of virus growth. Unlike the polio agent, the cold virus does not show direct signs of growth in the test tube. But Andrewes and his associates have passed the virus through a series of cultures until the original material would have been diluted to one part in 100,000, and this material still induces colds in volunteer subjects. Since dilutions greater than one part in 1,000 have never produced colds, it seems evident that the virus has multiplied.

Inside the Virus

A technique for splitting open individual bacterial viruses and examining their insides has been developed at the University of California's Virus Laboratory. The method, discovered by Dean Fraser and Robley C. Williams, may lead to important new information on how viruses duplicate themselves.

The feat was made possible by the "surprising" discovery that viruses which have been freeze-dried burst open when they are exposed to water again. The scientists, who describe their technique in the *Proceedings of the National Academy of Sciences*, attribute this effect to surface tension set up by the drops of water that gather on the virus particle. To examine a virus, they freeze-dry it on the electron microscope stage and then allow moist air to pass over it. "In this way," Williams explains, "there is not enough water on the specimen to slosh the contents of the virus around. . . . Instead the debris remains in an approximately circular array around the virus, convenient for study."

Photomicrographs show the emptied protein "overcoat" that encloses a virus, and they give a remarkably clear picture of twisted fibrils of DNA, the virus's internal material.

Electrocortin

What is believed to be the last of the important adrenal cortex hormones has now been obtained in crystalline

FASTER ANALYSIS WITH X-RAYS

Chemical analysis by x-ray absorption is now successful on a commercial scale with the G-E X-Ray Photometer, saving hours of valuable laboratory time, and freeing the analytical chemist from tedious routine work. Petroleum refiners slash time and cost determining tetraethyl lead in gasoline, and sulphur in oils.
See bulletin GEC-412B*.

NEW MERCURY VAPOR DETECTORS

Users of mercury compounds can now determine harmful concentrations of mercury vapor with the new, completely redesigned G-E Mercury Vapor Detectors. Electronic and chemical detectors provide either instantaneous or continuous indication. Electronic detector pictured being used to check curing oven in laboratory of silicone rubber plant.
See bulletin GEC-312*.

MEASURES MOISTURE IN GASES

G-E Dewpoint Recorder gives continuous indication and record of dewpoint temperature in gas streams from ambient to minus 90 deg. F. Manufacturers and distributors of gases measure moisture content at different stages of manufacture and various transmission points. See bulletin GEC-588A*.

***To obtain these publications, contact your nearest G-E Apparatus Sales Office, or write General Electric Co., Section 687-101, Schenectady, N. Y.**

Operator observes cracking pattern of natural gas sample with G-E Mass Spectrometer.

NEW ELECTRONIC INSTRUMENTS SPEED CHEMICAL ANALYSIS

Research and production chemists benefit by better results—faster

Rapid chemical analysis, by electronic means, makes the G-E Mass Spectrometer an important tool for the modern chemist. Because it measures a basic fundamental unit—mass—it does not suffer from many of the limitations of physical methods. For basic research and routine process control of most gaseous and liquid mixtures the G-E Mass Spectrometer is ideally suited.

It automatically records peaks at mass numbers ranging from 1 to 600, and separation of a dozen or more compounds is common practice. Immediate results save time in the identification of common impurities and traces of rare isotopes. High resolution permits complete separation of high-mass elements.

Here is another example of G-E research and development—linked to produce more and better instruments for modern industry. See bulletin GEC-587A*.

Convenient sample system facilitates introduction of unknown gas mixture.

GENERAL ELECTRIC

form. This substance, tentatively called electrocortin, controls the body's utilization of electrolytes. Its discovery was announced by Tadeus Reichstein, professor of organic chemistry at the University of Basel and co-winner of a Nobel Prize for his part in isolating and determining the chemical structure of cortisone and hydrocortisone.

Speaking before the Eighth International Congress of Rheumatic Diseases in Geneva, Reichstein said that electrocortin, hydrocortisone and corticosteroid are probably the three master hormones by which the adrenal gland controls metabolism. Electrocortin is available only in minute quantities, and its functions and practical uses will not be known until it has been tested further. The hormone was isolated by a group of British and Swiss scientists at Middlesex Hospital in London, by the Ciba Pharmaceutical Laboratories in Basel and in Dr. Reichstein's laboratory at the University of Basel.

Chemists Meet

Ten thousand chemists assembled in Chicago last month for the 124th meeting of the American Chemical Society. The world's largest professional society enrolled its 70,000th member at the session. Its 21 divisions listened to a record-breaking total of 1,193 technical papers.

This year's chief headline-makers were two young foreign chemists who reported that they had synthesized sucrose, common sugar. Workers in this field compared the feat to the scaling of Mount Everest; it had been attempted by “virtually every investigator in the field” beginning with the great Emil Fischer, who tried at least 20 methods himself. Raymond U. Lemieux, a 33-year-old Canadian, and George Huber, a 25-year-old Swiss, did the job in three months. Working under a grant from the National Research Council of Canada, Lemieux and Huber succeeded in joining derivatives of synthesized glucose and fructose to make the sucrose molecule. A major problem was to isolate the sucrose, which was only one per cent of the reaction product. Later they increased the yield to about 5½ per cent. The experimenters have made a fraction of an ounce of sugar so far.

The discovery appears to have no commercial application but may have considerable scientific importance. Lemieux says that it will be possible to place a radioactive carbon atom at any desired position in the sugar molecule so that biochemists can trace its path in

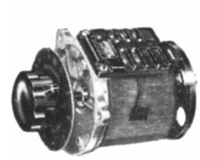
powerstat *Variable Transformers*

AN *EFFICIENT, ACCURATE, DEPENDABLE* SOURCE of CONTINUOUSLY-ADJUSTABLE A-C VOLTAGES

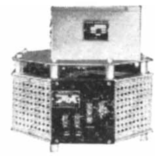
any type

MANUALLY-OPERATED OR MOTOR-DRIVEN . . . LOCAL OR REMOTE CONTROL . . . WALL, BENCH or BACK-OF-PANEL MOUNTING . . . EXPOSED OR ENCLOSED TERMINAL BOARD . . . FUSED or UNFUSED . . . DIRECT WIRING OR CORD-PLUG WITH OUTPUT RECEPTACLE CONNECTIONS

TYPE 116



TYPE 116U



TYPE M-1256

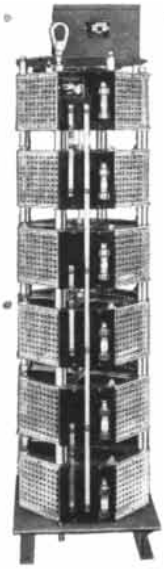
any capacity

TYPE 10

FROM 150 VA TO 100 KVA . . .

SINGLE AND MULTIPLE PHASE DUTY . . . 120, 240 and 480 VOLT SERVICE . . . FREQUENCIES OF 25, 50/60, 400/800 CYCLES . . . FROM ZERO TO OR ABOVE LINE OUTPUT VOLTAGES WITH THE MAXIMUM OUTPUT CURRENT AVAILABLE AT ANY SETTING

TYPE MW1156-6

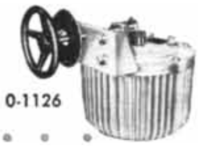


for any job

IN THE EXPERIMENTAL AND RESEARCH LABORATORY . . . THE TESTING AND INSPECTION DEPARTMENTS . . . ON THE PRODUCTION LINE . . . AS THE VARIABLE A-C VOLTAGE COMPONENT OF ANY EQUIPMENT . . . WHEREVER A CONTINUOUSLY-ADJUSTABLE VOLTAGE IS REQUIRED TO CONTROL HEAT, LIGHT, SOUND, POWER OR ELECTRONIC APPARATUS

under any conditions

AIR-COOLED ASSEMBLIES FOR NORMAL SURROUNDINGS . . . OIL-COOLED and EXPLOSION-PROOF UNITS FOR USE IN CORROSIVE or HAZARDOUS ATMOSPHERES . . . SPECIAL DESIGNS FOR SHIPBOARD, AIRBORNE and other MILITARY APPLICATIONS



TYPE 0-1126

TYPE X-1126

400/800 CYCLE MIDGET FRAME SIZE

and all featuring

EXCELLENT REGULATION . . . HIGH EFFICIENCY . . . CONSERVATIVE RATINGS . . . ZERO WAVEFORM DISTORTION . . . RUGGED MECHANICAL CONSTRUCTION . . . SMOOTH CONTROL . . . EASY MOUNTING

SEND NOW FOR COMPLETE INFORMATION

THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT

- **STABILINE** Automatic Voltage Regulators
- **POWERSTAT** Variable Transformers
- **VARICELL** D-C Power Supplies
- **VOLTBOX** A-C Power Supplies
- **SUPERIOR** 5-Way Binding Posts
- **POWERSTAT** Light Dimming Equipment

THE SUPERIOR ELECTRIC CO.
1211 Mae Avenue, Bristol, Conn.

Please send literature on POWERSTAT variable transformers.

NAME ____________________

POSITION ____________________

COMPANY ____________________

CO. ADDRESS ____________________

CITY __________ ZONE ____ STATE __________ metabolism. The Canadian scientist believes that his method shows the way to synthesize many other complicated substances.

Another highlight of the meeting was the first symposium ever to be held on the chemical treatment of virus diseases. About 10 groups of chemicals have proved effective against certain viruses in test tubes or infected animals. Several have succeeded in attacking viruses within a cell without destroying the cell.

A test for cancer which may throw some light on the mechanism of the disease was reported by Allen F. Reid of the University of Texas Medical School. By radioactive tracer studies, he found that the red blood cells of cancerous patients take up phosphorus much more rapidly than the cells of healthy subjects. He believes that a "Q factor" in normal blood regulates the phosphorous metabolism, and that this factor is missing in the blood of cancer patients. The test is still too difficult and time-consuming to use as a routine detection measure, but Reid hopes it can be refined and simplified.

A number of papers were devoted to non-medicinal uses of antibiotics. Louis L. Rushoff of Louisiana State University presented evidence against the prevailing opinion that these substances stimulate animal growth by affecting intestinal bacteria. Aureomycin accelerated bone development in cattle without materially decreasing the number of bacteria in their stomachs. Injection of the drug had the same effect as feeding it by mouth. Other workers reported that antibiotic sprays can control plant diseases such as halo blight of beans and fire blight in apple trees. A little aureomycin mixed with ice keeps fish fresh for longer periods. Brewers have learned that adding one part of polymixin to 100 million parts of beer retards souring.

Men and Women

Is a dominating male psychologically more robust than his submissive spouse? A group of anthropologists who recently studied the people of the Truk atoll in the Pacific have reason to doubt that he is.

To a visitor Truk looks like a male paradise. The men are the absolute rulers of their homes and their community. They order their wives about and beat them when the occasion seems to warrant. They hold all political power and all esoteric knowledge. They provide all the food, principally breadfruit and fish. In adultery, which is the dominant preoccupation of the Trukese, the man in-

variably takes the initiative. In every sphere of life the women seem self-effacing and obedient.

Digging beneath this surface picture, the anthropologists, led by George P. Murdock of Yale University, made a number of Rorschach and Thematic Apperception tests of men and women on the atoll. These were given for analysis to Seymour B. Sarason, associate professor of clinical psychology at Yale. His findings are reported by Thomas Gladwin, a member of the expedition, in *Transactions of the New York Academy of Sciences.*

Sarason discovered that the men of Truk were markedly more insecure and anxious than the women and that they would respond less well in situations of conflict or doubt. The anthropologists were incredulous. But when they went back over their data in the light of the Sarason interpretation, they found confirmations which radically revised their original impressions. They noticed, for example, that the few attempts at suicide on Truk (there was no record of a successful one) were all by men. When a boy and girl fall in love and want to marry in defiance of the parents, who in this culture generally arrange the marriages, it is always the girl who takes the initiative in overriding the parents.

The upbringing of boys and girls on Truk may account for the underlying psychological pattern. Because brothers and sisters are not permitted to live in the same home after puberty, the boy is banished to the home of a relative. When he marries, he moves in with his wife's family and becomes head of the household, but he remains always a foreigner in his home. While the women of Truk have no responsibility for raising food, being considered not strong enough for harvesting or preparing breadfruit and unlucky on fishing expeditions, the men are acutely aware of their role as providers and worry about their ability to keep the larder full.

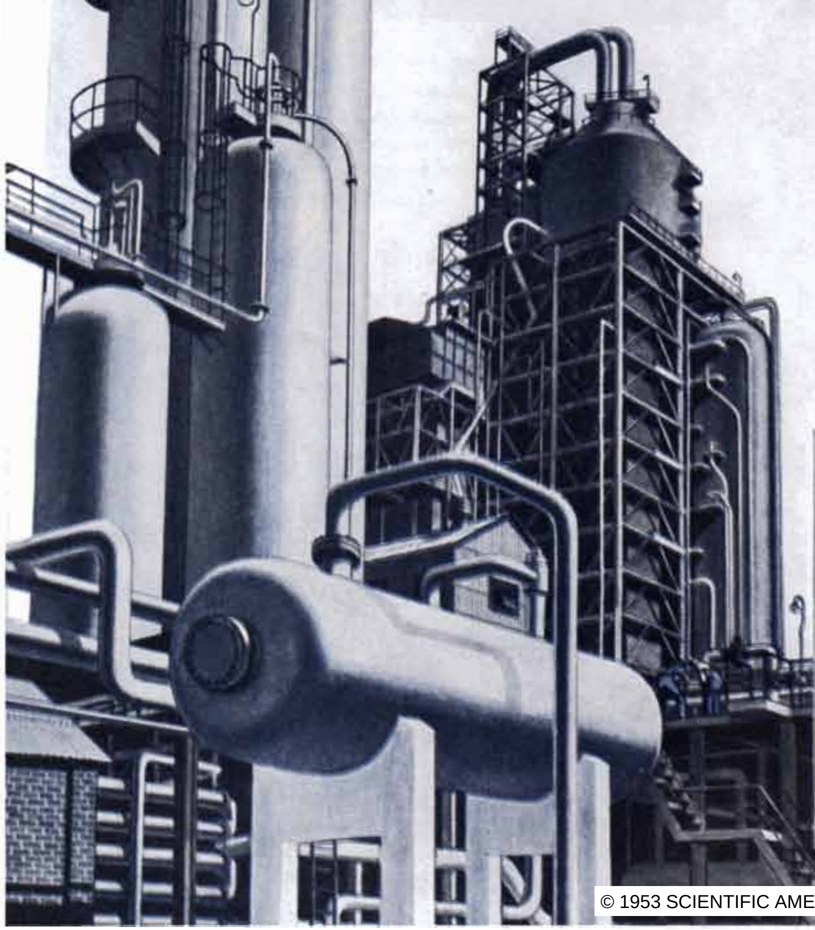
In the matter of adultery the men are surrounded by anxieties. The man initiates the liaison either by letter or by sneaking into the woman's house at night. In either case he risks the humiliation of a rebuff from her and the physical danger of being set upon by her aroused relatives. She is at liberty to succumb to his advances or to spurn them; if the affair is discovered, she feigns outraged innocence. On Truk a man is considered a failure as a lover if his partner does not have an orgasm, and males exchange much anxious gossip on the score of how easy or how difficult individual women are to satisfy.

Helping the Process Industries build for the future

...is part of the "Blaw-Knox Job" for Industry

Blaw-Knox facilities for engineering and producing process equipment and building complete chemical plants, include designing and fabricating products for such processes as distillation, gas absorption, solvent extraction and recovery, heat transfer, cracking, polymerizing, evaporation, crystallization, high pressure processing, impregnating, gas cleaning and others.

Blaw-Knox products and services can give a lift to your production, performance and profits in: Chemical and Food Processing, Plastics, Ferrous and Non-Ferrous Metals, Gas and Petroleum, Construction, Radio, TV and Public Utilities. The right-hand column indicates the scope of Blaw-Knox activities. For descriptive literature on any Blaw-Knox product or service write Blaw-Knox.



MEMBERS OF THE BLAW-KNOX "FAMILY" AND SOME OF THEIR PRODUCTS

Blaw-Knox Equipment Division
Blawnox, Pa.
- Concrete Road Paving Machinery
- Clamshell Buckets
- Contractors Equipment
- Gas Cleaning Equipment
- Open Steel Flooring
- Radio, TV and Transmission Towers
- Steel Forms for Concrete Construction
- Chemical and Process Equipment
- Water Cooled Equipment for High Temperature Furnaces

Buflovak Equipment Division
Buffalo 11, New York and Mora, Minn.
- Machinery for the Chemical and Food Processing Industries
- Specialized Machinery for the Dairy Industry

Chemical Plants Division
Pittsburgh 30, Pa.
- Complete Chemical, Petrochemical, Industrial and Petroleum Plants

Foote Construction Equipment Division
Nunda, New York
- Black Top Road Pavers
- Concrete Road Pavers

Lewis Machinery Division
Groveton, Pa.
- Rolling Mills and Auxiliary Machinery for Rolling Ferrous and Non-Ferrous Metals

National Alloy Division
Blawnox, Pa.
- Alloy Steel Castings for Extreme Temperatures, Abrasion and Corrosion Resistance

Power Piping and Sprinkler Division
Pittsburgh 33, Pa.
- Prefabricated Piping Systems for High Pressures and Temperatures. Pipe Hangers
- Automatic Sprinkler Systems for Fire Protection

Rolls Division
(Pittsburgh and Lewis Rolls)
Pittsburgh 1, Pa.
- Rolls for Steel and Non-Ferrous Rolling Mills

Union Steel Castings Division
Pittsburgh 1, Pa.
- Heavy Steel Castings

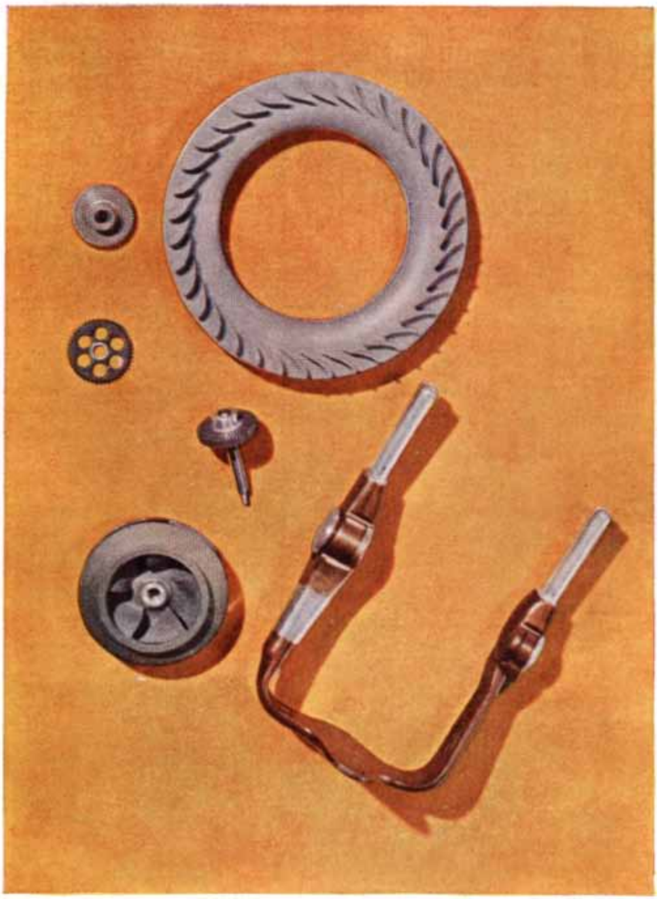
BLAW-KNOX

BRANCH OFFICES:

Birmingham 3, Alabama
Chicago 3, Illinois
Philadelphia 3, Pennsylvania
New York 17, New York
San Francisco 5, California
Washington 5, D. C.
Tulsa 1, Oklahoma
Export—New York 17, New York

BLAW-KNOX *Company*
FARMERS BANK BUILDING
PITTSBURGH 22, PA.

WE'LL IMAGINEER WITH



FILE HARD COATINGS . . . New ways to apply an extremely hard, thick anodic coating on aluminum have been developed by Alcoa's finishing labs. Of controlled thickness and density, these coatings offer a high degree of resistance to wear and abrasion.

RAINBOW COLORS . . . New improvements in Alcoa's Alumilite finishes permit most forms of aluminum to be given almost any color that is desired. This smooth, easy to clean finish cannot chip or peel . . . is widely used for appliances and giftware.

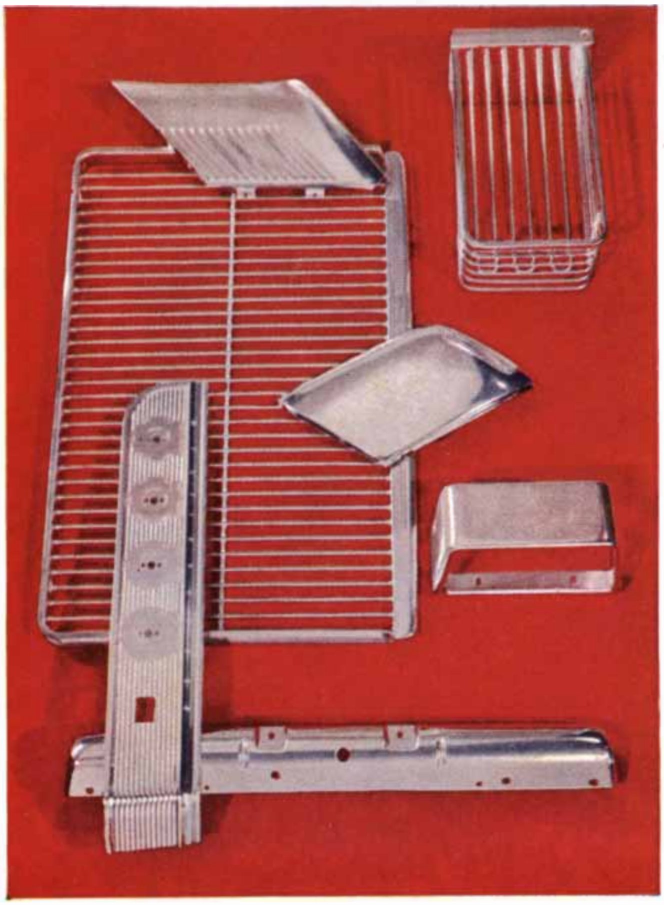
It's not unusual to find a company that will give you design help and application advice where their product is involved. Your company probably works with customers this way. Ours does—through our Development Division.

The unusual part of our service is the distance we will take a project for an interested user. Basic research? We offer the facilities of the world's greatest aluminum research laboratories—where most of the aluminum alloys were born. Physical testing? Products or processes can be tested under every conceivable service condition—using the most advanced equipment known.

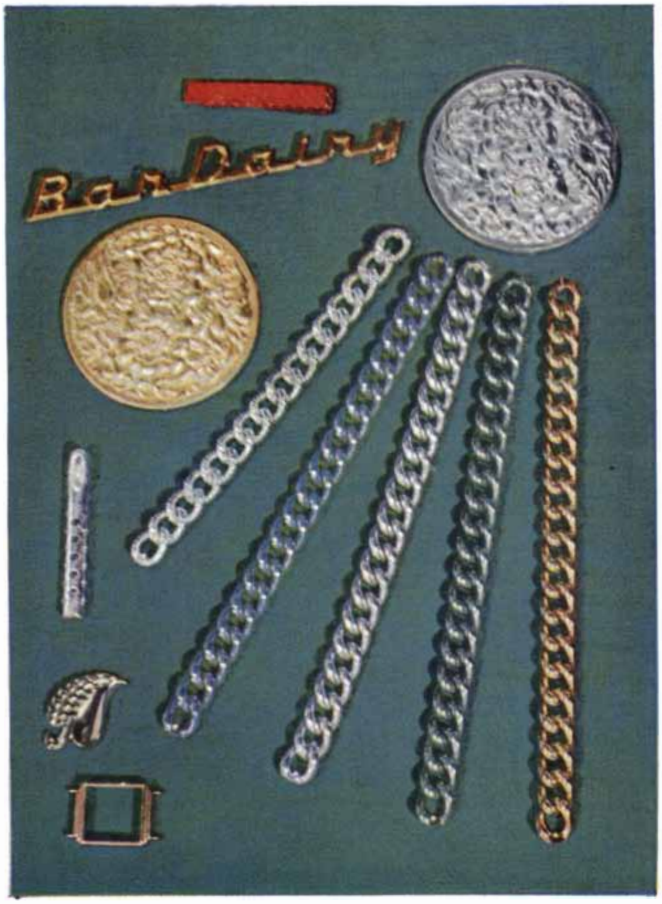
But beyond research and testing, we offer another service—process and product fabrication. In our Process Development Laboratories are facilities for forming, joining, casting and finishing aluminum by every possible means. We can help you create a practical pilot model of your product or process—then suggest low-cost ways for its manufacture.

One example of this "start-to-finish" service is finishes themselves. Our laboratories offer the most complete facilities for developing aluminum finishes known to industry. Chemical, mechanical, and electroplated finishes are con-

YOU FROM START TO FINISH



A RIVAL FOR CHROME PLATE... Alcoa's new C57S alloy was specially developed for the anodic finish. Brighter, more lustrous surfaces possible suggest this new alloy for automotive trim and appliance parts. It is easy to form and work with ordinary shop equipment.



LOW-COST SPARKLE... Alcoa's finishing labs have developed a new chemical brightening process for aluminum . . . R5 bright dip. Intended to replace electrobrightening, it requires less equipment and no electricity. Parts brightened by this process have a very high lustre, ready for anodizing and coloring.

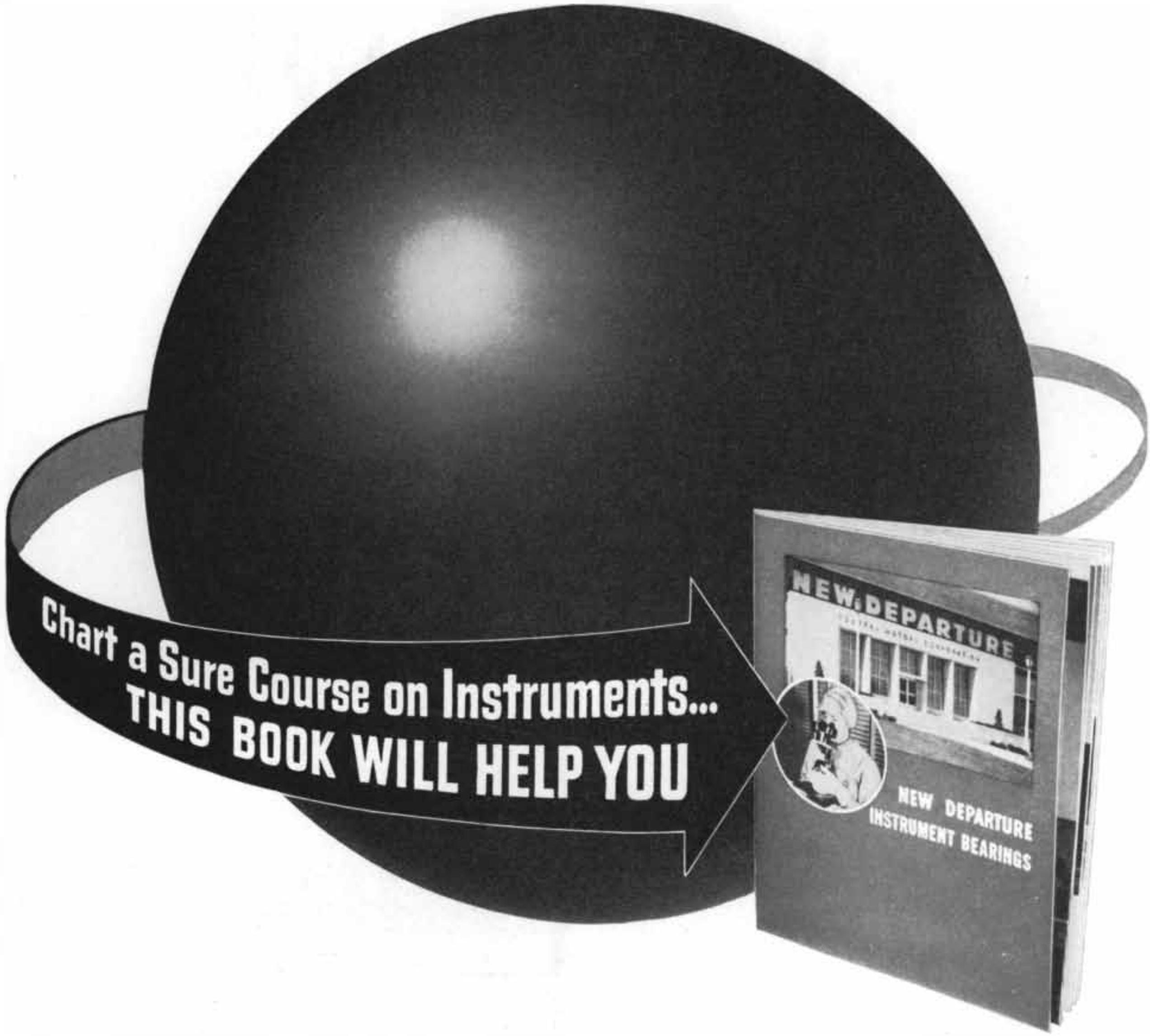
stantly being studied and improved here.

Perhaps in these examples of new anodic finishes you will find something that sparks your imagination. If so, call your local Alcoa sales office or write for a free copy of *Road Map to a Better Product*. It describes in detail the complete facilities available through our Development Division. It could truly be your first step to a better product for these competitive days we face.

ALUMINUM COMPANY OF AMERICA,
2182-L Alcoa Building, Pittsburgh 19, Penna.

Alcoa Aluminum

ALUMINUM COMPANY OF AMERICA



Strict quality control keynotes every step in the manufacture of New Departure instrument bearings. The book pictured above takes you through New Departure's instrument bearing manufacturing facilities, showing the measures taken to achieve the closest possible approach to perfection. You'll see that New Departure enforces the most exacting standards—from raw material to finished product, to bring you the very finest bearing for *every* instrument application.

If you design or manufacture products demanding high-precision instrument bearings, this book will interest you. Write for your copy—and for the complete instrument bearing catalogue—to New Departure, Bristol, Conn.

NOTHING ROLLS LIKE A BALL

Automatic torque testers measure starting characteristics of every low-torque bearing. It is just one of many exacting control devices developed by New Departure engineers specifically for instrument bearing manufacture.

NEW DEPARTURE

BALL BEARINGS

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT
Also Makers of the Famous New Departure Coaster Brake

THE GAS TURBINE

The evolution of this new heat engine proceeds at a brisk pace. Originally developed for airplanes, it has now been tested in trucks, locomotives and stationary power plants

by Lawrence P. Lessing

The gas turbine, today popularly known as the jet engine, has reached a stage of development where it is fruitful to look at its present and future. The jet, born barely a dozen years ago, has come forward with enormous speed, not only in aircraft, where it is already pre-eminent, but also in a widening range of other applications. No engine in history has had so rapid a development. By 1965, if not sooner, it will be indisputably the engine of the age.

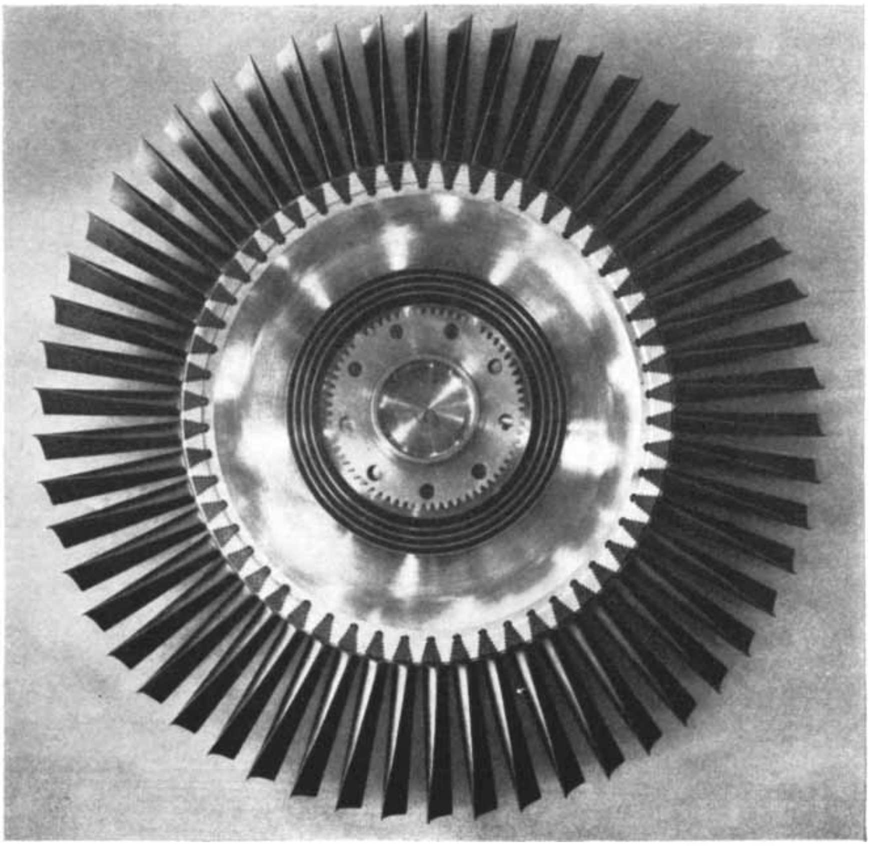
The internal combustion or piston engine opened its era of dominance just 50 years ago this December, when it powered man's first flight at Kitty Hawk. That anniversary gives particular point and perspective to an examination of the gas turbine. It had taken some 50 years from the invention of the Otto cycle in 1864 for the piston engine to reach maturity. The jet has done it in little more than 10 years. In half a century the piston engine has been built up from the 12 horsepower of the Wright brothers' first power plant to a peak of some 3,500 horsepower today. The jet already has gone beyond 20,000 horsepower at supersonic speeds. One of the new jet fighter aircraft has power equivalent to three Diesel locomotives. The new B-52 jet bomber develops well over 100,000 horsepower.

The jet engine was almost literally born in the air, but it is coming down to the ground. It is likely to reshape all surface transportation and revolutionize the stationary generation of power. The gas turbine, indeed, is the most versatile prime mover that man has yet built.

If any one name should be attached to the jet engine, as James Watt's is to the steam engine, that name would be Frank Whittle, another mechanically ingenious Englishman. Whittle filed the first patent for an aerial gas turbine in 1930. It took him 10 years to persuade the British Government to build a flying model, and in 1941 the Whittle engine succeeded in powering the famous Gloster plane to the first sustained jet flight. Meanwhile Germany, Switzerland, Sweden and Italy had also been busy: the Germans got a jet-powered Heinkel to fly briefly in 1939, and the Italians flew a jet-powered Campini for a 10-minute flight in 1940. Jet-engine development progressed rapidly during World War II, but it did not really get under way until after the war.

From Newton's Third Law

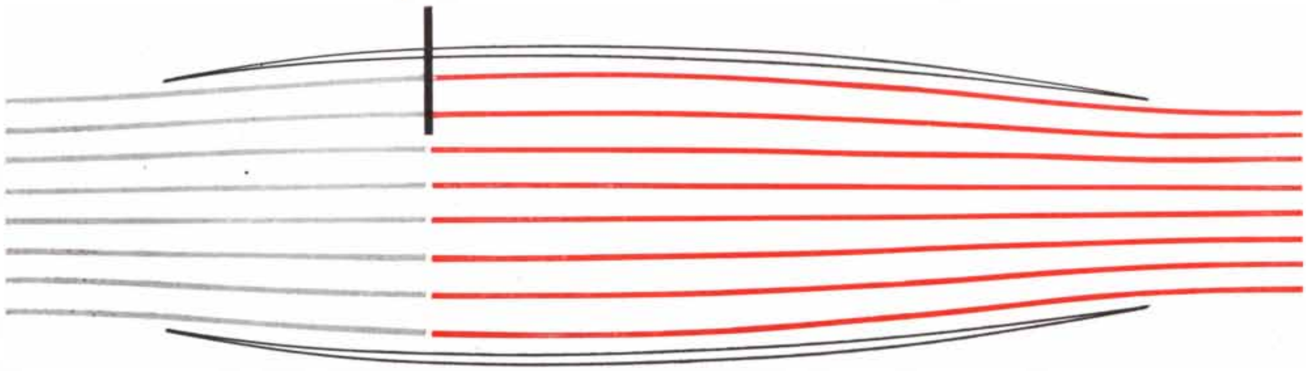
The gas turbine idea itself, of course, is very old—it goes back to the early Chinese and the ancient Greeks. The principle of jet propulsion is stated simply in Newton's third law of motion: for every action there is an equal and oppo-



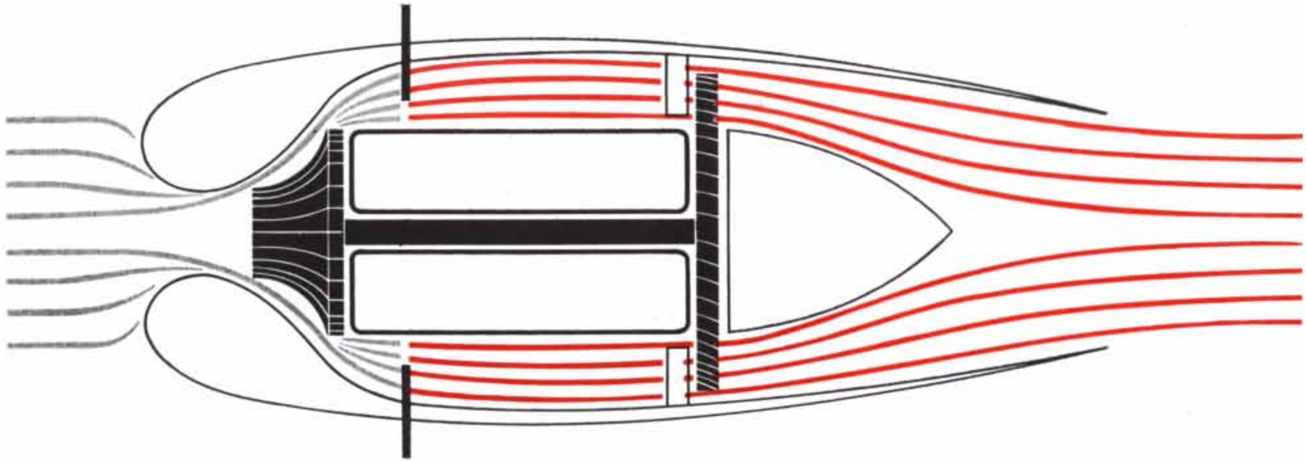
TURBINE ROTOR is a symbol of the gas turbine. This one is from an aircraft jet engine: the Pratt & Whitney J-48. It drives a centrifugal compressor (*see drawings on next page*).

site reaction. Classic examples are the recoil of a gun or the action of a rower who moves his boat forward by pushing masses of water backward with his oars. In the same way the gas turbine moves forward by spewing rearward volumes of heated air and gases. From the earliest days of steam turbines engineers dreamed of turning turbine wheels with gas instead of steam or water. But not until modern scientists, beginning with the English chemist Robert Boyle, had learned the necessary thermodynamics did the gas turbine become possible.

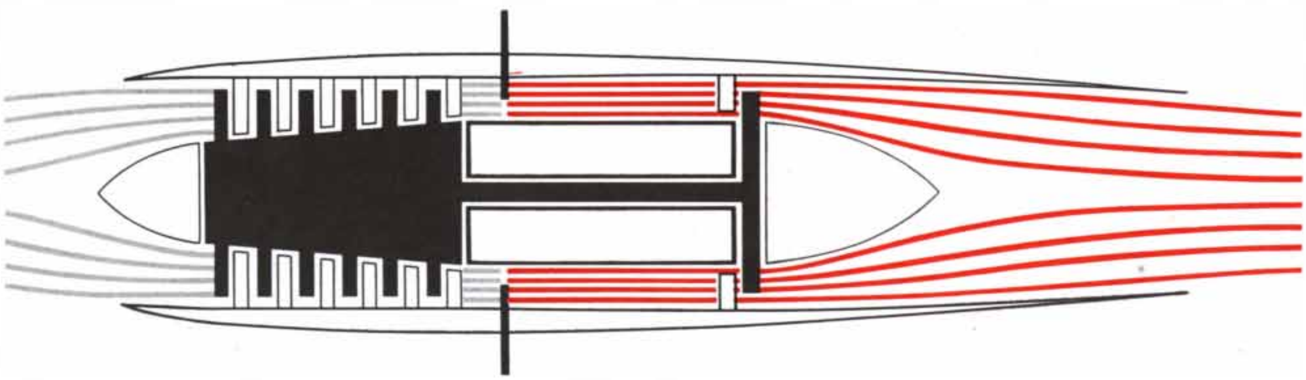
Its attraction is simplicity and a high rate of energy conversion. The gas turbine has only three major parts: a rotary compressor, a combustion chamber and a turbine connected by a shaft to run the compressor. The compressor takes in a stream of air and after building up



BASIC PRINCIPLE of the gas turbine is illustrated by this simplified cross section of a ramjet, which has no turbine at all. Air entering the engine from the left is heated by the injection of fuel. This increases the momentum of the gas and produces thrust.



CENTRIFUGAL COMPRESSOR is characteristic of the first gas turbines. Here part of the thrust drives a rotor (*right*) which drives a compressor (*left*). In this kind of turbine the air is compressed by spinning it out to the edge of a single-bladed impeller.



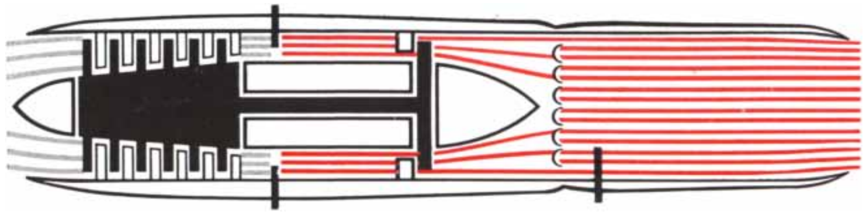
AXIAL-FLOW COMPRESSOR has the advantage of a smaller cross section. Here the air is compressed by a whole series of rotors (*black*) and stators (*white*). As in the case of the centrifugal type, the turbine rotor and the compressor turn on a single shaft.

its pressure sends the compressed air into the combustion chamber, where fuel is injected and part of the air is burned in a continuous hot flame. From the combustor a continuous stream of expanded hot air and combustion gases is hurled out through the exhaust nozzle at high velocity. On the way to the nozzle it turns the turbine wheel that drives the compressor.

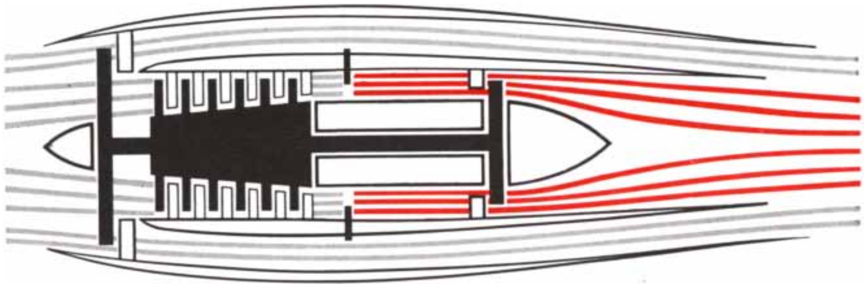
There are two types of compressor, giving the names to two basic types of engine [*see diagrams on the opposite page*]. The first is centrifugal, employing a single, large, bladed impeller that takes in air at the center and whirls it out radially off the rim. The second, called axial-flow, drives the air straight along the axis by means of a series of rotors and stators studded with precisely curved blades.

Since the turbine and the compressor are connected by a shaft, there is actually only one moving part. The continuous flow makes it possible to put through much greater volumes of gas in a shorter time than in the intermittent combustion cycle of a piston engine, and the light gas does not require a ponderous turbine system such as is needed to move steam or water. Because combustion is continuous, the engine has a wide tolerance as to type of fuel. But until the late 1930s the severe problems raised by the high speed of air flow over compressor and turbine blades had not been solved, nor were there any readily available metals to withstand the temperatures of 1,200 degrees Fahrenheit, or higher, necessary in such an engine. Wartime research swiftly produced the needed knowledge about high-speed compressors, high-speed combustion and alloys.

There were compelling reasons for going to the gas turbine for air power. The piston engine plus propeller, being a mechanical system of fixed horsepower, had about reached its practicable limits. Every additional increase in horsepower was beginning to cost too much in labor, complexity and weight. The speed of planes was restricted by limitations of power and propeller efficiency. The gas turbine is a different matter, an aerodynamic engine of no fixed horsepower. It delivers power directly, with a minimum of mechanical intervention, in the form of thrust. Thrust is the reactive force exerted by the engine's combustion gases on the engine itself to drive it forward. It is measured in pounds of pressure. A pound of thrust is equal at 375 miles per hour to one horsepower. At double that speed horsepower is doubled, and so on. The faster the engine goes, the more air is rammed into its system, the more power it develops and the more efficient it becomes. The jet's power was made for supersonic flight. Practically speaking, there was no other way of achieving it.



AFTERBURNER can increase the thrust of a gas turbine by as much as 60 per cent for short periods. It consists of an added section (*right*) into which more fuel is injected and burned.



DUCTED FAN augments the thrust of a gas turbine by increasing the volume of gas passing through it. A small propeller is added (*left*) to push the air through an outer duct.

The International Race

The most powerful jet engine in production today is Pratt & Whitney Aircraft's J-57, still under military security. It reaches some 10,000 pounds thrust, or over 25,000 horsepower at operational speed. It powers the Boeing B-52 bomber and the new North American Aviation F-100 Super Sabre, which this summer proved to be the first production-line fighter able to go regularly faster than the speed of sound in level flight. As this article goes to press the world's jet speed record is being contested between the English Hawker Hunter with Rolls-Royce Avon engine, which flew some 730 miles per hour, and the U. S. Douglas Skyray with Westinghouse J-40 engine, which reached 753 miles per hour. Since both engines are rated at about 8,000 pounds thrust, it may be assumed that the J-57 in the Super Sabre is considerably faster.

Thus the U. S. is rapidly pulling ahead in the speed race. England's head start was augmented right after the war by a bold decision to throw all its aircraft engineering resources into jet development. The U. S. had done very little work on the gas turbine, even theoretically, until the war. During the war its aircraft engine-makers were so loaded with piston-engine production for immediate military use that development of the first jets had to be assigned to the big steam-turbine builders, the General Electric Company and the Westinghouse Electric Corporation. In remarkably short order G.E. built and put into the air in 1942 a jet engine based on an English design. Westinghouse worked on its own design. After the war most U. S. companies still had to adopt advanced English models for production, since their own designs were just starting. Only now are the special skills of the aircraft engine builders being felt in U. S. jets.

For the U. S. to have come so far so fast required the rapid building up of a vast new research establishment. The amounts spent on jet propulsion are second only to those on atomic energy. The effort engages the armed forces, the National Advisory Committee on Aeronautics and a number of engine and air frame builders. Jet-engine research is of an entirely different magnitude from piston-engine work. Much of it touches on fundamental science. Where a piston engine was generally designed by one man or engineering group, the jet is worked over by teams of experts and requires large, specialized research facilities. These range from wind tunnels capable of generating air speeds of 4,000 miles per hour to compression chambers able to duplicate altitude pressures up to 65,000 feet and air temperatures from 200 degrees above zero to 85 below. Any tendency to cut back research could easily lose the U. S. its slim, barely won lead.

Today over half of all U. S. aircraft horsepower and airplane production is in jets. On this score the U. S. is definitely ahead of England, whose production of all types equals only one tenth the production of a single U. S. model: the Sabre with the G.E. J-47 engine. The U. S. is likewise ahead on timing, selecting the right size and type of engine for development—important in a race in which it takes about five years to get a new engine from design board into production. The new J-57 engine has overleaped the field in power. But England has announced a new engine in development, the Gyron, of about 15,000 pounds thrust, and the British are still abreast if not ahead of the U. S. in technical development.

The U.S.S.R. has high production and a high jet-engine technology. How it compares with the U. S. in the race is a moot question; U. S. Sabres scored 12-to-1 over Soviet jet fighters in Korea, but whether this means that the planes were superior is a subject of debate among the experts.

In jet transports the race is strictly between the U. S. and Britain. The English led off in 1951 with the small Comet I, uneconomical by U. S. airline standards. Next summer the Boeing Airplane Company expects to fly the first U. S. all-jet airliner, using four J-57 engines. Some months later England promises to deliver the advanced Comet III. Between 1955 and 1960 jet liners, providing comfortable, almost vibrationless flight at 500 or more miles per hour, probably will be competing on all the world's airlines.

Jet Developments

In sheer power the jet is already several generations beyond the mightiest piston engine ever built. And its weight is less than one quarter that of a piston engine of comparable output. Progress is being made along several technical roads. Thermal efficiency, the thrust energy left after driving the turbine, has been raised to about 30 per cent. Compressor-turbine efficiencies have been brought close to the maximum possible —92 per cent. Combinations of propellers and turbines are being developed. Of the turboprops—the gas turbine-propeller combination which is designed to improve on the fuel economy of a piston engine at 350 to 450 miles per hour—the latest, Pratt & Whitney's T-34, develops 5,700 horsepower. The Wright Aeronautical Company has produced a turbo-compound engine—a conventional piston engine and propeller with a full gas turbine hooked onto the rear to operate on the piston's exhaust gases and augment the thrust. This power plant is in about the same speed bracket and range of fuel economy as the turboprops.

But the engine of the hour for high-performance aircraft is the pure axial-flow jet. It is superseding the centrifugal design that Whittle originated. Though less simple and economical to build than the centrifugal type, the slim axial-flow engine is aerodynamically more efficient, offering a much smaller frontal area and better streamlining.

This does not mean that there are no problems, improvements or surprises left in the gas turbine. Some method must be found to cut down the jet's thunderous noise around airports. Some way must be found to reverse thrust or speed on landings, other than the present use of dragging parachutes. There are internal problems of harmonic vibration in the hundreds of thin, whirling blades and in the turbine and compressor, which tend to buck one another. There are problems in maintaining smooth combustion in the thin air of high altitudes. There are problems in materials.

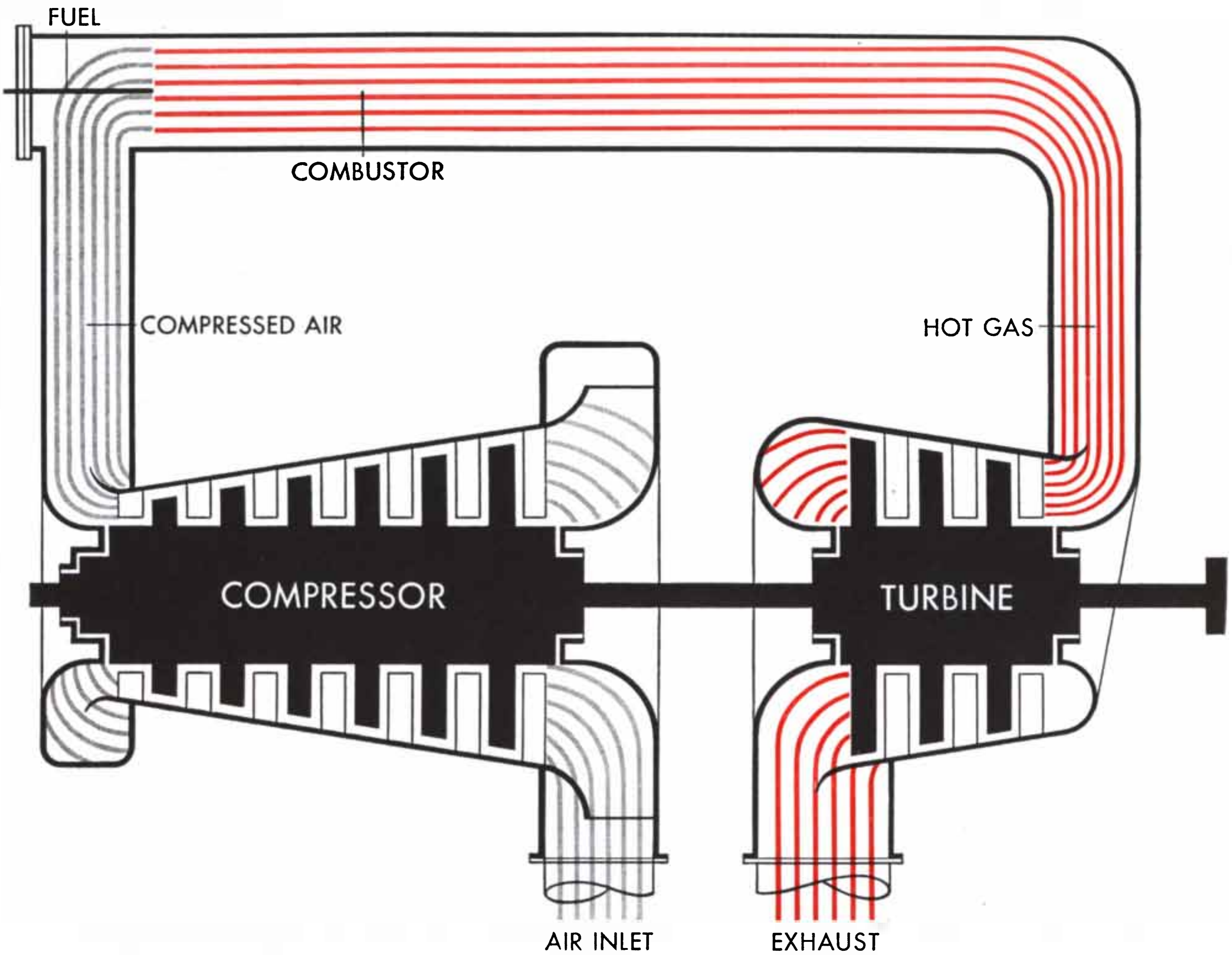
Some refinements may still be made in compressor-turbine cycles, and a good deal may be done in weight reduction (*e.g.*, making smaller parts of titanium) with direct benefits to fuel economy. Fuel consumption is still the jet's prime weakness. One model eats up as much fuel in 500 hours of operation as half the original cost of the engine. Improvements in the jet engine so far have cut fuel consumption by one fifth—from 1.25 pounds to 1 pound of fuel per hour per pound of thrust. But already the margins of possible improvement are running thin.

The jet has its own inherent efficiency limits as a heat engine. Its thrust is produced by the change in momentum of the gases as they pass through the engine. Thrust may be boosted by increasing either the speed or the mass of air propelled through the engine. The latter is preferred, because it does not require raising the temperature and yields greater thrust from a given expenditure of energy. Airflow through a unit of given size has already been doubled and a further increase of 50 per cent is possible. The English are pressing development of two devices for increasing airflow. One is the ducted fan, a small propeller set within the front inlet to push additional air through ducts around the combustion chamber into the exhaust. The other is a by-pass engine which simply rams additional air through ducts into the exhaust.

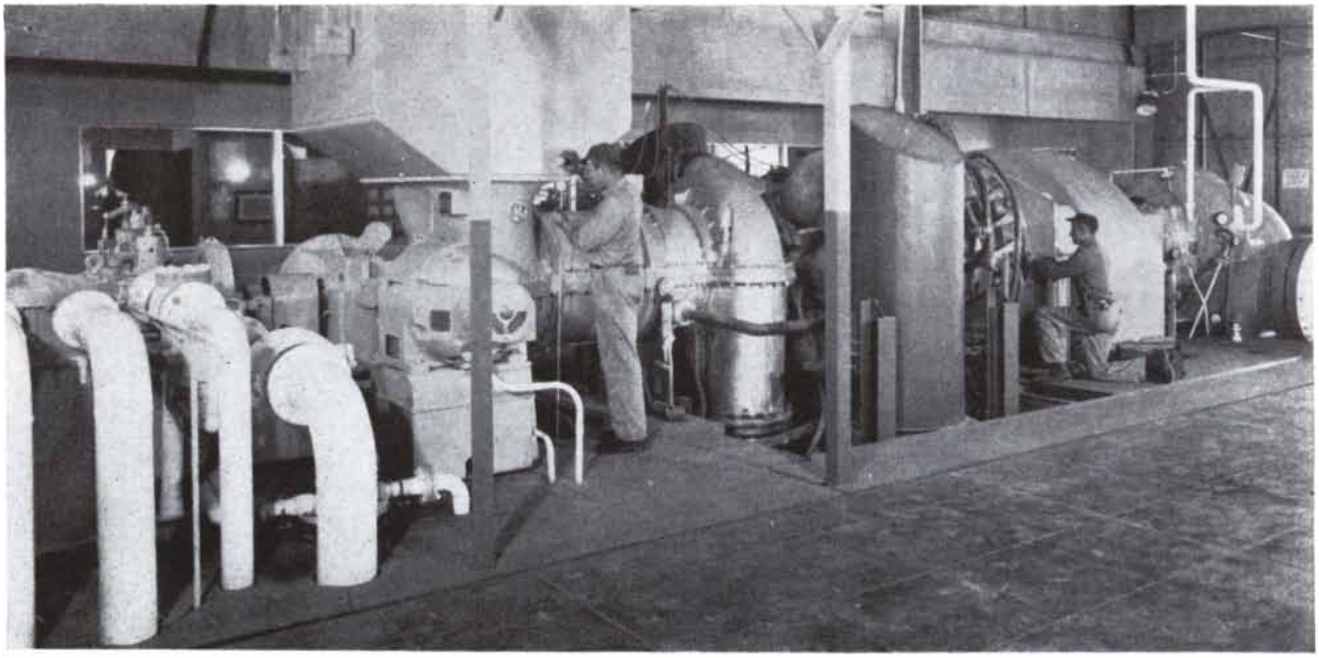
Another way to increase efficiency and thrust is to raise the compression ratio between the compressor's inlet and outlet. But ratios have now been run up through as many as 16 stages and 1,000 compressor blades, raising pressures as high as 300 pounds per square inch. At such high pressures the engine may be subject to a pulsating series of violent backfires that may reverse the engine's entire airflow—a condition called surging. Surge is to the gas turbine what knock was to the piston engine. Its cause is still mysterious: under certain transient conditions, varying with speed, altitude and angle of attack on the air, the compressor blades may intermittently stall, just as a plane's wing stalls. Enough has been learned about surge to draw a curve which predicts its occurrence under given engine conditions at various altitudes, but occasionally a compressor surges for no apparent reason through a region as much as 10 per cent above or below the predicted curve. Jets today are designed to run just below the threshold of surge. To raise their compression ratios further some way must be found to by-pass surge.

As for raising combustion temperatures to increase jet exhaust velocities, present turbine inlet temperatures (1,500 to 1,600 degrees F.) have nearly reached the critical point beyond which any further rise will eat up large additional amounts of fuel without adding much to thrust. The reason is that the kinetic energy of a given mass of air in the exhaust stream is proportional to the square of its velocity, while momentum or thrust increases only directly with the velocity. At sharply increasing velocities the jet begins to lose propulsive efficiency, much as a car's rear wheels lose traction while spinning faster on an icy drive. Thrust has been augmented 40 to 60 per cent by a development called the afterburner or reheat—a tubular extension of the tail cone in which excess air from the combustor is burned with additional fuel. But this gain is possible only for short intervals, because of excessive fuel consumption and loss of propulsive efficiency.

While the jet propulsion engine is nearing its limit of development, this is not true of the stationary, mechanically

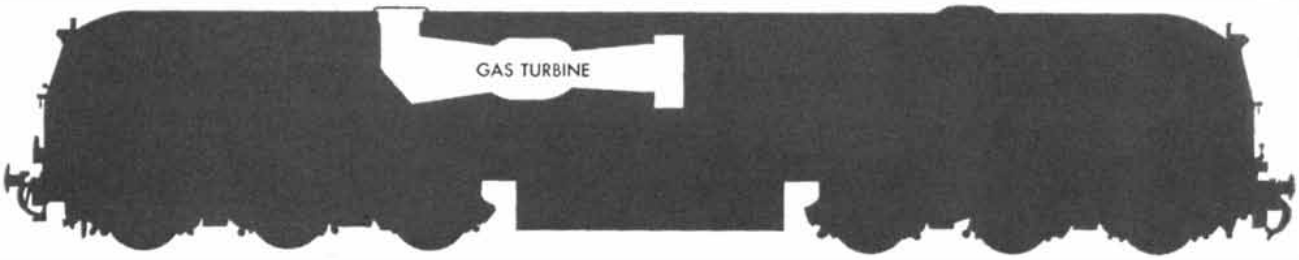


STATIONARY GAS TURBINE, or any other gas turbine whose output is used to turn a shaft rather than to accelerate a stream of air, utilizes its thrust solely to drive a rotor. In this schematic drawing the rotor turns a compressor of the axial-flow type.

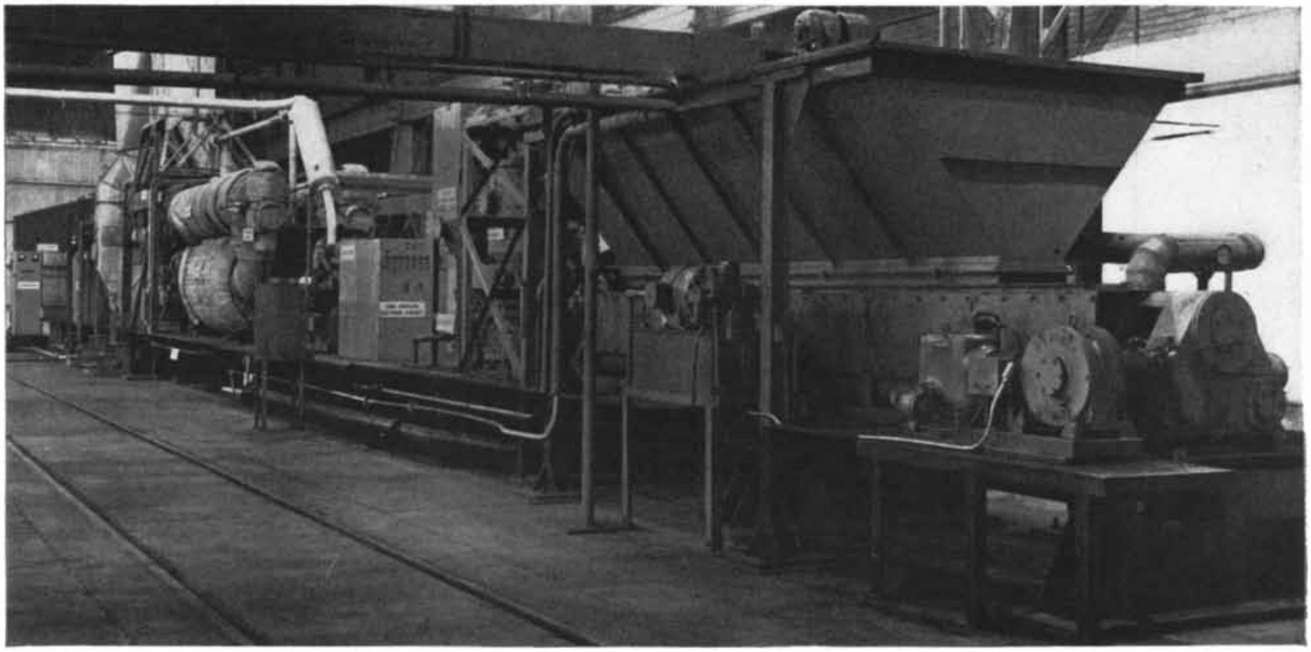


PIPELINE PUMPING STATION of the El Paso Natural Gas Company uses a 5,000-horsepower gas turbine made by the General Electric Company. Gas turbines have been successful in such stations principally because the natural gas provides a cheap fuel.

GAS-TURBINE LOCOMOTIVE is one of 10 ordered by the Union Pacific Railroad from the General Electric Company. Equipped with oil-burning gas turbines of 4,500 horsepower, these machines will be used to haul heavy freight trains over the Rockies.



SIZE AND WEIGHT of the engine in a gas-turbine locomotive are much less than those of the power plant in a Diesel locomotive. This outline is based on the gas-turbine locomotive made by the English firm of Metropolitan Vickers Electrical Company, Ltd.



COAL-BURNING GAS TURBINE has been built at the plant of the American Locomotive Co. in Dunkirk, N. Y. The joint project of several coal companies and railroads, the turbine could be used either in a stationary power plant or in a locomotive.

geared gas turbine. That engine, which is designed to apply the thrust power to turning the turbine wheel rather than at the exhaust, is not subject to the heat limitation. The hotter such an engine runs, the greater is its thermal efficiency and the greater the power applied to the turbine. Here the main problem becomes the development of heat-resistant materials and of methods of cooling the turbine blades. The materials called cermets—combinations of ceramics and metal carbides—are one of the most promising developments in this field.

The Power Plant

As a general power plant the gas turbine offers the same inducements that it did in the air: compactness, a greater power-to-weight ratio and an entirely new flexibility. The first to build gas-turbine power plants on the ground were the Swiss. In 1940 and 1941 they erected one in Zurich and one in Neuchâtel, the first an Escher Wyss 2,000-kilowatt demonstration unit, the other a Brown Boveri 4,000-kilowatt emergency stand-by unit. The Swiss companies have been extremely active on a world scale ever since. Not until well after the war could England and the U. S. get around to the industrial gas turbine. The two big U. S. steam-turbine builders, General Electric and Westinghouse, put their first gas-turbine power units into operation almost simultaneously in 1949, and most of the development dates from then. There are 20 now in the U. S., the largest a 15,000-kilowatt plant under construction by Westinghouse for an Oklahoma utility. Altogether some 120 gas-turbine power or process units have been built or are building over the world.

The number of possible gas-turbine cycles for industrial purposes is almost endless. Most of the power units built thus far are small auxiliary plants of 3,000 to 5,000 kilowatts, for the gas turbine cannot yet compete with the big steam plant; its fuel costs are too high. Shortages of the metals and materials it needs in order to capitalize on its potential simplicity of design and efficiency at high temperature have restricted the gas-turbine plants to the lower operating temperatures and equipment of steam plants, including regenerators and heat exchangers. Even so, the small gas-turbine plant already equals comparable steam units in efficiency (25 to 40 per cent). In areas where liquid fuel or gas is available at low cost, the gas turbine can compete with steam. One place where it is already superseding other engines is in pipeline pumping stations; more than 40 gas turbine engines are in place or on order for such stations. A gas turbine does the job at one third less cost than a piston engine. It feeds economically on fuel from the line and operates so automatically that one yearly inspection is enough.

A gas turbine may be designed to burn anything from natural gas to peat or coal. One English firm actually is offering today a peat-burning gas-turbine plant of 1,000 kilowatts for regions poor in other fuels. Possibly the most significant project is the effort of Bituminous Coal Research, Incorporated, in the U. S. to develop a coal-burning gas turbine. Since 1946 it has been experimenting on the use of powdered coal, fed into the combustion chamber in a liquid-like stream. The major problem was to prevent the highly abrasive ashes and other products of combustion from wearing down the turbine blades. The problem was solved by a system which removes even the finest fly-ash before it can strike the blades. This turbine, designed for locomotive as well as industrial power, is now moving into the last stages of development. Commercial production of a simple coal-burning turbine would revitalize coal as a fuel. Among the possibilities would be the construction of batteries of such units at the mine head for direct conversion of coal to power and at industrial plants for supplying flexible blocks of packaged power.

Awheel and at Sea

The advantages of the gas turbine as an engine for vehicles are not yet fully appreciated, but without doubt they soon will be. The main advantage, of course, is lightness, as is already well recognized in aircraft. A locomotive powered by a gas turbine can be as much as 50 per cent lighter than a conventional one, and its thermal efficiency is nearly two and a half times that of a normal steam engine and about equal to that of the best Diesel. Its ratio of tractive power to weight is much better than the Diesel's. In ships the weight reduction would be even more marked.

After the war the British, with some of the excitement of the early days of steam, ordered a 2,500-horsepower Swiss gas-turbine locomotive for test. Since then the English firm of Metropolitan Vickers has built one of its own of 3,000 horsepower. Around 1948 both G.E. and Westinghouse in the U. S. put pilot gas turbines on the rails, each of about 4,000 horsepower, and the Union Pacific Railroad has ordered 10 G.E. locomotives for heavy service over the

SMALL GAS TURBINE has been developed by the Boeing Airplane Company. It has been installed experimentally in trucks and boats. Here it appears in the back of a helicopter.

Rockies. All these are oil-burning turbines. The coal-burning turbine, which would greatly widen the field of usefulness, is now going from its stationary tests into an experimental locomotive chassis for actual runs. Both the U. S. and Britain have ship units on test.

In the automotive field the most spectacular gas-turbine development is the Boeing 175-horsepower truck engine, which is just completing a year of regular haulage service on the mountainous West Coast. This little engine is almost lost under the hood of a standard heavy-duty truck. Its 240-pound installed weight is less than half that of the smallest standard automobile engine; compare it with the 3,000 pounds of a Diesel truck engine. Yet it pulls a 25-ton trailer with a smoothness unknown in piston-engine drives. Boeing designed it mainly for powering small Navy mine-sweepers, and it is also being tried in a helicopter, but its promise for land vehicles is much greater. Although the gas turbine does not seem suitable for passenger cars, because of high fuel consumption, all the major automobile makers are running gas-turbine experiments.

The gas turbine's fuel consumption is still so high that, even burning the cheapest residual oil, it has higher fuel costs than a Diesel or gasoline engine. But the route to fuel economy in the geared gas turbine is through higher operating temperatures. And in this respect the future is more promising for the gas turbine than for any other form of heat engine.

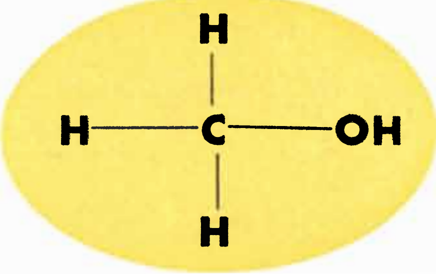
The most obvious characteristic of the new power age that the gas turbine has started is the sharp, exponential boost in the horsepower it has made available to man. The rocket engine, which is another form of the jet propulsion, has already developed some 600,000 horsepower at top speed (in the V-2) and has driven an airplane at 1,238 miles per hour. This growth of power in the past 50 years is something new in history. And no one yet knows the gas turbine's limit of power. Jets more capacious and powerful than those of today undoubtedly will be built. One manufacturer predicts that jet engines some day will drive aircraft at two or three times the speed of sound at altitudes of 100,000 feet. When and if atomic energy is harnessed, its most likely application will be to a gas turbine, with a reactor replacing the combustor.

The secondary characteristics of the new age are no less far-reaching. Jet-engine technology is propelling into use a host of new, light, heat-resistant metals, beginning with titanium. The fundamental studies in combustion it has initiated are being applied widely to all heat-engine development, to power technology and to chemistry. The jet engine is developing materials and techniques for faster, hotter, more automatically controlled industrial processes in metals and chemicals.

As a new engine gains ascendancy, its technology eventually affects all the tools and appurtenances of man's living. The world the gas turbine is shaping is one of sharply contracting distances and accelerated change. It will be more powerful and more dangerous than any man has yet seen.

For purity, uniformity and dependability
...Specify DU PONT METHANOL

CHECK THESE RIGID SPECIFICATIONS OF



DU PONT METHANOL

Methanol	99.85% Minimum
Non-volatile content	0.0010% Maximum
Acetone	0.003% Maximum
Hydrocarbon	To Pass Test*
Acidity, as acetic acid	0.003% Maximum
Alkalinity, as NH_3	0.003% Maximum
Carbonizable Substances, A. P. H. A.	50 Maximum
Distillation Range at 760 mm., (A. S. T. M. Method D-268) first drop to dry	1.0°C Maximum Including 64.7°C.
Specific Gravity 25°/25°C.	0.78934 Maximum
Appearance, Clarity	Substantially free from suspended matter & sediment
Color, A.P.H.A.	.5 Maximum
Odor	Characteristic and free from foreign odors
Permanganate Test	30 Mins. Minimum

(All percentages on weight basis)

*No clouding when diluted with 2 parts water

Whether you are using methanol as a solvent or intermediate . . . as an extractant, drying agent or in any of the other jobs that only methanol can perform so economically and efficiently . . . it will pay you to investigate and specify the *standard of the industry*—Du Pont Methanol.

Made to rigid specifications by the pioneer manufacturer of synthetic methanol, Du Pont Methanol is guaranteed pure (99.85%) synthetic methanol featuring a high degree of uniformity and dependability from shipment to shipment. When you specify and use Du Pont Methanol, you have the assurance that your supply will be of consistent high quality at all times . . . that variations in your products and processes based on the use of methanol will be held to a minimum.

Why not investigate the use of Du Pont Methanol in your business? We'll be happy to send you more information on this versatile, basic chemical—specifications, properties, suggested uses, etc. Just clip the coupon below or write on your letterhead for your copy of our new pamphlet, "Methanol—The Chemical With 1000 and 1 Uses." E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Wilmington 98, Delaware.

AVAILABILITY—Du Pont Methanol is available nationally through agents, shipped from strategically located stock points in tank cars; tank transports and tank wagons from some locations; and 55-gallon non-returnable steel drums.

SEND FOR THIS PAMPHLET TODAY!

DU PONT

REG. U.S. PAT. OFF.

Better Things for Better Living
. . . through Chemistry

Polychemicals
DEPARTMENT

CHEMICALS • PLASTICS

E. I. du Pont de Nemours & Co., (Inc.)
Polychemicals Department 5911, Wilmington, Delaware.

Please send me more information on Du Pont Methanol—specifications, properties, uses, bibliography, etc.—including a copy of your new pamphlet "Methanol—The Chemical With 1,000 and 1 Uses."

*Name*__________________ *Title*__________

*Firm*__________________

*Address*__________________

*City*__________________ *State*__________

How Children Form Mathematical Concepts

Describing some remarkable experiments which the reader, if he has a subject handy, may perform himself. Among other things they show that in a child the historical development of geometry is reversed

by Jean Piaget

It is a great mistake to suppose that a child acquires the notion of number and other mathematical concepts just from teaching. On the contrary, to a remarkable degree he develops them himself, independently and spontaneously. When adults try to impose mathematical concepts on a child prematurely, his learning is merely verbal; true understanding of them comes only with his mental growth.

This can easily be shown by a simple experiment. A child of five or six may readily be taught by his parents to name the numbers from 1 to 10. If 10 stones are laid in a row, he can count them correctly. But if the stones are rearranged in a more complex pattern or piled up, he no longer can count them with consistent accuracy. Although the child knows the names of the numbers, he has not yet grasped the essential idea of number: namely, that the number of objects in a group remains the same, is "conserved," no matter how they are shuffled or arranged.

On the other hand, a child of six and a half or seven often shows that he has spontaneously formed the concept of number even though he may not yet have been taught to count. Given eight red chips and eight blue chips, he will discover by one-to-one matching that the number of red is the same as the number of blue, and he will realize that the two groups remain equal in number regardless of the shape they take.

The experiment with one-to-one correspondence is very useful for investigating children's development of the number concept. Let us lay down a row of eight red chips, equally spaced about an inch apart, and ask our small subjects to take from a box of blue chips as many chips as there are on the table. Their reactions will depend on age, and we can distinguish three stages of development. A child of five or younger, on the average, will lay out blue chips to make a row exactly as long as the red row, but he will put the blue chips close together instead of spacing them. He believes the number is the same if the length of the row is the same. At the age of six, on the average, children arrive at the second stage; these children will lay a blue chip opposite each red chip and obtain the correct number. But they have not necessarily acquired the concept of number itself. If we spread the red chips, spacing out the row more loosely, the six-year-olds will think that the longer row now has more chips, though we have not changed the number. At the age of six and a half to seven, on the average, children achieve the third stage: they know that, though we close up or space out one row of chips, the number is still the same as in the other.

In a similar experiment a child is given two receptacles of identical shape and size and is asked to put beads, one at a time, into both receptacles with both hands simultaneously—a blue bead into one box with his right hand and a red bead into the other with his left hand. When he has more or less filled the two receptacles, he is asked how they compare. He is sure that both have the same number of beads. Then he is requested to pour the blue beads into a receptacle of a different size and shape. Here again we see differences in understanding according to age. The smallest children think that the number has changed: if, for instance, the beads fill the new re-

Experiment with chips demonstrates the development of the concept of number by children from the ceptacle to a higher level, they think there are more beads in it than in the original one; if to a lower level, they think there are fewer. But children near the age of seven know that the transfer has not changed the number of beads.

In short, children must grasp the principle of conservation of quantity before they can develop the concept of number. Now conservation of quantity of course is not in itself a numerical notion; rather, it is a logical concept. Thus these experiments in child psychology throw some light on the epistemology of the number concept—a subject which has been examined by many mathematicians and logicians.

The mathematicians Henri Poincaré and L. E. J. Brouwer have held that the number concept is a product of primitive intuition, preceding logical notions. The experiments just described deny this thesis, in our opinion. Bertrand Russell, on the other hand, has supported the view that number is a purely logical concept: that the idea of cardinal number derives from the logical notion of category (a number would be a category made up of equivalent categories) while the notion of ordinal number derives from the logical relationships of order. But Russell's theory does not quite fit the psychological processes as we have observed them in small children. Children at the start make no distinction between cardinal and ordinal number, and besides, the concept of cardinal number itself presupposes an order relationship. For instance, a child can build a one-to-one correspondence only if he neither forgets any of the elements nor uses the same one twice. The only way of distinguishing one unit from another is to consider it either before or after the other in time or in space, that is, in the order of enumeration.

Study of the child's discovery of spatial relationships—what may be called the child's spontaneous geometry—is no less rewarding than the investigation of his number concepts. A child's order of development in geometry seems to reverse the order of historical discovery. Scientific geometry began with the Euclidean system (concerned with figures, angles and so on), developed in the 17th century the so-called projective geometry (dealing with problems of perspective) and finally came in the 19th century to topology (describing spatial relationships in a general qualitative way—for instance, the distinction between open and closed structures, interiority and exteriority, proximity and separation). A child begins with the last: his first geometrical discoveries are topological. At the age of three he readily distinguishes between open and closed figures: if you ask him to copy a square or a triangle, he draws a closed circle; he draws a cross with two separate lines. If you show him a drawing of a large circle with a small circle inside, he is quite capable of reproducing this relationship, and he can also draw a small circle outside or attached to the edge of the large one. All this he can do before he can draw a rectangle or express the Euclidean characteristics (number of sides, angles, etc.) of a figure. Not until a considerable time after he has mastered topological relationships does he begin to develop his notions of Euclidean and projective geometry. Then he builds those simultaneously.

Curiously enough, this psychological order is much closer to modern geometry's order of deductive or axiomatic construction than the historical order of discovery was. It offers another example of the kinship between psychological construction and the logical construction of science itself.

Let us test our young subjects on projective constructions. First we set up two "fence posts" (little sticks stuck in bases of modeling clay) some 15 inches apart and ask the child to place other posts in a straight line between them. The youngest children (under the age of four) proceed to plant one post next to another, forming a more or less wavy line. Their approach is topological: the elements are joined by the simple relationship of proximity rather than by projection of a line as such. At the next stage, beyond the age of four, the child may form a straight fence if the two end posts parallel the edge of the table, or if there is some other straight line to guide him. If the end posts are diagonally across the table, he may start building the line parallel to the table's edge and then change direction and form a curve to reach the second post. Occasionally a youngster may make a straight line, but he does so only by trial-and-error and not by system.

At the age of seven years, on the average, a child can build a straight fence consistently in any direction across the table, and he will check the straightness of the line by shutting one eye and sighting along it, as a gardener lines up bean poles. Here we have the essence of the projective concept; the line is still a topological line, but the child has grasped that the projective relationship depends on the angle of vision, or point of view.

One can proceed to study this with other experiments. For instance, you stand a doll on a table and place before

age of five or younger (hands at left), *through six* (center) *to six and a half or seven* (right). *The experiment is described in detail in the text.*

Child of three draws this but not rectangle

it an object oriented in a certain direction: a pencil lying crosswise, diagonally or lengthwise with respect to the doll's line of vision, or a watch lying flat on the table or standing up. Then you ask the child to draw the doll's view of the object, or, better still, ask him to choose from two or three drawings the one that represents the doll's point of view. Not until the age of about seven or eight can a child deduce correctly the doll's angle of vision.

A similar experiment testing the same point yields the same conclusions. Objects of different shapes are placed in various positions between a light and a screen, and the child is asked to predict the shape of the shadow the object will cast on the screen.

Ability to coordinate different perspectives does not come until the age of 9 or 10. This is illustrated by an experiment I suggested some time ago to my collaborator Dr. Edith Meyer. The experimenter sits at a table opposite the child, and between the child and herself she places a cardboard range of mountains. The two see the range from opposite perspectives. The child is then asked to select from several drawings the ones that picture both his own and the opposite person's views of the mountain range. Naturally the youngest children can pick out only the picture that corresponds to their own view; they imagine that all the points of view are like their own. What is more interesting, if the child changes places with the experimenter and sees the mountains from the other side, he now thinks that his new view is the only correct one; he cannot reconstruct the point of view that was his own just a little while before. This is a clear example of the egocentricity so characteristic of children—the primitive reasoning which prevents them from understanding that there may be more than one point of view.

It takes a considerable evolution for children to come, at around the age of 9 or 10, to the ability to distinguish between and coordinate the different possible perspectives. At this stage they can grasp projective space in its concrete or practical form, but naturally not in its theoretical aspects.

At the same time the child forms the concept of projective space, he also constructs Euclidean space; the two kinds of construction are based upon one another. For example, in lining up a straight row of fence posts he may not only use the sighting method but may line up his hands parallel to each other to give him the direction. That is, he is applying the concept of conservation of direction, which is a Euclidean principle. Here is another illustration of the fact that children form mathematical notions on a qualitative or logical basis.

The conservation principle arises in various forms. There is first the conservation of length. If you place a block on another of the same length and then push one block so that its end projects beyond the other, a child under six will suppose that the two blocks are no longer of equal length. Not until near the age of seven, on the average, does the child understand that what is gained at one end of the block is lost at the other. He arrives at this concept of the conservation of length, be it noted, by a process of logic.

Experiments on a child's discovery of the conservation of distance are especially illuminating. Between two small toy trees standing apart from each other on a table you place a wall formed of a block or a thick piece of cardboard, and you ask the child (in his own language, of course) whether the trees are still the same distance apart. The smallest children think the distance has changed; they are simply unable to add up two parts of a distance to a total distance. Children of five or six believe the distance has been reduced, claiming that the width of the wall does not count as distance; in other words, a filled-up space does not have the same value as an empty space. Only near the age of seven do children come to the realization that intervening objects do not change the distance.

However you test them, you find the same thing true: children do not appreciate the principle of conservation of length or surface until, somewhere around the age of seven, they discover the reversibility that shows the original quantity has remained the same (*e.g.*, the realignment of equal-length blocks, the removal of the wall, and so on). Thus the discovery of logical relationships is a prerequisite to the construction of geometrical concepts, as it is in the formation of the concept of number.

This applies to measurement itself, which is only a derived concept. It is interesting to study how children spontaneously learn to measure. One of my collaborators, Dr. Inhelder, and I have made the following experiment: We show the child a tower of blocks on a table and ask him to build a second tower of the same height on another table (lower or higher than the first) with blocks of a different size. Naturally we provide the child with all the necessary measuring tools. Children's attempts to deal with this problem go through a fascinating evolution. The youngest children build up the second tower to the same visual level as the first, without worrying about the difference in height of the tables. They compare the towers by stepping back and sighting them. At a slightly more advanced stage a child lays a long rod across the tops of the two towers to make sure that they are level. Somewhat later he notices that the base of his tower is not at the same level as the model's. He then wants to place his tower next to the model on the same table to compare them. Reminded that the rules of the game forbid him to move his tower, he begins to look around for a measuring standard. Interestingly enough, the first that comes to his mind is his own body. He puts one hand on top of his tower and the other at its base, and then, trying to keep his hands the same distance apart, he moves over to the other tower to compare it. Children of about the age of six often carry out this work in a most assured manner, as if their hands could not change position on the way! Soon they discover that the method is not reliable, and then they resort to reference points on the body. The child will line up his shoulder with the top of his tower, mark the spot opposite the base on his thigh with his hand and walk over to the model to see whether the distance is the same.

Eventually the idea of an independent measuring tool occurs to the child. His first attempt in this direction is likely to be the building of a third tower next to and the same height as the one he has already erected. Having built it, he moves it over to the first table and matches it against the model; this is allowed by the rules. The child's arrival at this stage presupposes a process of logical reasoning. If we call the model tower A, the second tower C and the movable tower B, the child has reasoned that B = C and B = A, therefore A = C.

Later the child replaces the third tower with a rod, but at first the rod must

Child of seven straightens a row of "fence posts" by sighting along them

Child of six measures the height of a tower of blocks with her body

be just the same length as the height of the tower to be measured. He then conceives the idea of using a longer rod and marking the tower height on it with his finger. Finally, and this is the beginning of true measurement, he realizes that he can use a shorter rod and measure the height of the tower by applying the rod a certain number of times up the side.

The last discovery involves two new operations of logic. The first is the process of division which permits the child to conceive that the whole is composed of a number of parts added together. The second is the displacement, or substitution, which enables him to apply one part upon others and thus to build a system of units. One may therefore say that measurement is a synthesis of division into parts and of substitution, just as number is a synthesis of the inclusion of categories and of serial order. But measurement develops later than the number concept, because it is more difficult to divide a continuous whole into interchangeable units than to enumerate elements which are already separate.

To study measurement in two dimensions, we give the child a large sheet of paper with a pencil dot on it and ask him to put a dot in the same position on another sheet of the same size. He may use rods, strips of paper, strings, rulers or any other measuring tools he needs. The youngest subjects are satisfied to make a visual approximation, using no tools. Later a child applies a measuring tool, but he measures only the distance of the point from the side or bottom edge of the paper and is surprised that this single measurement does not give him the correct position. Then he measures the distance of the point from a corner of the paper, trying to keep the same slant (angle) when he applies the ruler to his own sheet. Finally, at about the age of eight or nine, he discovers that he must break up the measurement into two operations: the horizontal distance from a side edge and the perpendicular distance from the bottom or top edge. Similar experiments with a bead in a box show that a child discovers how to make three-dimensional measurements at about the same age.

Measurement in two or three dimensions brings us to the central idea of Euclidean space, namely the axes of coordinates—a system founded on the horizontality or verticality of physical objects. It may seem that even a baby should grasp these concepts, for after all it can distinguish between the upright and lying-down positions. But actually the representation of vertical and horizontal lines brings up quite another problem from this subjective awareness of postural space. Dr. Inhelder and I have studied it with the following experiments: Using a jar half-filled with colored water, we ask our young subjects to predict what level the water will take when the jar is tipped one way or another. Not until the age of nine, on the average, does a child grasp the idea of horizontality and predict correctly. Similar experiments with a plumb line or a toy sailboat with a tall mast demonstrate that comprehension of verticality comes at about the same time. The child's tardiness in acquiring these concepts is not really surprising, for they require not only a grasp of the internal relationships of an object but also reference to external elements (*e.g.*, a table or the floor or walls of the room).

When a child has discovered how to construct these coordinate axes by reference to natural objects, which he does at about the same time that he conceives the coordination of perspectives, he has completed his conception of how to represent space. By that time he has developed his fundamental mathematical concepts, which spring spontaneously from his own logical operations.

The experiments I have described, simple as they are, have been surprisingly fruitful and have brought to light many unexpected facts. These facts are illuminating from the psychological and pedagogical points of view; more than that, they teach us a number of lessons about human knowledge in general.

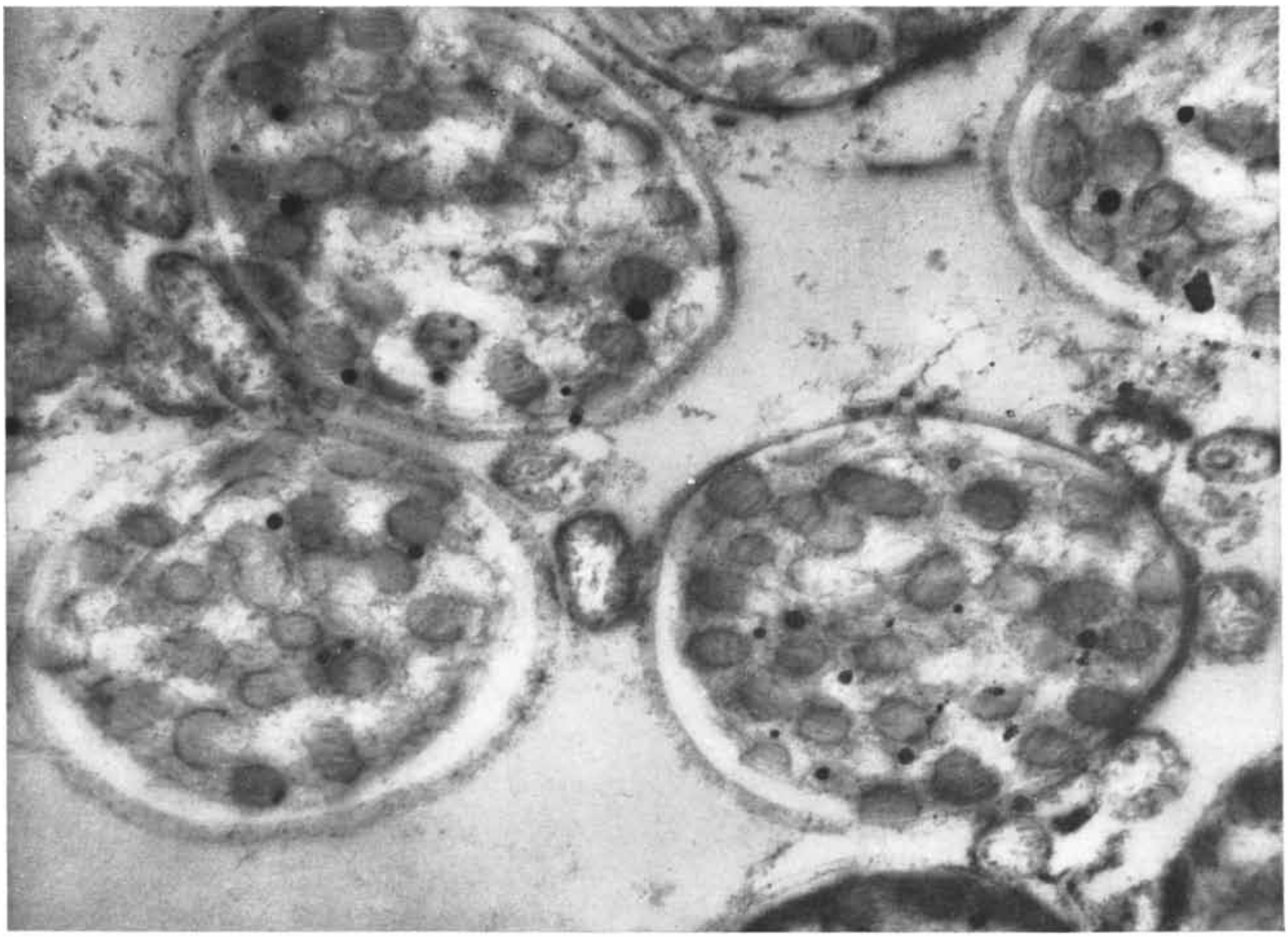
PROGRESS IN PHOTOSYNTHESIS

In which the author describes some developments since his article of 1948, which summarized our knowledge of how plants can harness sunlight to make the stuff of life out of carbon dioxide and water

by Eugene I. Rabinowitch

Photosynthesis—the synthesis of organic compounds from carbon dioxide and water by plants in light—remains one of the great unsolved problems of biology. Five years ago, summing up our knowledge of the subject, I wrote: "In photosynthesis, we are like travelers in an unknown country around whom the early morning fog slowly begins to rise, vaguely revealing the outlines of the landscape." [Scientific American, August, 1948.] Since then new landmarks have emerged from the fog but the road still is shrouded in mist. In fact, in some places the fog has become even denser—a veritable smog!

However, we are beginning to see the source of our confusion: it is that photosynthesis is much more complex than used to be thought. In spite of extensive work by many investigators, the task



CHLOROPLASTS of a tobacco leaf are enlarged 18,000 diameters in this electron micrograph by George E. Palade of the Rockefeller Institute for Medical Research. The chloroplasts are the large oval bodies; within them are the smaller particles called grana.

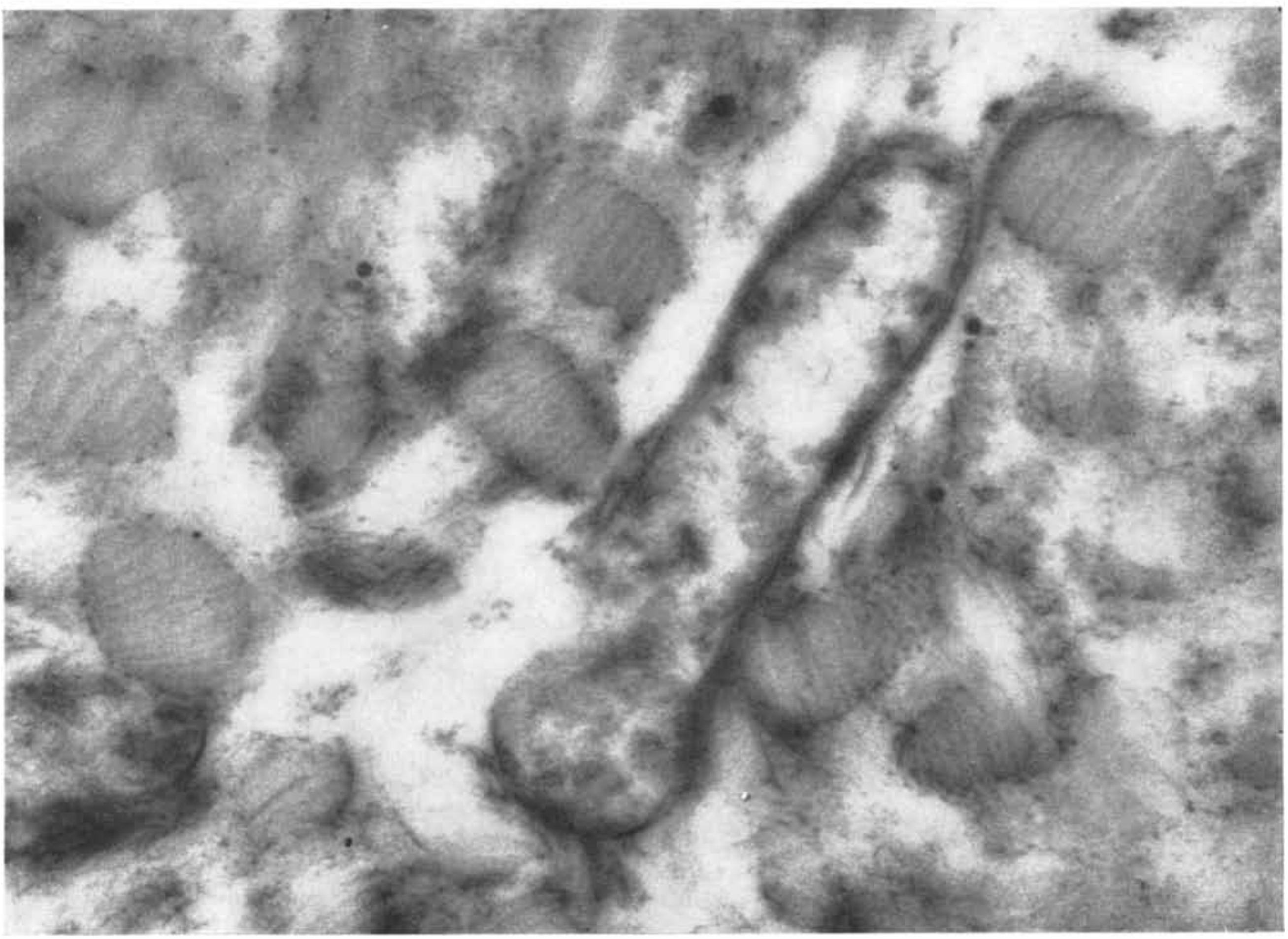
of separating it from other life processes in the cell and analyzing it into its essential chemical reactions has proved to be more difficult than was anticipated.

The photosynthetic process, like certain other groups of reactions in living cells, seems to be bound to the structure of the cell; it cannot be repeated outside that structure. We can imagine that several enzymes, concerned in the sequence of chemical transformations, are arranged in a structural frame, and the molecules undergoing transformation are hustled through this structure along prescribed paths, like palace visitors on a conducted tour. There is a special reason for such a mechanism in photosynthesis: the process produces unstable intermediates which cannot be permitted to tumble around freely in the reaction space lest they be lost by recombination. Before the products are permitted to leave the catalytic structure, they must be converted into molecular oxygen at one end and into organic compounds (such as sugars) at the other.

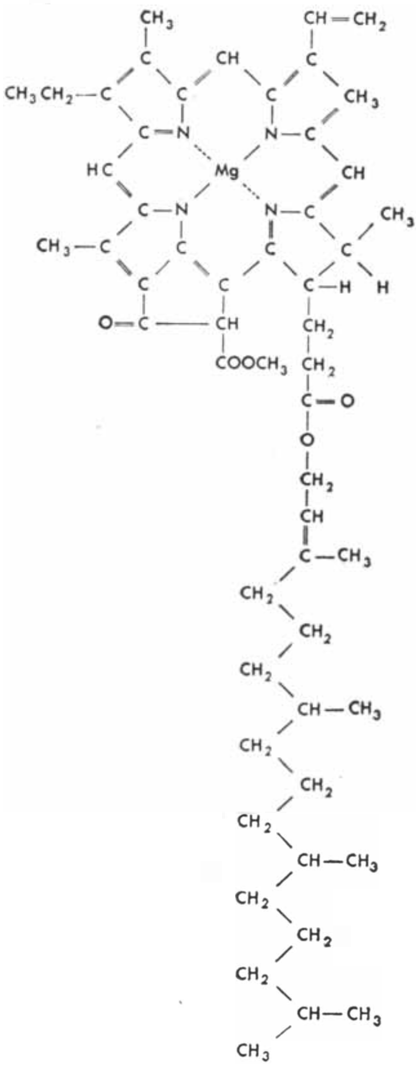
Much has been learned about the structure of the photosynthetic apparatus. Chlorophyll, the catalyst that is essential to photosynthesis, is located in almost all plants in the so-called chloroplasts, small green bodies within the cells. There it appears to be concentrated in even smaller particles called grana. The electron microscope has shown that the grana are flat and cylindrical, about half a micron in diameter and about a fifth of a micron thick. A granum is sometimes seen to disintegrate into 20 to 30 thin disks, like an overturned pile of coins. It has been suggested (on the basis of treatment with different solvents) that these disks are made of proteins and are held together by a fatlike substance, like bread slices stuck together with layers of butter. Each disk is only a twentieth of a micron thick—the thickness of a single or double layer of protein molecules.

What light may these facts shed on the disposition of the chlorophyll and the plot of the photosynthetic play? It is known that the chlorophyll molecule has the shape of a tadpole with a green, square, flat head ("chlorophyllin") and a long, colorless tail ("phytol") attached to one corner of the head. In the social life of organic molecules, like attracts like. The head of the chlorophyll molecule is "polar," that is, it carries a positive and a negative charge. Water also is a polar compound. Since polar molecules associate with other polar molecules, the chlorophyllin head is attracted to water; it is "hydrophilic." On the other hand, the tail is non-polar, therefore "hydrophobic." Proteins are hydrophilic and lipoids are hydrophobic. It has been surmised that chlorophyll accumulates at the boundary between the protein disks and the lipoid layers, with its head sticking into the protein and its tail dipping into the lipoid. This picture is speculative, but eminently plausible.

From analysis of leaves and algae, it is estimated that there are about one billion molecules of chlorophyll in each chloroplast. Spread out in a monomolecular layer, a billion chlorophyll molecules, it can be calculated, would cover 1,000 square microns. Now the interesting thing is that if we multiply the area of a protein disk (.4 of a square micron)



GRANA of the duckweed are magnified 33,000 diameters in this micrograph by Palade. The micrographs were made by a technique in which the material is impregnated with plastic and sectioned. The grana have layers which indicate that they are made up of disks.



CHLOROPHYLL MOLECULE has a ring-shaped section called chlorophyllin (*top*) and long, thin tail called phytol (*bottom*).

by the number of disks in a granum (about 25) and then multiply that by the number of grana in a chloroplast (about 100) we also get 1,000 square microns. In other words, there is just about enough space on the surface of the disks for the available chlorophyll to cover them with a monomolecular layer. The calculation claims no precision beyond that of the order of magnitude, but even so the agreement is gratifying.

It is a tempting hypothesis that the protein disks are the stage upon which the structure-bound part of photosynthesis is played. Some of the proteins in these disks may take the star roles of enzymes, while others may play supporting roles. The lipoid layers between the disks provide avenues for the diffusion of non-polar organic intermediates to and away from the disks. Other reactions of photosynthesis, not structure bound, may be completed there, or perhaps even outside the grana or outside the chloroplast itself.

The nearest thing to photosynthesis yet achieved outside the living cell is the so-called "Hill reaction," named after the Cambridge University plant physiologist Robin Hill. He showed that chloroplasts that were separated from the cell and suspended in water could oxidize water in light, liberating oxygen. But they need an outside supply of oxidant to maintain this oxidation for any length of time. Various oxidants—ferric salts, ferricyanide, quinone, many organic dyes—have been found suitable for the purpose.

In photosynthesis the oxidation of water is effected by carbon dioxide. This requires considerable energy, because water clings tenaciously to its hydrogen atoms and carbon dioxide is extremely reluctant to take on hydrogen. The energy is supplied by light, which is then stored as chemical energy in the plant. The oxidants used in the Hill reaction accept hydrogen much more readily than carbon dioxide does; therefore the reaction does not store as much light energy as photosynthesis does.

Several investigators have tried to increase the storage of energy by supplying chloroplast suspensions with increasingly reluctant oxidants. These attempts run into the difficulty I have already mentioned: the instability of the intermediate products and their tendency to react back. It is like pitching a ball onto a roof. The ball will keep falling back unless it is trapped by a gutter. In the living cell some enzymes evidently function as traps, holding the intermediate products at the high level of energy to which they have been boosted by light. These enzymes are lost in the preparation of chloroplast suspensions. The problem is to find out what they are and how they act.

Severo Ochoa and Wolf Vishniac at New York University and L. J. Tolmach at the University of Chicago have contrived artificial traps. As oxidants they offered to chloroplasts pyridine nucleotides, which are only slightly less reluctant hydrogen acceptors than carbon dioxide. As the trap they used pyruvic acid, and they added certain enzymes to "funnel" hydrogen into the trap. It was hoped that the enzymes would get hold of some of the hydrogen atoms tossed upon the pyridine nucleotides and would transfer them to pyruvic acid before they rolled back. The products of reduction of pyruvic acid are relatively stable. Thus some of the intermediary oxidation products of water, lacking unstable partners with which to react back, might be converted into oxygen which would escape from the cell.

The trap worked. Some pyruvic acid was indeed reduced, and an equivalent amount of free oxygen was evolved into the atmosphere. But the oxygen yields so far have been very poor. Perhaps photosynthesis in the living cell owes its high efficiency at least partly to structural properties of the trapping agents, which are lost in the breakup of the cells. There are indications that only enzyme molecules attached to a piece of chlorophyll-bearing structure are effective in transforming the intermediates formed in that piece.

In 1948 a Russian physical chemist named A. A. Krasnovsky discovered a chemical reaction of chlorophyll in solution which may bear some relation to the way in which light-excited chlorophyll mediates the transfer of hydrogen atoms from water to carbon dioxide. He illuminated chlorophyll solutions in pyridine to which ascorbic acid (vitamin C) had been added. Ascorbic acid is a mild reductant. It was oxidized, and chlorophyll was reduced to a pink compound. When the light was turned off, the reaction went back. The reversal was especially rapid if an oxidant, such as air or quinone, was added. The net result was the oxidation of ascorbic acid and the reduction of the added oxidant, with chlorophyll having acted as a "photocatalyst," as in photosynthesis. Krasnovsky adduced some evidence that even a pyridine nucleotide can be reduced by chlorophyll solutions in this manner—which would be a very remarkable result, since, as we recall, chloroplasts reduce these compounds only if an elaborate trap for hydrogen atoms is provided.

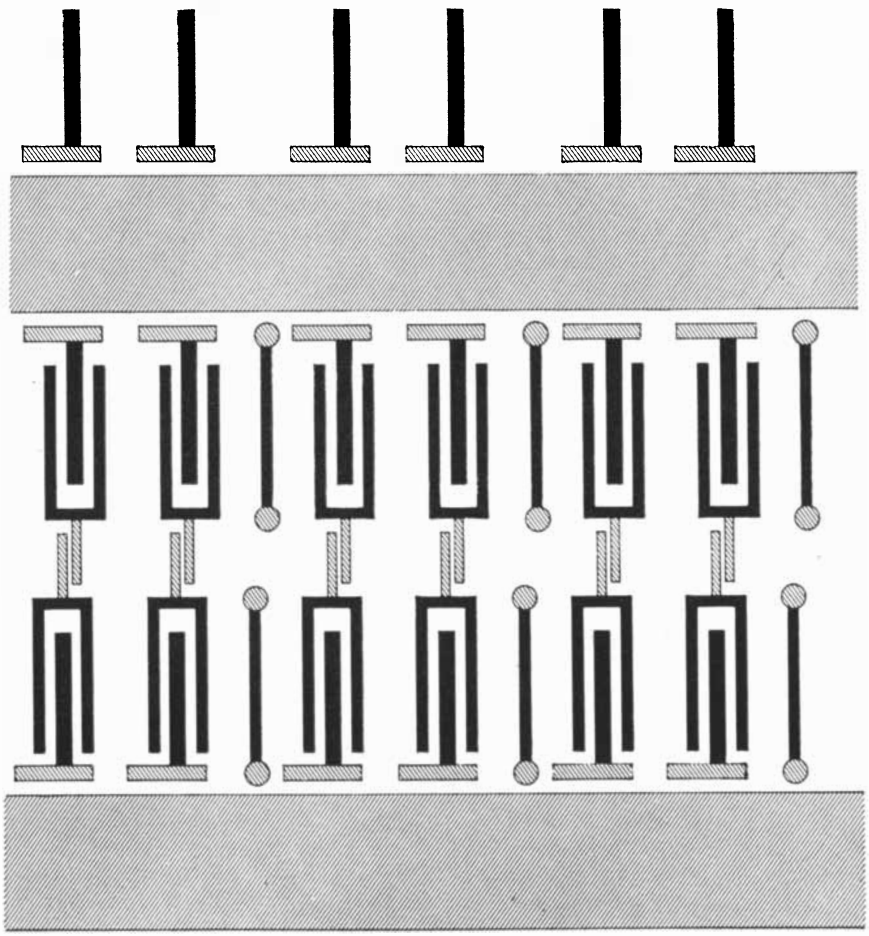
Of course taking hydrogen atoms away from ascorbic acid is much easier than taking them away from water. Thus the "Krasnovsky reaction" bears the same relation to the "Hill reaction" as the latter to photosynthesis. The Hill reaction can operate on the same reductant (water) as photosynthesis, but it requires more willing oxidants than carbon dioxide. The Krasnovsky reaction can use the same oxidants as the Hill reaction (say quinone), but it requires a more willing reductant than water.

In 1937 Joseph Weiss and I found that chlorophyll in solution can be reversibly oxidized by ferric salt. The degree of oxidation is enhanced in light. Here, too, some light energy—although perhaps only a small amount—is stored as chemical energy. Chlorophyll is thus a very peculiar substance: it can act both as an oxidant and as a reductant! It may perform either of these functions, or both, in photosynthesis.

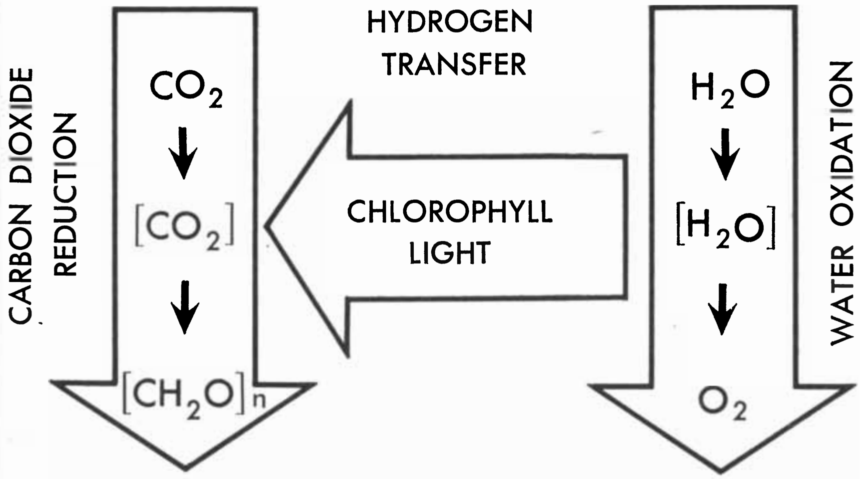
Further experiments are desirable on the photochemistry of chlorophyll preparations, including not only solutions but also colloidal or crystalline particles and monomolecular layers, imitating the hypothetical arrangement of chlorophyll molecules in the living cell.

The main chemical job of photosynthesis is to reduce carbon dioxide to carbohydrate, from which all organic matter on the earth is derived. We have dealt so far only with the take-up of light energy to liberate oxygen from water and to transfer hydrogen to various more or less unwilling acceptors. The hydrogen acceptor is the bridge that leads from photosynthesis the powerhouse to photosynthesis the chemical factory. In the opinion of the majority of investigators, there is a "universal" hydrogen acceptor (always associated with chlorophyll in the grana) which, after taking up the hydrogen from water in light, transfers it without further help from light to whatever compound is to serve as the ultimate oxidant, be it carbon dioxide or quinone or pyridine nucleotide. It seems most likely that if this first product is not utilized immediately it is lost by back reactions within a matter of seconds, although some investigators believe that the cells retain their reducing power for several minutes after light is shut off.

The next question is: By what chemical mechanism does the primary reduction product convert carbon dioxide into a carbohydrate? Here the isotopic tracer method comes to our aid. By supplying cells with carbon dioxide tagged with radiocarbon, letting them use it for a few seconds and then killing them, Melvin Calvin, A. A. Benson and their coworkers at the University of California and Hans Gaffron, E. W. Fager and associates at the University of Chicago have been able to identify the first product of carbon dioxide reduction. It is phosphoglyceric acid, a combination of phosphoric acid and glyceric acid. Disregard for the time being the phosphoric acid; it seems to be as universally useful in



CHLOROPLAST STRUCTURE has been suggested by B. Hubert of the Netherlands. The two horizontal layers are composed of protein. The T-shaped structures are molecules of chlorophyll; the tuning-fork-shaped ones, lipoid; the dumbbell-shaped ones, carotenoid.



TWO PROCESSES of photosynthesis are the oxidation of water into oxygen (*right*) and the reduction of carbon dioxide into carbohydrate (*left*). The hydrogen removed from the water is transferred to the carbon dioxide through the agency of light and chlorophyll.

metabolic processes as lubrication in machinery. Looking at the glyceric acid part only, we note that this compound, $C_3H_6O_4$, is halfway between CO_2 and glucose, $C_6H_{12}O_6$, in respect to the number of carbon atoms. It is more than halfway in respect to the "reduction level," *i.e.*, the ratio of hydrogen to oxygen atoms in the molecule, which is zero in carbon dioxide, 1½ to 1 in glyceric acid and 2 to 1 in glucose. Thus glyceric acid is an appropriate half-way station on the path from carbon dioxide to sugar. Probably carbon dioxide is first grafted upon some organic compound present in the cell, and this product is then reduced in light to glyceric acid. Subsequent transformations of glyceric acid must lead to the formation of glucose and to regeneration of the carbon dioxide acceptor, permitting the repetition of the cycle.

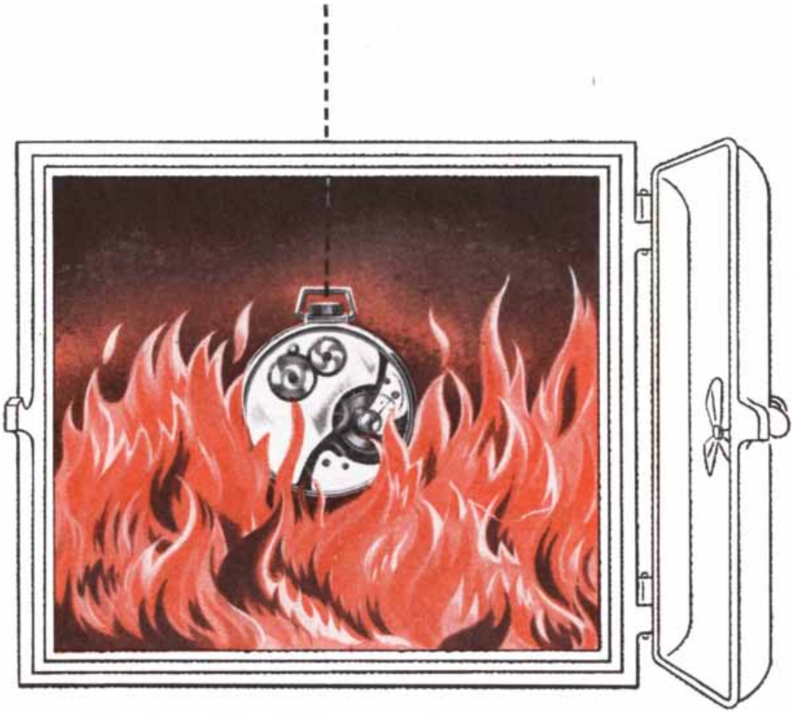
This picture of a process in which the growth of the carbon chain and its reduction to the carbohydrate level are carried out with a carbon dioxide molecule grafted upon a carrier comes naturally to biochemists. They use similar mechanisms to explain respiration, the reverse of photosynthesis—*i.e.*, in respiration organic molecules such as glucose are broken down and oxidized to water and carbon dioxide. The best known example of such a mechanism is the so-called Krebs cycle. Some of the reactions in this cycle are reversible: that is, they occur with little release of energy and could be made to run backward simply by supplying their products in overabundance and removing the synthesized organic compounds by some trapping mechanism.

The path by which photosynthesis proceeds from phosphoglyceric acid to sugars is soon lost in the mists. After glyceric acid the next product identified in tracer experiments is pyruvic acid; this may be the next intermediate in the main sequence or a side product. Another early product is malic acid, but it seems definitely not involved in the main sequence. Both pyruvic acid and malic acid may serve as cross-links between photosynthesis and respiration, because both also occur as intermediates in the Krebs cycle of respiration.

Particularly puzzling is the part of the cycle that leads back to the carbon dioxide acceptor. Desk chemistry says that a compound which would form glyceric acid by the uptake of carbon dioxide can contain only two carbon atoms in the molecule. There are relatively few such compounds, but the search for one in photosynthesizing plants has not been successful.

Various possible paths for photosynthesis, leading from glycerate to glucose, have been laid out in detail. Calvin's most recent itinerary takes in compounds with seven and five carbon atoms in the molecule, before ending in the more common ones with six, such as glucose.

The number of possible paths is enormous, and it is by no means certain that photosynthesis takes the same one under all conditions and in all organisms. The upstream path of photosynthesis may branch and communicate on many levels with the descending paths of respiration. Through these cross-connections intermediate products of respiration may be fed into the pumps of photosynthesis and intermediates of photosynthesis may find their way back into the downstream of respiration.



Want to "hang a Watch" in a furnace...and make it run?

Something as technically difficult *is* being done now. For instance, the "buckets" (paddles) and turbine rotor assemblies we make for aircraft jet engines.

These buckets have to stand up against 10,000 revolutions a minute and a flame 1400° hot. Yet, they are made to closer tolerances than many of the parts in your watch and your automobile.

To accomplish this, the Jet Division developed a special technique to finish-forge unusual tougher-than-steel alloys to accurate curves even smoother than glass...with no final machining required! And we helped develop the alloys.

You're probably planning a new product . . . or how to make a present one better, stronger, at lower cost. *Now is the time to call on the Jet Division for recommendations and technical advice.*

We offer you our experience in making more jet-engine "buckets" and turbine rotors than any other producer.

JET DIVISION

Thompson Products, Inc.

DEPARTMENT JS-11 • CLEVELAND 17, OHIO

OYSTERS

They have a subtle apparatus to determine when the water is suited to their needs and to filter good things from it. This and other aspects of their way of life are studied to increase their numbers

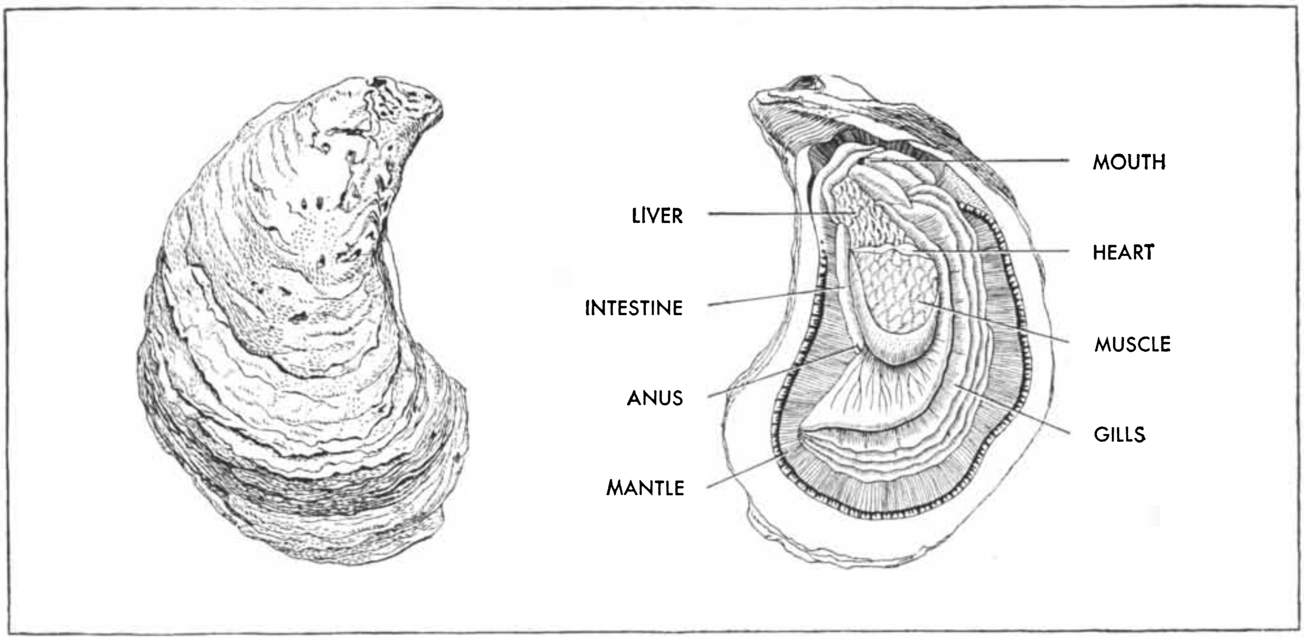
by Pieter Korringa

Anyone who studies the oyster's way of life cannot help feeling a closer, even almost congenial, kinship to all our fellow vertebrates, however primitive. The existence of the oyster is so different from a vertebrate's experience that even with the most unprejudiced study we find it hard to understand. Although thousands of investigations have been made of the bivalve, its life is still mysterious. The creature defies many elementary rules of animal biology. An oyster has almost no mobility; it spends its sedentary lifetime practically in the place where it was born. It leads a double life—by turns with and without oxygen. Its systems of feeding and of reproduction are the most precarious imaginable. Even anatomically we cannot make head or tail of the oyster, for it possesses neither of those organs. In this respect it is more peculiar than other mollusks, such as snails and cuttlefishes, which do at least have heads and tails.

Yet in spite of its lack of a brain and its seemingly poor equipment for survival the oyster deserves our boundless admiration. It has senses (chemical and tactile) which are extremely acute, a feeding system which is extraordinarily delicate and effective, a metabolism which ministers to its needs in a highly versatile way and a bagful of other resources which enable it to survive even though it seems one of the most defenseless of creatures, a passive thing altogether at the mercy of its environment.

To see how the oyster deals with the environment, perhaps the best place to begin is its pumping operation. Basically the bivalve lives by pumping sea water through its system. The water brings in food and oxygen and carries out its waste products. The oyster's pumping also performs other functions, as we shall see. It pumps by means of the coordinated beating of millions of cilia in its gills, which brings in a regular flow of water through the gill-slits. Some species of oysters have been observed to pump as much as 35 quarts of water per hour for many hours in succession.

Textbooks generally picture the oyster's pumping system as a kind of submarine vacuum cleaner, sucking in almost everything in the sea water indiscriminately. But thorough studies of this pumping, carried out by U. S. biologists with ingenious apparatus, have shown that the process is much more delicate and complex than used to be supposed, and that the comparison with a vacuum



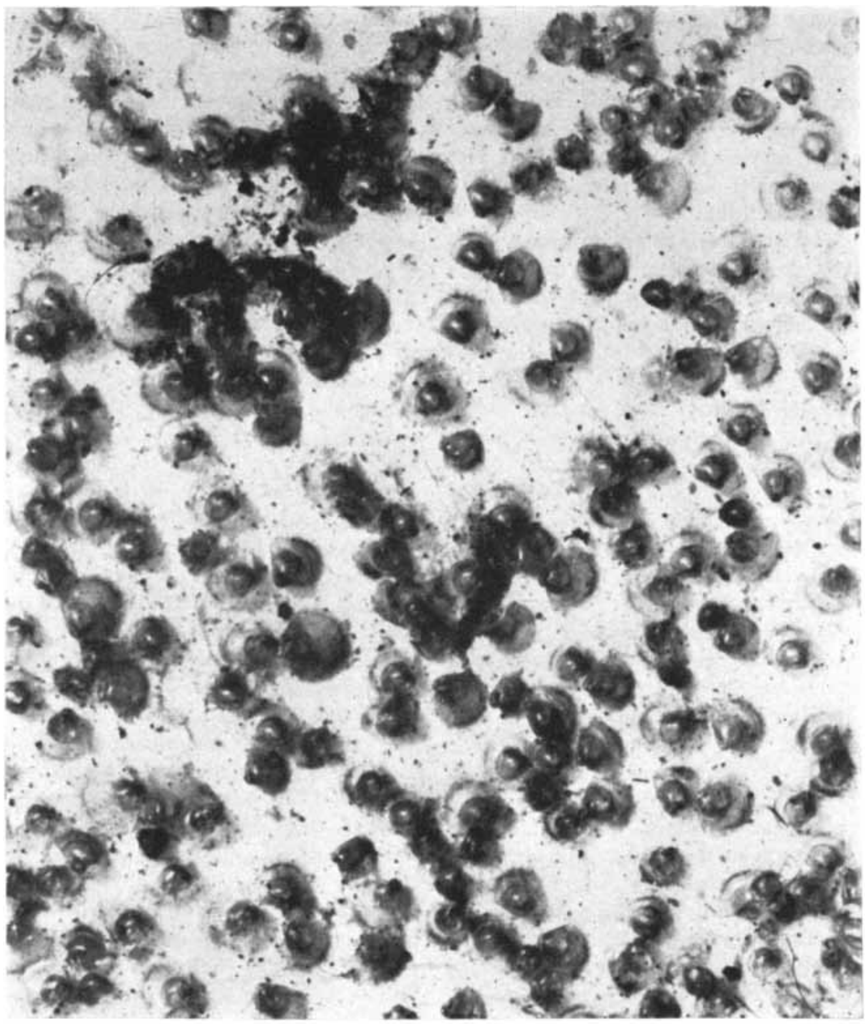
AMERICAN OYSTER (*Gryphaea virginica*) is found along the East Coast of North America. Its anatomy is depicted at right. The central muscle opens and closes the shell. The gills are covered with mucus which traps particles in water pumped through the shell.

cleaner is absurd. With its pumping the oyster couples a filtering system, for which it uses mucus. Very thin sheets of mucus pass continuously over the oyster's gills. The mucus traps food particles, even those of extremely tiny size, and conveys them to the bivalve's mouth. Both the pumping and the filtering mechanisms are sensitive to environmental conditions. The oyster does not feed continuously; it tests the water from time to time, and it sets its intricate feeding mechanism into operation only when the quality of the water meets certain requirements. It "measures" the concentration of certain soluble organic substances, among other things, and begins feeding when the concentration is right. Its chemical receptors apparently also warn it not to feed when certain organic excretions or other poisons are in the water. And its filtering mechanism enables it to segregate from its intake and throw out organisms or particles which it presumably recognizes as inimical.

The oyster's opening of its shell to test its surroundings is not, of course, without hazards. Some of its enemies are well aware of the chink in its armor. When, for example, an oyster closes its shell against an attack by a starfish, the latter just waits patiently until the oyster opens its valves slightly; it then adroitly injects a paralyzing poison which prevents them from closing. The common notion that the starfish pulls the bivalve's shells apart by sheer force is probably nothing but a myth.

The manufacture of the oyster's shell is an intricate, fascinating operation. The mollusk has herds of small glands which secrete calcite, a crystalline form of calcium carbonate. It deposits the calcite on a thin network of protein, steadily enlarging and thickening the shell as it grows. The oyster finds the calcium it needs in a dissolved state in the surrounding sea water. Almost certainly it does not utilize dissolved calcium carbonate, which is rather sparse in sea water, but captures calcium ions. Just how the oyster catches those ions and pours them out again through its shell-secreting glands to form the calcite layer of its shell is unknown. Probably some phosphate compound carries the ions. We know that the oyster captures many polyvalent ions besides calcium and stores them temporarily somewhere in its body, sometimes even in quantities dangerous to its own well-being. Apparently getting rid of these ions is more of a problem than collecting them. As a result the oyster accumulates copper,

EUROPEAN OYSTERS (*Ostrea edulis*) are affixed to a tile. Because the finding of a home is a bottleneck in oyster survival, oystermen sometimes provide surfaces for larvae.



LARVAE of the American oyster are shown a few days after fixation. When the conditions for fixation are favorable, there is not enough room for all of the larvae to grow to maturity.

Oysters are harvested by tongs near Chatham, Mass.

zinc, iron, manganese and rare metals to concentrations thousands of times higher than in the surrounding sea water. These elements, accumulated in an easily digestible form, make the oyster a rich as well as a succulent food, and contribute to its stimulating and aphrodisiac qualities.

The oyster has to create a home of a very definite shape, even though the space in which it is growing may make this difficult. Moreover its construction must be right the first time, for the shell cannot be broken down or remolded. Investigators have been amazed to find that the oyster pads out the thick places in the shell with "cheaper" construction —a chalky, porous deposit which requires only about one fifth as much building material. Just how it controls the making of the different types of shell is hard to understand.

The two valves of the shell are hinged by a rubberlike elastic ligament which pushes the valves apart when the oyster does not hold them closed; that is why weak or dead oysters gape open. The closing of the valves is controlled by a powerful central adductor muscle. This muscle has a "quick" part, which can open or snap the valves shut very rapidly, and a "catch" part, which can keep the shells tightly closed for a long time, apparently without getting tired. The oyster must, in fact, keep its valves hermetically closed for long periods when it is left stranded by extremely low tides or is exposed to grossly polluted or fresh water. Under these circumstances the closed-up oyster has to shift to a purely anaerobic way of living. Its heartbeat and digestion come to a complete standstill. The chemical processes that go on during this phase are fueled by some storage product, perhaps glycogen. Some types of oysters (*e.g.*, the American Atlantic oyster) can live for several months out of water, provided they are kept cool and damp.

Prolonged low temperature greatly reduces an oyster's activity, especially its pumping, and this is one of the most serious dangers in its natural habitat. I mentioned that the oyster's pumping of water has other functions besides feeding, respiration and elimination. Its pumping gives it what small mobility it has. The oyster is often in danger of being smothered by sand or silt, especially when gales or floods stir up the bottom. If the layer burying it is not too thick, it can free itself by pumping. The oyster cautiously sucks in water, holding out the sediment, and forcefully squeezes the water out again. In this manner it washes away the encumbering deposits and, since its specific weight is usually somewhat less than that of silt or sand, it manages to rise to the top. But when low water-temperature reduces its activity, it cannot pump strongly enough to disengage itself. Most of the winter losses of oysters are caused not by freezing but by suffocation. Stormy weather, stirring up sediment, can produce heavy mortality among oysters in winter.

The higher the temperature, the more active an oyster becomes and the more water it pumps. But it cannot live in very warm water. Above 85 degrees Fahrenheit it no longer pumps the optimum volume of water and it fails to keep its valves ajar sufficiently.

The oyster's lack of mobility obviously is a severe handicap in mating. The male oyster has to content itself with ejecting sperm into the surrounding sea water, in the hope that some of its spermatozoa may find an oyster egg to fertilize. Plainly this hit-or-miss system requires a colossal production of eggs.

The edible oysters can be divided into two large groups, which differ primarily in the way they take care of their newly born progeny. One group is the genus Gryphaea (or Crassostrea), which includes the American Atlantic oyster, the Japanese oyster and others. In this group, when the sperm meets an egg in the water and fertilizes it, the fertilized egg goes through a series of metamorphoses which culminates in a tiny larva possessing a velum (a ciliated organ for swimming) and bearing two little shells. At that stage the larva can begin to take particles of food from the surrounding sea water. Because mortality among the younger larvae is very heavy, the oysters of this type produce enormous numbers of eggs. When the fertilized eggs happen to hit favorable survival conditions, the success of reproduction among these oysters may be overwhelming.

The other group of oysters is the genus Ostrea; its members include the European flat oyster and the Olympia oyster. These bivalves follow a somewhat more efficient reproduction system. First of all, they are alternating hermaphrodites; that is, they change their sex repeatedly, first producing sperm, then (usually the following summer) eggs, then sperm again, then eggs and so on. They yield larger and larger numbers of sperm and eggs as they grow older. They produce fewer eggs than Gryphaea oysters do, but they give some care to their offspring. Instead of spawning the eggs freely into the water, they deposit the eggs on their gills. There the fertilized eggs go through their early developmental stages, nourished after a time by the food-rich water and protected from the many dangers of the outer world. After an incubation of about eight days the mother oyster proceeds to throw all her larvae into the sea. As a rule oysters, individualistic as they may seem, manage to synchronize their spawning, so that great numbers of eggs or larvae come into the water at the same time, enhancing their chances of fertilization and survival. Just how this synchronization is performed is still rather obscure. In Gryphaea oysters chemical stimulation by the mutual sex products seems to be a contributory factor; in Ostrea oysters the sequence of spring and neap tides may be involved. In Dutch waters, for instance, large numbers of larvae can be expected to make their appearance about 10 days after the full and the new moon; the peak each year comes in the fortnight between June 26 and July 10.

When the Ostrea larvae are ejected by the mother oyster, they join the plankton—the small floating animal life of the sea near the surface. The larvae, at this stage only about 170 microns (less than a hundredth of an inch) in diameter, have a powerful ciliated organ with which they can swim and stay in certain layers of water. This ability is of especial importance in waters like the Norwegian oyster pools, where the upper layers are completely fresh and the bottom layers devoid of oxygen—both unfavorable to oyster life.

Though the larvae have some control over their movements in a vertical direction, they are at the mercy of the powerful horizontal currents, which wash them to and fro. The life of the young oyster is far from peaceful. It is easy prey to herds of plankton-eating fish and other animals, many of them wasteful feeders that entangle in mucus anything they can get hold of and just swallow it. The daily toll of oyster larvae is heavy.

Those larvae that have the good luck to find enough food and to escape from

diversification:

another reason why

Lockheed in

California offers...

better careers for engineers

diversified production

Huge luxury airliners, cargo transports, fighters, bombers, trainers and radar search planes are rolling off Lockheed assembly lines. Twelve models are in production.

diversified development projects

The most diversified development program in Lockheed's history is under way—and it is still growing. The many types of aircraft now in development indicate Lockheed's production in the future will be as varied as it is today—and has been in the past.

diversified living

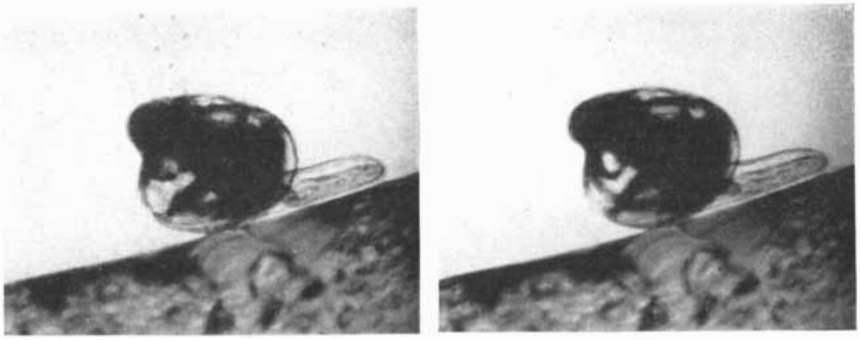
You work better in Lockheed's atmosphere of vigorous, progressive thinking—and you live better in Southern California. You enjoy life to the full in a climate beyond compare, in an area abounding in recreational opportunities for you and your family.

This capacity to develop and produce such a wide range of aircraft is important to career-conscious engineers. It means Lockheed offers you broader scope for your ability. It means there is more opportunity for promotion with so many development and production projects constantly in motion. It means your future is not chained to any particular type of aircraft—because Lockheed is known for leadership in virtually all types of aircraft. Lockheed's versatility in development and production is also one of the reasons it has an unequaled record of production stability year after year.

result of diversification:
new career positions
at Lockheed are listed at right

Lockheed AIRCRAFT CORPORATION

BURBANK, CALIFORNIA



CRAWLING LARVA of the American oyster was photographed by H. F. Prytherch. The larva sticks out a "foot" to pull itself along a surface until it finds a suitable place to settle.

their enemies grow to a "mature" phase in which they develop an extensible foot. They are now ready to settle down. But their hazards have really only begun. This is the most critical phase in the life of an oyster; if mortality was high during the free-swimming stage, it is almost catastrophic at this point. For it is not easy for an oyster to find a suitable home: not more than 1 in 10,000 will find one. The larva must locate a suitable object on which to fasten itself. It does this by gluing the left valve of its shell to the object with a sticky substance secreted by a special gland. When the swimming larva finds a possible site, it sticks out its "foot" and crawls over the surface to explore it. While crawling, the larva feels the full strength of the tidal currents, which threaten to sweep it away. Only in sheltered sites and at slack water can it gain a foothold. Its greatest difficulty is to find on the vast sea bottom a suitable foundation to which to fix itself. Its glue will stick only to a surface which is hard and clean. Shells and pebbles on the sea bottom, unfortunately, as a rule are covered with a thin film of sediment or algal growth to which the glue will not adhere. Since the larva's gland has only one filling of glue, it must choose right the first time. On natural oyster beds usually the only clean objects are the new growth-shoots of shells of adult oysters. We therefore often find one generation of oysters roosting on another.

Even when an oyster larva has established a home and successfully accomplished its metamorphosis into a tiny sedentary creature, its chances of developing into an adult oyster still are not great. During the first few months after settling down it is in the gravest danger of being smothered by sand or silt or overgrown by more vigorous creatures such as sponges, Bryozoa or sea squirts. Surely the oyster's path of life is not strewn with roses!

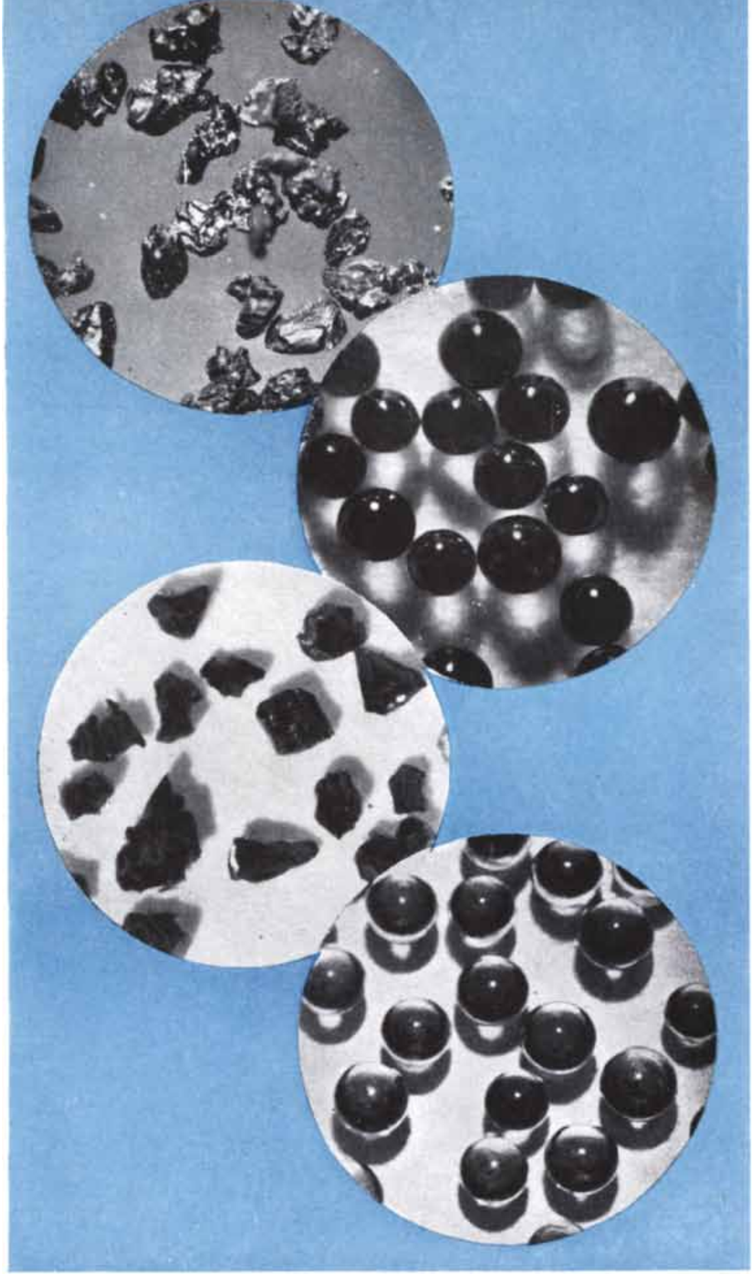
Untouched natural oyster beds are rare nowadays. Ever since man discovered what a succulent, wholesome and delicious morsel the oyster is, hardly a bed has been left in peace. A natural oyster population is like capital: if one takes the interest only, it may last forever, but as soon as one digs into the capital itself, a gradual decline is unavoidable. In fishing oysters from a natural population, one not only reduces the parent stock but also removes on a large scale the most abundant home sites of new larvae, namely the shells of living oysters. Furthermore, careless fishermen destroy alarming numbers of young oysters attached to the shells of the marketable oysters. If at last the oysters in a bed become so scanty that a complete fertilization of the eggs is no longer ensured, the bed is doomed to disappear, no matter how many years the fishermen leave it in peace. This has been the fate of many natural oyster beds that once fringed the coastlines of western Europe.

Most fortunately there is a way out: protect the young oysters until they attain marketable size and offer the larvae suitable sites on which to settle. By doing so, oyster farmers in some districts have improved the survival chances of mature larvae from 1 in 10,000 to 1 in 100. Ostreologists have also found methods of combatting oyster enemies and diseases, thus making it possible to grow many more oysters in a given area than natural beds ever saw in the past. Careful oyster culture in the Oosterschelde beds of Holland has increased the annual yield from 500,000 marketable oysters per year to more than 25 million.

In many a country oystermen are still pursuing the dream of growing oyster larvae under perfect protection in tanks or ponds. Some empirical progress has been made toward that goal, but the oyster still hides many mysteries from us. To grow bigger, better and cheaper oysters, we need to know much more about the bivalve's heredity, breeding, growth and ways of living.

PERMUTIT ION EXCHANGERS

...remarkable new tools for science and industry—



Photomicrographs of some Permutit Ion Exchangers

INDUSTRIAL ION SNATCHERS

Even though positive and negative ions cannot be separated in dilute solution, it is possible to *substitute* one kind of positive ion for another, or one kind of negative ion for another.

This "ion exchange" process helps science and industry in removing impurities from foods, drugs and fine chemicals, salvaging metals from wastes, separating ions of many kinds, numerous other tasks.

The photomicrographs show some of the Permutit ion exchangers which make this possible. These insoluble granular and beadlike solids have active exchange sites to permit ions of many materials to move freely in and out.

IT IS EASY to imagine why valuable new applications of ion exchange are being discovered almost daily.

For ion exchange is amazingly flexible. It makes it possible—at low cost—to get rid of an impurity by exchanging it for something harmless. Or to recover costly materials from waste solutions.

Interestingly enough, the first applications were confined to water treatment. Back in 1912, Permutit used the first synthetic ion exchanger to remove ions causing hardness (calcium and magnesium) from water.

This Permutit process soon came into widespread use. For softened water reduces soap and detergent costs from 20 to 80 per cent in laundries and textile mills, as well as homes. It also prevents ruinous scale in industry's boilers . . . saving fuel and avoiding costly replacements.

Newer Permutit ion exchangers and equipment provide *chemically pure* water for the rigid requirements of high pressure boilers and critical processes. It is actually purer than distilled water—yet costs much less to produce.

Other Permutit ion exchangers are at work recovering valuable metals from textile and plating wastes, purifying antibiotics, assaying the potency of drugs, fractionating and concentrating rare earth ores.

Perhaps Permutit's long experience in ion exchange can be a short cut to proper solution of your problem. Write to THE PERMUTIT COMPANY, Dept. SA-11, 330 West 42nd Street, New York 36, N. Y., or Permutit Company of Canada, Ltd., 6975 Jeanne Mance Street, Montreal.

CATION EXCHANGERS	ANION EXCHANGERS	ION EXCHANGE EQUIPMENT
Permutit Q	Permutit S-1	Water Softeners
Permutit H-70	Permutit S-2	Demineralizers
Decalso®	Permutit A	Metal Recovery
Zeo-Dur®	Permutit W	Waste Treatment
Zeo-Karb®	De-Acidite®	Automatic Contr

Ion Exchange Headquarters for Over 40 Years

PERMUTIT®

G. F. FitzGerald

He conceived the "FitzGerald contraction" to explain the failure of a celebrated experiment to detect the aether. He died in 1901, too soon to know that his notion led to the theory of relativity

by Sir Edmund Whittaker

In the last years of the 19th century, when I was a very young man, I was one of the secretaries of the mathematical and physical section of the British Association for the Advancement of Science, and so I came to know one of the most regular attenders and prominent speakers at its annual meetings, the eminent physicist George Francis FitzGerald of Dublin.

While I knew well the Oxford and Cambridge mathematicians and physicists, in the midst of whom I lived, it was only at the British Association gatherings that one had an opportunity of meeting the Irishmen. (It is amazing, incidentally, how many great mathematicians and physicists of the 19th century sprang from the Anglo-Irish stock: there were William Rowan Hamilton, Humphrey Lloyd, George Gabriel Stokes, Lord Kelvin, George Salmon, Joseph Larmor and FitzGerald.) FitzGerald fascinated me. He was an arresting figure—bearded, with piercing eyes, and strikingly handsome. His ample gray locks gave him a venerable appearance, though in fact he was not yet 50 when he died in 1901. "He reminded me," said one of his nonscientific colleagues, "of the bust of some Greek philosopher, which we cannot look upon without that instinctive feeling of respect which intellect and character command among civilized men."

FitzGerald's father was the Right Reverend William FitzGerald, Bishop of Cork and the most distinguished prelate of the former Established Church. His mother was a sister of George Johnstone Stoney, a well-known mathematician and physicist, to whom we are indebted for the word "electron." Young FitzGerald was educated at home. It is surprising how many of the privately tutored sons of cultured parents are later recognized as men of genius; a conspicuous living example is Bertrand Russell. Why this should be so, I shall not inquire. A cynic might say that the tendency of school education is to make everybody second-rate, and the reason why schooling does no harm to most boys is that they would never be more than second-rate in any case. FitzGerald was certainly fortunate in his private tutor, who was the sister of George Boole, the creator of symbolic logic.

At the age of 16 he entered the University of Dublin, where he took a brilliant degree in mathematics and experimental science in 1871. In those days there were no Ph.D. courses, and the next step for one who wanted to continue his education was to read for a fellowship. At Dublin the candidate was expected to make a profound study of the illustrious Frenchmen Joseph Lagrange, Pierre Laplace, Simeon Poisson and Jean Fourier, as well as of the great Dublin mathematical physicists Hamilton and James MacCullagh. FitzGerald read deeply in their writings, and was attracted also to the metaphysical works of the Irish philosopher George Berkeley. He succeeded in obtaining a fellowship in 1877, and in 1881 was elected to Dublin's professorship of Natural and Experimental Philosophy.

Until this time there had been no teaching of practical physics in Dublin. The first university physical laboratory intended for the instruction of ordinary students was, so far as I know, that opened by Professor P. G. Tait in Edinburgh in 1868, though at Glasgow William Thomson (afterwards Lord Kelvin) had for some years used his best honors students as research assistants. The Cavendish professorship at Cambridge was not created until 1871. FitzGerald, on his appointment to the chair at Dublin, persuaded the Board of Trinity College to assign to him an unused chemical laboratory. There he began classes in experimental physics.

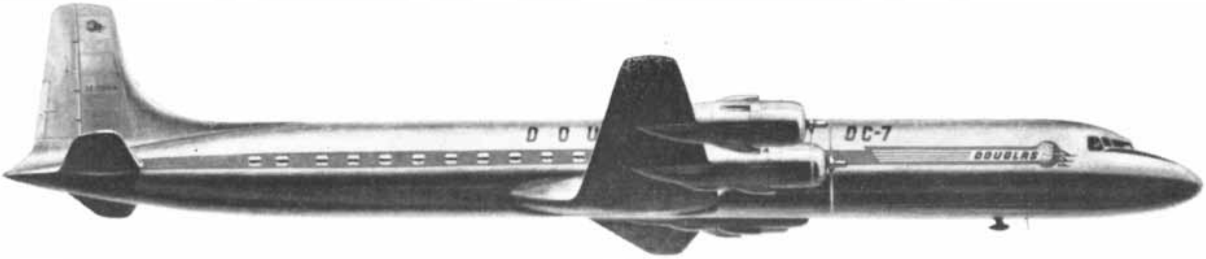
But FitzGerald himself was by choice primarily a theoretical worker, and it was to theoretical problems that he turned his main attention. The question that concerned him was the aether. He accepted Newton's celebrated dictum: "To suppose that one body may act upon another at a distance through a vacuum, without the mediation of anything else, . . . is to me so great an absurdity, that I believe no man, who has in philosophical matters a competent faculty for thinking, can ever fall into." FitzGerald, like Descartes, was convinced that space, even interplanetary space, is occupied by a medium which, though imperceptible to the senses, is capable of transmitting force and exerting effects on material bodies immersed in it. This medium, the aether, must therefore possess mechanical properties. Were these properties those of a solid, a liquid or a gas?

Descartes had suggested that the aether was constituted of extremely fine particles continually in motion and everywhere pressing upon or colliding with one another. In the following century the French-Swiss scientist George Louis LeSage had considered it as composed of an infinite number of very small, rapidly moving corpuscles, so small that not more than one out of every hundred of them meets another corpuscle during millions of years. Aethers of this kind more or less resembled a gas as pictured in the kinetic theory, and natural philosophers of the 17th and 18th centuries were inclined to regard the aether as a kind of gas permeating all bodies and filling interplanetary space; they likened the propagation of light in the aether to that of sound in a gas. But early in the 19th century this theory was faced by an insuperable objection. Thomas Young discovered in 1817 that the vibrations

A portrait of FitzGerald based on a photograph published with his obituary notice

of light are executed at right angles to the direction of propagation, whereas the vibrations of sound are in the same direction as its propagation. Thus the analogy between sound and light broke down in an essential feature. Some change in the conception of the aether was necessary, and this was provided in 1821 by Augustin Fresnel. He suggested that the aether behaved not like a gas but like an elastic solid: its resistance to attempts to distort its shape accounted for transverse vibrations.

The phenomena so far considered in connection with the aether were those of gravitation and light. But there are other physical effects which can be transmitted through a so-called vacuum or the aether: namely, electricity and magnetism. As early as 1800 Young had remarked: "Whether the electric ether is to be considered the same with the luminous ether, if such a fluid exists, may perhaps at some future time be discovered by experiment." Fifty years later Michael Faraday wrote: "It is not at all unlikely


D O U
DC-7
DOUGLAS

that if there be an aether, it should have other uses than simply the conveyance of radiation." When electrical effects were considered, however, the most satisfactory kind of aether seemed to be a liquid. Lord Kelvin showed that a bar magnet has properties resembling those of a straight tube immersed in a perfect fluid, the fluid entering at one end and flowing out by the other. If like ends of two such tubes are presented to each other, they attract; unlike ends repel. The forces are thus diametrically opposite in direction to those of magnets, but in other respects the laws of mutual action between these tubes and between magnets are precisely the same.

When FitzGerald attacked the problem of the aether, he did not sink into the crude materialism that characterized all these theories. He regarded the medium as *sui generis,* not necessarily capable of being described in terms of any familiar kind of matter. Indeed, he remarked as early as 1878 that James Clerk Maxwell's electromagnetic theory, if it "induced us to emancipate ourselves from the thralldom of a material aether, might possibly lead to most important results in the theoretic interpretation of nature."

FitzGerald brought two dominant motives to bear on the investigation: first, the conviction that a single aether must suffice to explain all physical phenomena, and secondly, a firm belief in the truth of Maxwell's electromagnetic theory of light. Maxwell had published his theory in 1861 to 1864, but for more than 20 years it was not widely accepted. FitzGerald was one of its earliest and stoutest champions. He realized that the aether needed to have both the properties of a liquid and the properties of a solid, and these apparently contradictory requirements he succeeded in satisfying.

His starting point was a theory of matter which had been proposed by Lord Kelvin. Kelvin had pointed out that the mutual interaction of atoms might be illustrated by the behavior of smoke rings, which after approaching each other closely are observed to rebound. He had suggested that many of the properties of atoms, including the conservation of matter, might be explained by the hypothesis that they were constituted of vortex rings in a perfect fluid. He conceived the idea of a "vortex-sponge"—a mass of fluid in which rotating and nonrotating portions were finely mixed together.

FitzGerald saw that the concept of a vortex-sponge would solve his problem. For vortex-filaments in a perfect fluid are types of motion that possess permanent individuality throughout all changes, and their presence gives the fluid a certain stiffening, so to speak. They perform the same kind of function as the steel bars embedded in reinforced concrete: the fluid remains still a fluid, but a finite morsel of it would resist distortion. From the point of view of its fine structure, it would be a liquid, but from the point of view of its coarse structure, it would have some of the properties of a solid.

It was now necessary to identify the electric and magnetic vectors of Maxwell's theory with features of the vortex-sponge. Since vorticity in a perfect fluid cannot be created or destroyed, FitzGerald reasoned that an electric field was a modification of the system in which the vortex motion was polarized. Long vortex-filaments might be bent spirally about axes parallel to a given direction. When filaments were bent in a spiral form the fluid would have more energy than when they were straight, and the increase in energy could be measured by a vector parallel to their directions. The presence of a single spiral filament in the fluid would bend the surrounding parallel straight ones, and from this action a model of magnetic force could be constructed. FitzGerald went on to study the dynamics of a vortex-sponge, and showed that the density of energy was the sum of the square of two quantities which might be interpreted as the electric and magnetic intensities. It will be noticed that electromagnetic phenomena in this aether are essentially statistical in character, since they depend on its coarse structure.

FitzGerald wrote many memoirs develo, .ig Maxwell's electromagnetic theory; it was he who first gave what are commonly called the Maxwell-Lorentz equations, which connect the electric and magnetic vectors with the positions and motions of the charges. He applied the Maxwellian theory to the rotation of the plane of polarization of light by reflection from a magnet, and to problems such as the electric and magnetic fields due to a moving charge, the Faraday magnetic rotation of light and its relation to the Zeeman effect, the Kerr effect and the generation of radiant energy by a small electric current, in which the current-strength is varied according to a simple periodic law. The electric oscillators he proposed were closely akin to those used a few years later by Heinrich Hertz in his historic experimental demonstration of the

Electrical Characteristics

SENSITIVITY

0.14% of span or 4 microvolts, whichever is greater.

ACCURACY

± ¼% of scale span or 45 microvolts.

MINIMUM SPAN

3 millivolts.

PEN SPEED

½ second, full scale.

CHART SPEED

1, 2, 3, or 4 inches per second—or optionally, 2, 4, 6, or 8 inches per minute.

INPUT SIGNAL

any d-c millivoltage.

IF YOUR research program calls for recording variables that change with split-second speed—investigate the new *ElectroniK* High-Speed recorder. Its pen can streak across the full width of the **11-inch chart** in **only one-half second!**

This exceptional speed across a wide chart assures faithfully detailed recording of swiftly changing conditions . . . shows every significant "wiggle" that other instruments have to overlook.

To achieve high pen speed without overshoot, the instrument embodies an improved velocity damping circuit that brings the pen to a fast, smooth stop at its balance position. Chart speeds as fast as 4 inches per second spread out the vertical time base for maximum readability. Power reroll of paper is available at the high chart speeds.

Like all *ElectroniK* instruments, this model records any d-c millivoltage signal . . . operates with thermocouples, strain gauges, and a host of other transducers. It can be supplied for full scale spans as small as one millivolt.

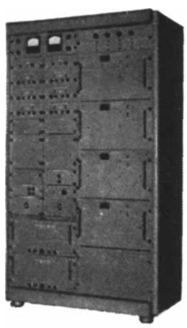
Your local Honeywell engineering representative will be glad to discuss how this new instrument can help you in your laboratory. Call him today . . . he is as near as your phone.

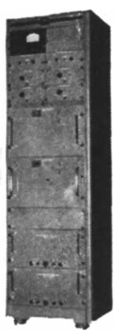
MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* 4580 Wayne Ave., Philadelphia 44, Pa.

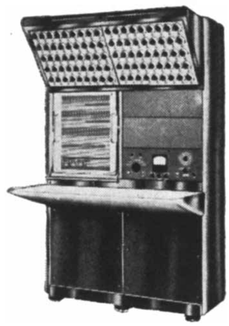
● **REFERENCE DATA: Write for Data Sheet No. 10.0-13**

H HONEYWELL

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls







existence of electric (Hertzian) waves.

Yet FitzGerald doubtless will always be best known as the discoverer of the "FitzGerald contraction." He devised this hypothesis to explain a very puzzling result which the U. S. physicists A. A. Michelson and E. W. Morley had found in trying to measure the velocity of the earth relative to the aether. With an interferometer they had compared the time of travel of light over a fixed distance in the direction of the earth's motion and at right angles to this direction. It was expected that the optical lengths of these paths would be different, but no difference could be observed. This suggested that the aether was carried along with the earth—a supposition hard to reconcile with the theory of astronomical aberration and other known facts. Discussing this dilemma one day with Oliver Lodge in Lodge's study in Liverpool, FitzGerald suddenly remarked that it would be solved if one could assume that the apparatus automatically contracted in the direction of the earth's motion. Following up this idea, he calculated that the contraction must be measured by the ratio $\sqrt{(1-v^2/c^2)}$ to 1, with v representing the earth's velocity relative to the aether and c, the velocity of light.

The Irish mathematician Joseph Larmor shortly afterward pointed out that clocks, as well as rods, must be affected by motion; to put the matter somewhat loosely, that a clock moving with velocity v must run slower in the same ratio as the contraction of length. Larmor's assertion has had a remarkable experimental verification recently in the observation of the rate of disintegration of mesons, the particles produced in cosmic rays. According to Larmor's theory, to a stationary observer the rate of disintegration of a meson should appear to be slower, the faster the meson is moving. This was found in 1941 to be actually the case.

The discoveries that the length of a rigid rod and the indications of a clock are not absolute properties of the rod and the clock, but depend on their motion, made it possible to explain the failure of all the experiments that had been made for the purpose of determining the velocity of the earth relative to the aether. They also led directly to the modern theory of relativity, which may be said to have begun with the discovery of the FitzGerald contraction in 1892. Unhappily FitzGerald died in 1901, barely missing the momentous outcome of the revolution in the philosophy of physics which he had started.

What General Electric people are saying . . .

L. TONKS

*Dr. Tonks is Manager—
Physics Section—Knolls Atomic Power Laboratory*

For several years we have been operating a reactor which is serving not as a prototype or a direct source of power-reactor performance information but as an auxiliary in such a program—much as a cathode ray tube can be useful in testing television sets. We had experienced the limitations of a Ra-Be source in a graphite pile and foresaw that an experimental thermal reactor could serve as a very valuable tool. Purely as a substitute for the graphite pile, it could easily give us many more neutrons even at low power. Thus, activation experiments either for weighing absorbing foils or fuel itself could be carried out more rapidly. It became reasonable to think that with sufficient intensity and using a chopper we might make actual differential cross-section measurements, and a certain type of exponential experiment in fissionable material became a possibility. Finally, the criticality condition in a reactor makes it suitable for neutron absorption measurements by observing the effect of the material under test on reactivity.

These were the considerations that led us to build our first thermal test reactor based on the fundamental design of Dr. Steward of this Laboratory . . .

Our thermal test reactor has undergone a logical evolution in accordance with its proved usefulness. From a small beginning with a power level of one watt, all-manual controls, makeshift shielding and borrowed fuel, it has justified development into the 10,000-times-more powerful reactor we are about to complete. It is still small as reactors go and yet can give thermal neutron fluxes for experimental purposes which are comparable with far larger units. And by exploiting danger coefficient techniques it can measure thermal capture cross sections of small samples and weigh isotopes.

*at the American Physical Society,
Rochester, N. Y.*

E. J. LAWTON

Mr. Lawton is with X-Ray Research, Electron Physics Research Department, General Electric Research Laboratory

We have recently found that certain polymers, or plastic materials are cross-linked or "cured" when bombarded with high-velocity electrons. This curing process cross-links, or ties together, the long chain-like molecules that make up the plastic material. Some of the properties of this cross-linked material are greater form stability at high temperatures and improved solvent resistance. For example, consider polyethylene bottles or containers (squeeze bottles). These, as you might expect, will collapse if subjected to high temperatures. A short time electron bombardment of such a bottle, however, will change its characteristics so much that it can stand up under steam sterilization. You can start an almost endless list of applications with sterile but unbreakable containers for pharmaceutical and biological materials which require sterilization after packaging. Unbreakable, re-usable milk bottles can be another possible use. Other plastic materials that can be cross-linked by the electron beam are nylon, rubber, and silicone products.

In some of our earlier work we found that certain liquid materials would polymerize to solid plastics when exposed to the electron beam. In this process, there is a joining together of many smaller molecules to form the long chain-like molecules that make up the solid plastic. This means of initiating polymerization does not necessitate the use of catalyst and high temperature that is required in the conventional chemical polymerization process. In fact, we found that polymerization could be initiated at temperatures as low as about 100° Fahrenheit below zero. Further, by controlling the pattern of the electron beam, it was found that specific solid plastic shapes could be produced in the liquid, thus providing a new and interesting way of casting objects.

*General Electric Science Forum
WGY, Schenectady, N. Y.*

C. A. BURKHARD

Dr. Burkhard is a Research Associate at the General Electric Research Laboratory.

When one desires to find information concerning a field or particular compound he is confronted with the problem of consulting abstract journals, books or files to find the data which he desires. It is possible by use of either hand-sort or machine-cards and equipment to prepare technical libraries which will have available files of information pertaining to the entire field of science. Then one confronted with the task of making a survey of a given field could consult such a library, and, by making the proper sorts by hand or by machine, obtain (1) a list of references pertaining to the subject in question (2) obtain pertinent data concerning the subject. As an ultimate in this type of activity it would be possible with the machine sort cards to rapidly prepare printed sheets of references, lists of compounds and their physical properties, or lists of materials having certain physical properties. By the use of such type files it would also be possible to correlate and analyze data pertaining to particular research and development problems from time to time without requiring the necessity of using research personnel to conduct such surveys.

*at the American Chemical Society
Chicago, Ill.*

You can put your confidence in—

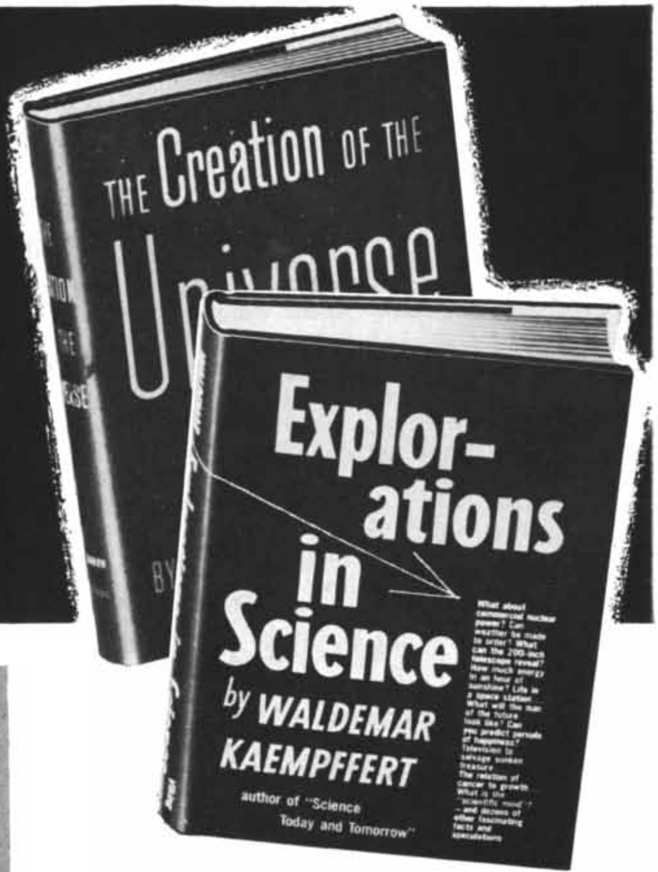
GENERAL ELECTRIC

THESE TWO FASCINATING BOOKS

FREE

TO NEW MEMBERS OF THE

science book club



THE CREATION OF THE UNIVERSE

By GEORGE GAMOW

Now for the first time in a book for science-minded people, Dr. Gamow discusses the origins of galaxies, stars and planets in the light of known nuclear reactions. In a witty, readily understood manner, he traces the expansion of the universe through three billion years of gas-to-liquid and liquid-to-solid evolution. To support his interesting conclusions and contentions, he draws upon geology, astronomy and the newest concepts in the fields of nuclear and atomic reactions.

EXPLORATIONS IN SCIENCE

By WALDEMAR KAEMPFFERT

This is a fascinating non-technical exposition of the scientific wonders that have made startling headlines in recent years, and the dramatic stories behind them. Intended as a "guided tour" for the intelligent reader who wants to keep abreast of today's increasingly important and complex scientific developments, this book deals with current problems such as: the use of atomic energy in war and peace, the mystery zone of supersonic speeds, the enigma of cancer, the cyclopean eye of Palomar, and even the prospects of made-to-order weather. The author is a former Editor of *Scientific American* and is currently the Science and Engineering Editor of the *New York Times*.

Combined retail price $7.25 **BOTH FREE to new members**

BENEFITS YOU ENJOY AS A MEMBER

THIS NEW KIND OF BOOK CLUB is for people interested in Science . . . who want to keep abreast of scientific discoveries, inventions and developments of all kinds, the world over.

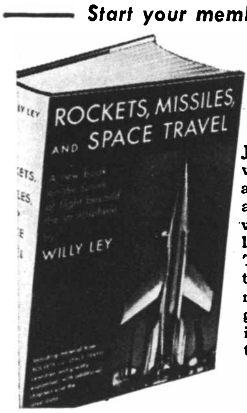
Each month the Club's editors select an outstanding book. This and other significant works in the same field are described in *The Science Report* which you receive free.

On joining you receive *Explorations in Science* and *The Creation of the Universe* FREE with your first selection, *Rockets, Missiles, and Space Travel.* For every four additional selections you accept, you receive another valuable Bonus Book FREE.

You do not have to accept every selection — as few as four a year fulfills your sole membership obligation. You accept *only* the books you want, and pay only the member's special reduced price, plus a small fixed mailing charge, *after* you have received them.

It costs nothing to join and you may cancel your membership at any time after accepting four selections. Send no money. Just mail coupon now to: Science Book Club, Dept. 2052, 11 East 36th Street, New York 16, N. Y.

Start your membership with



ROCKETS, MISSILES and SPACE TRAVEL

By WILLY LEY

Just how far *has* Science advanced toward making interplanetary space travel a reality? Here are facts much stranger and more exciting than any fiction ever written—and theories that may be established facts much sooner than we think. The question is no longer whether space travel theory is serious, or correct. It is now simply a matter of how quickly engineering practice can catch up with existing theory! Illustrated with many photos, drawings and charts.

Retail price $5.95

To members, only $4.75

JOIN NOW! — get $13.20 worth of books for only $4.75

This FREE GIFT Coupon Makes You a Member

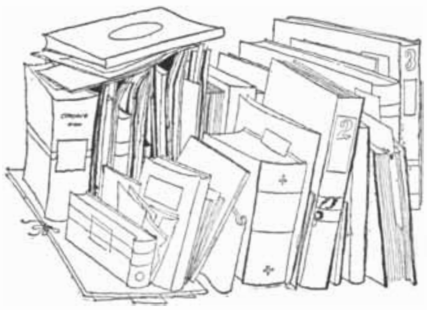
SCIENCE BOOK CLUB, Inc., Dept. 2052
11 East 36th St., New York 16, N. Y.

Please enroll me as a member. I am to receive FREE, as a gift upon joining, *Explorations in Science* and *The Creation of the Universe.* With them, send as my first selection, *Rockets, Missiles and Space Travel,* at the special member's reduced price of only $4.75, plus 25c for postage and packing. For each four additional selections I accept, I am to receive a valuable Bonus Book FREE. I am also to receive the Club's Science Report each month *free.* My only obligation is to accept as few as four Club selections the first year I am a member.

Name..

Address..

City.............................. Zone.............. State..............................



BOOKS

The first volume of an imposing biography of Sigmund Freud by one of his disciples

by James R. Newman

THE LIFE AND WORK OF SIGMUND FREUD, Vol. I, 1856-1890, by Ernest Jones. Basic Books, Inc. ($6.75).

One evening in Vienna, when he was already famous, Sigmund Freud made an unannounced visit to a large medical society meeting where a vehement dispute was in progress as to the meaning of certain passages in his *The Interpretation of Dreams*. The disputants did not pay the slightest attention to his presence. It seemed not to enter anyone's head to suggest that, since Freud was not only alive but in the very room where the issues were being debated, it might be helpful to hear his own interpretation of words he had written. Freud's theory had a life of its own, a life independent of its creator. Freud was immortal, but he was also superfluous. The exegesists were now in charge.

This anecdote illustrates one of the many difficulties confronting a biographer of Freud. He cannot expect that any portrait of the master, regardless of its fidelity, will win general approval. The disciples consider that they have a vested interest in the master's life. They have their own impressions of its course, their treasured remembrances of personal contact—the slighter the contact the more elaborate the remembrances. Those bent on disparaging Freud's character will not welcome a balanced account; and, if it is a distorted and unfriendly one, they will envy the biographer the practice of his malice. The biographer cannot even draw encouragement from the thought that his subject would have applauded the undertaking. On one of the two occasions when Freud destroyed his correspondence, notes, diaries and manuscripts, he wrote to his betrothed in gleeful spite: "Let the biographers chafe; we won't make it too easy for them. Let each one of them believe he is right in his 'Conception of the Development of the Hero'; even now I enjoy the thought of how they will go astray."

Ernest Jones has undertaken to write a definitive life of Freud, of which this book is the first volume, covering the period from Freud's birth in 1856 to 1900. Jones is fully aware of the difficulties and pitfalls of his task. It is good that he had courage and would not be deterred. He is not writing, he tells us, a popular biography, but this should lead no one to conclude that his book is addressed to that small incestuous circle which is apparently determined to convert Freud's great human concepts into a pastiche of gibberish and black magic. Nor is it a book, Jones says, "that would have met with Freud's own approval."

Freud's attitude toward fame was nonsense, as he himself must have known. But it was nonsense which, during his life at least, he could partly enforce, and even after his death his family for a time did their best to guard his privacy by withholding his papers. "What changed their attitude later was the news of many false stories invented by people who had never known him, stories which were gradually accumulating into a mendacious legend." They then decided to give Jones their full support. The book confirms the wisdom both of their decision and their choice.

Jones has been for many years the most distinguished British exponent of orthodox psychoanalytical theory. For 40 years he was Freud's close friend; he is the only survivor of a small circle of co-workers (the "Committee") which kept in constant intimate contact with Freud. Jones says that he and Freud passed through the identical disciplines on the way to psychoanalysis: philosophy, neurology, disorders of speech, psychopathology. This "has helped me to follow the work of his pre-analytical period and its transition into the analytical one." He says that as "the only foreigner (and, incidentally, the only Gentile)" in the circle, he was able to maintain "some degree of greater objectivity than the others." His biography is not an "idealized portrait of someone remote from humanity." It is a work of love, devotion and critical honesty. It is also a work of high intellectual mark and literary excellence. Jones is renowned for his brilliant papers of psychoanalytical interpretation: I need only mention his famous essays on Hamlet and the symbolic significance of salt.

It is clear from this first volume that the full biography will be a landmark of literature, a remarkable appreciation of one of the remarkable spirits of the modern age. It is impossible even in a long review to give more than a few highlights of Jones's book, but these may serve to indicate the scope and quality of his achievement.

Freud was born in Freiberg in Moravia. His grandfather and great-grandfather were rabbis; his father was an indifferently successful wool merchant. To his father, it is said, he owed his sense of humor, his "shrewd scepticism about the uncertain vicissitudes of life, his custom of pointing a moral by quoting a Jewish anecdote, his disbelief in matters of religion." His mother was a warm and lively woman who reached the great age of 95. Sigmund was her first-born and her favorite. "A man who has been the indisputable favorite of his mother," he wrote later, "keeps for life the feeling of a conqueror, that confidence of success that often induces real success."

Freud was early introduced to paradox: he was born an uncle with a year-old nephew, the child of a son of his father by an earlier marriage. Sigmund's childhood relationship with his nephew John, who was stronger and pushed him around, was ambivalent. He loved and hated his nephew intensely. This inner conflict determined a pattern for the future. Sigmund wrote: "An intimate friend and a hated enemy have always been indispensable to my emotional life; I have always been able to create them anew, and not infrequently my childish ideal has been so closely approached that friend and enemy have coincided in the same person; but not simultaneously, of course, as was the case in my early childhood."

It is one of Freud's teachings that the "essential foundations of character are laid down by the age of three and that later events can modify but not alter the traits then established." Jones, who accepts this view, makes clear what circumstances shaped Freud. Besides those already related, there were his Catholic nurse, who implanted in him the fear of Hell and the faint hope of Heaven; his enormous admiration for his father and respect for paternal authority; the early uprooting of his family and removal to Vienna—an event which made Sigmund fear he would lose his home and which later led to a phobia of traveling by train, from which he suffered for about a dozen years before it was dispelled by his self-analysis.

Even if one is not prepared to swallow the notion that a man is a finished article by the age of three, one must realize the important consequences of Freud's belief in this notion. Searching deep within himself for the roots of his character, Freud as a mature man recaptured, or at least thought he had recaptured, the momentous substance of the past. In these remembrances, real or fancied, lay the key to self-knowledge, the emancipation from dark anxieties and self-torment, the clue to discoveries not only about himself but about all men. It is no exaggeration to say that Freud remade himself through his memories. He became not so much the person he had to be as the person he thought he had to be. Thus in a sense his own triumph was a refutation of his doctrine of early ossification.

Freud grew up in Vienna and spent most of his life in that beautiful city. He hated it. He thought the city anti-Semitic, vulgar and heartless; he blamed Vienna for his father's lack of success and all that he himself had to endure before gaining recognition.

In the typical Jewish tradition, his family did everything possible to further his career. Money was found to send him through the University. His parents and his five brothers and sisters crowded into three bedrooms so that Sigmund could have a study to himself. His room had the only oil lamp, the others being lit by candles. His sister liked to play the piano, but Freud was morbidly sensitive to all "noise," and so the piano was removed and none of the children was permitted to study music.

"After 41 years of medical activity," Freud wrote in the 1920s, "my self-knowledge tells me that I have never really been a doctor in the proper sense. I became a doctor through being compelled to deviate from my original purpose, and the triumph of my life lies in my having, after a long and roundabout journey, found my way back to my earliest path. I have no knowledge of having had in my early years any craving to help suffering humanity. My innate sadistic disposition was not a very strong one, so that I had no need to develop this one of its derivatives. . . . In my youth I felt an overpowering need to understand something of the riddles of the world in which we live and perhaps even to contribute something to their solution. The most hopeful means of achieving this end seemed to be to enroll myself in the medical faculty. . . ."

Yet Freud's inclination was speculative, philosophical and literary rather than primarily scientific. "He could never have been a mathematician or physicist or even an expert solver of chess problems," says Jones. He had an orderly mind but he found exactitude and precise definition wearisome. When he was reproached for obscurities and ambiguities in his writings, he admitted wryly that the cause was pure "*schlamperei,*" *i.e.*, sloppiness.

In the physiology laboratory of Ernst Brücke, Freud worked happily and productively as a histologist and neuroanatomist, acquiring the principles on which, according to Jones, his psychological theories were later constructed. Brücke was a leader of the Helmholtz school of medicine, whose slogan was: "No other forces than the common physico-chemical ones are active within the organism." At first thought it is hard to believe that Freud ever took this tenet to heart. But on this crucial point Jones is convincing. It is true that Freud eventually discarded the more mechanical aspects of the Helmholtz school, and that he adopted more or less explicitly the very old dualistic concept that something known as matter produces by mysterious transformation something known as mind. But what Freud never relinquished was a belief in the strict sequence of cause and effect. He acknowledged a determinism which was as rigid and implacable in the shadow world of neuroses as in the substantial world of neurones. His emancipation from the Helmholtz influence was only partial, and, what is even more significant, the emancipation was pragmatic. In his student days Freud was a radical materialist. He soon modified his philosophy but remained always an empiricist. Though he finally abandoned the hope of explaining mental processes in terms of brain physiology, he never rejected the principle that psychic phenomena rest on a physical basis.

Freud gave up the strictly physiological approach to mental disease because it didn't work, because existing anatomical, chemical and physiological knowledge was inadequate to make mental disturbances intelligible, let alone to give relief to the mentally ill. Of his own psychological approach, however, he wrote in a letter in 1898: "I have no inclination at all to keep the domain of the psychological floating, as it were, in the air, without any organic foundation. But I have no knowledge, neither theoretically nor therapeutically, beyond that conviction, so I have to conduct myself as if I had only the psychological before me." And from this position, as Jones points out, he never moved. In 1904, for instance, he stated that "it should be possible to represent [psychical paths] by organic elements of the neurone system in ways that cannot yet be suggested." Again, in 1917 he wrote of the psychoanalysts' search for "the common ground" on which "bodily and mental disturbances" come together.

I have spent some time on this point because Freud's attitude has been widely misconstrued and distorted. Whatever the deficiencies of his theories, however excessive his preoccupation with sexuality, however blind his indifference to the role of social and environmental causes of mental illness, Freud cannot be justly charged with rejecting scientific method, with replacing reason by dogma or with substituting inspirational hocus-pocus for explanations founded on natural law.

I must pass over quickly the fascinating chapter in which Jones recounts Freud's cocaine period (1884-1887), when he thought this drug a panacea for all ills from "neurasthenia" to diabetes. One of the unfortunate consequences of this enthusiasm was the death of Freud's good friend Ernst von Fleischl-Marxow, whom Freud converted into a cocaine addict in a feckless though well-intentioned attempt to break him of the morphine habit. Another distressing interlude was Freud's long friendship with Wilhelm Fliess, a Berlin nose and throat specialist who was also a numerologist. For many years Freud was completely taken in by this charming hokum artist, who had concocted a comprehensive metaphysical and cabalistic theory based on the 28-day menstrual cycle and on the bisexuality of all human beings. Freud pictured him as a man of supreme intellect, "of impeccable critical judgment, and thoroughly schooled in the physical and mathematical principles of science." Freud outgrew Fliess; their friendship ended unpleasantly, as did several of Freud's relationships with men of much greater worth. But it was important to Freud, emotionally and intellectually, while it lasted. Fliess was a vital, catalytic element in the evolution of Freud's thought; a loved friend and a hated enemy who provoked the curious equilibrium of tension and relaxation, the cycle of euphoria and depression, of self-confidence and self-doubt which Freud asserted were essential to his creative work.

A far more stirring emotional stimulus was Freud's relationship with Martha Bernays. There is reason to believe that his was the rare case of a man who loved only once. He met his wife-to-be in 1882; they became engaged two months later, but were not married until 1886. Their happy union lasted until Freud's death 53 years later. The chronology is simple but the events it covers are not. The engagement period, as depicted in 900 letters Freud wrote to his betrothed, was marked by a "tremendous and complicated passion," a gamut of emotion almost as exhausting to the reader as it must have been to its principals. It is in love and in games that men are mercilessly exposed. More light is cast upon Freud's personality by these letters, hitherto unseen by any outsider, than by all the other writings of and about Freud. He had a great capacity for love and tenderness, and an almost equal capacity for jealousy, hurtfulness and self-torment. Freud himself explained this puzzle of opposites with his usual acuteness: "Only in logic are contradictories unable to coexist; in feelings they quite happily continue alongside each other."

He told Martha he loved her for her beauty, also that he loved her because she was homely. He did his best to find fault with her attitude toward her mother and brother; he was always looking for trouble, and if he could not find it he made it. He was an expert in conjuring up hated rivals. He was possessive and childish. Martha fortunately was a sensible girl and able to support his tempestuousness and arrogance. When she tried to smooth the messes he made, he accused her of weakness and cowardice; when she wrote him soothing, reasonable letters, he detected hypocrisy between the lines. One winter during their separation she asked his permission, dutiful little goose that she was, to go ice-skating. He sternly refused, not, as one might suppose, because she might injure herself, but because she might have had to skate arm in arm with another man. Three days later he relented, but only on condition that she skate alone. In this tragicomedy one sees Freud as a spoiled, first-born, best-loved son in the painful process of finding a poor substitute for mama. But there is something more. The passions that shook him, that he was unable in this case to repress or sublimate, were of inestimable value in provoking new thoughts which were to become an essential part of psychoanalysis.

Throughout these formative years everything that happened to Freud influenced the evolution of his theories. The work of even a physicist or mathematician is shaped by experiences having nothing to do with physics or mathematics. How much more obviously must this be true of a novelist, a playwright or a creator of theories about human behavior. Freud's search for understanding was not confined to the laboratory or the clinic; he did not divide his day between working hours and leisure. He was a restless seeker, an untiring observer, who found what he needed in his personal as much as in his professional life. He probed into himself as well as into others. Thus he achieved the fulfillment of two ancient adages: he knew himself and he healed himself.

Freud started to practice medicine in the same year that he married. Financial security came slowly, but with the help of an occasional loan and a few rich patients, both supplied by his good friend and fellow-scientist Josef Breuer, he made his way. Once his reputation was established, the fees became very large. The book offers many glimpses of Freud's personal life before 1900. He found time, no matter how busy he was, for wide and intensive reading: Byron, Burns, Dickens, Fielding, Thackeray, George Eliot, Disraeli, Mark Twain, Thomas Huxley, John Stuart Mill (all of whom he read in English, of which he had complete mastery), Cervantes, and Goethe, Schiller, Heine and other German classics. His health worried him. The physical ailments were less troublesome than what he called his "neurasthenia," which was responsible for a variety of symptoms from indigestion to heart trouble. He thought it likely he would die in middle age from "rupture of the heart."

He hung a copy of the Declaration of Independence in his study where he could draw inspiration from the weight of its words. He enjoyed an occasional game of chess, played cards with a group of friends every Saturday evening, paid a daily visit to the barber, had a telephone installed in his flat as early as 1885, frequented the theater and counted as his "greatest thrill" seeing Sarah Bernhardt play in Sardou's *Théodora.*

In Paris Freud once visited the wife and son of his family doctor. They had gone there from Vienna so that the 10-year-old son could study music at the Conservatoire. Freud regarded the entire undertaking as appalling; the boy's "wretched father," he said, should have "secretly throttled the infant prodigy" instead of sending him to Paris. "Just think of the expense, the separation, the breaking up of the household." The name of the boy was Fritz Kreisler. Freud's feelings about the attention lavished upon young Kreisler may perhaps have been colored by guilt concerning the sacrifices his own family had made to educate him. Freud did not dislike children. He adored his own and enjoyed working with youngsters in his clinic. "I find them," he once wrote of his small patients, "both on account of their format and because they are mostly well washed, more attractive than the large edition of patients."

The steps by which Freud arrived at the theory that was to revolutionize modern thought are now well known. In 1885 he spent four months in Paris working at the Salpêtrière with the great French neurologist Jean Charcot. Following closely upon the deep impression that had been made on Freud by Breuer's classical case of hysteria, that of Fraulein Anna O. (her name, which deserves to be remembered, was actually Bertha Pappenheim), the brief association with Charcot was a crucial episode in the transformation of Freud's ideas. It impelled him to a decisive break with the prevailing methods of diagnosing and treating mental illness. For Charcot, as Jones points out, was the first to grant hysteria a place as "a perfectly respectable" disease of the nervous system. He succeeded in demonstrating that in suitable subjects the symptoms of hysteria, whatever their unknown neurological basis, could be both evoked and made to disappear by hypnotism. Here was a real disease which could be treated by ideas alone; in other words, it had a "psychogenic origin."

For almost two years after his return from Paris, Freud still clung to electrotherapy, bath and massage—the methods in fashion at the time for the treatment of neurotic patients. Then in December, 1887, he turned to hypnotic suggestion, which he practiced and championed with "his characteristic ardor." A year and a half later Freud for the first time employed the cathartic method which is now the basis of psychotherapy. Being still under Charcot's influence, he induced the purging flow of painful reminiscences by hypnosis. We do not know exactly when he changed over to

free association as the means of eliciting memories; the technique evolved gradually during the period 1892-1895. With it Freud was able "to penetrate into the previously unknown realm of the unconscious proper and to make the profound discoveries with which his name is imperishably associated." Jones characterizes the devising of the free-association method as one of "the two great deeds" of Freud's scientific life, the other being his self-analysis.

Although Freud explained his decision to use free association as an "obscure intuition," Jones offers his own conjectures, which, however, are more ingenious than persuasive. Whatever the preparatory circumstances, once Freud resolved to put his trust in this tool, new concepts and insights poured from his mind in a flood. In less than six years the entire structure of psychoanalysis was completed. In *Studies in Hysteria* (1895), a joint publication with Breuer, he gave his reasons for believing that sexual disturbances were the "*essential* factor in the etiology of both neuroses and psychoneuroses." Psychoanalysis is usually said to date from the publication of this work. His concepts of "resistance," "transference," "childhood sexuality"; his recognition of the important relation between painful memories and fantasies; his notions of "defense mechanisms," "repression," passively suffered "traumas"—all these were hammered out by 1897.

In the summer of that year he commenced the heroic task of self-analysis—a labor requiring supreme determination and courage and costing him unspeakable torment. "I believe," he wrote at an early stage of his probing, "I am in a cocoon, and God knows what kind of beast will creep out of it." He recognized the ordeal, however, to be an essential step in resolving his own neurosis and in driving his theories to completion. While carrying on his self-analysis, he wrote *The Interpretation of Dreams*. He finished its writing in a garden near the ill-omened Bavarian resort of Berchtesgaden.

Many years later Jones asked Freud to name his favorite writings. He took from the shelves *The Interpretation of Dreams* and the *Three Essays on the Theory of Sexuality*, saying of them in turn "I hope this one will soon be out of date through being generally accepted, but that one should last longer." With a quiet smile he added: "It seems to be my fate to discover only the obvious: that children have sexual feelings, which every nursemaid knows; and that night dreams are just as much a wish fulfillment as daydreams."

Jones's analysis of the growth of Freud's ideas is masterly. One cannot fail to admire his skill and sensitivity in assembling this astonishingly complex mosaic, even if one differs with him regarding the validity of certain of Freud's concepts. Jones's orthodoxy is undeviating. The most evident shortcoming of his book, however, lies in its failure to bring out adequately the intellectual background of Freud's ideas. While he does make some attempt to link Freud's theories to the work of contemporaries such as Breuer, Charcot, G. T. Fechner and Hermann Helmholtz, his emphasis is on Freud's originality. In this volume Jones has much more to say on how little Freud owed to his predecessors than on the organic connection between his thought and the thought of his time. But a general appraisal of Jones's biography must await the succeeding volumes. What he has given us so far is a rich, full-bodied portrait. He has shown us the style of Freud's thought, the complexion of his qualities, his emotional life, his daily habits, his creativeness, his foibles, his humanity. Thanks to Jones's labor, we understand how Freud came to be what he was—one of those who, as the German poet Christian Hebbel says, has "troubled the sleep of the world."

Short Reviews

The Origins of Art, by Gene Weltfish. The Bobbs-Merrill Company Incorporated. ($4.50). Dr. Weltfish is a very capable anthropologist who has for many years studied primitive technology and art. She now presents a unified theory of how art originates. The primitive toolmaker worked for nearly a thousand centuries to perfect a flint instrument with good clean edges and a sharp point and eventually produced a beautiful masterpiece. This triumph was followed by the deliberate fashioning, in cave drawings and pebblestone sculpture, of images of things which man admired or which figured importantly in his experience. When climate forced changes in man's existence, "a new art was born out of that new way of life. New industries were developed, and when they were mastered, patterns began to emerge on their surfaces and man became interested in design." One of the merits of Dr. Weltfish's account is her detailed, diagrammatic demonstration of the link between design and the processes of handcrafts. The handsome pattern of a woven basket reflects not only the weaver's imagination and skill but also the strength and soundness of its construction. Dr. Weltfish may at times overburden the argument that art is primarily "a celebration of the skill of work well done and enjoyed," but this in no way detracts from the value of the evidence which she has so patiently accumulated and so creatively fused into a challenging hypothesis.

THE WORLDLY PHILOSOPHERS, by Robert L. Heilbroner. Simon and Schuster ($4.00). A brisk, popular survey of the lives and ideas of most of the principal economists: Adam Smith, Thomas Robert Malthus, David Ricardo, John Stuart Mill, Karl Marx, Henry George, Alfred Marshall, Thorstein Veblen, John Maynard Keynes. Heilbroner, a practiced writer on economics, canters nimbly over many hard and often dreary roads. While he is apt to detour difficult obstacles and has a tiresome penchant for sharp journalistic antitheses, in measured doses this is an entertaining and intelligent book.

A HISTORY OF BOARD-GAMES OTHER THAN CHESS, by H. J. R. Murray. Oxford University Press ($11.50). This remarkable volume is a sequel to Murray's magnificent *History of Chess*, published 40 years ago. His catalogue covers 270 games played in different parts of the world, from ancient times to the present. Murray divides board-games into five main groups, corresponding to the early activities and occupations of man: (1) games of alignment and configuration (*e.g.*, pegity, halma, ticktacktoe or, as in Sweden, tripp-trapp-trull); (2) war games (*e.g.*, chess, checkers, go); (3) hunt games (*e.g.*, fox and geese); (4) race games (*e.g.*, backgammon, parchisi); (5) mancala games, played extensively in southern Asia and Africa, in which "the board consists of two, three or four rows of cup-shaped depressions or holes, each of which is large enough to contain a number of beans, and the method of play is to lift the beans from a hole and deal or sow them one by one in the following holes." The war game wei-k'i, played in China, Korea and Japan, deserves notice: "The game ends when the two territories are in absolute contact, or when both players agree that no more territory can be gained. The dead men are then removed." Wei-k'i "demands far-reaching calculations, which make it one of the most difficult games that man has invented."

CYBERNETICS, edited by Heinz von Foerster. Josiah Macy, Jr., Foundation ($4.00). The transactions of the Ninth Conference on Cybernetics, sponsored by the Macy Foundation and reported in this volume, display the now familiar "multidiscipline" approach to certain scientific problems whose novelty invites, and whose complexity demands, the attention of the more venturesome experts in many different fields. The subjects include "The Position of Humor in Human Communication" (Gregory Bateson), "The Place of Emotions in the Feedback Concept" (Lawrence S. Kubie), "Homeostasis" (W. Ross Ashby), "Discrimination and Learning in Octopus" (J. Z. Young), "Mechanical Chess Player" (W. Ross Ashby), "Boolean Functions" (John R. Bowman), "Investigations on Synaptic Transmission" (Walter Pitts). The conversations are lively and do not require the reader to concentrate too long on any one point, but they leave him wondering whether he really understands.

ALFRED NORTH WHITEHEAD, selections by F. S. C. Northrop and Mason Gross. The Macmillan Company ($12.50). Whitehead was a commanding figure of mathematics and logic and perhaps the outstanding philosopher of recent decades. Yet by his own standards he might be judged a failure as a philosopher. "Philosophy," he wrote, "is either self-evident, or it is not philosophy." Whitehead's system is grand and deep and influential, but it is certainly not self-evident. It is in fact so abominably obscure in some parts that few philosophers claim to understand it completely. That they all, nevertheless, acknowledge its importance is evidence of Whitehead's position in contemporary thought. The editors of this anthology give a very fair sample of Whitehead's writings. The selections include his extremely interesting essay "The Organization of Thought," which provides the general reader with a glimpse of what was involved in Whitehead and Russell's epochal *Principia Mathematica*. The book makes available for the first time Whitehead's important 1905 paper "On Mathematical Concepts of the Material World." It publishes portions of *Principles of Natural Knowledge, The Concept of Nature, The Principle of Relativity, Science and the Modern World, Adventures of Ideas* and the exceptionally difficult *Process and Reality*.

STUDIES IN THE PHILOSOPHY OF CHARLES SANDERS PEIRCE, edited by Philip P. Wiener and Frederic H. Young. Harvard University Press ($5.00). This excellent book is composed of essays by scholars on the life and thought of Charles Sanders Peirce, the founder of pragmatism. They evaluate his contributions to the theory of meaning, his work in logic, his interpretations of the history of science, his metaphysics and philosophy of religion. One of the most interesting essays describes Peirce's brief teaching career at The Johns Hopkins University, whose president, Daniel Coit Gilman, though an educator of some discernment, was unable to cope with Peirce's eccentricities and emotional instability. Thus this singular genius never gained a permanent place on the teaching staff. Peirce worked terribly hard and was immensely productive, yet during his lifetime he was neglected and had as disciples only a few unusually perceptive spirits, including William James. One of Peirce's mistakes was that he failed to write a book on his philosophy—a foolish oversight for any philosopher. Today his merit is widely recognized, thanks in part to the writings of James, John Dewey, Morris Cohen and others, and to an admirable edition of some of his papers by Charles Hartshorne and Paul Weiss.

Notes

ADVANCES IN CANCER RESEARCH, edited by Jesse P. Greenstein and Alexander Haddow. Academic Press, Inc. ($12.00). The first installment of a new series of reports on cancer research by workers in the U. S., vividly exemplifying the "gallant and dedicated quest for comprehension and mastery of an ancient and elusive disease."

EXPERIMENTAL NUCLEAR PHYSICS, Vol. II, edited by E. Segré. John Wiley and Sons, Inc. ($12.00). The second volume of this survey of experimental nuclear research consists of two monographic contributions: by Philip Morrison on nuclear reactions and by T. Feld on the neutron.

BIOCHEMISTRY AND PHYSIOLOGY OF NUTRITION, edited by Geoffrey H. Bourne and George W. Kidder. Academic Press, Inc. ($13.00). The first volume of a cooperative compendium, including papers on the early studies of nutrition, the history of vitamins, the biosynthesis of proteins, and so on.

ADVANCES IN BIOLOGICAL AND MEDICAL PHYSICS, edited by John H. Lawrence and C. A. Tobias. Academic Press, Inc. ($8.00). Volume III in this series of research reports presents papers on radioactive isotopes, antibodies as specific chemical reagents, biological actions of ultrasonic waves, X-ray microscopy, ultraviolet microscopy and microspectroscopy.

630. DICTIONARY OF SCIENCE AND TECHNOLOGY.
Separate indexes in French, German and Spanish permit two-way reference with English entries. Complete with conversion tables and technical abbreviations for engineering and scientific use.
Pub. at $6.00. *Now only* **1.98**

123. CHINESE WATERCOLORS.
Set of 6 charming color prints portraying brilliant Oriental birds perched on exotic fruits and flowers—against textured backgrounds of silk. Flawlessly reproduced from the famous Tung Lai-Chen originals. 11" x 15" portfolio. *Pub. at $15.00. All 6 only* **2.98**

238. OSCAR WILDE.
A biography by Andre Gide, French Nobel Prize Winner. Translated from the French by Bernard Frechtman. Gide's personal memories of Wilde before his imprisonment make fascinating reading.
Pub. at $2.75. *Now only* **.97**

747. HISTORY OF RUSSIAN PHILOSOPHY.
By N. O. Lossky. A comprehensive and complete survey of the development of Russian philosophical thought—the only such history in the English language. 416 pages. *Pub. at $10.00.* *Only* **3.88**

251. MATHEMATICAL BASIS OF THE ARTS.
By Joseph Schillinger. A work of revolutionary implications in aesthetics, this book formulates the basic laws of mathematical logic underlying all art structures. Profusely illustrated. *Pub. at $15.00.* *Only* **2.98**

30. UTRILLO: MONTMARTRE.
A superb full-color reproduction of one of the most charming Parisian scenes ever painted by Utrillo. Actual picture size measures 20" high x 24" wide. Ideal for framing. *Pub. at $10.00.* *Now only* **1.98**

21. LAUTREC: MOULIN ROUGE.
Absolutely perfect facsimile of *Moulin Rouge*—the famous Lautrec Dance Hall Poster. This faithful silk-screen reproduction measures a giant 31½" high x 23½" wide. *Pub. at $20.00.* *Now only* **2.98**

94. DEGAS BALLET DANCERS.
With startling authenticity, these 10 superb reproductions capture all the poetic imagination and delicate understanding of Degas' prized ballet sketches. Each plate measures a full 17" x 13" . . . each is printed on a color-tinted paper individually chosen for the particular subject. Frame them for your home—you'll find no finer portrayal of the ballet's rare grace and beauty! *Pub. at $7.50.* *Only* **2.98**

262. DICTIONARY OF WORD ORIGINS.
By Joseph T. Shipley. Stories of the words we use—how they grew across centuries and countries. Thousands of word histories. *Pub. at $5.00.* *Only* **1.98**

778. THE WISDOM OF CONFUCIUS.
Ed. and trans. with notes by Lin Yutang. The wisdom of the East is in this book. A large 6½" x 10½" gift edition illustrated in color by Jean Yee Wong. *Special* **1.49**

729. NEW APPROACHES TO DREAM INTERPRETATION.
By Dr. Nandor Fodor. Recent findings by a famous psychoanalyst in the analysis of birth dreams, number dreams, telepathic dreams, conception fantasies and various nightmares. *Pub. at $5.00.* *Only* **1.98**

509. DICTIONARY OF PHILOSOPHY.
Edited by Dagobert D. Runes. Both teacher and layman will find this handy, all-embracing volume invaluable in his philosophical studies. *Pub. at $6.00.* *Now only* **2.98**

214. MODERN ABNORMAL PSYCHOLOGY.
Ed. by William H. Mikesell. Twenty-five of the nation's most eminent psychologists discuss diagnosis and treatment of all abnormal psychiatric conditions. 880-page volume. *Pub. at $10.00. Now only* **2.98**

545. DICTIONARY OF WORLD LITERATURE.
Edited by Joseph T. Shipley. A survey of the forms and techniques of the various literary arts, their principles and problems, arranged in dictionary form for ready reference. Prepared with the collaboration of 260 scholars, including G. A. Borgese, Andre Maurois, Lewis Mumford and Allen Tate. New and completely revised edition. 453 pages.
Pub. at $7.50. *Only* **2.98**

648. EINSTEIN: THE WORLD AS I SEE IT.
No other book is so complete a key to the understanding of Albert Einstein's personality. Charming, witty comments and intimate revelations bring Einstein's great heart and mind to life. Here are Professor Einstein's own views on the world around him, and on his scientific labors. New abridged edition.
Pub. at $2.75. *Only* **.97**

111. RAOUL DUFY: BLUE MEDITERRANEAN.
Redecorating? This beautiful reproduction of Dufy's *Mediterranean at Nice* will add an enchanting note to any room in your home. The famous Casino at Nice with its palm trees and sandy beach is pictured against the azure Mediterranean Sea. Reproduced by the superbly colorful silk-screen process, this 22" wide x 18" high (actual picture area) print is ideal for framing. *Pub. at $15.00.* *Only* **3.88**

392. NEW DICTIONARY OF PSYCHOLOGY.
By Philip Lawrence Harriman. For the first time, all the principal concepts and technical vocabulary of psychology are conveniently defined in one handy volume. *Pub. at $5.00.* *Now only* **2.98**

581. FREUD: DICTIONARY OF PSYCHOANALYSIS.
Ed. by Nandor Fodor and Frank Gaynor. Preface by Theodore Reik. Long-awaited reference dictionary of psychoanalysis—all the basic terms and concepts as formulated, defined and explained by Dr. Sigmund Freud. *Pub. at $3.50.* *Now only* **.97**

649. SEXUAL LIFE IN ANCIENT ROME.
By Otto Kiefer. Sexual activities in early Rome clearly and analytically explained. Authentically discusses Roman sadism in sex, free love, savage spectacles, marriage, religion, philosophy, literature, etc. 379 page volume. Illustrated. *Only* **4.88**

MARBORO BRINGS YOU TREMENDOUS SAVINGS

SALE

ORDER BY MAIL TODAY

marboro books

Dept. SAI
222 Fourth Avenue, New York 3, N. Y.

Please send me, postage prepaid, the book bargains circled below:

☐ *Enclosed find $____* ☐ *Send C.O.D.*

20	21	30	81	82
83	84	94	97	111
123	200	214	238	251
259	262	326	392	507
509	545	581	630	638
648	649	650	658	659
729	747	778	806	818
819	827	900	958	975

Name____________________

Address____________________

City__________Zone____State________

New York City residents add 3% city sales tax. A few cents extra for C.O.D. Add 25¢ per title for deliveries outside U. S. A. and possessions.

GUARANTEE: If not satisfied, return books after 10 day examination and money will be refunded.

507. BORDERLANDS OF SCIENCE.
By Alfred Still. Fascinating study including Black Magic, Superstitions, The Occult, Magic, Witchcraft, Vampirism, Divining Rods, Levitation, Intuition, Hypnotism, Clairvoyance, Telepathy, Ghosts, etc. 424 pages. *Pub. at $3.75.* *Now only* **1.98**

326. WISDOM OF THE TALMUD.
By Rabbi Ben Zion Bokser. A large annotated cross-section of one of the great cultural treasures of mankind—*available in English for the first time.* Includes the choicest material in Talmudic literature.
Pub. at $3.75. *Now only* **1.98**

97. TOULOUSE-LAUTREC: SEATED CLOWN.
A superb true-to-the-original reproduction of La Clownesse (The Seated Clown) for your home. 17" wide x 22" high. *Pub. at $10.00. Very special, only* **1.98**

975. THE FILM TILL NOW:
A Survey of World Cinema. By Paul Rotha and Richard Griffith. Revised edition, 775 pages. *Illus. with 175 photographs.* The classical history of world cinema. *Pub. at $12.00.* *Only* **3.88**

958. NOBLE ESSENCES.
By Sir Osbert Sitwell. The 5th and final volume of one of the richest and most versatile biographies of our time. Sir Osbert delineates an era and himself through people of exceptional talent, wit and genius: writers and artists dear to him in England's golden day. *Pub. at $4.50.* *Only* **1.49**

658. ENCYCLOPEDIA OF SUPERSTITIONS.
By E. and M. A. Radford. Superstitions in existence throughout the world presented in a single encyclopedia for the first time. Any superstitions related to any subject can be found easily. There are 2,300 superstitions listed. *Pub. at $6.00. Now only* **1.98**

MIRO MURALS.
The daring and brilliance of Miro's figures in red, black, white, green and chartreuse are skillfully imposed on a background of graded blues and whites. Each mural reproduction measures 3⅓ feet long by 9 inches high. Used together, the three sections make a magnificent frieze 10 feet long. Ideal with or without framing for den, game room, foyer, or any modern decor.
81. MIRO MURAL #1. *Only* **2.98**
82. MIRO MURAL #2. *Only* **2.98**
83. MIRO MURAL #3. *Only* **2.98**
84. ALL THREE MIRO MURALS. *Pub. at $45.00. Special only* **7.88**

259. DICTIONARY OF MIND, MATTER AND MORALS.
The world's greatest living philosopher, Bertrand Russell, 1950 Nobel Prize Winner, compiles his opinions and views on over a thousand subjects. Arranged for quick reference in dictionary form. 304 pages. *Pub. at $5.00.* *Only* **1.98**

20. TEN JAPANESE PRINTS.
Reproduced from the originals in the *Metropolitan Museum of Art.* All the subtleties of shading and delicate pastel beauty of the full-color originals reproduced in the minutest detail on large 11" x 17" unbacked sheets. These 17th to 19th century prints include Hokusai's celebrated *Great Wave Off Kanigawa* and other famous works by Shunsho, Hiroshige, Harunobu, etc. Accompanying text by Alan Priest.
Pub. at $7.50. *Now only* **2.98**

818. UNUSUAL WORDS.
By Edwin Radford. An alphabetically arranged collection of unusual expressions and words with the story of how they came about. From "above board" to "zounds." *Pub. at $3.75. Now only* **1.98**

900. WORLD BOOK OF MODERN BALLET.
By John Martin, dance critic of the *New York Times.* America's leading authority presents an informative and entertaining commentary on all the principal ballets, ballet companies, dancers, choreographers, and movements that have made ballet one of the notable arts of our time. The refreshingly critical text is complemented by 160 photographs, many in color. *Pub. at $6.00. Only* **2.98**

806. ALICE IN WONDERLAND & Through the Looking Glass.
By Lewis Carroll. Two handsome volumes with the famous Tenniel illustrations colored by Fritz Kredel. Slip case. *Pub. at $5.00.* *Only* **1.98**

650. SEXUAL LIFE IN ANCIENT GREECE.
By Hans Licht. Thoroughly explains the sexual background of the philosophy and art of Ancient Greece. Deals with marriage customs; the human figure; festivals; Greek literature; sexual relationships; prostitution; homosexual love; etc. Beautifully bound, 556 page volume. Illustrated. *Only* **5.88**

200. EXISTENTIALISM.
By Jean Paul Sartre. Here is the heart of Sartre's philosophy—that man is personally responsible for what he does—that there are no values external to man—that man may therefore choose different values. *Pub. at $2.75.* *Now only* **.97**

659. ENCYCLOPEDIA OF CRIMINOLOGY.
Ed. by Vernon C. Branham, M.D. and Samuel B. Kutash, Ph.D. Nearly 600 pages. A compendium of existing facts on criminology by 61 outstanding specialists. *Pub. at $12.00.* *Special* **2.98**

638. SHORT NOVELS OF COLETTE.
Edited by Glenway Wescott. "Colette's descriptions of the actual physical manifestations of a love affair make Lady Chatterley seem one-dimensional"—*New York Times.* Six novels. 775 pages. *Special* **3.49**

819. PHENOMENA, ATOMS AND MOLECULES.
By Irving Langmuir, Nobel Prize winner. This collection of 20 papers attempts to interpret phenomena in terms of mechanisms or atomic and molecular interactions. 436 pages. *Pub. at $10.00. Only* **2.49**

827. UNDER THE SEA-WIND.
Again Rachel Carson brings to the reader the special mystery and beauty of the sea which she caught and translated so memorably in "The Sea Around Us."
Pub. at $3.50 *Only* **1.49**

THE AMATEUR SCIENTIST

Mainly about a theory of color harmony and a new book for the telescope maker

Conducted by Albert G. Ingalls

Roger Hayward, whose drawings for this department unfortunately can be made only in black and white, has been for many years a student of color, both as an amateur painter and as a successful architect in Los Angeles. Here are his interesting conclusions on the subject.

"People," he says, "are unreasonable about color. At least, most of them do little reasoning about it. I used to think that only artists were privileged to express opinions about color and I resented scientists meddling in it. After sitting in conferences with artists for more than 30 years, however, and listening to them defend their individual preferences with passion while disagreeing violently among themselves, I now think the artists are the dumbest of the lot. Most of them think the only thing that matters is their blessed emotions, a sentiment open to doubt.

"Physicists who know about light have unwittingly implied that they also know about color, but the two are not exactly the same thing. The stimulus for color is light, all right, but color is a sensation in the brain and can be termed strictly a psychological effect. A red light in an otherwise dark room will cease to appear colored after a few minutes. A piece of gray paper may appear brown or green or red, depending on the background. A piece of red paper may appear red or black or white, depending on the color of the light source. Again, although blue is a popular color, a blue beefsteak would be nauseating. Bright yellowish green is wonderful in primroses but ghastly as a complexion.

"However expert a physicist may become in the field of colorimetry, the color sensations experienced by the human brain must remain outside his field. They are a mixture of (1) the color of the surface as measured in white light; (2) the color of the light source; (3) the color of the background; (4) the colors which the observer has been viewing in the previous few minutes; (5) the color the observer expects the object to be; and (6) the color that the observer's friends and relatives believe appropriate for the object in question.

"Artists, though far from scientific, are in some measure objective in their view of color. They usually think of color as such as part of a color scheme. They take the position that people's likes or dislikes of individual colors, such as pink, have no meaning. Some of the significance of a color depends on its relation to other colors, just as a word has part of its meaning implied by the context."

Thus color, like music and economics, appears to partake both of science and art. A mathematical basis underlies musical harmony. Is this also true of color? Is it possible to find a quantitative basis for the expression of color harmony and to explore color values by means of logical processes? Some scientists have thought so, and Hayward became convinced that painstaking experiment and research might turn up some mathematical rules for predicting color combinations that would be generally accepted as harmonious and pleasing—at least in the narrow field of color decoration. He decided to find out. Now, after several years of work, he not only has a working theory of color harmony but a full-scale avocation. His experiments are fascinating, and anyone can easily repeat them. Moreover, they enable an amateur of limited artistic endowment to turn out pleasing color designs on the first try.

The tool that Hayward uses in his investigations is the so-called "color top," first employed in color research by the physicist James Clerk Maxwell. "The color top," says Hayward, "is the simplest device with which a quantitative study of color can be made. It is merely a spindle, capable of rotating 30 or more revolutions a second, on which adjustable colored sectors can be mounted. As it spins, the colors are seen as a mixture, and the hue you see will depend on the proportions of exposure of the individual colors.

"An unused fan motor is ideal as the basis for construction of the top [*see drawing on the opposite page*]. Prepare some disks of colored cardboard and punch a hole in the center for the spindle and make a single radial cut in each disk. Now when you mount the disks on the spindle you can interleave them so as to expose as little or as much of each color as you wish. A slightly larger disk, placed behind the colored disks and calibrated in hundredths of a circle, will enable you to read directly the percentage of the circle occupied by sectors of each color.

"For coloring the disks it is desirable to use show-card colors, such as Prang's Tempera, so that you can always be sure you have the same colors. It is unwise to do any mixing of paints, because of the difficulty of duplicating any color exactly.

"Suppose you start the experiment with three disks of the primary colors—Prang's red, green and ultramarine blue. If you adjust the disks to expose approximately 34 per cent red, 46 per cent green and 20 per cent blue, when you spin the wheel you will get a shade of gray. Now put on the spindle a pair of smaller disks, one black and one white [*as shown in drawing*]. By carefully adjusting the relative amounts of black and white exposed, as well as the mixture of primary colors, you can obtain the same shade of gray with both combinations when the wheel spins.

"The mixture of red, green and blue needed to match the black-and-white gray depends on the light source: it is different in daylight from that in artificial light. The difference is a measure of the colors of the two light sources. Individual observers also differ in the way they make the match—very markedly if they are color blind or partly so.

"With different proportions of primary colors you get different colors when the wheel is spun. Now if you cover part of the disk with black sectors, the addition of black to the mixture will make the color darker, but the hue will be the same.

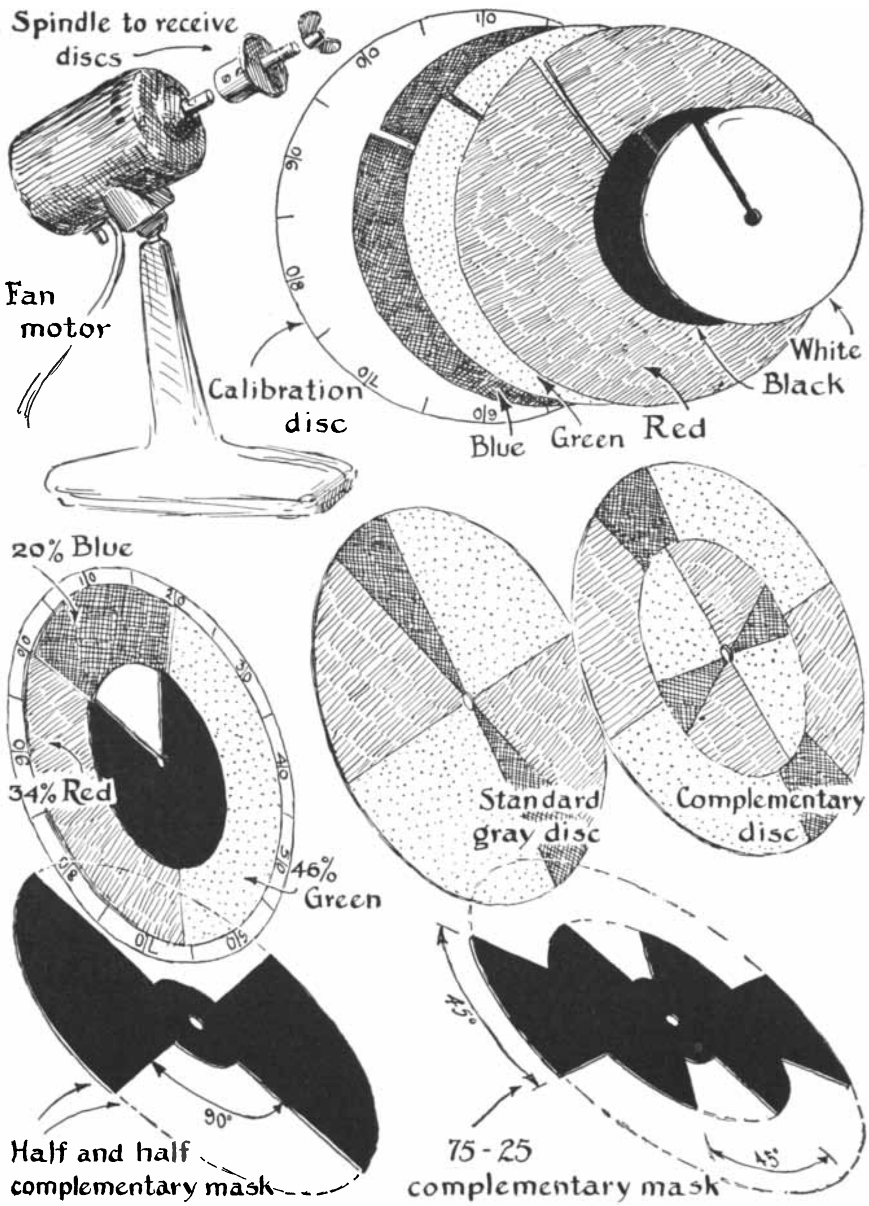
"One can now start reasoning about color. Since the original set of colors makes gray, any two parts of the wheel must be complements. Actually two complementary colors, when mixed, make white, but we get gray in this case because there is some black in the mixture. If we turn the black sector step by step so that it exposes various parts of our color wheel, we can see the whole range of complements. We can display all the complements simultaneously by making a color wheel in two parts, the central area having the color sequence in one position and the outer ring displacing the same sequence by 90 degrees [*detail at right in middle row of drawing*]. When a black mask which leaves only opposite quadrants exposed is placed over the disk, the central color will always be the complement of the outer part. Other masks can be cut to show various combinations of complements and near-complements.

"I have experimented with a number of such combinations to find complements. For example, let the outer section of the wheel be 34 per cent red and 16 per cent green; the inner section, 30 per cent green and 20 per cent blue. The sum of the two sections is 34 per cent red plus 46 per cent green plus 20 per cent blue, which equals 100, or gray. Now the red and green combination in the outer section gives a reddish orange, while the green and blue combination in the inner section gives a blue green. The experiment shows that these two colors, adding up to gray, are complements. Similarly I have found that an apple green composed of 4 per cent red and 46 per cent green is the complement of a reddish purple made of 30 per cent red and 20 per cent blue. A brownish yellow made of 23 per cent red and 27 per cent green complements a purplish gray made of 11 per cent red, 19 per cent green and 20 per cent blue. Note that in this last a mixture of red and green produces a dark yellow. Yellow is not a true primary, despite the contrary teaching of many schools. A mixture of red and green can be matched with a mixture of yellow, black and white (the white being added to dilute the yellow, because Prang's red and green are not as bright as one could wish).

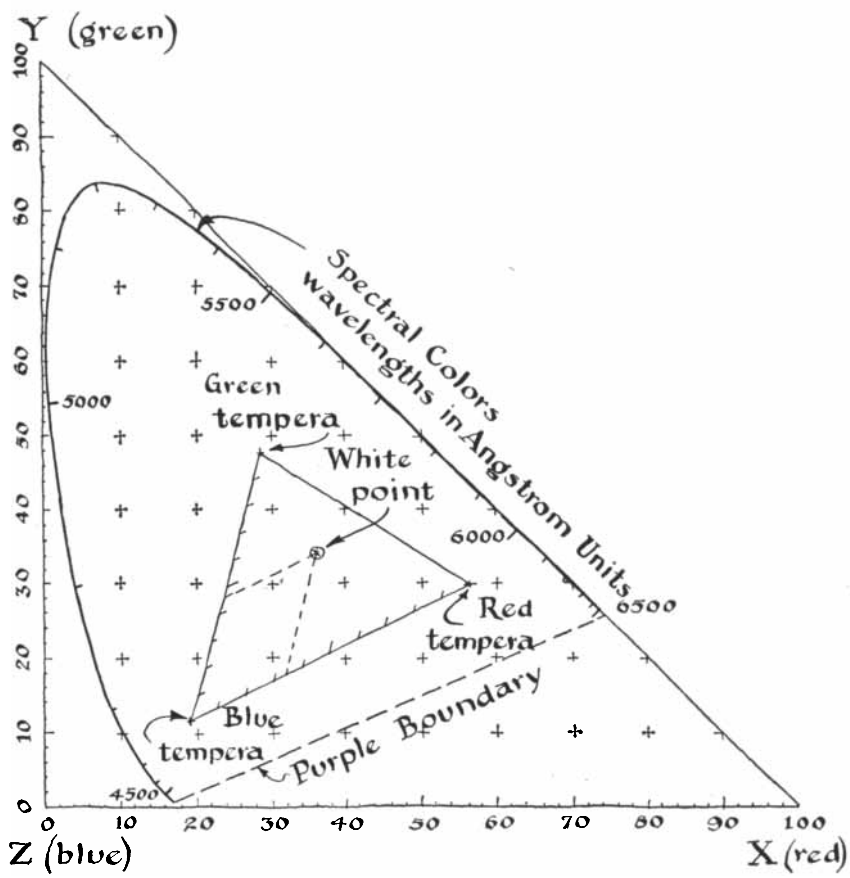
"From the results of color-wheel experiments extending over several years, it seems to me that a possible numerical theory of color harmony can be stated in the following terms: The general formula is that the sum of the components of each color, when multiplied by the fraction of the area of the design which that color is to occupy, should be equal to gray (100). In the simplest case, that of a two-color pattern with each color occupying half the space (*e.g.*, a checkerboard), the sets of color complements given above would yield harmonious combinations.

"Now suppose we have a two-color pattern in which one color is to occupy twice the area of the other. First we select one of the two colors, according to personal taste, and decide that this color will occupy one third of the area. Let us say we select bright green. What color should we choose for the other two thirds to make a harmonious and pleasing pattern? We multiply by three each of the components of gray (34 red, 46 green and 20 blue). This gives us 102 red, 138 green and 60 blue, equaling three times gray. Now we subtract the color-wheel value of our green (100) from the value of three-times-gray and divide the result by two. Thus we get 102 minus zero divided by two, or 51; 138 minus 100 divided by two, or 19; 60 minus zero divided by two, or 30. This gives us the components of the color that will harmonize with bright green in our pattern; the color will be composed of 51 per cent red, 19 per cent green and 30 per cent blue. This color is plum.

"One of the traditional rules of color harmony is that the smaller areas should have the brighter color. Observe that in this example the theoretical working out



A wheel for investigating Hayward's theory of color harmony



Hayward's tempera primaries plotted against spectral colors

of a harmonious complement for bright green did indeed yield a duller color. It is interesting to make experiments with other combinations as a further test of the theory.

"The theory can be applied to combinations of several colors in any given area proportions.

"Suppose, for instance, we want to use four colors in the proportions of 1:2:2:4. Say we select red as the first color, to occupy one tenth of the area, and yellow as the second, occupying two tenths of the area. The third color will occupy three tenths and the fourth, four tenths. The combination as a whole must equal 10 times gray, that is, the primary colors must add up to the proportions 340 red, 460 green and 200 blue. The red component will give us 100 red (100 times 1); the yellow component, 100 red and 100 green (50 red times 2 and 50 green times 2). To obtain the required totals for 10 times gray we need 140 more red, 360 more green and 200 blue. The requirements are satisfied if we use a light blue as the third color, occupying three tenths of the area (180 green and 120 blue), and a light plum as the fourth color for four tenths of the area (140 red, 180 green and 80 blue)."

Hayward recognizes the obvious limitations of his theory. As he points out, it applies only to simple patterns and treats all colors as emotionally equivalent. "Another defect," he writes, "is that it assumes all colors to have approximately the same value whether light or dark. Black may have to be included as a color. Physically black is merely the absence of light, but psychologically it appears to have almost the same properties as any other color. Within these limitations, however, the theory yields quantitative answers to questions in the field of color harmony, however strange it may seem to be working out such schemes with numbers."

The fact that a third book of the *Amateur Telescope Making* series is just off the press may be interesting news for amateur astronomers. The new book's title is *Amateur Telescope Making: Book Three*. "ATM-3," as it will be known to the amateur, is not a revision of *Amateur Telescope Making* (Book One) or of *Amateur Telescope Making—Advanced* (Book Two). It is a generally new work, of 644 pages with 320 illustrations, setting forth new optical projects for the amateur who has made telescopes and learned the feel of optical work. The preface explains:

"The amateur telescope making pursuit began with the simple aim of making telescopes, but in next to no time the nimble-minded people to whom it appealed were running all over the field of precision optics in search of other instruments they could build, while some delved into physical optics to understand its theory, and all to some extent did both. The old demarcation between amateur and professional optics receded, became blurred or vanished. Neither can that demarcation be found in the present volume, which is for all who are interested in optics, though essentially for amateurs. Some of its authors are amateurs, some are professionals who began as amateurs and have remained so in their spirit of enthusiasm, and a few are professionals who never were amateurs but nevertheless have fun with optics.

"Some of the chapters describe projects and procedures, others techniques, others tests, others professional methods adaptable to amateur use; still others the design of telescope lenses by professional methods, including ray tracing, made lucid by sympathetic writers who have striven not to 'keep 'em mystified.' There are chapters on the selection of lenses, plates and films for astronomical photography, and on the construction of lens systems for the same purpose. Others are on the construction of spectrographs, a spherometer, a precise photoelectric photometer for variable-star work, a monochromator for solar observation, and on the mechanical understanding, complete overhaul and accurate adjustment of binoculars. A chapter explains the design considerations for eyepieces, describes 91 eyepiece types and includes the specifications for 39 eyepieces. Another is on the understanding of diffraction. Others are on the Barlow lens, optical flat making, Schmidt camera making and making elementary camera lenses, lens production on a small professional scale, coating of lenses and aluminizing of telescope mirrors, building and using an optical testing bench, preparing scratchless optical abrasives, a null test and an ultraprecise test for mirrors, and a procedure for designing a Maksutov Herschelian telescope. An innovation is a brief, intimate biography of each contributor, from which the reader may discover human interest that should increase his enjoyment of the book."

James G. Baker, who made a three-inch telescope lens from a glass bathroom shelf when in high school and is today a noted optical designer, gives complete data on making two optical systems for astronomical photography. The first is a detachable correcting lens which converts a photographically narrow-field paraboloidal telescope into a wide-field photographic telescope that gives full Schmidt performance—anastigmatic—and will photograph stars clear out to the 18th magnitude. The second is a three-inch (six-inch if desired) Cooke triplet lens of high quality and light-gathering power. Data for two designs are given, one for blue-violet (photographic), the other photo-visual. Detailed plans for the lens mounts are included.

Earle B. Brown of the Farrand Optical Company, who began as an amateur, writes understandingly of amateurs' problems in building and using high-vacuum equipment for aluminizing mirrors and coating lenses. To his fellow "T.N.s" (telescope nuts—the amateurs' own name for themselves) he writes: "Not the least of the appeal of high vacuum to the T.N. is its natural perversity. Compared to a high-vacuum system, the most recalcitrant optical surface is a paragon of meek submissiveness. This sort of thing makes raving maniacs of most people, but T.N.s are of the peculiar breed of cat that thrives on frustrations." Fully to describe all the techniques of vacuum practice would call for an entire shelf of literature, to which Brown gives references in an ample bibliography. Following the policy of the ATM series, the names and addresses of the sources of all the materials needed are included.

During the entire life of the amateur optical hobby there has existed virtually no practical literature on spectrograph construction. Therefore 80 pages of ATM-3 are devoted to that subject. In one chapter the physicist C. Fred Clarke describes in minute detail, with scale drawings, the construction of a laboratory spectrograph with a small replica grating of 106 centimeters focal length mounted on an old 54-inch lathe bed. In another, Strathmore R. B. Cooke and Robert A. Wilson describe in equal detail the design and construction of a larger laboratory spectrograph using a small grating of five-foot focal length. Such instruments, if bought ready-made, would cost several thousand dollars. If well constructed, they are capable of professional chemical analysis. Several smaller spectrographs are described in the spectrograph section of the book.

R. E. English, a professional maker of optical flats who began as an amateur, describes his method of making flats having an accuracy of one five-millionth of an inch.

Patrick A. Driscoll once coined the descriptive term "amateur-professional-amateur" for the amateur who has become a professional but nevertheless remains an amateur in the original sense of the word (lover). In a detailed chapter the amateur-professional-amateur optical workers Fred Ferson and Peter Lenart, Jr., fully describe lens production on a limited scale in a professional plant. Their contribution has three special values to the amateur. The methods are applicable to small production runs in the hobby shop; the description satisfies amateur curiosity about professional methods, and, best of all, it contains numerous details and insights having direct applicability to the one-piece work that amateurs do.

Irvine C. Gardner's instructions permit the worker to build a special spherometer for precise measurement of the curvature of small short-focus lenses such as eyepiece lenses.

The "G-sum" method of designing achromatic objective lenses is described by Alan E. Gee of the Frankford Arsenal. His algebraic method is a little more difficult than those of Ellison and Haviland, but it gives full control over spherical aberration and sometimes over coma. It more nearly approaches the exactness of ray tracing.

Practical literature on binoculars up to now has been virtually non-existent. In World War II, G. Dallas Hanna, a California Academy of Sciences paleontologist with a flair for the mechanics of precision instruments, headed a group of amateurs who were making roof prisms until they were discovered by the U.S. Navy and asked to recondition its optical instruments. They reconditioned 6,000 Navy binoculars. In ATM-3 Hanna records all that he learned, not alone on the overhaul and exact adjustment of binoculars but on their basic principles. Hanna explains those basics clearly. He also gives instructions for building, around a telescope mirror, an autocollimator for testing the prisms used in binoculars, as well as other prisms.

Lives there an amateur telescope maker who has never been baffled or driven to desperation by mysterious scratches that appear on his optical surfaces while he works them? Hanna discovered a major cause of the scratches. Agglomeration of the fine abrasive grains strongly held together produces large grains called "cobblestones." Many discouraged workers have tried separation of grain sizes by washing, but as Hanna states, segregation is not that easy. A dispersing agent, or deflocculent, is necessary. He and the amateurs who kept his wartime workers supplied with optical surfaces developed a technique for breaking the powerful attractive forces that clump the grains. This requires only two jars, a chemical and a siphon. He writes: "We use our abrasive alongside roughing mills and never take any precautions such as taking a bath before fine grinding, yet it has been a long time since any of us has had scratches on glass."

While excellent Barlow lenses are on the market, an amateur may be prouder of his Barlow if he designs and builds it himself. In his chapter on the Barlow lens C. R. Hartshorn tells how.

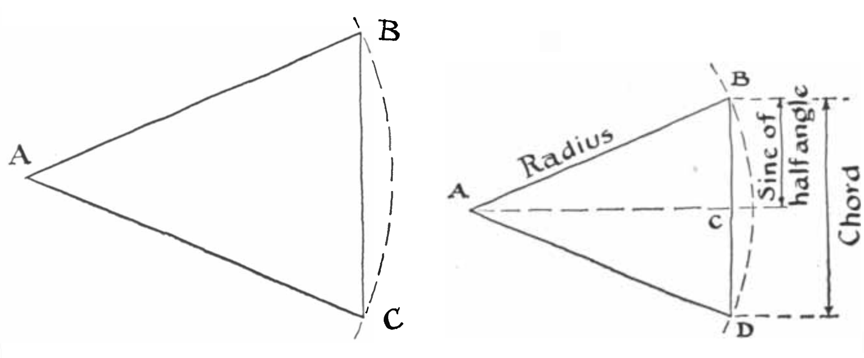
The photoelectric photometer is becoming a must for scientific variable-star observing, and it has other uses. Gerald E. Kron of Lick Observatory (another amateur-professional-amateur) minutely gives data for building two amplifiers for use with them—one for battery current, the other for lighting current. He also provides a lead to a source of inexpensive instructions for building the photometer.

In a chapter on lenses for astronomical photography and another on plates and films Henry E. Paul distills his extensive experience with both, saving the reader from making the standard expensive mistakes and enabling him to become expert relatively early.

Amateurs have made relatively few Schmidt cameras, largely because of the scarcity and inaccessibility of practical instructions. They have clamored for such instructions for years. Paul's Schmidt chapter should give the Schmidt a new birth. He demonstrates the optimum focal ratio for Schmidts and describes the construction. He includes a test for the deep sphere which will be new to most, and tells a new method of figuring correcting plates. He lists the best half-dozen of hundreds of existing articles on the Schmidt. These articles are reprinted in the book. An editor's note explains: "Theoretically the articles cited in the preceding selected bibliography are available to everybody. You just drop in at a large public library and read them to your heart's content. Actually, this would be so difficult for most of the owners of this book that the articles might almost as well not exist. Even if you knew of a library that had them all, you'd probably have to travel some distance and snatch at the articles and you couldn't take them home with you. What you want is something that's yours, at home, where you can refer to it whenever you feel like it." The reprinted articles include two by British authors on figuring correcting plates and on the construction of a whole Schmidt, and the classic Mount Wilson Optical Shop piece on 18 unconventional types of Schmidts and on the design of correcting plates. The Schmidt section also has an intimate biography of Bernhard Schmidt himself—the eccentric bachelor with only one hand who always worked in a claw-hammer cutaway coat and striped trousers, chain-smoked cigars and cared more for schnapps than for money. A translation of Schmidt's own classic paper is included in the reprints.

A description of every detail of the construction of Henry E. Paul's most recent quartz polarizing monochromator for solar prominence observation, written by him immediately after he had finished it, while the job was still "warm," is included in this volume. It is followed by Edison Pettit's classic paper, which he has revised and expanded, on the interference polarizing monochromator.

Irwin H. Schroader describes a test which not only detects but actually measures errors as small as one five-millionth of an inch on a telescope mirror. Those who argue that this is finer precision than is needed overlook two facts: first, that one of the mainsprings that drive the telescope maker is the enjoyment derived from the highest possible mechanical precision; and second, that extreme precision *is* significant in resolving fine detail on the planets and moon; the higher the precision, the better the resolution. The tests described by



The chord of the arc BC equals twice the sine of the half angle

What means most to an Engineer?

PROFESSIONAL RECOGNITION

GOOD SALARY

UNEXCELLED FACILITIES

SUBURBAN LIVING

A Career at RCA offers all Four!

RCA offers opportunities now—real career opportunities—for qualified ELECTRONIC, COMPUTER, ELECTRICAL, MECHANICAL and COMMUNICATIONS ENGINEERS . . . PHYSICISTS . . . METALLURGISTS . . . PHYSICAL CHEMISTS . . . CERAMISTS . . . GLASS TECHNOLOGISTS.

Positions are open in research, development, design and application. Long range work in many fields is being carried on both for commercial developments and military projects for war and peace.

At RCA you'll work in an exciting professional atmosphere, with technical and laboratory facilities unsurpassed anywhere in the radio-electronic industry. You are in close and constant association with leading scientists and engineers. Individual accomplishment is not only recognized, it is sought out. Delightful suburban living is easily available for your family. And there's ample opportunity for income and position advancement.

Plus, Company-paid hospitalization for you and your family . . . accident and life insurance . . . progressive retirement plan . . . fine recreational program . . . modern tuition-refund plan at recognized universities for advanced study.

Join the team at RCA, world leader in electronic development, first in radio, first in recorded music, first in television. Rest easy in the knowledge that your future is secure, the rewards many and varied.

Personal interviews arranged in your city.
Please send a complete resume of your education and experience to:

MR. ROBERT E. McQUISTON, Manager
Specialized Employment Division, Dept. 201K
Radio Corporation of America
30 Rockefeller Plaza, New York 20, N.Y.

***Positions Open In*: RESEARCH—DEVELOPMENT—DESIGN—APPLICATION**
in any of the following fields:

RADAR—Circuitry—Antenna Design—Servo Systems—Information Display Systems—Gear Trains—Stable Elements—Intricate Mechanisms

COMPUTERS—Digital and Analog—Systems Planning—Storage Technique—Circuitry—Servo Mechanisms—Assembly Design—High Speed Intricate Mechanisms

COMMUNICATIONS—Microwave—Aviation—Mobile—Specialized Military Systems

MISSILE GUIDANCE—Systems Planning and Design—Radar and Fire Control—Servo Mechanisms—Vibration and Shock Problems

NAVIGATIONAL AIDS—Loran—Shoran—Altimeters—Airborne Radar

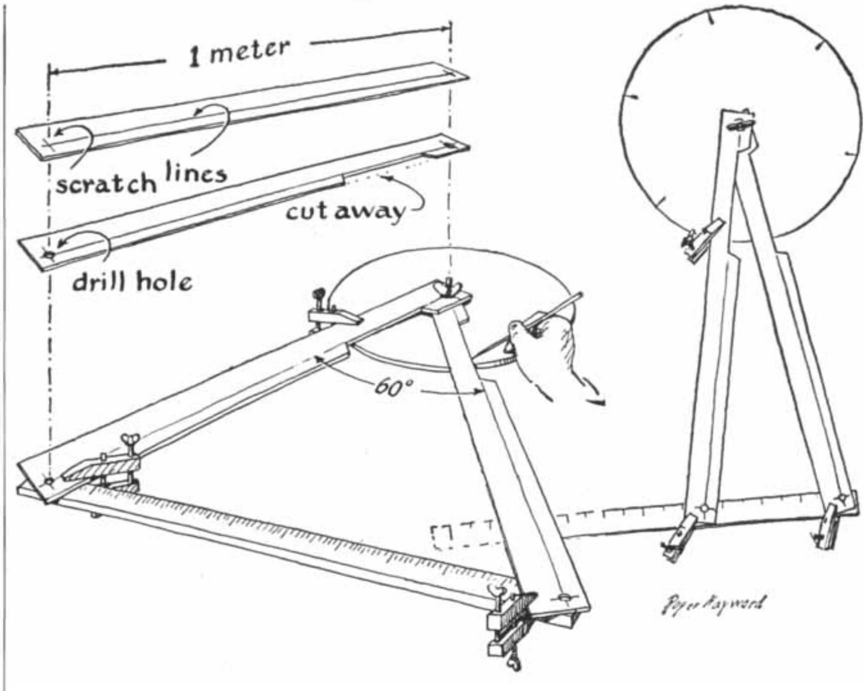
TELEVISION DEVELOPMENT—Receivers—Transmitters and Studio Equipment

COMPONENT PARTS—Transformer—Coil—Relay—Capacitor—Switch—Motor—Resistor

ELECTRONIC TUBE DEVELOPMENT—Receiving—Transmitting—Cathode-Ray—Phototubes and Magnetrons

ELECTRONIC EQUIPMENT FIELD ENGINEERS—Specialists for domestic and overseas assignment on military electronic communications and detection gear.

RADIO CORPORATION of AMERICA



Laying out a telescope setting-circle

Schroader are at their best on short-focus mirrors.

No telescope maker can become an advanced amateur until he has learned what diffraction is. Horace H. Selby describes it in a chapter titled "Interference of Light." He explains diffraction in elementary terms and interprets the various edge appearances of a mirror and their causes by means of a diagnostic table. In another chapter Selby shows drawings of the 91 types of eyepieces and gives specifications for constructing 39 of them. In a third he describes a homemade optical bench with which you can mount lenses of all kinds, even complete telescopes, in proper and variable relationship to one another for analysis, demonstration and testing. Bench methods are rapid, direct and fundamental, and put an end to guesswork.

Thousands of telescope makers have clamored for years for instructions for making their own camera lenses. The amateur-professional-amateur James W. Shean of the Bausch & Lomb Optical Company has supplied instructions and data for making a number of these lenses. The ultimate effect of his chapter should be the enlargement of the amateur optical hobby by a substantial new wing.

A chapter by Charles L. Woodside describes a method by which an objective lens may be computed from glasses having unknown constants.

Franklin B. Wright gives a procedure for designing and building a superb Herschelian telescope having a Maksutov lens.

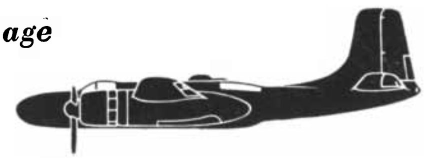
The last word in optical exactness is ray tracing by trigonometric methods. Most amateurs have believed it beyond their ken—mainly, perhaps, because no book treating it sympathetically has existed. In a detailed chapter James H. Wyld robs "ray trace" of its mathematical mystery, leads the tyro by the hand and shows that the bogey is largely a myth. The requisites for ray tracing are patience, persistence, accuracy, a knowledge of common algebra and a little trigonometry—far less than is given in high-school courses. Wyld writes: "The amateur telescope builder who takes a real pride in exact workmanship, and who wishes to keep his theoretical design studies on the same high plane as his practical work with glass, pitch and rouge, will find a great mental satisfaction in carrying out his designing by exact ray-trace methods; he will furthermore develop an invaluable insight into the whole subject of theoretical optics which no amount of book study can supply."

The last chapter of ATM-3 contains the editor's informal biographies and snapshots of the contributors. Throughout the book are innumerable side observations which should illuminate many puzzles that bedevil optical workers.

Six methods of dividing a circle into degrees for setting circles on telescopes are described in *Amateur Telescope Making—Advanced*. T. R. Macfarlane of Regina, Saskatchewan, now adds a seventh. His method is based on

World War II Veteran

holds its own in the new jet age

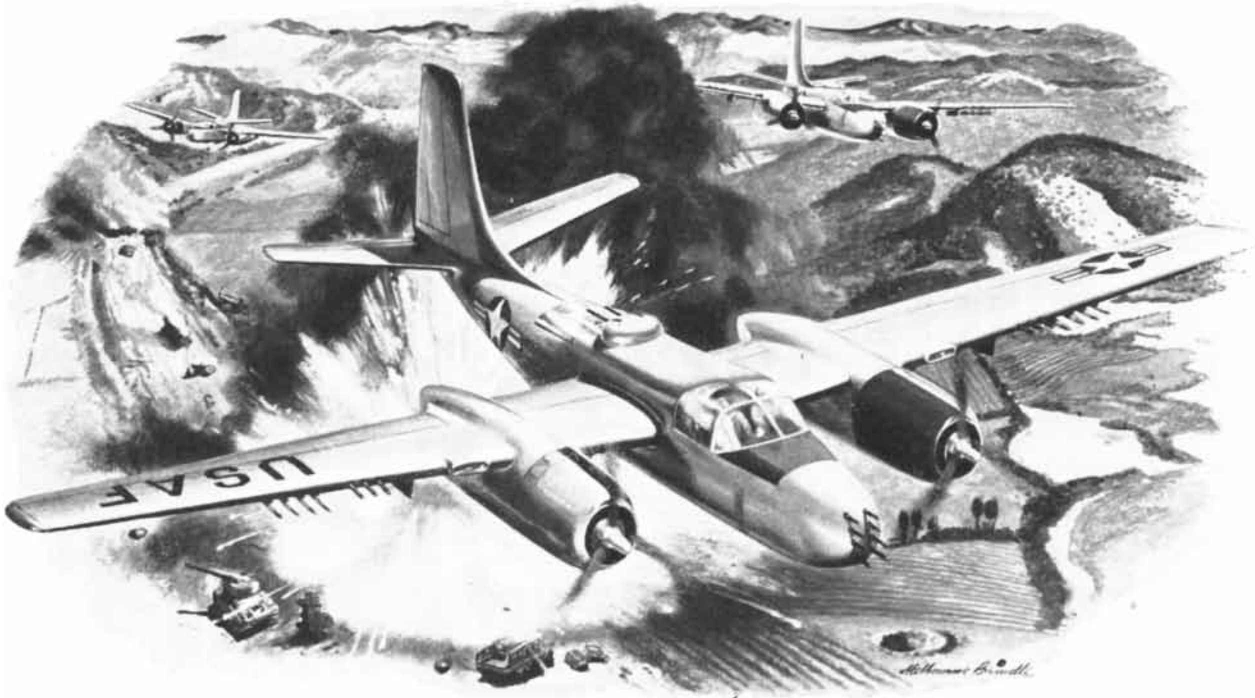


the Douglas B-26 Invader

During World War II, over both Europe and the Pacific, the Douglas B-26 Invader spearheaded major allied advances. It was still the standard USAF light bomber when war broke out in Korea.

Laminar-flow, high-speed wing design gives Invader the speed and maneuverability of a piston-engine fighter. With 3-man crew and 6,000-lb. bomb load, combat radius is over 900 miles. Firepower is crushing... sixteen .50 caliber machine guns, fourteen of them in the nose and wings. In Korea, despite the advent of fast new jets, Invader's agility and heavy armament have made it a mainstay in advanced, low-level ground support of our troops.

Performance of the B-26 Invader is another example of Douglas leadership. *Faster and farther with a greater payload* is a basic rule of Douglas design.



Enlist to fly in the U. S. Air Force

Depend on *DOUGLAS* **First in Aviation**

the tables of chords of arcs used by some engineers, architects and mechanics. Each angle is represented by a decimal fraction. To lay off an angle you multiply the fraction by the radius of the circle, which gives you the chord. For example, .5345 corresponds to 31 degrees, and to inscribe a 31-degree angle on a circle eight inches in diameter, you multiply .5345 by the radius, four. The product, 2.138, is the number of inches in the chord for the arc of this angle [*see drawing at left on page 116*]. Roger Hayward points out that if no table of chords is available the answers may still be derived from a table of sines. The chord is equal to twice the sine of half the angle [*drawing at right on page 116*].

Since the arithmetical work needed for converting decimal fractions of an inch is laborious, it is easier to use a metric scale, laid off in decimal fractions. Macfarlane describes the procedure as follows [*see drawing on page 118*].

"Drill a small hole neatly in a sheet of metal. With this as a center cut a circle of size desired.

"Provide two flat strips of metal a bit over a meter in length and a one-meter steel rule.

"Scratch a clean straight line on each of the strips, near one edge, as shown in the third drawing.

"Carefully measure one meter along these lines, mark the points and drill holes in both strips.

"Cut away the sides of the strips back to the scratched lines to give access to the radius of the circle.

"Bolt the strips to the circle, mark the starting point with one strip, swing the other until the meter rule has the correct length of chord for the desired angle. As an example, 60 degrees calls for a chord of exactly one meter, 90 degrees for 1.414 meter.

"As a preliminary practice run, to test your precision before inscribing any lines, cut the zero scratch, mark the 60-degree line with a fine pencil point, start at this point for a new 60-degree point and continue around the circle to see how nearly you close after the six measurements with their random and systematic errors. If you come out precisely enough to satisfy your requirement, reset at the zero point and make needle scratches to be cut as coarse as needed for legibility."

Hayward, a fine mechanic, points out that the precision of the method is limited by the precision with which the bolt holes are positioned (drills always wander a little from a centerpunch mark) and by the precision with which the bolt fits the holes.

INDEX OF ADVERTISERS

NOVEMBER, 1953

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful. The lists are not intended as bibliographies of source material for the articles. The references selected will provide supplementary information.

TRADE WINDS

THE BIRTH AND DEATH OF A CUMULUS. Joanne Starr Malkus in *Weatherwise*, Vol. 3, No. 3; June, 1950.

CLOUD STREETS. R. S. Scorer in *Gliding*, Vol. 3, No. 4, page 167, 1952.

CONVECTION IN THE ATMOSPHERE. F. H. Ludlam and R. S. Scorer in *Quarterly Journal of the Royal Meteorological Society*, Vol. 79, No. 341, page 317; July, 1953.

CUMULUS, THERMALS, AND WIND. Joanne Starr Malkus in *Soaring*, Vol. 13, pages 6-12, 1949.

THE JET STREAM. Jerome Namias in *Scientific American*, October, 1952.

ON THE ROLE OF THE TROPICS IN THE GENERAL CIRCULATION OF THE ATMOSPHERE. H. Riehl in *Tellus*, Vol. 2, No. 1; February, 1950.

RECENT ADVANCES IN THE STUDY OF CONVECTIVE CLOUDS AND THEIR INTERACTION WITH THE ENVIRONMENT. Joanne Starr Malkus in *Tellus*, Vol. 4, No. 2; May, 1952.

SOARING IN SPAIN, 1952. R. S. Scorer in *Weather*, Vol. VII, No. 12, page 373; December, 1952.

TROPICAL METEOROLOGY. Herbert Riehl. McGraw-Hill Book Company, Inc., 1954.

SCINTILLATION COUNTERS

SCINTILLATION COUNTER SYMPOSIUM. *Nucleonics*, Vol. 10, Nos. 4-8; April-August, 1952.

SCINTILLATION COUNTER SYMPOSIUM. *Science*, Vol. 115, pages 491-492; May 2, 1952.

A FORGOTTEN EMPIRE OF ANTIQUITY

ANCIENT INDIA. *Bulletin of the Archaeological Survey of India*, No. 1, 1946.

NEW LIGHT ON THE MOST ANCIENT EAST. V. Gordon Childe. K. Paul, Trench, Trubner & Co., Ltd., 1934.

PREHISTORIC INDIA. Stuart Piggott. Penguin Books, 1950.

REVEALING INDIA'S PAST. Edited by Sir

CONCERT HALL QUALITY

...in your own home

Since the early days of recorded sound audio engineers and music lovers have looked forward to the day when concert hall quality and fidelity could be enjoyed in the home. The contribution of Altec engineers to the realization of this dream has been a major one.

Altec pioneered in the development and perfection of high-quality loud speaker systems for theatres. Calling upon their experience and their unmatched skill, Altec developed the first complete home music system. Today in the rapidly expanding high fidelity market, Altec equipment is still the finest for quality and dependability.

From the study and use of sub-audible sounds to the charting and analysis of overwhelming sounds, to the achievement of the highest fidelity in recorded sound production, sound is the province of Altec. The demand for Altec home music systems is so great that in many parts of the country there is a shortage of this superlative equipment. Don't compromise with quality in filling your needs. Ask for Altec ...the name you can depend on for the finest.

ALTEC LANSING CORPORATION

ALTEC SERVICE CORPORATION

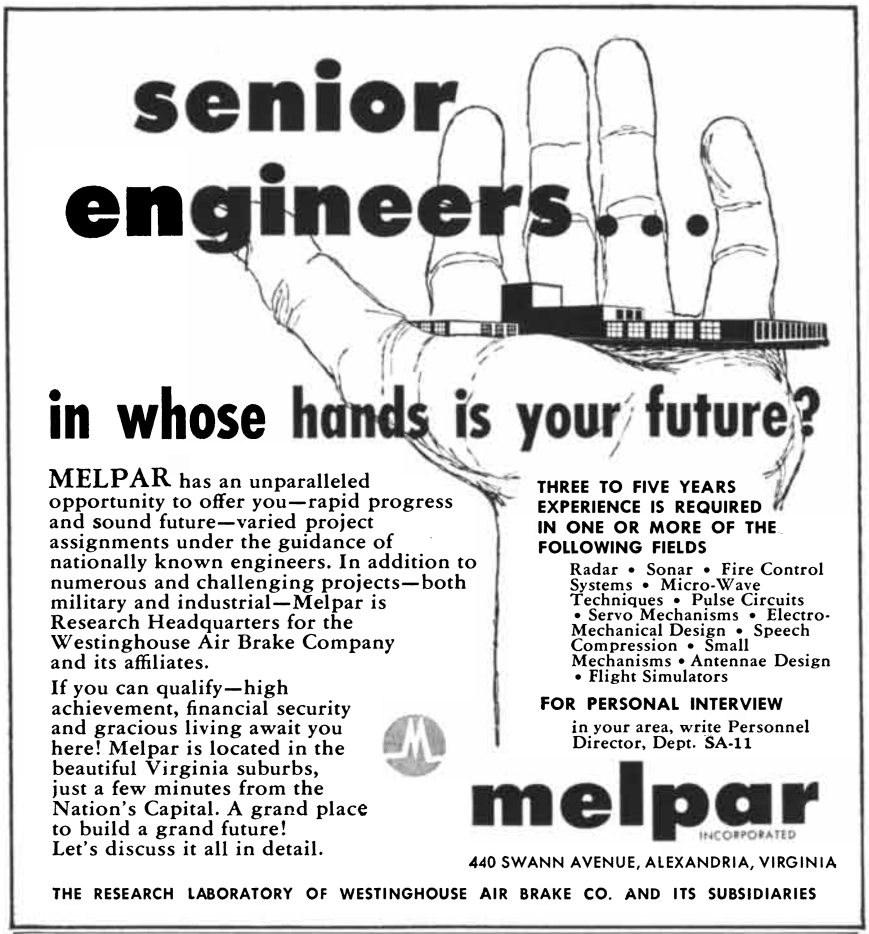
PEERLESS ELECTRICAL PRODUCTS

THE ALTEC COMPANIES

SPECIALISTS IN SOUND

9356 SANTA MONICA BLVD., BEVERLY HILLS, CALIF.

161 SIXTH AVENUE, NEW YORK 13, N.Y.



John Ghest Cumming. The India Society, 1939.

SOME ANCIENT CITIES OF INDIA. Stuart Piggott. Oxford University Press, 1945.

THE GAS TURBINE

PRINCIPLES OF JET PROPULSION AND GAS TURBINES. M. J. Zucrow. John Wiley & Sons, Inc., 1948.

HOW CHILDREN FORM MATHEMATICAL CONCEPTS

THE CHILD'S CONCEPTION OF PHYSICAL CAUSALITY. Jean Piaget. Harcourt, Brace and Company, 1930.

THE CHILD'S CONCEPTION OF THE WORLD. Jean Piaget. Harcourt, Brace and Company, 1929.

JUDGMENT AND REASONING IN THE CHILD. Jean Piaget (in collaboration with Mlles E. Cartalis, S. Escher and others). Harcourt, Brace and Company, 1928.

PROGRESS IN PHOTOSYNTHESIS

PHOTOSYNTHESIS AND RELATED PROCESSES. Eugene I. Rabinowitch. Interscience Publishers, Inc., 1945.

PHOTOSYNTHESIS AND RELATED PROCESSES. Eugene I. Rabinowitch. Interscience Publishers, Inc., Vol. II, Part 1, 1951.

PHOTOSYNTHESIS. Walter Stiles. Longmans Green, 1925.

PHOTOSYNTHESIS. Herman Spoehr. American Chemical Society Monograph Series, 1926.

OYSTERS

RECENT ADVANCES IN OYSTER BIOLOGY. P. Korringa in *The Quarterly Review of Biology*, Vol. 27, pages 266-328, 339-365.

G. F. FITZGERALD

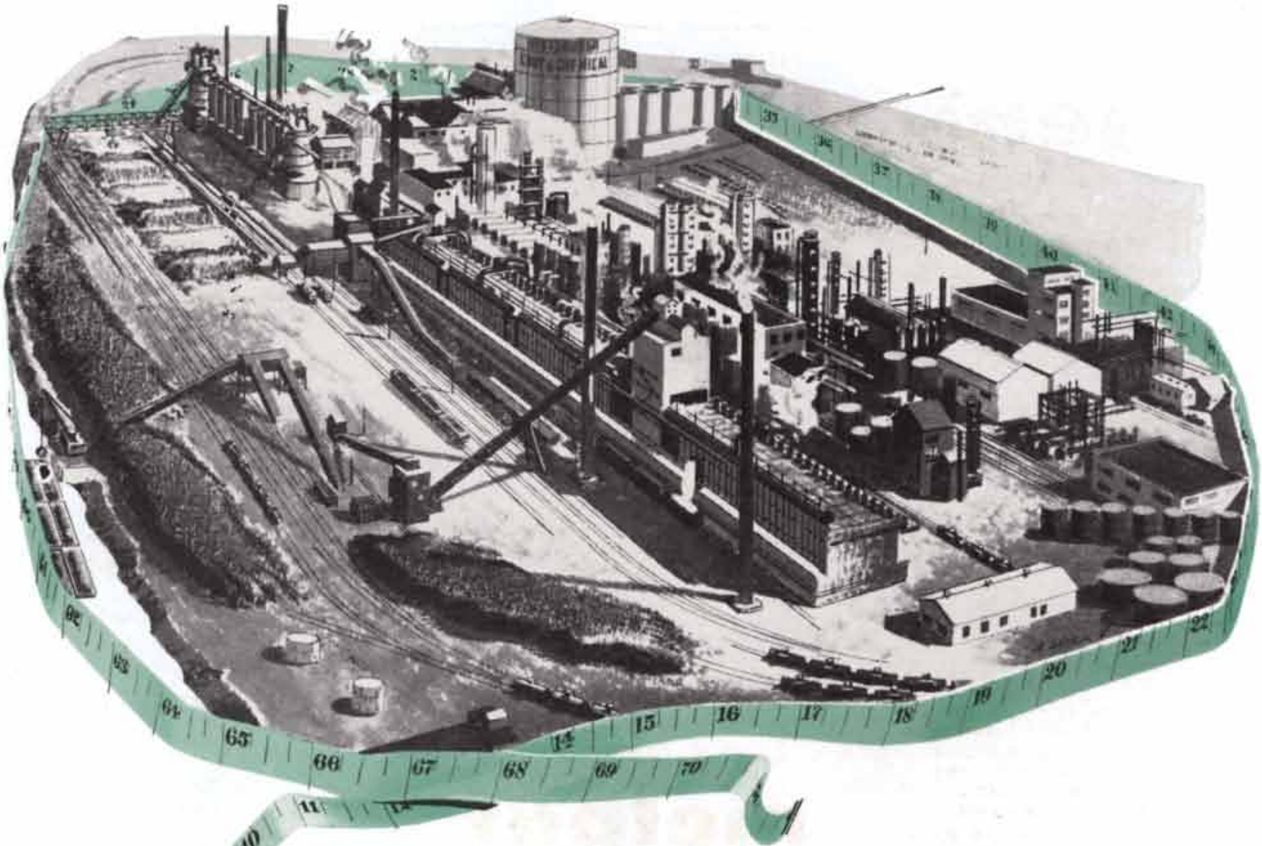
THE SCIENTIFIC WRITINGS OF THE LATE GEORGE FRANCIS FITZGERALD. Dublin University Press Series, 1902.

THE AMATEUR SCIENTIST

COLOR: IN THEORY AND PRACTICE. H. D. Murray. Chapman and Hall, 1952.

AMATEUR TELESCOPE MAKING. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

AMATEUR TELESCOPE MAKING—ADVANCED. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.



You can measure integration in YARDS

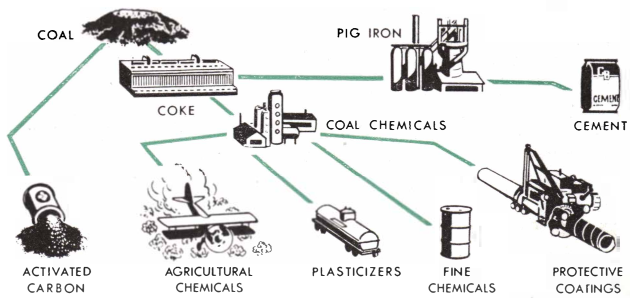
at PITTSBURGH COKE & CHEMICAL

YARDS . . . steps . . . or a stone's throw. Measure it as you will. The operation of Pittsburgh Coke & Chemical's Neville Island plant adds up to one of the most highly integrated manufacturing plants in the world today.

Within a few hundred yards . . . within a few dozen hours . . . this plant transforms small mountains of coal into insecticides, dyes, pig iron, cement and a score of other coal-derived or coal-related products that serve American industry and agriculture.

Is integration so highly developed as this *really* important? We think it is . . . and so do Pittsburgh Coke & Chemical customers. Because it enables us to keep an engineering finger on quality at *every* step of production, and to provide our customers with a reliable continuity of supplies that can stem only from an operation that's genuinely basic. *Aren't those the assurances you want, too?*

W&D 4729



PITTSBURGH
COKE & CHEMICAL CO.
Grant Building • Pittsburgh 19, Pa.

Photograph by Howard Luray

MAKE WAY FOR CONSTRUCTION!

If you want to see a typical example of American skill, energy and enterprise at work, take a look around your community. Chances are you will see several types of new construction going on.

The dynamic construction industry, working with improved methods and equipment, is building America at an unprecedented rate. Construction of housing, highways, public utilities, public buildings, airports, industrial plants and other projects has increased until the total has reached a volume of over thirty billion dollars a year!

The construction industry has also contributed to the growth and progress of American Cyanamid Company as a leader in the chemical field. Several new Cyanamid plants, offices, warehouses and other facilities are now being built or have recently been completed. These will help Cyanamid supply additional materials and services to more than 200 industries which, in turn, manufacture products used in building and construction. Here is another example of how American business works to strengthen and expand our national economy.

AMERICAN *Cyanamid* COMPANY

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.