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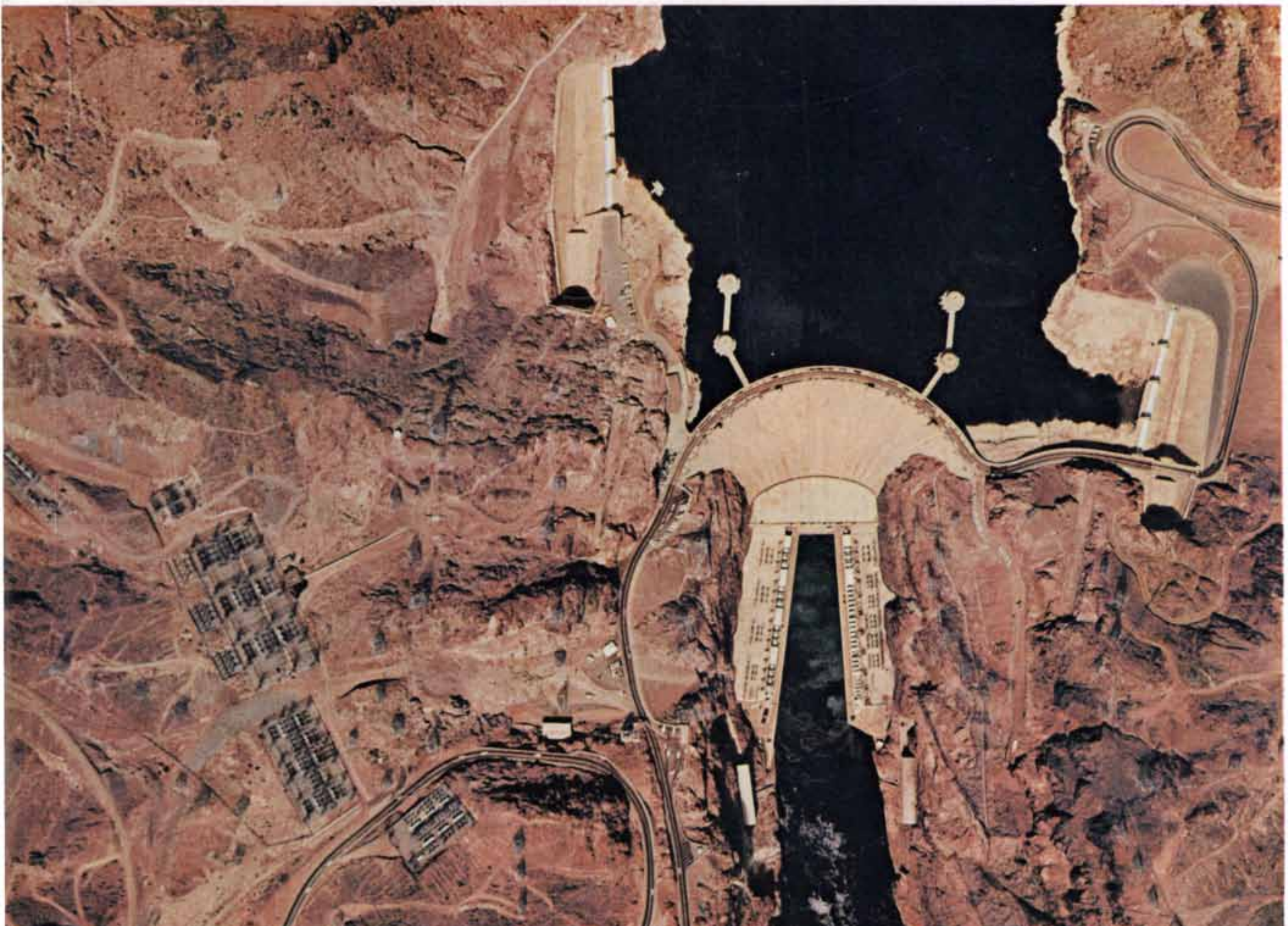
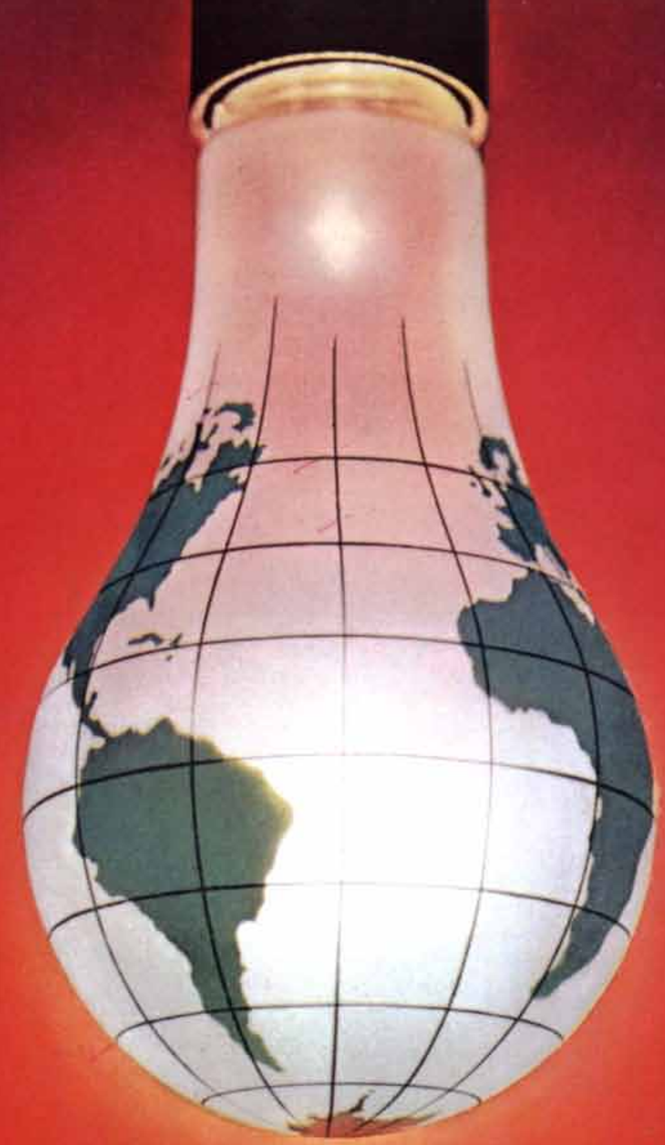


TECHNOLOGY AND ECONOMIC DEVELOPMENT

FIFTY CENTS

September 1963



VARIAN INSTRUMENTS AT WORK

VARIAN associates
INSTRUMENT DIVISION, PALO ALTO, CALIFORNIA
IN EUROPE: VARIAN A.G., ZUG, SWITZERLAND

Electromagnets, frequently the heart of a physics experiment, often thwart the efforts of experimenters by varying their field strength randomly

with changes in ambient temperature and line power, or with the placement of the experiment in the air gap. These deviations are most obvious and troublesome during experiments which require a high degree of field stability or linearity of field sweep.

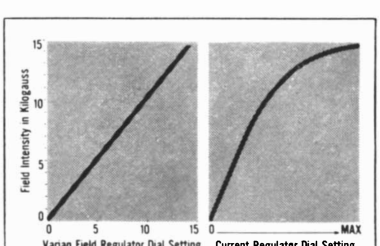
Varian's new FIELDIAL* magnetic field regulator virtually eliminates these frustrating field shifts. It also provides more than an order of magnitude improvement in the stability and control of the magnetic field compared with conventional current regulation methods.

FIELDIAL regulators employ feedback from a sensor located in the magnet air gap to control magnet current input, thereby reducing unwanted fluctuations to zero almost instantly. This unique sensor, based on the well-known Hall-effect principle, is the result of an extensive crystallography research program at Varian.

In addition to improving internal field control, the FIELDIAL regulator (as its name implies) provides direct dialing and digital readout of the desired field intensity. It also permits linear field sweeps despite non-linear current input. Field values dialed yesterday or last year can be repeated with the assurance that hysteresis will not affect field values selected.

The FIELDIAL regulator is compatible with previous Varian electromagnets, thus making the instrument available for conversion of existing systems. Bob Abler, Instrument Magnet Products, has a new brochure if you wish further information.

*TM Varian Associates



Atomic clocks, whose precision and stability are unsurpassed in the world of measurement, are an outstanding example of how basic scientific

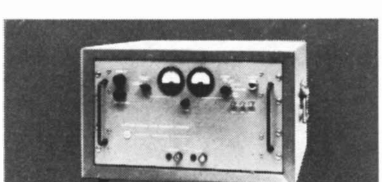
principles translate into practical instruments.

Varian scientists started with a complex laboratory experiment which was evolved into our rubidium vapor frequency standard. In this instrument, electron transfer between energy levels is monitored during optical pumping. These transition frequencies are so stable that they provide an ultra-reliable reference against which crystal oscillators are calibrated. Formerly, these crystal oscillators were the last word in frequency control.

To evolve a routinely produced instrument from this elaborate prototype was a taxing but scientifically rewarding challenge. The result was that today rubidium frequency standards are performing impressively in many critical applications which involve measurement and control of time and frequency.

Missile tracking and timing systems use them to recover range and velocity data on deep-space probes; VLF propagation studies and communications control systems find them helpful; they are also valuable as laboratory standards because they give drift-free stability (parts in 10^{11}) and have the reliability of proven solid-state systems.

Frequency comparison is now the most precise method for making physical measurements; atomic standards are the best way to compare frequencies. Naturally, these precise instruments demand sophisticated circuitry and packaging techniques and, as a result, cost more than typical crystal units. Scientists who make measurements in fields which demand exceptionally high accuracy are convinced that the results justify the expense. Gordon Harper, Instrument Special Products, will gladly tell you more.



The chemistry of a product often determines how durable it will be, how effective, even how safe for human use. Hundreds of examples immedi-

ately come to mind in the areas of food products, drugs, paints, oils, insecticides, and fertilizers.

Manufacturers must strive constantly to eliminate any chance of error in chemical composition. Ethics, competition, certain patents, and often government regulation demand rigid quality control.

Research chemists have long used the analytical capabilities of Nuclear Magnetic Resonance (NMR) to identify the precise chemical structure of compounds by determining the number and location of hydrogen atoms within the molecule.

Scientists recognized that the same techniques could be used to monitor finished products, but that this would put too large a work load on the research instrument. Varian therefore developed the A-60 Spectrometer as a less expensive instrument designed specifically to handle fast, routine, non-destructive analyses.

With the easy-to-operate A-60, results are reproduced on pre-calibrated charts, so that technicians can perform hundreds of analyses a day and check the readings against known spectra.

You can see the A-60 at work in any of our three Applications Laboratories located in Pittsburgh, Pa.; Zurich, Switzerland; and Palo Alto, Calif. For more information briefly describe your interest in a letter to Wayne Lockhart, Analytical Instruments.

only the language changes!

assicurazione di qualitá . . . qualité assurée . . . waarborg voor kwaliteit . . . calidad segura . . . calidad asegurada . . .

"Quality assurance" has the same precise meaning in Texas Instruments plants around the world, regardless of the language spoken in the area they serve. Rigid emphasis on reliability and quality assurance procedures is part of every step from processing of basic material to final life-tests of finished products. In TI's 10 international plants as in its Kentucky, Texas and Massachusetts facilities, these strict quality control procedures serve as the common denominator in assuring identical quality from plants continents apart.

For example, electrical controls produced in Italy meet the same stringent requirements imposed by automatic test equipment as do their counterparts manufactured in Argentina, Australia, Brazil, Canada, France, Holland, Mexico, and the U.S.A. This demand for strict attention to product quality has kept pace with the planned expansion of TI's international manufacturing operations.

Although Texas Instruments has served international customers for more than 30 years through its geophysical exploration activities, it was only in late 1957 that it established its first overseas semiconductor manufacturing facility, in Bedford, England. Now, less than six years later, TI facilities outside the U. S. consist of manufacturing plants in nine countries.

Overseas support for both domestic and international activities is maintained by 39 Texas Instruments sales and operations offices in 23 countries. TI products range from basic materials, electronic components and systems to worldwide services — including electrical circuit design assistance, technical consultation and training, and application of the earth sciences for government and industry.

For information how these TI capabilities can help you please write to Information branch.

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Established 1845 **SCIENTIFIC AMERICAN** September 1963 Volume 209 Number 3

ARTICLES

DEPARTMENTS

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THE COVER

The aerial photograph on the cover symbolizes the theme of this issue of SCIENTIFIC AMERICAN: technology and economic development. The photograph shows the great semicircle of Hoover Dam, on the Colorado River 250 miles northeast of Los Angeles. The black area above the dam, which is 726 feet high, is a small part of Lake Mead, the dam's huge reservoir. To the left and right of this area are two straight overflow dams. The four round objects immediately above the main dam are the intake towers of its hydroelectric generators. The greenish tinge on the water below the dam indicates the turbulence of the water flowing through the generators. The geometrical arrays on the left side of the photograph are power substations.

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Cover photograph by Fairchild Aerial Surveys

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IN GHANA. The Volta River project—major hydroelectric development to electrify most of Ghana—has economic support in Volta Aluminium Company, Ltd., the nation's first major power customer, first primary aluminum producer (Kaiser Aluminum sponsored).

IN JAMAICA. Kaiser Bauxite Company—which supplies the ore for Kaiser Aluminum production in the U.S.—has operated successfully for 16 years on a unique program which has helped improve the island's economy and the welfare of its people.

IN INDIA. Hindustan Aluminium Corporation, Ltd.—integrated aluminum production and fabricating facilities constructed and operated with Kaiser Aluminum technical assistance—is owned by the G. D. Birla and other Indian national interests and Kaiser Aluminum.

Whatever the needs of the free world — whether technological needs, economic needs or industrial needs — they exist only in relation to people. So it is the human need that we must fill; and the pioneering we do, the industries we build, the assistance we give, all have value and permanence only to the extent that they are identified with the goals and ambitions of a people.

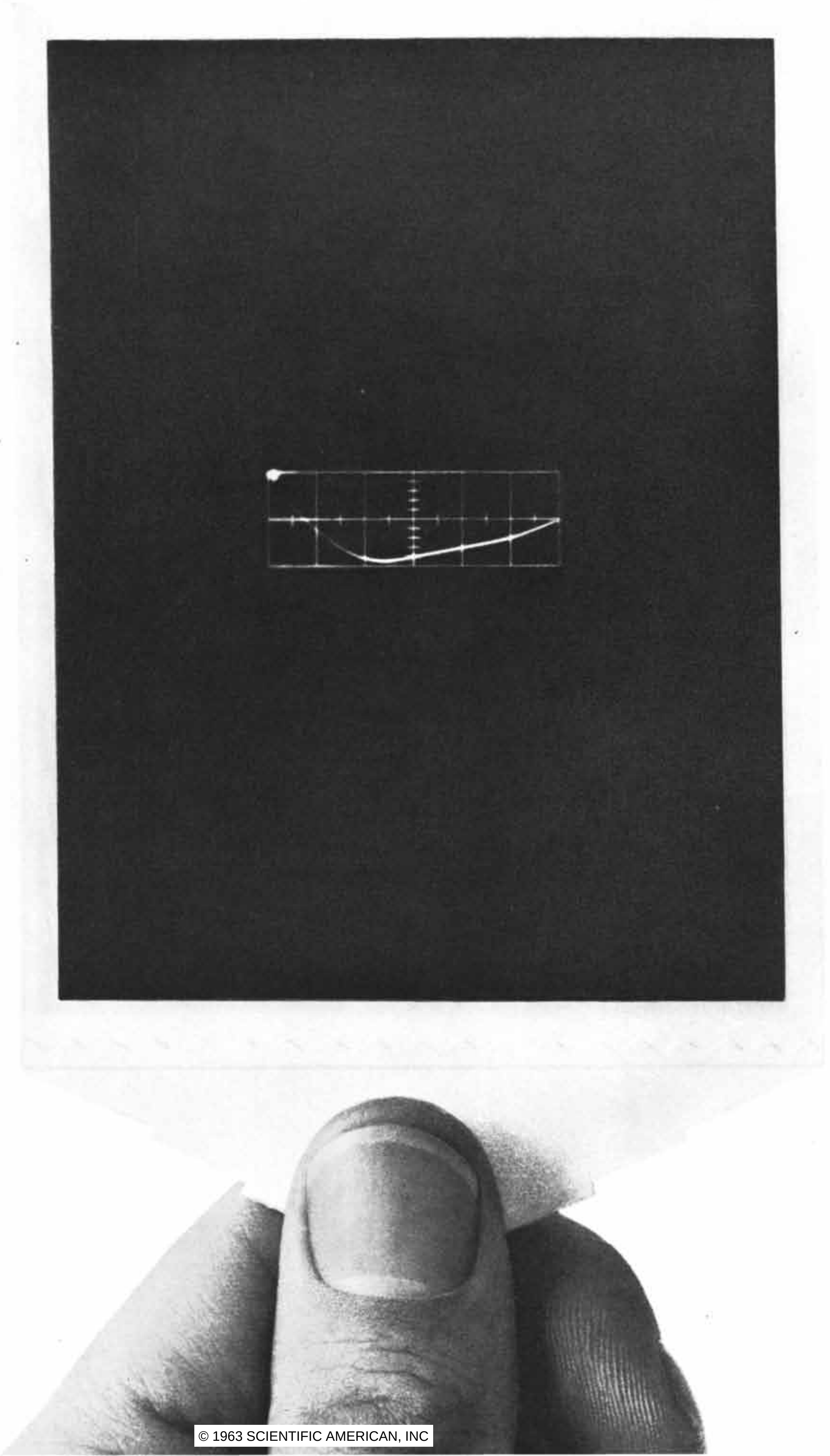
KAISER ALUMINUM

IN THAILAND. Thai Metal Works Company, Ltd.—one of Thailand's largest utensil manufacturers now expanding with Kaiser Aluminum financial participation and technical assistance—will produce flat aluminum for transportation, construction, other industries.

IN SOUTH AMERICA. Kaiser Aluminio S.A. (Argentina) operates the continent's most modern fabricating facilities. Aluminio Nacional S.A. (organized by Kaiser Aluminum with Venezuelan investors) is the first to produce aluminum foil in Venezuela.

FIND A NEED. FILL IT. On every continent, Kaiser Aluminum's pioneering is guided by this purpose. In hydroelectric development, or in supplying metal and technology, our participations are planned for permanent benefits to the people and markets we serve.

For a 36-page report on the worldwide activities of Kaiser Aluminum, write: Kaiser Aluminum, Room 848, Kaiser Center, Oakland 12, California



This is a picture of something you can't see

Polaroid 10,000-speed Land Film can record traces too fast for the human eye.

Polaroid 10,000-speed Land Film is the most sensitive photographic material you can buy.

It not only records, it can *discover* things.

In the field of oscillography, for example, it makes it possible for you to study phenomena such as this scintillation pulse with a rise time of less than five nanoseconds.

Though this film is fairly new, Polaroid Land films and oscilloscope recording are old working partners. Getting a finished picture on the spot was a big advantage even in the days when it took a full minute.

But now, of course, it only takes 10 seconds. Simply fit your scope with any one of several different oscilloscope cameras equipped with a Polaroid Land Camera Back. Then make your setup and snap the shutter. 10 seconds later you can take a finished picture out of the camera back.

PolaScope film has advantages whether you can see the trace or not. It gives you an immediate record you can analyze or file for future reference. And because the film is so sensitive you can use small camera apertures and low intensity settings. You get a sharp, high-contrast image that is easy to read.

PolaScope 10,000-speed film is one of 8 different emulsions in 17 film types which are providing on-the-spot pictures in almost every branch of science and industry. For more information, write to Polaroid Corporation, Technical Sales Dept., Cambridge 39, Mass.

New Polaroid PolaScope Land film for oscillography.

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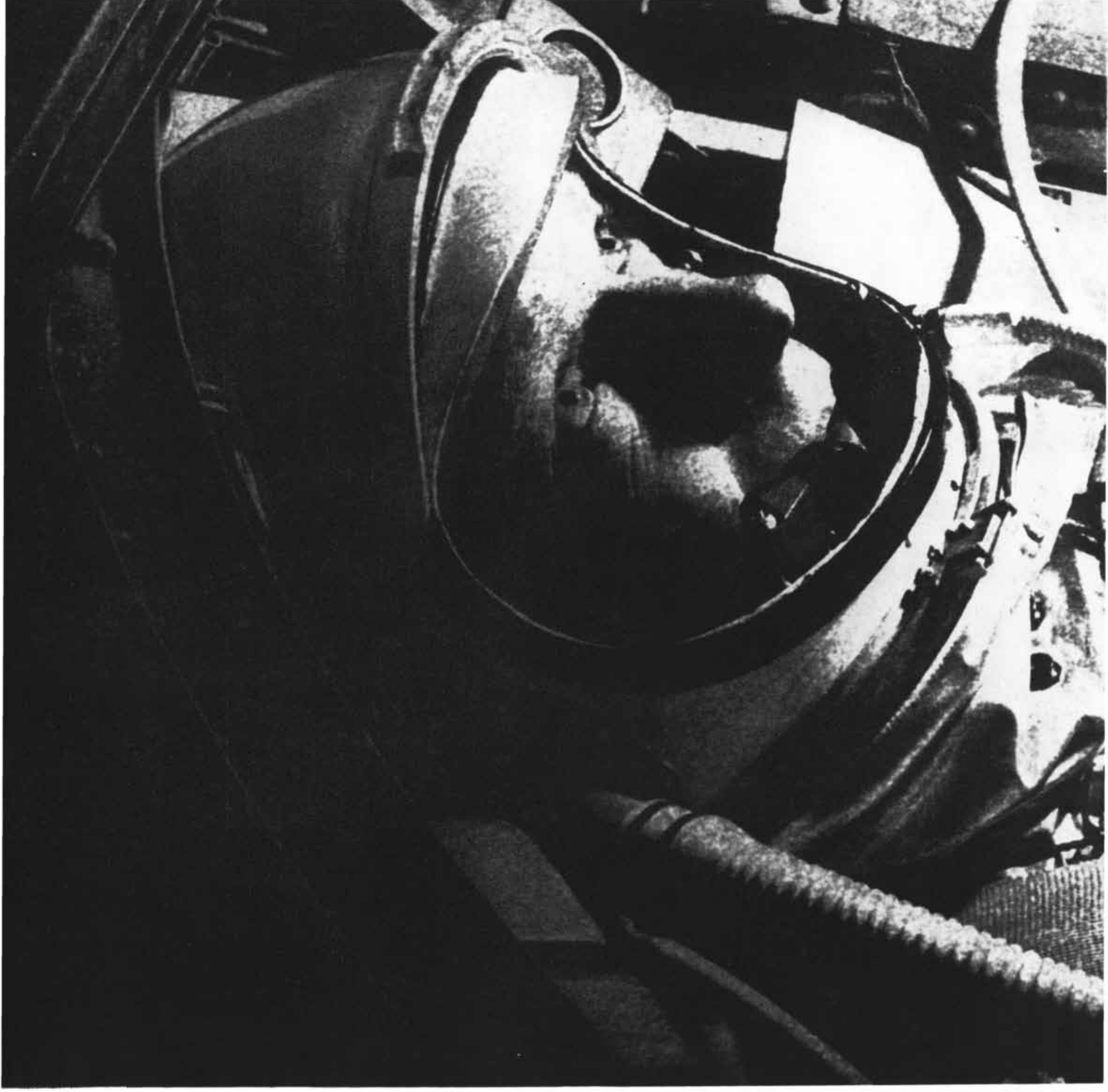


DURING RE-ENTRY, JOHNS-MANVILLE INTERNAL INSULATION AUGMENTS THE MAIN HEAT SHIELD TO GIVE OUR ASTRONAUTS ADDITIONAL PROTECTION

Re-entry? No sweat.

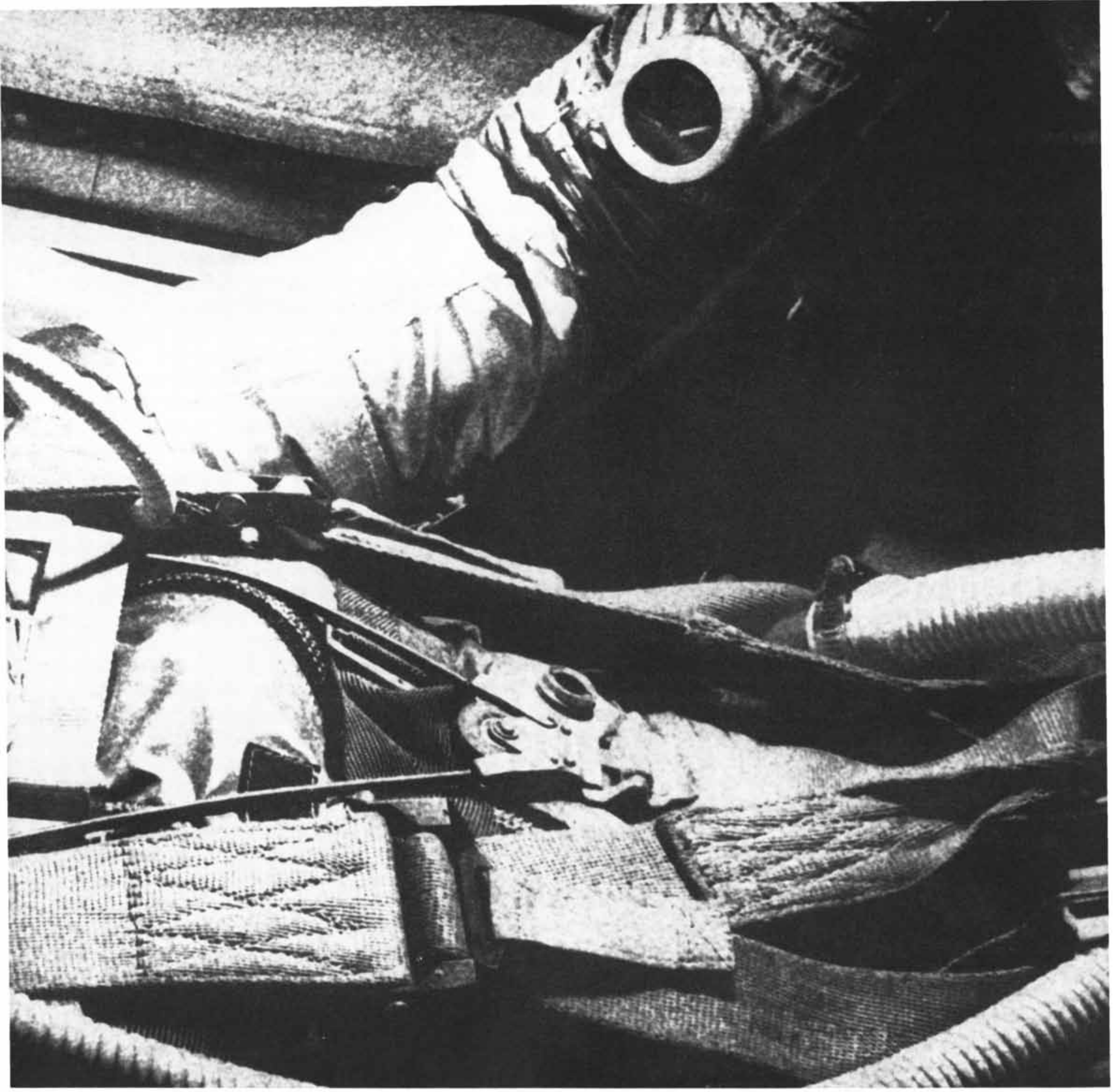
EVEN THOUGH THE SKIN OF HIS SPACECRAFT MAY GLOW AS HOT AS 1300°F.

Mercury, Gemini, Dyna-Soar . . . wherever manned space projects have reached the materials specification stage, you'll find Johns-Manville insulations.

Simply because they do the impossible.

For instance, J-M cooked up a bonded structure reinforced with asbestos and containing appreciable quantities of particulate matter. They called it Min-K®. Scientists called it magnificent. Min-K, you see, has a thermal conductivity lower than that of still air...an achievement considered theoretically impossible just a short time ago.

Then there's Thermoflex®, a blanket-like material



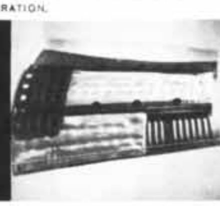
AGAINST THE EXTREMELY HIGH SKIN TEMPERATURES OF THE SPACECRAFT.   PHOTO COURTESY NATIONAL AERONAUTICS & SPACE ADMINISTRATION.

of ceramic fibers that stands up to temperatures which will melt the fibers of practically any other known material.

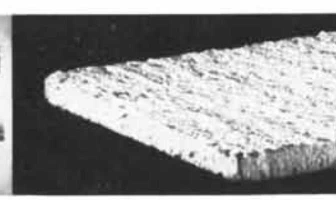
And Dyna-Quartz, a unique glass fiber so heat-resistant it's been specified to insulate Dyna-Soar's primary internal structure. During re-entry, Dyna-Soar's outer skin temperature is expected to reach more than 2000°F.

It all adds up to one thing. Johns-Manville insulation systems are literally out of this world. Which explains why so many people feel they're getting the best protection on *earth* when they use Johns-Manville insulations.

MIN-K... used to protect the ducting for the reaction control system aboard Mercury and the structural ribs aboard both the Mercury and Gemini spacecraft.



THERMOFLEX . . . used between outer and inner shells of spacecraft to help keep cabin temperature safe for astronauts and to attenuate noise aboard Mercury and Gemini.



DYNA-QUARTZ . . . the only known lightweight material which will maintain its dimensions when subjected to the severe heat expected on coming Dyna-Soar flights.

Johns-Manville

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it's time to contact HARSHAW

Harshaw Crystal-Solid State Division Capabilities:

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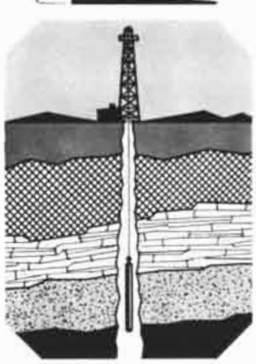
Nuclear Radiation Detectors

Harshaw produces Scintillation Crystals for the detection of Alpha and Beta particles, and Neutron and Gamma radiation.

Silicon Surface Barrier Charge Particle Detectors and Gas-Filled Radiation Detectors (boron-10 trifluoride neutron counters and halogen-quenched G-M tubes) are offered to complete the line of radiation detectors.

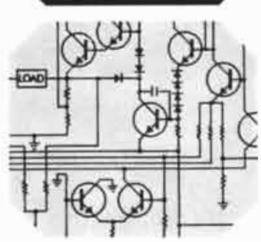
Lithium Fluoride Thermoluminescent Dosimeter Powder is available for medical research and X-ray therapy dose measurement. Lithium-6 Fluoride, and Lithium-7 Fluoride Thermoluminescent Dosimeter Powder provides discrimination between neutron dose and gamma dose received in a mixed radiation field.



2
Thin Film Solid State Technology

Harshaw is marketing radiation-resistant, flexible cadmium sulfide solar cells offering longer space life, more watts per pound, and lower fabrication cost. Flexibility of these thin cells permits a wide variety of compact configurations which may be readily assembled or unfolded in space.

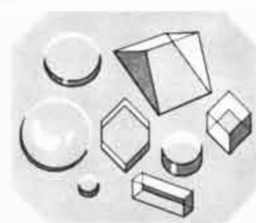
At present we are engaged in development studies on photoconductors, phosphors, thermistors, thin film transistors, and other solid state effects.



3
Infra Red & Ultra Violet Transmitting Materials

ROUGH BLANKS AND POLISHED OPTICS.

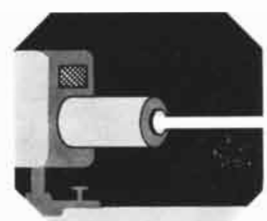
Harshaw Alkali Halide Crystals span the wavelength range from the far vacuum ultra violet to the far infra red. Harshaw high purity vacuum-grown lithium fluoride has the shortest known cut-off wavelength, approximately 1040 Angstroms, while cesium iodide and thallium bromide-iodide offer transmission out to about 40 microns. Windows, prisms lenses, and polarizing elements are available from Harshaw's Optical Polishing Facility. Now available . . . T-12, a new crystalline compound transmitting 1 to 12 microns. *Developed specifically to resist thermal and mechanical shock.*



4
Materials

II-VI Compounds—Cadmium Sulfide, Cadmium Selenide, Zinc Sulfide, Zinc Selenide, and Zinc Telluride are offered in both powder and single crystal form. As a service, single crystals will be provided with the desired orientation.

Laser Crystals—CaF_2 and BaF_2 rare earth activated. Tungstate and molybdate crystals are also available. In-house research on new Laser materials is continuing.



You are invited to contact CRYSTAL-SOLID STATE DIVISION, the Harshaw Chemical Company if any of your present or future endeavors embrace the science of crystal or solid state technology. Our large staff of physicists, scientists, and technicians will be pleased to work with you.

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The earth photographed from space during Project Mercury flight.

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Why not take a fresh look at our little planet? To do that, you might start where global explorations are all in a day's work—from pole to pole and from the oceans' depths to the wastes of space. At ITT World Headquarters in New York City.

From this point ITT pursues its corporate goals on a planetary scale for the benefit of its shareholders and employees. And for the benefit of this and 48 other nations on six of the earth's continents in which the ITT System works, builds and does substantial business.

What kind of business? Communications and electronics. ITT believes in the concept of a small, intimate world—one in which information and ideas flow freely, quickly, abundantly. The 48 companies of ITT build the needed hardware.

Some examples: In Vienna, an ITT company manufactures intercom equipment. From Antwerp come integrated, mechanized postal systems. From Copenhagen, mobile and maritime radio-telephone equipment. In Paris, an ITT company is prime contractor for a highly sophisticated troposcatter communication system extending 8,500 miles—from Norway to Turkey.

An ITT company in Stuttgart manufactures air-navigation and transmission systems. Another, in Milan: microwave equipment. In the Hague: teleprinter exchanges. In Oslo: wire and cable. In Lisbon: radiosondes for weather prediction. In Madrid: telecommunication cable and marine navigation aids. In Stockholm: telephone switching equipment. In Zurich: pneumatic ticket tube systems. In Croydon, England: teleprinters. In London: the undersea cables and repeaters that link continents by voice. In Chicago: military and industrial communication systems.

Radio and television sets are built by ITT companies in Buenos Aires and Rio de Janeiro. Firms in Santiago and Mexico City make telephone receivers. And operating subsidiaries of ITT are providing comprehensive telephone service in Chile, Puerto Rico, the Virgin Islands, Brazil, and Peru.

A broad range of communication equipment is manufactured by ITT companies and licensees in Australia, New Zealand, and Japan. Their products are sold throughout the Far East in a vast marketing operation based in Hong Kong.

ITT's busy everywhere: at home, where 22,500 people are at work in 55 locations from Fairbanks, Alaska to Houston, Texas, and in Africa, Canada and the Arctic. In all, 23,000,000 square feet of ITT System plants, labs and offices—employing more than 150,000 persons—are humming with activity around the world. This cosmopolitan company is, in fact, the largest international supplier of electronics and telecommunication equipment on the face of our globe.

International Telephone and Telegraph Corporation, World Headquarters: 320 Park Avenue, New York 22, New York.

worldwide electronics and telecommunications ITT

LETTERS

Sirs:

In the interesting article by Arthur L. Schawlow ["Advances in Optical Masers," SCIENTIFIC AMERICAN, July] there are several inaccuracies in the table of laser types that could be misleading to the uninitiated.

Specifically, three groups of solid lasers are stated to operate continuously at 20 degrees centigrade. In fact, all of these should have the same designation as gallium arsenide in the same table, namely pulsed at 20 degrees C. and continuous at -196 degrees C. To the best of my knowledge there is still only one solid material that will operate continuously (direct current) at room temperature: neodymium 3^+ in calcium tungstate (L. F. Johnson, G. D. Boyd, K. Nassau and R. R. Soden, *Physical Review*, Volume 126, pages 1406–1409; 1962), which was not included in Schawlow's listing.

K. NASSAU

Bell Telephone Laboratories
Murray Hill, N.J.

Sirs:

I am grateful to Dr. Nassau for pointing out this error in our table. It arose

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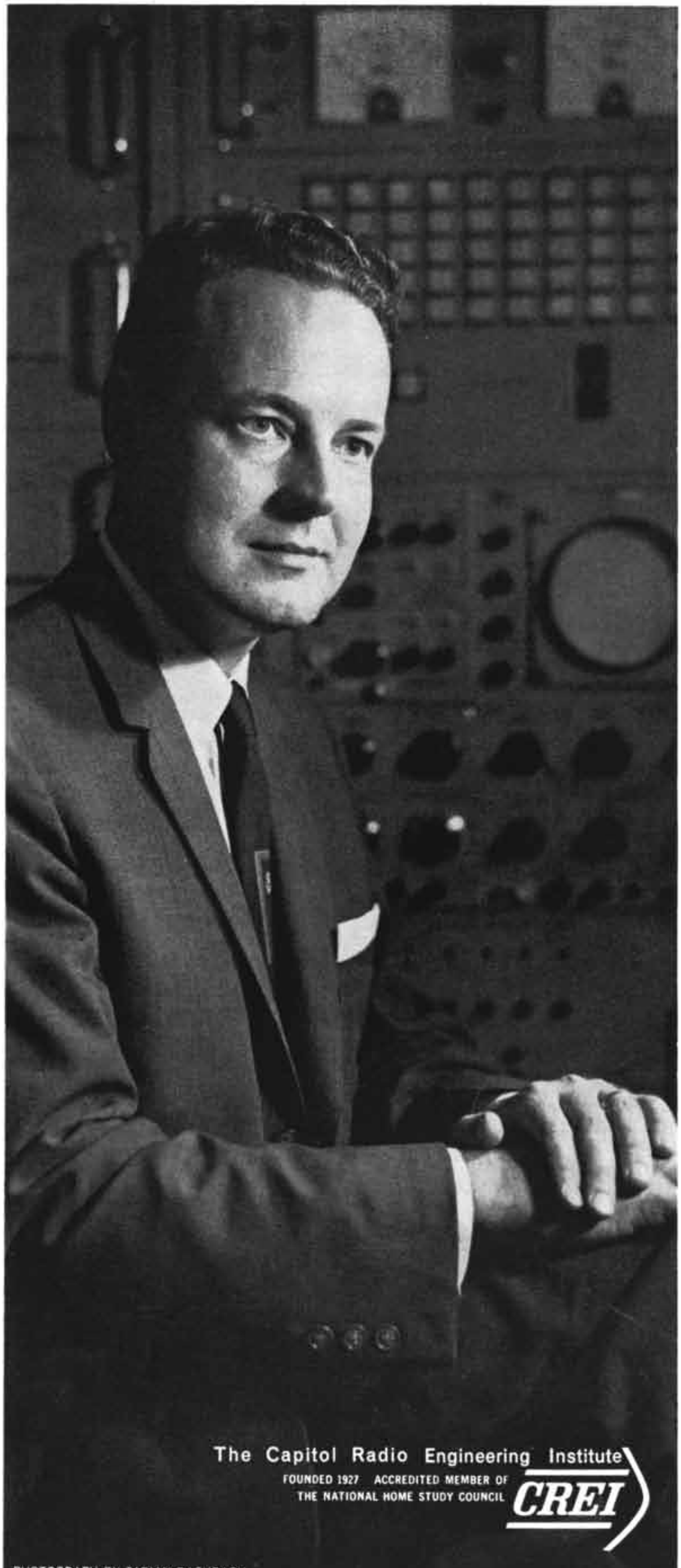

CREI home study programs in electronics help Defense Electronics, Inc. cut recruitment costs.

"In an organization expanding as rapidly as ours—we grew from five employees to over 300 in three years—recruitment costs can be substantial. We keep costs in line by upgrading promising employees. CREI's advanced technical education helps us do this. We design and manufacture advanced RF communications, surveillance, telemetry, data handling equipment and systems. Our products are used on all major missile ranges, NASA installations, and AEC test areas. CREI has tailored programs to meet our very special technical requirements. We regard the CREI curriculum as one of the very finest in the nation and our company-sponsored employee Educational Program pays for a substantial part of the tuition upon satisfactory completion of the program."

MILLER S. REDDEN, JR.
Vice President and Chief Engineer
Defense Electronics, Inc. Rockville, Md.

CREI currently provides advanced technical educational services to employees of more than 1,700 organizations in industry and government. Programs cover every major field of electronics including space and nuclear engineering technology and meet the needs of every level of electronics man—from the technician to the graduate engineer who must keep abreast of new developments. Programs are available on an individual basis or are developed to meet specific training objectives.

A CREI Field Service Representative will be glad to discuss CREI Programs with you or your employees. For a visit or information, write on company letterhead to H. E. McCallick, Executive Vice-President, **The Capitol Radio Engineering Institute,** 3224 Sixteenth St., Washington 10, D. C.

inadvertently during an effort to reduce a longer table to concise and readable form. The error in temperature is an unfortunate matter of terminology. For the ionic materials, which are numerous, only the highest operating temperature was reported, whether it corresponds to pulsed or continuous operation. Usually only pulsed operation is attained at the highest temperatures. Semiconductor laser materials are not yet as numerous and so we were able to distinguish explicitly between the temperatures for pulsed and for continuous maser operation.

ARTHUR L. SCHAWLOW

Stanford University
Stanford, Calif.

Sirs:

Since I came to Iowa six years ago I have been watching the changing moiré patterns that show in the wire corncribs when one travels past the local farms. The cover of your May issue immediately caught my eye, and I was delighted with the article by Gerald Oster and Yasunori Nishijima ["Moiré Patterns," SCIENTIFIC AMERICAN, May]. I should like to add a few words about an engineering application of moiré patterns. They are used in the determination of strain analysis. In this country A. J. Durelli of the Illinois Institute of Technology, among others, has conducted research on this aspect of moiré patterns.

ENZO O. MACAGNO

Institute of Hydraulic Research
University of Iowa
Iowa City, Iowa

Sirs:

There is an error in Martin Gardner's department "Mathematical Games" for July. Gardner defines chromatic number as follows: "The chromatic number is the maximum number of regions that can be drawn on the surface in such a way that each region has a border in common with every other region." According to common mathematical usage the chromatic number is defined as it is by E. M. Patterson (*Topology*, Interscience Publishers, 1959, page 15): "The minimum number of colours required to colour a map on a given surface is called the *chromatic number* of the surface."

DALE WOODS

Kirksville, Mo.

etc.*

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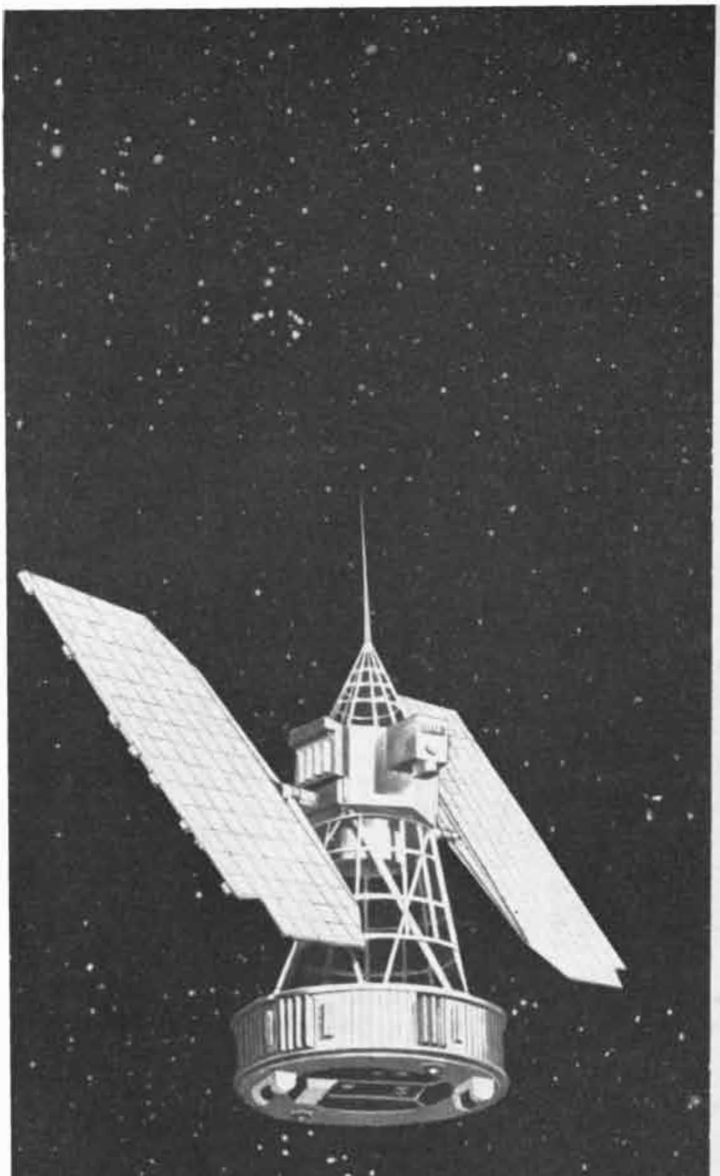
Long lists of achievements are fine, and we are proud of ours . . . but at ***ALLIS-CHALMERS*** we tend to be still more enthusiastic about what is coming next.

*New products, improvements in existing products, better ways of serving our customers . . . these are the definite ways in which Allis-Chalmers does its share to help you share in a better future.


"orbiting" Nimbus
NASA's new solar-powered weather satellite, NIMBUS, will be launched this year. The Thor-Agena B rocket system will boost NIMBUS into a polar orbit at 80.45° inclination, timed to pass over the equator at high noon. TV cameras aboard the satellite will cover weather patterns over the entire globe every 24 hours.
CO_2 at work



on a gas bearing

Scene: The Space Environment Simulation Chamber at General Electric's Valley Forge Space Technology Center. NIMBUS, the first earth-oriented weather satellite, perches atop a frictionless platform anchored to a spherical bearing . . . a bearing that moves in a pressure medium of carbon dioxide from a Liquiflow* system.

Inside the chamber, NIMBUS encounters the simulated conditions of a 500-mile-high orbit for 60 consecutive days. Structure controls, cameras and radiometers react to the bone-snapping cold of outer space, the intense light of the sun, the proximity of warm Planet Earth.

NIMBUS' flight maneuvers are simulated with the aid of the carbon dioxide-lubricated stainless steel bearing. This unique method of lubrication helps to maintain the required thermal vacuum . . . any gas escape from the bearing freezes on the walls of the chamber as dry ice.

The gas bearing has proved to be the most trouble-free component of the testing system. Reliability has been achieved by General Electric with the help of Liquid Carbonic Sales Engineers.

Look to Liquid for professional assistance on any problem involving controlled applications of carbon dioxide, oxygen, nitrogen, argon, helium. We are at your service.

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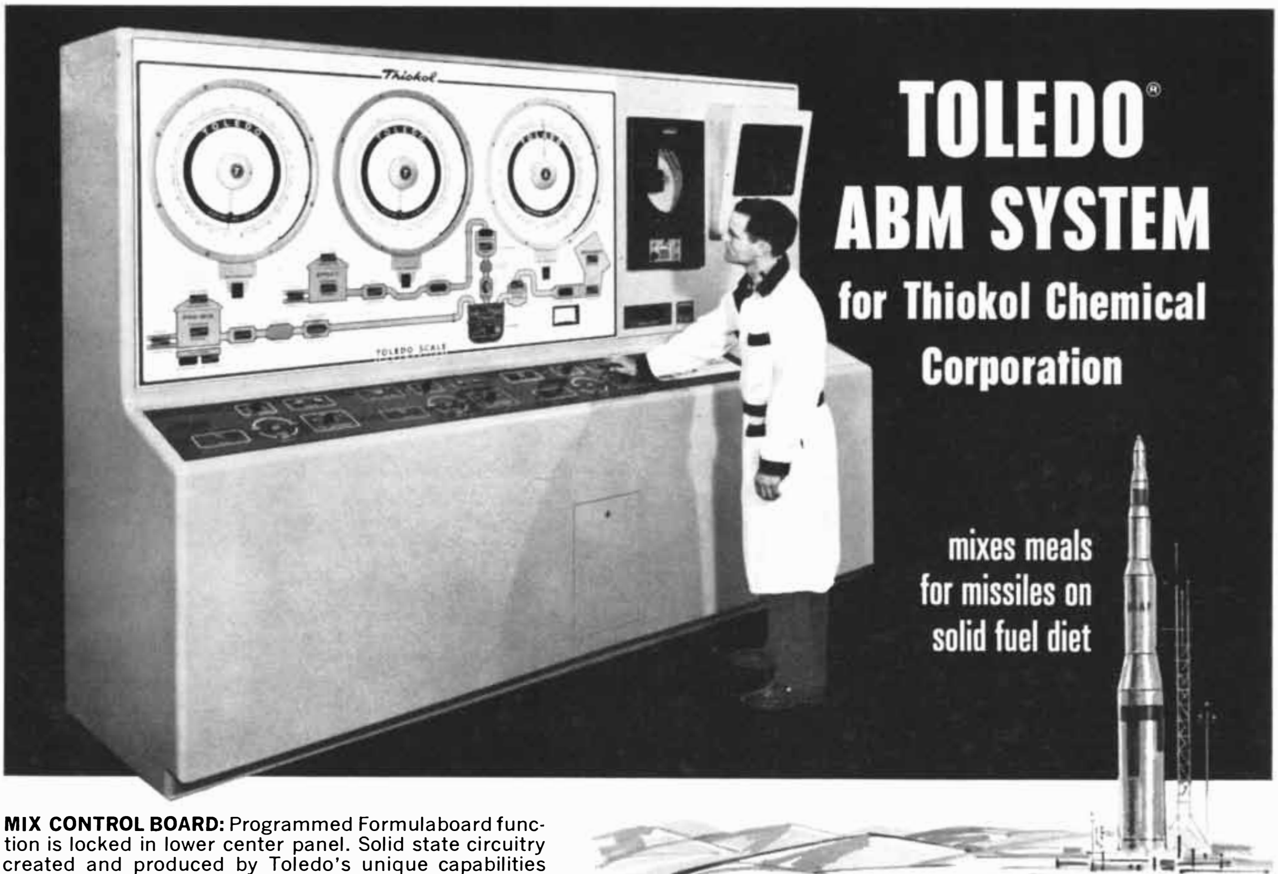
FROM TOLEDO SCALE: A WORLD OF PROGRESS IN THE WORLD OF WEIGHING



MIX CONTROL BOARD: Programmed Formulaboard function is locked in lower center panel. Solid state circuitry created and produced by Toledo's unique capabilities assures highest reliability and long life.

LOSS-IN-WEIGHT MIX FACILITY: All three ingredient inputs are in position. Oxidizer tote is in tilt position on load cells; premix can in foreground rests on load cells. Curing agent handling mechanism is behind premix can. Propellant mixing can is simulated beneath installation.

MASTER CONTROL CONSOLE: Typewriter logs record of operations performed through each mix control board. Key lock functions are also located at master control console. Color coding and unique concepts in operating logic are applied to achieve the highest order of man-machine integration.

Will help cut cost, boost reliability of the Minuteman first-stage engine: Preparing solid propellants for missiles is ticklish business. It calls for proportioning, mixing and blending of ingredients to a precise formulation for rigid control of physical characteristics and burning rate. Errors are unthinkable.

This digitalized Toledo Automated Batch Mixing System (ABM) was developed for Thiokol Chemical Corporation, leading manufacturer of solid propellants. It provides the accuracy, automation and quality control so vitally needed, with a 25% production increase over previous batch mixing methods. But, more than that, it is a breakthrough that makes possible development of solid propellant motors many times more powerful than those we have today.

The System permits accurate proportioning of ingredients by control and automatic check of each ingredient's weight to a fraction of a pound within thousand-pound lots. The Toledo plug-in Formulaboards allow changing the weights and ratios of ingredients to produce any number of propellant formulations. A continuous operating log is prepared automatically by electric typewriters, and interlocking key controls prevent unauthorized changes in programming.

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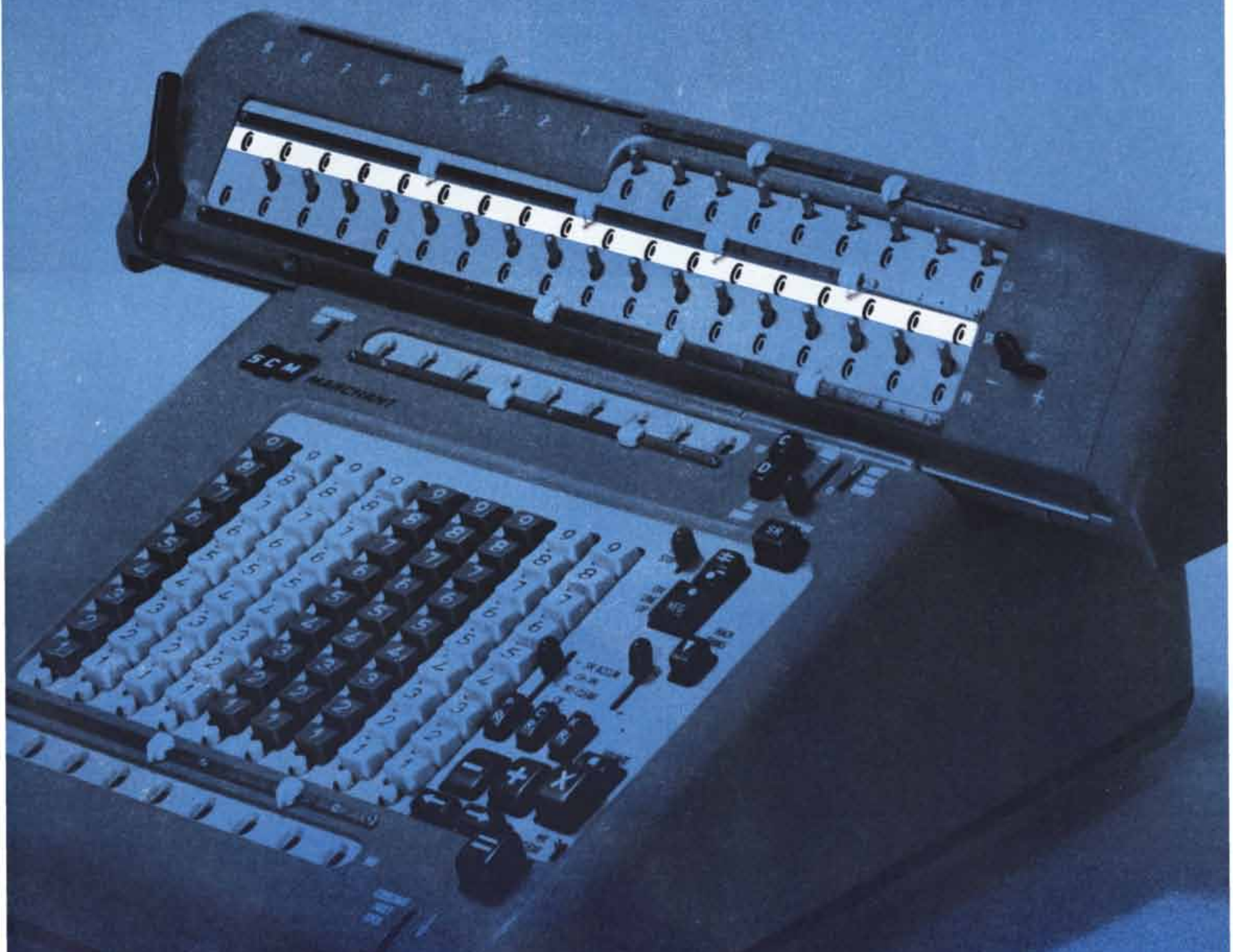

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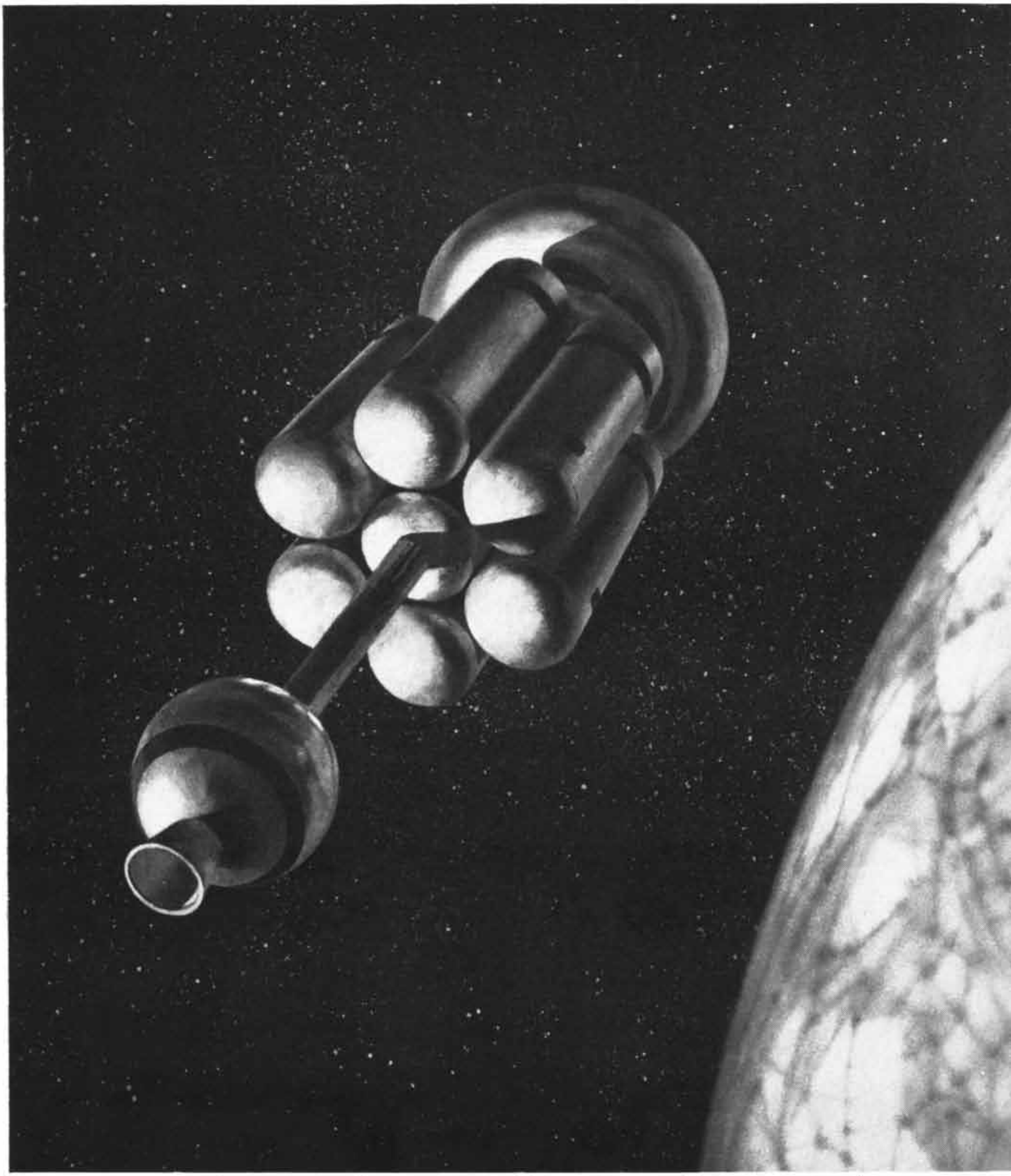
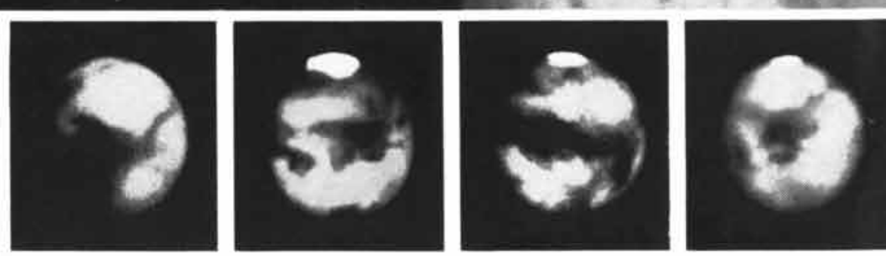


(*above*) The excursion module has just left its nuclear-powered mother ship 600 miles above Mars and is descending to the surface. (*at right*) Photos showing the waxing and waning of the polar ice cap on Mars indicate seasonal changes on the red planet.



How will we go about our first explorations of Mars?

...another example of the complicated problems Douglas and the aerospace industry are helping NASA to solve

You are 600 miles from Mars, and dropping to the surface in your landing module...

You have just left the orbiting mother spacecraft on which you made a six-months-long voyage from Cape Canaveral. This bulbous, nuclear-powered ship will wait in orbit, outside the Mars atmosphere, for you to return in your excursion module and start your trip back to Earth. The stars shine brightly in the blackness of space, but the sun seems only about two-thirds the size it appears from Earth.

Below you, scarred by marks that astronomers called canals when first discovered in 1873, circles the red planet. Its cool surface, almost devoid of atmosphere, awaits your exploration.

Fantastic? Ten years ago, yes. Five years ago, perhaps. Today, just one of the realities to which Douglas engineers and other scientists in the aerospace industry are devoting all-out effort. In fact, the rocket that is a big step toward boosting our astronauts to Mars is already in being.

This is Saturn, a giant among rockets—nearly 16 stories high. Its first stage has already been successfully fired down the Cape Canaveral range. The second, or S-IV stage—now being built by Douglas—has had a completely "A-OK" firing in a static test bed at Sacramento, California. Another version, the Douglas S-IVB, is being developed as the third stage of a still more powerful rocket—the gigantic Saturn V, a 35-story, 6,000,000 pound space vehicle scheduled for flight tests in 1965.

How does one go about designing and building so vast and complex a machine?

You begin, as Douglas began, by assigning a team of tough-minded visionaries to the project—men with the courage to think years ahead of the times, and the tenacity to stick with seemingly hopeless assignments to the successful end.

You need specialists in human engineering, to make sure the machine is suited to man's use—since man is the one part of the great complex it is difficult to modify. You need metallurgists to select and fabricate materials, electronic engineers, propulsion specialists, chemists to develop fuels or new heat-resistant plastics. Name any craft, art or science imaginable. Chances are it's part of the Douglas Saturn team, applied in some of the most modern and extensive facilities in the aerospace industry.

DOUGLAS

Major Douglas Divisions are located in Santa Monica and Long Beach, California, Tulsa, Oklahoma, and Charlotte, North Carolina

THE AUTHORS

ASA BRIGGS ("Technology and Economic Development") is professor of history and dean of the School of Social Studies at the University of Sussex in England. A native of Yorkshire, Briggs received an M.A. in history from the University of Cambridge in 1941 and studied economics at the University of London before entering the British Intelligence Corps in 1942. In 1945 he joined the faculty of the University of Oxford, where he became Reader in Recent Social and Economic History. Briggs came to the U.S. in 1953 to spend a year at the Institute for Advanced Study in Princeton, N.J. He left Oxford in 1955 to become professor of modern history at the University of Leeds, and in 1961 he joined the faculty of the University of Sussex. Since 1958 he has served as president of the Workers' Educational Association of the Royal West of England Academy. Briggs is the author of several books on the history of economic development, including *History of Birmingham (1865–1938)*, published in 1952.

KINGSLEY DAVIS ("Population") is professor of sociology and chairman of International Population and Urban Research at the University of California at Berkeley. He was graduated from the University of Texas in 1932 and acquired an M.A. and a Ph.D. from Harvard University in 1933 and 1936 respectively. After teaching for a year at Clark University he joined the faculty of Pennsylvania State College, where he was made head of the sociology department. In 1942 he went to Princeton University to work in the Office of Population Research; he was a member of the Princeton faculty until 1948, when he was appointed associate director and later director of the Bureau of Applied Social Research at Columbia University. From 1946 to 1952 he was a member of the joint committee on South Asia of the Social Science Research Council and from 1952 to 1954 he directed a research project on population trends and demographic behavior in Jamaica. He joined the Berkeley faculty in 1955. Davis served as U.S. representative to the United Nations Population Commission from 1955 to 1961.

NEVIN S. SCRIMSHAW ("Food") is professor of nutrition and head of the Department of Nutrition and Food Science at the Massachusetts Institute of Technology. A graduate of Ohio Wesleyan University, Scrimshaw received an M.A. and a Ph.D. from Harvard University in 1939 and 1941 respectively. He did postdoctoral work in nutrition and endocrinology at the University of Rochester and received an M.D. from that university's medical school in 1945. After interning at Gorgas Hospital in the Canal Zone he returned to the University of Rochester in 1946 to do research in the department of obstetrics and gynecology. In 1948 he went back to Panama to do field research on nutrition and pregnancy and shortly thereafter became chief of the Nutrition Section of the World Health Organization's Pan American Sanitary Bureau. From 1949 to 1961 Scrimshaw served as director of the Institute of Nutrition of Central America and Panama. He acquired a degree in public health from Harvard in 1959 and was adjunct professor of public health nutrition at the Columbia University College of Physicians and Surgeons from 1959 until 1961, when he took up his present post. Scrimshaw has served as adviser on world nutrition problems to various Government and United Nations agencies. At M.I.T. he is currently engaged in studies involving the effect of stress on nutritional requirements and the effect of nutrition on resistance to infection and on mental development.

ROGER REVELLE ("Water") is University Dean of Research at the University of California and director of that university's Scripps Institution of Oceanography. Revelle began his long association with the Scripps Institution in 1931, two years after acquiring an A.B. in geology from Pomona College. He received a Ph.D. from Scripps in 1936 and was professor of oceanography there in 1951, when he became the first alumnus of that institution to be appointed its director. During World War II Revelle served as a commander in the U.S. Navy and immediately after the war joined the Office of Naval Research as head of the Geophysics Branch. In 1946 he organized the oceanographic expedition associated with the atomic bomb test in Bikini Lagoon, measuring the diffusion of radioactive waters and their effects on marine organisms. During the early 1950's he led several other expeditions to the central and southern Pacific, developing new methods for measuring the flow of heat out through the floor of the ocean. He served as president of the first International Oceanographic Congress held by the United Nations in 1959, and

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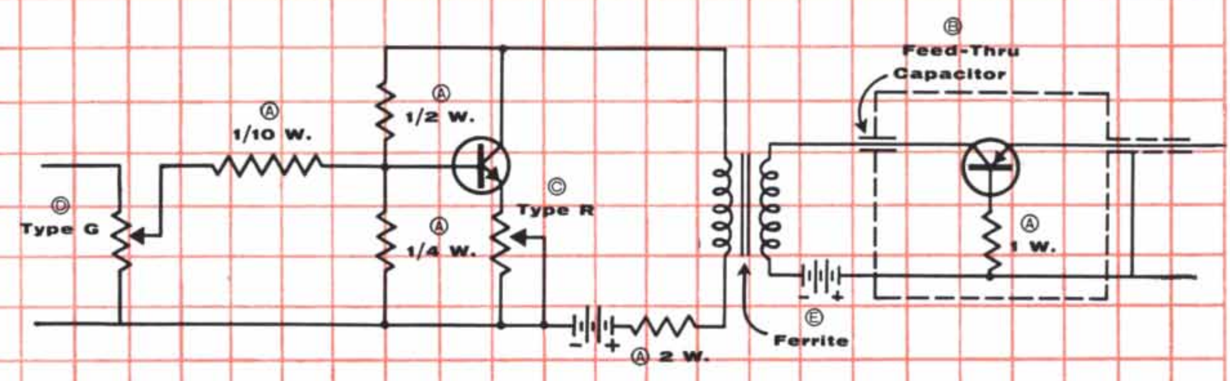

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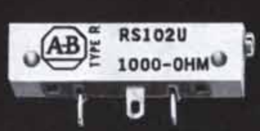

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QUALITY ELECTRONIC COMPONENTS | **ALLEN-BRADLEY** in 1961 he became the first man to hold the post of science adviser to the Secretary of the Interior. Revelle is currently president of the Committee on Oceanographic Research of the International Council of Scientific Unions and a member of the U.S. Commission to the UNESCO Office of Oceanography.

SAM H. SCHURR ("Energy") is director of the Energy and Mineral Resources Program of Resources for the Future, Inc., a private research organization sponsored by the Ford Foundation. Schurr acquired his B.A. and M.A. degrees from Rutgers University in 1938 and 1939 respectively and shortly afterward joined the staff of the National Bureau of Economic Research. During World War II he served in the Office of Strategic Services and on the War Production Board. From 1946 to 1949 he did research on the economic aspects of atomic power for the Cowles Commission for Research in Economics at the University of Chicago. He was appointed chief of the manufacturing and mining branch of the U.S. Bureau of Labor Statistics in 1949 and a year later became chief economist for the U.S. Bureau of Mines. Schurr spent a year as chief of economic research for the Rand Corporation before taking up his present post in 1954.

JULIAN W. FEISS ("Minerals") is staff assistant for metals to the Assistant Secretary of the Interior for Minerals and Fuels. He is also assistant to the director of the U.S. Geological Survey. Feiss was graduated from Princeton University in 1927 with honors in geology and did graduate work at the Arizona School of Mines before going to Africa as field geologist with the Rhodesian Congo Border Concessions in 1929. He returned to this country three years later to become consulting engineer with the firm of Crowell and Murray. This work took him to mine sites in northern Canada, Chile and Peru. In 1938 he became geologist at the Climax Molybdenum Company's mine in Climax, Colo.—the largest underground metal mine in the U.S. During World War II Feiss served in Kenya and Ethiopia as liaison officer to the King's African Rifles. After the war he was editor of *Mining Congress Journal* for two years before joining the U.S. Bureau of Mines in 1947. From 1952 to 1961 he worked as geologist for the Kennecott Copper Corporation.

FREDERICK HARBISON ("Education for Development") is professor of economics and director of the Industrial Relations Section of Princeton University. He was graduated from Princeton in 1934 and acquired his Ph.D. there in 1940. During World War II he served as consultant to various Government agencies dealing with labor and manpower problems. In 1945 he went to the University of Chicago to become professor of economics and executive officer of that university's Industrial Relations Center. He held both posts until 1955, when he joined the Princeton faculty. In 1962 Harbison was in Geneva as a member of a committee to explore methods of forecasting world manpower and education requirements for the International Labor Organization. He returned to Geneva early this year as a delegate to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas. Harbison is currently a member of the Special Commission on Education, Science and Culture of the Alliance for Progress and consultant to various Government and international organizations, including the National Planning Association, the U.S. Department of Labor, the Agency for International Development, the Organization for Economic Co-operation and Development, UNESCO and the Peace Corps.

WASSILY LEONTIEF ("The Structure of Development") is Henry Lee Professor of Economics and director of the Economics Research Project at Harvard University. Born in St. Petersburg, Russia, in 1905, Leontief was graduated from the University of Leningrad with the title of "Learned Economist" in 1925. He did research in economics at the University of Kiel and at the University of Berlin, receiving his Ph.D. from the latter institution in 1928. In 1929 he went to Nanking as economic adviser to the Chinese government and two years later came to this country to do research at the National Bureau of Economic Research. He joined the Harvard faculty in 1931. During World War II Leontief served as consultant to the U.S. Department of Labor, where he applied his "input-output" system of analysis to the problems created by the impending shift from a war to a peacetime economy. He has also served the United Nations as consultant on the economic aspects of disarmament and on the economic development of newly emerging countries.

WOLFGANG F. STOLPER ("The Development of Nigeria") is professor of economics at the University of Michigan. He is currently on leave from that uni-

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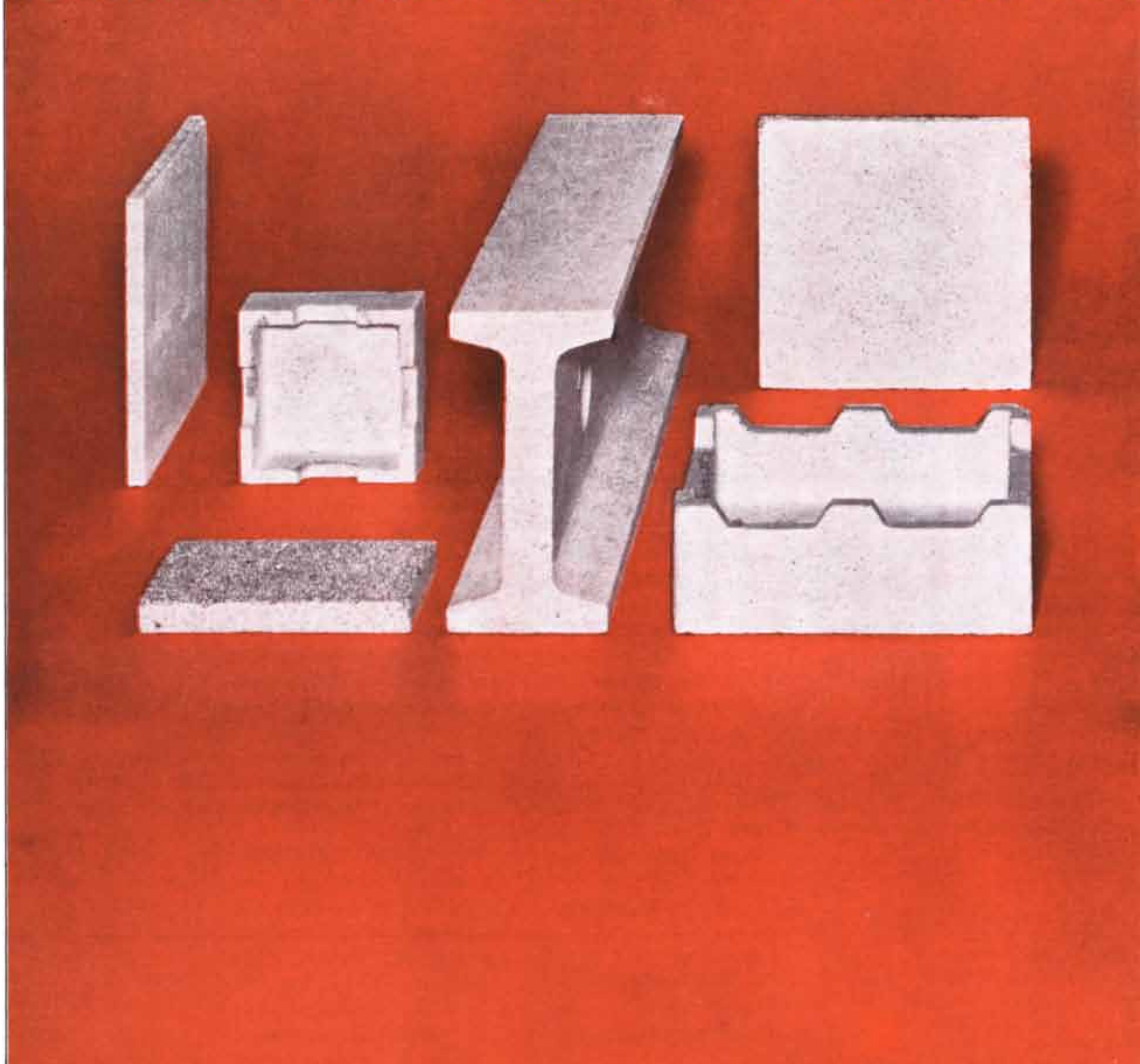

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versity and is doing research at the Center for International Affairs of Harvard University. Stolper was born in Vienna in 1912 and studied at the universities of Berlin, Bonn and Zurich before coming to this country in 1934. He received an M.A. and a Ph.D. from Harvard in 1935 and 1938 respectively and afterward taught at Harvard and at Swarthmore College before joining the Michigan faculty in 1949. Stolper first worked on problems of economic development in 1946 when he co-authored, with Chiang Hsieh, the report *Social Policy in South-east Asia* for the International Labour Office. On leave from Michigan during the academic year 1955–1956, he did research at the Center for International Studies at the Massachusetts Institute of Technology that resulted in a book, *The Structure of the East German Economy*. In 1960 he was appointed head of the Planning Unit of the Nigerian Ministry of Economic Development and spent most of the next two years in Lagos, working out Nigeria's first economic-development plan. Earlier this year Stolper was in Malta as chief of the United Nations Economic Mission to that country; next month he expects to go to Ethiopia as an adviser to the Economic Commission for Africa.

PITAMBAR PANT ("The Development of India") is Chief of the Perspective Planning Division of the Indian Planning Commission.

CELSO FURTADO ("The Development of Brazil") is head of the Superintendency for the Development of the Northeast (SUDENE) and minister without portfolio in the Ministry of Planning Affairs of the João Goulart government. Furtado was born in the city of Pombal in the state of Paraíba in 1920 and was graduated from the National Faculty of Law of the University of Brazil at Rio de Janiero. He received a Ph.D. in economics from the University of Paris in 1948 and did research for a year at the University of Cambridge before joining the permanent team of economists attached to the United Nations Economic Commission for Latin America in 1949. He later became chief of the Development Division of ECLA and worked on problems of economic development in Brazil, Mexico and Venezuela. In recent years Furtado has served the Brazilian government as Minister for Economic Planning and Development and as Director of the National Bank for Economic Development.

ARTHUR GOLDSCHMIDT ("The Development of the U.S. South") is Director for Special Fund Activities in the United Nations Department of Economic and Social Affairs. Goldschmidt was born and raised in Texas and was graduated from Columbia University in 1932. A year later he joined the newly formed Federal Relief Administration and subsequently worked for various other Government agencies, including the Senate Committee on Interstate Commerce, the National Bituminous Coal Commission, the National Power Policy Committee and the Department of the Interior. During this period he was one of a group of southerners in Government who prepared the "Report on Economic Conditions in the South" discussed in the present article. In 1944 he was appointed director of the Division of Power in the Department of the Interior. He served on the National Commission for UNESCO in 1949 and was U.S. delegate to the UN Scientific Conference for the Conservation and Utilization of Resources. Goldschmidt joined the UN Secretariat in 1950 as a director in the Technical Assistance Administration and was appointed to his present post in 1959. His work has taken him to most of the developing countries of Asia, Africa and Latin America. He wishes to make clear that the views expressed in this article are personal and not necessarily those of his institution.

EDWARD S. MASON ("The Planning of Development") is Lamont University Professor of Economics at Harvard University. A graduate of the University of Kansas, Mason received an M.A. from Harvard in 1920 and a B.Litt. from the University of Oxford in 1923. He returned to Harvard later in the same year to become instructor in economics, acquired his Ph.D. from that university in 1925, and has been a member of the Harvard faculty ever since. Over the past 25 years Mason has served as economic consultant to various Government agencies, including the Department of Labor, the Office of Strategic Services and the State Department. In 1947 he was appointed chief U.S. economic adviser to the Moscow Conference of Foreign Ministers. From 1947 to 1958 he was dean of the Harvard Graduate School of Public Administration.

ERICH FROMM, who in this issue reviews C. G. Jung's *Memories, Dreams, Reflections*, recorded and edited by Aniela Jaffé, is professor of psychology at two universities: the National University of Mexico and the University of Michigan.

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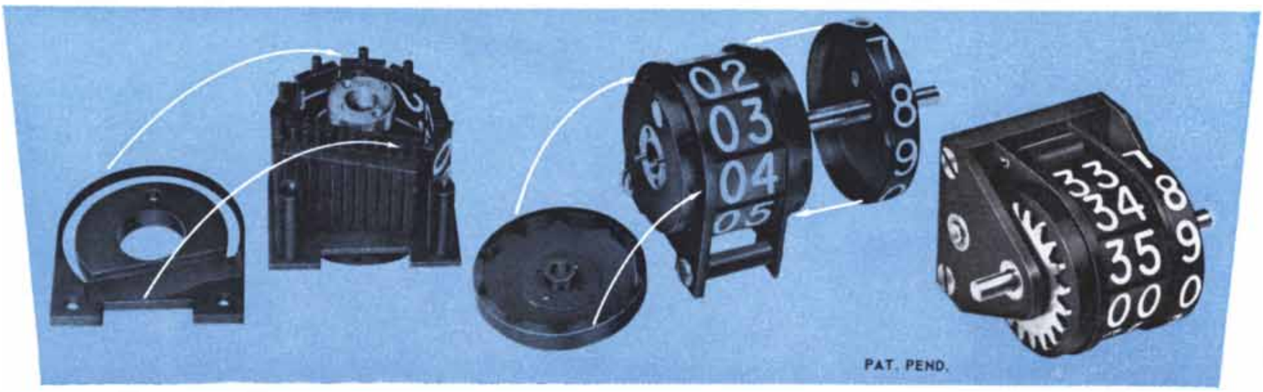

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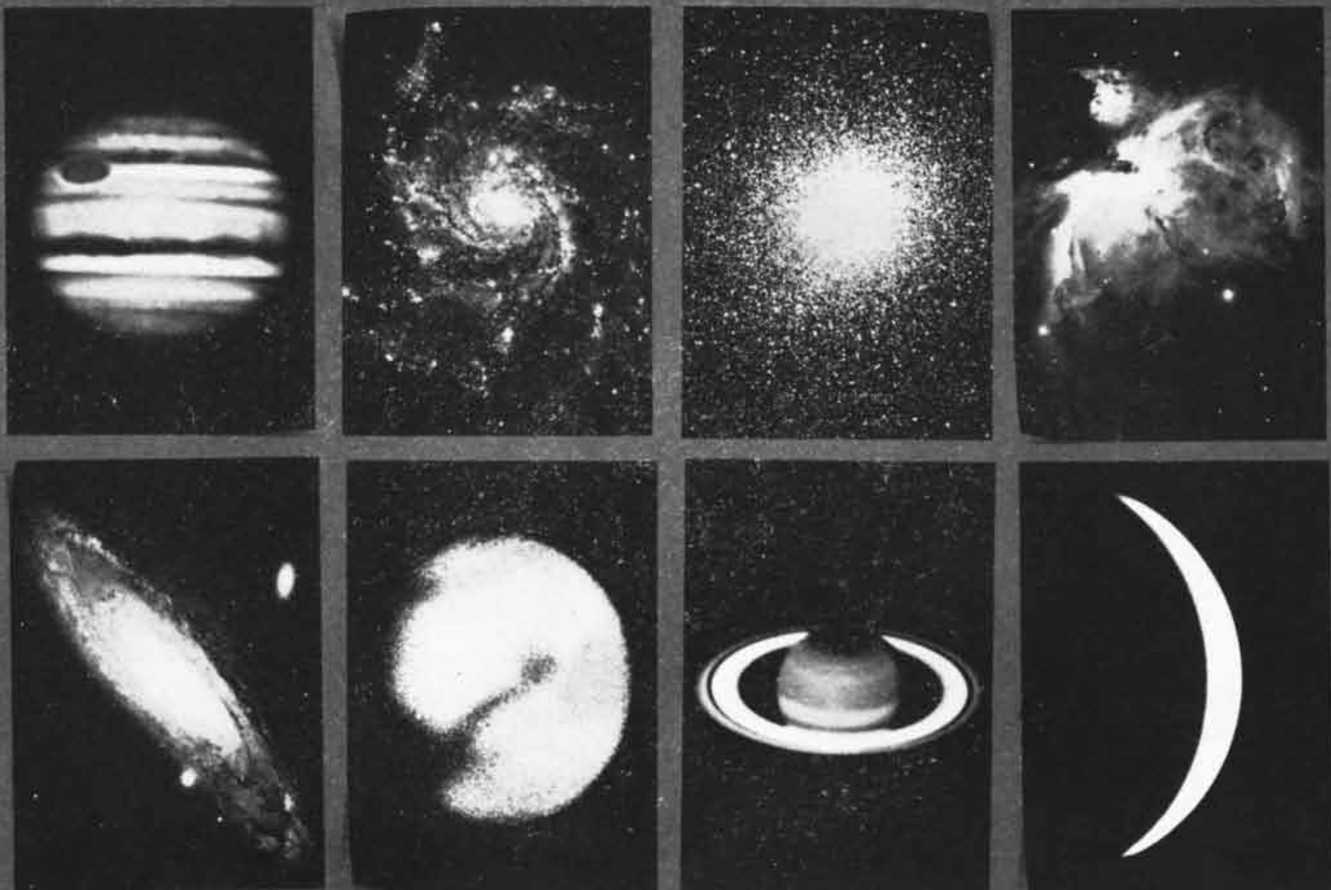


TAKE A CLOSER LOOK

Project Stratoscope II will do just that. From an 80,000-foot-high balloon platform, above 96% of the earth's dusty and turbulent atmosphere, its precision telescope will provide a photographic resolution three times greater than earth-based instruments.

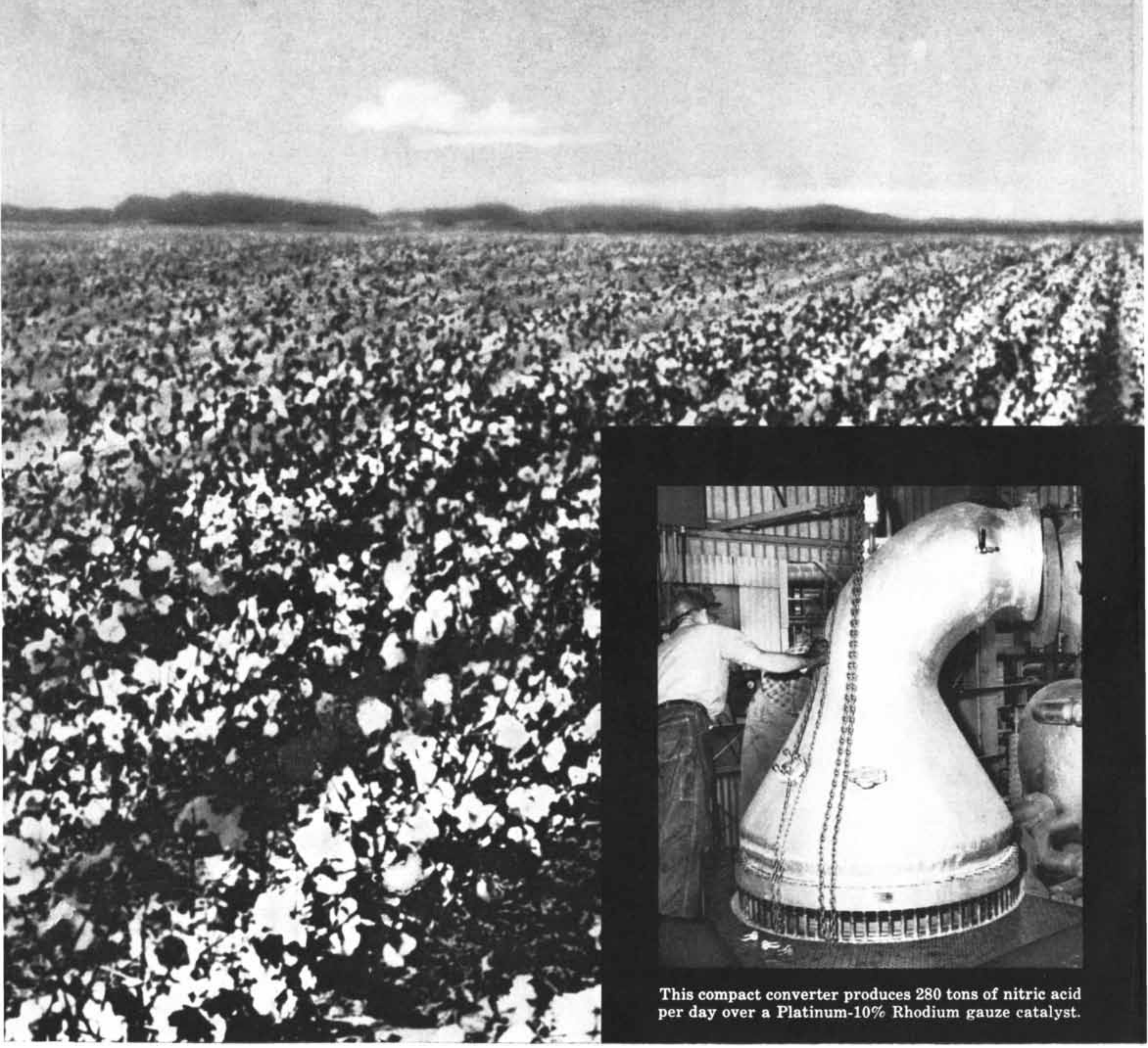
Stratoscope, directed by Princeton University and sponsored by the National Science Foundation, Office of Naval Research and NASA, may help answer many basic questions about the universe—What is the composition of Mars' atmosphere, the nature of Venus' cloud patterns? What clues to stellar evolution and the formation of the sun lie hidden in the core of nebulae and star clusters?

The Stratoscope telescope, a forerunner of satellite observatories, was designed and built by Perkin-Elmer. New concepts were employed to devise its complex command and telemetry, precise guidance and optical systems.

This telescope system is another example of Perkin-Elmer's dedication to the development of instruments and techniques for precise measurement for industry, science and defense. The Perkin-Elmer Corporation, Norwalk, Connecticut.

March 1-2, 1963. Stratoscope II, on its first flight, successfully obtained infrared data on the composition of Mars' atmosphere.

PERKIN-ELMER



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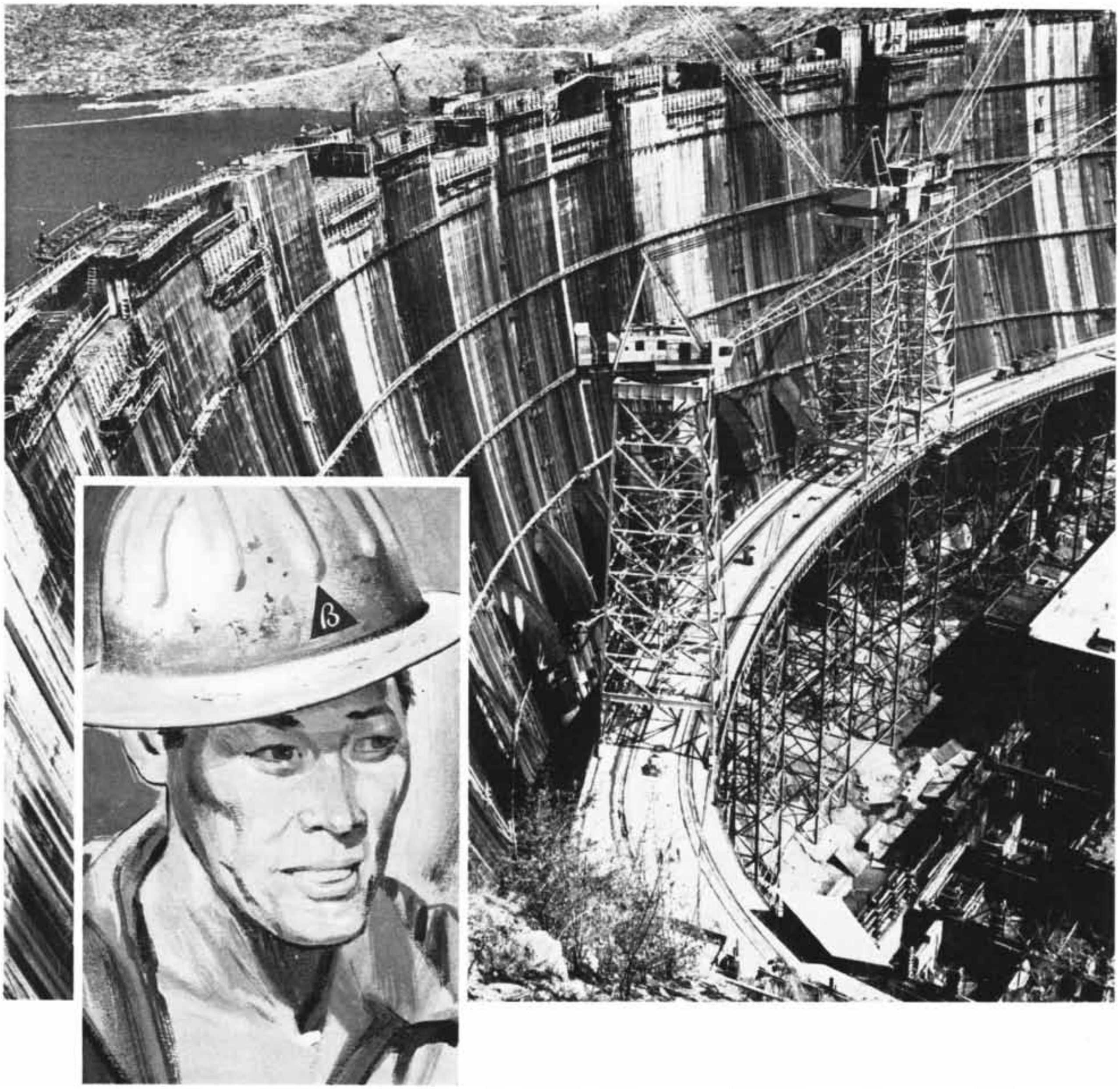

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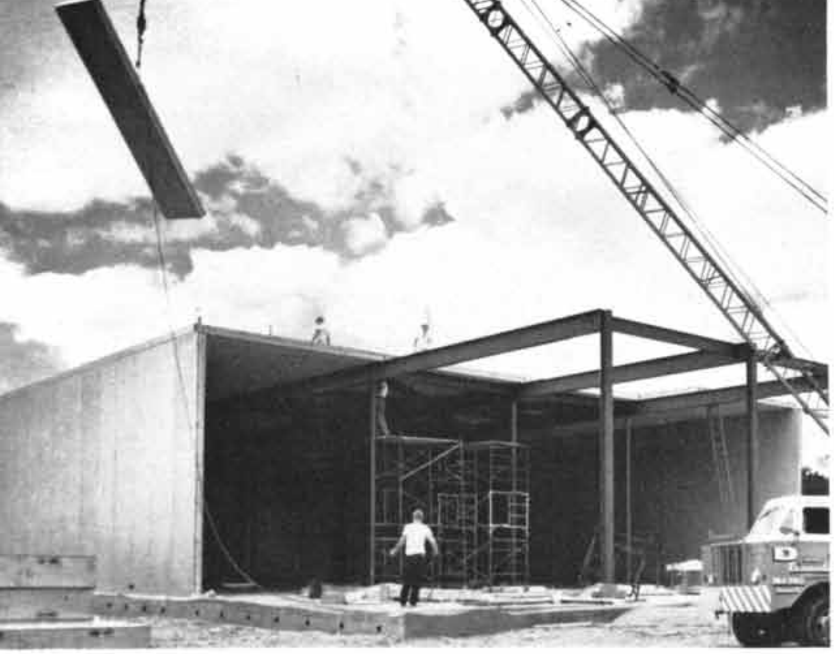
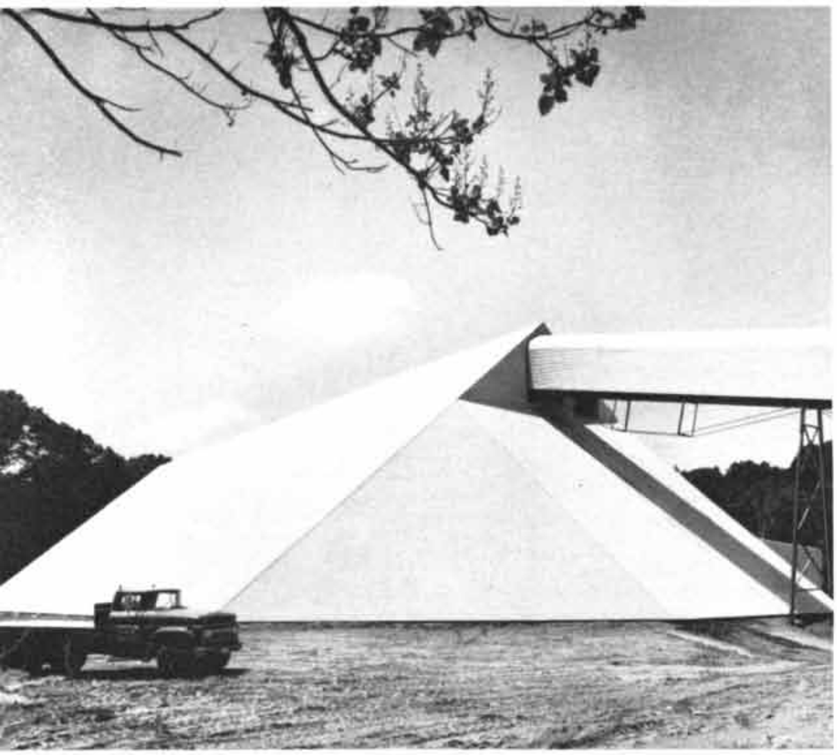


New DYLITE refrigeration panels save $25,000 and 30 working days

Five men erected the walls and roof of this 116,000-cubic-foot freezer warehouse in only five days! It was built with DYLITE® Refrigeration Panels for the Columbus, Ohio, branch of S. M. FLICKINGER, INC.

All the wall and roof panels were shipped to the job site ready to erect. Each consists of exterior and interior facing material, with a molded-in-place insulating core of DYLITE expandable polystyrene—a rigid, closed cell foam plastic that is one of the most effective insulators known for this kind of construction. Because these panels are load bearing, there's no need for perimeter steel framing, decking, or masonry. The builder estimated that conventional construction would have cost $25,000 more, plus an additional 30 days' building time.

Koppers makes DYLITE Refrigeration Panels for any size refrigerated facility, from walk-in coolers to large warehouses. Check the coupon.



Wood that fights fire solves corrosion problem

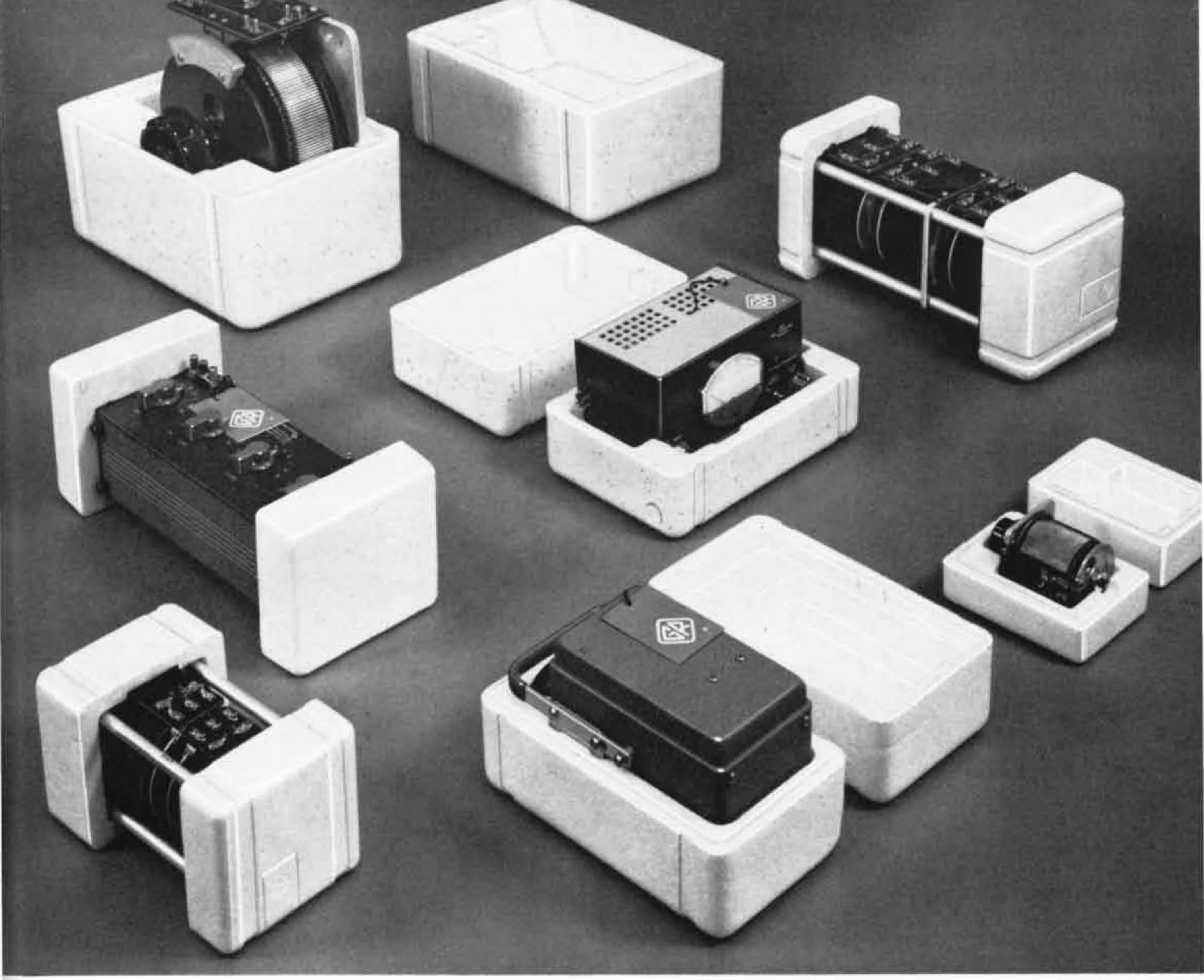
Bulk fertilizer corrodes a metal warehouse. You can eliminate the corrosion problem with wood, but with ordinary wood you have to install a complex sprinkler system to comply with fire regulations. SMITH-DOUGLASS COMPANY, INC., solved both the corrosion and fire protection problems when they built their new warehouse in Danville, Va., with NON-COM® fire protected lumber.

NON-COM lumber is pressure impregnated with chemicals that provide permanent fire protection. At temperatures well below the ignition point of wood, the chemicals produce carbon and water vapor that choke off any flame and prevent fire spread. NON-COM lumber also is protected against termites, rot and decay. The insurance industry has approved NON-COM lumber as a full alternate for noncombustible materials in many applications. Check the coupon.

Shipping damage claims cut 50% with moistureproof corrugated boxes

BUD ANTLE, INC., grows and markets nearly 10,000 railroad carloads of lettuce every year. When the company switched from wooden crates to corrugated boxes, they not only cut their packaging material costs, but also reduced damage claims by 50%. Hard knocks don't shatter the corrugated boxes as they did the crates. And because the corrugating adhesive is based on Koppers Resorcinol, it is waterproof; the boxes resist damage from water and humid atmosphere.

If you've been missing the cost savings offered by corrugated boxes because you're troubled about possible moisture damage in shipping or storage, your problem may be solved by corrugated containers made with resorcinol-based waterproof adhesives. Moisture cannot break down the glue line, weaken the box, nor unfurl the corrugated paper. Check the coupon for more information about resorcinol-based waterproof adhesives.



Savings as high as $1.28 per package!

When General Radio Company, West Concord, Mass., redesigned eleven of their electronic and industrial instrument packages, they selected Dylite® expandable polystyrene as the packaging material to do the job. The new foamed plastic packages molded from Dylite provide better protection for the items, cut unit packaging time in half, in most instances, and reduce shipping weight and cube. Each new Dylite package *costs less than the package* it replaced. Savings are as high as $1.28 per package.

Dylite expandable polystyrene makes a lightweight, rigid foam package that has high shock resistance. Dylite can be molded to almost any size or shape to fit any product. Because they look attractive, Dylite packages frequently double as display cases as well as shipping containers for consumer products. Check the coupon for information about how Dylite can lower *your* packaging costs.

Packages molded by Preferred Plastics Corp., *North Grosvenordale, Conn.*

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Divisions: Chemicals & Dyestuffs
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Metal Products • Plastics
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☐ DYLITE® REFRIGERATION PANELS—factory-made, insulated walls.

☐ NON-COM® FIRE PROTECTED WOOD—provides permanent, built-in fire protection.

☐ RESORCINOL-BASED ADHESIVES—for waterproof bonding of cellulosic, resin and plastic materials.

☐ DYLITE® EXPANDABLE POLYSTYRENE — Foam plastic for packaging.

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50 AND 100 YEARS AGO

SEPTEMBER, 1913: "That the parachute may become a factor as a lifesaving device for aviators was demonstrated at Châteaufort recently by the noted French airman M. Adolphe Pégoud. Pégoud's experiment consisted of leaping from his monoplane at a height of about 900 feet and descending slowly and safely to the ground by means of a specially constructed parachute, the invention of M. Bonnet. Pégoud is the aviator who is reported as having recently accomplished the daring feat of flying an aeroplane upside down and again righting the machine."

"In a paper presented before the Birmingham meeting of the British Association for the Advancement of Science, Mr. C. R. Enock maintained that the economic problems before the world at the present time call for the establishment and exercise of a comprehensive and constructive science whose aim would be to evolve and teach the principles under which economic equilibrium in the life of communities may be attained. It was argued that the real science of living on the earth, or 'human geography,' the adaptation of natural resources and national potentialities to the life of the community, has never been formulated. The congestion of the population in towns, the desertion of the countryside, the high cost of living, low wages, unemployment and so forth are related phenomena, intimately connected with the conservation and development of natural resources. The axiom was advanced that the world is capable of supporting all its inhabitants in sufficiency, and its failure to do so is due to the non-emergence so far of an organizing science whose deliberations would be aloof from egoistic or partisan influences. It was affirmed that the teaching and operation of such a science are necessary if social security is to be maintained and civilization advanced; and it was suggested that to give effect thereto an institution should be established which would bear the same relation to the science of living as their corresponding institutions do to physical, geographical, medical and other sciences."

"At a recent meeting of the old-time Telegraphers' Historical Association at Mount Clemens, Mich., Thomas A. Edison sent a message over the wire to President Wilson. The occasion was of special interest because Mr. Edison stood upon the same site and used the same instrument he used 51 years ago when, as a boy of 14, he sent his first message over the lines of the Grand Trunk Railway. Back in the pre-telegraphic days, when Edison was only a newspaper boy on the railway, he showed his youthful enterprise by printing and selling a small newspaper containing the news along his route. He kept a little font of type in the baggage-car and printed the paper on the train, so its items were strictly up to the minute. It was during this period that a trainman lifted him by the ears, which later caused the deafness that now blurs his hearing."

"The St. Petersburg correspondent of the Parisian sporting journal *Aero* telegraphs to his paper that Igor Sikorsky, recently a student at the technical high school of St. Petersburg, has built what is probably the biggest aeroplane which has thus far appeared. Sikorsky's machine is a biplane, the upper surface of which is somewhat larger than the lower. The span of the biplane is 27 meters and its total lifting surface is 130 square meters. The aeroplane weighs 3,000 kilogrammes and has an enormous lifting capacity. Besides 10 passengers it is designed to carry provisions, fuel for 20 hours and a miscellaneous load of 800 kilogrammes. As might be expected, the power plant is huge. Four engines, each of 100 horse-power and each driving a screw propeller, are mounted in the machine. The fuselage is of wood and is shaped to form an observation cabin, a spacious pilot house with glass windows for two pilots, a rather large cabin for passengers, stores, tools, a corridor and finally another cabin in which a couch is actually to be found for those who wish to sleep."

SEPTEMBER, 1863: "The struggle for the possession of Charleston still goes on between our forces and the rebels. The army, under the able generalship of Gillmore, and the iron-clads are each endeavoring to subdue the rebellious foe and are making encouraging progress. In relation to the monitors themselves there can be no criticism upon their value as impenetrable and serviceable ships for war purposes. Day after day they engage the heaviest ordnance and go into and come out of action without material damage; their turrets are bruised all over with honorable scars but they are still in good order. We hope to hear before many days that the way to the city of Charleston is open and that the grim and sullen-looking little monitors have their guns covering it so that further resistance will be useless."

"A noted Eastern artist now on an expedition to the Rocky Mountains writes of the main buffalo herd of Kansas:—'The sight I saw there no money could buy from my memory. I always thought the Buffalo stories which we hear at the East and the pictures which we see must be greatly exaggerated. In truth they are underdrawn. For two miles on the table-land before me, and stretching sideways twice as far, the earth was overwhelmed with one deluge of stampeding buffaloes. It is literally accurate to assert that one could not see the ground between them. I could think of nothing but a black sea, with humps for billows and the thunder of a shaking prairie for the music of its surge. I raised my field glass and far beyond the stampede saw the broad plateaus towards the White Rock Creek covered with quietly feeding bisons, as thick as on the prairie right before me. Flies on the head of a leaking molasses barrel, ants on a hill, ducks on a Florida lagoon, all familiar symbols of multitude, gave hopelessly out before the task of representing that herd of buffaloes.' "

"The editor of the Scranton (Pa.) *Republican* says:—'We saw a curious embellishment the other day—a five-dollar bill on the Pottsville Bank which contains in one corner a vignette of James Buchanan. Some loyal person had bunged his eyes with red ink, drawn a gallows above his head from which a rope was suspended that went round his neck, and then branded his forehead with the word "Judas." This is but one of hundreds. The bank has had to call in all its issues with that portrait on it, so unmistakable are the manifestations of popular indignation against the man who, had he the will or the pluck, might have nipped this rebellion in the bud, as Jackson did before him.' "


Polaris:
the first 6 years
Polaris has done a lot of growing since January, 1957, when the U. S. Navy first announced its plans for a ballistic missile to be launched from submerged submarines. The original A-1 has a range of 1200 miles. The A-3, now in flight test at Cape Canaveral, has a range of 2500 miles.
The 144 Polaris missiles now on patrol are the mainstay of the nation's deterrent force. The Navy plans a total of 41 Polaris submarines, each carrying 16 missiles it can launch from the depths in as many minutes.
Polaris is a versatile missile. Compact, easy to transport, and extremely reliable, it can be launched from surface ships—or, by remote control, could be launched from the floor of the sea. Today the Navy-Lockheed team is prepared to meet whatever new challenges lie ahead for Polaris.
Lockheed
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Lockheed Aircraft Corporation
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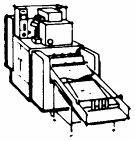
Why waste time . . .

...when it's this easy to find and re-file drawings?



If you've ever tried to locate and pull an original drawing for prints, and then re-file it, you know what an annoying waste of time it is. Why do it? ■ Record your drawings on microfilm, mount them in easy-to-handle aperture cards. From these cards a Xerox Copyflo® or 1824® Printer can produce crisp, clear, work-size prints in seconds on ordinary paper, for pennies! Or, make vellums or offset masters in the same quick, easy way. ■ An aperture card can be found, used and re-filed in *less* than a minute! It's a time and money-saving system that makes real sense. Get all the facts from the leading specialists in reproduction from microfilm. For information write: XEROX CORPORATION, Dept. CF, Rochester 3, New York. Branch offices in principal U. S. and Canadian cities. Overseas: Rank Xerox Ltd., London, and Fuji-Xerox Co., Ltd., Tokyo.

XEROX
CORPORATION

Why you should wear ACCUTRON® instead of a watch

ONLY THE ACCUTRON TIMEPIECE is guaranteed 99.9977% accurate on your wrist (not just in a test laboratory).

ONLY THE ACCUTRON TIMEPIECE does away with the hairspring and balance wheel, the parts which limit the accuracy of all watches.

ONLY THE ACCUTRON TIMEPIECE—with just 12 moving parts—is so rugged, so trouble-free you can forget about usual watch maintenance and repair.

ONLY THE ACCUTRON TIMEPIECE keeps time by the constant vibrations of a tuning fork activated electronically. It doesn't tick. It hums.

THE ACCUTRON TIMEPIECE never, never needs winding—even off your wrist. Power cell lasts a full year. Second year's cell free. Additional cell only $1.50.

ACCUTRON has been selected as a timing device in U. S. space satellites and Telstar 1.

Above: Revolutionary electronic tuning fork mechanism of ACCUTRON seen through transparent dial of "Spaceview" model. 14-KT gold case. $200*

ACCUTRON is the only timepiece guaranteed 99.9977% accurate on your wrist. It makes the finest watches—even electric watches—obsolete.

The ACCUTRON timepiece keeps time by a revolutionary new principle. This miniature tuning fork, driven by a transistorized electronic circuit, vibrates at a constant 360 times a second. Result? ACCUTRON is the only timepiece that's guaranteed 99.9977% accurate on your wrist.

The ACCUTRON timepiece already has become the new world standard of accuracy. It was purchased by the U.S. Air Force for every X-15 pilot. It's approved for use by all major railroads. And it's the timepiece of leaders in science, industry and government.

See ACCUTRON—the most distinctive timepiece you can own, the most unique gift you can give. Your choice of many distinguished waterproof* and shock-resistant styles, from $125 to $2500*.

For name of nearest ACCUTRON dealer and free booklet, write Bulova Watch Co., Inc., Dept.SA, 630 Fifth Avenue, New York 20, New York. Don't you owe it to yourself to wear ACCUTRON instead of a watch?

Read the ACCUTRON guarantee of accuracy! ACCUTRON is guaranteed by Bulova not to gain or lose more than one minute a month in actual daily use on your wrist. For one full year from date of purchase, the authorized jeweler from whom you purchased your ACCUTRON timepiece will adjust it to this tolerance, if necessary, without charge.

ACCUTRON "214" Brilliant stainless steel case, raised dial markers. $125*

ACCUTRON *A RESEARCH BREAKTHROUGH BY* **BULOVA**

EACH OF THESE JOBS IS DONE BETTER WITH NATURAL DIAMONDS

The grinding and finishing jobs shown on these pages are being performed on alumina ceramic, tungsten carbide, and copper plating. Yet they all share one important detail: in every case diamonds are doing the job quickly—and economically.

When you use diamonds, you get the unique combination of excellent cutting ability linked with fantastic endurance. Result: diamond tools last longer than any others. Your people spend more time producing, less time changing tools.

If you cut, sharpen, grind or smooth anything in your business, you can probably use natural diamonds to advantage. Test them against the method you're using now. You'll discover how efficient—and economical—a diamond tool can be.

BEST GRIT FOR METAL-BOND WHEELS DEVELOPED BY THE DIAMOND RESEARCH LABORATORY IN JOHANNESBURG

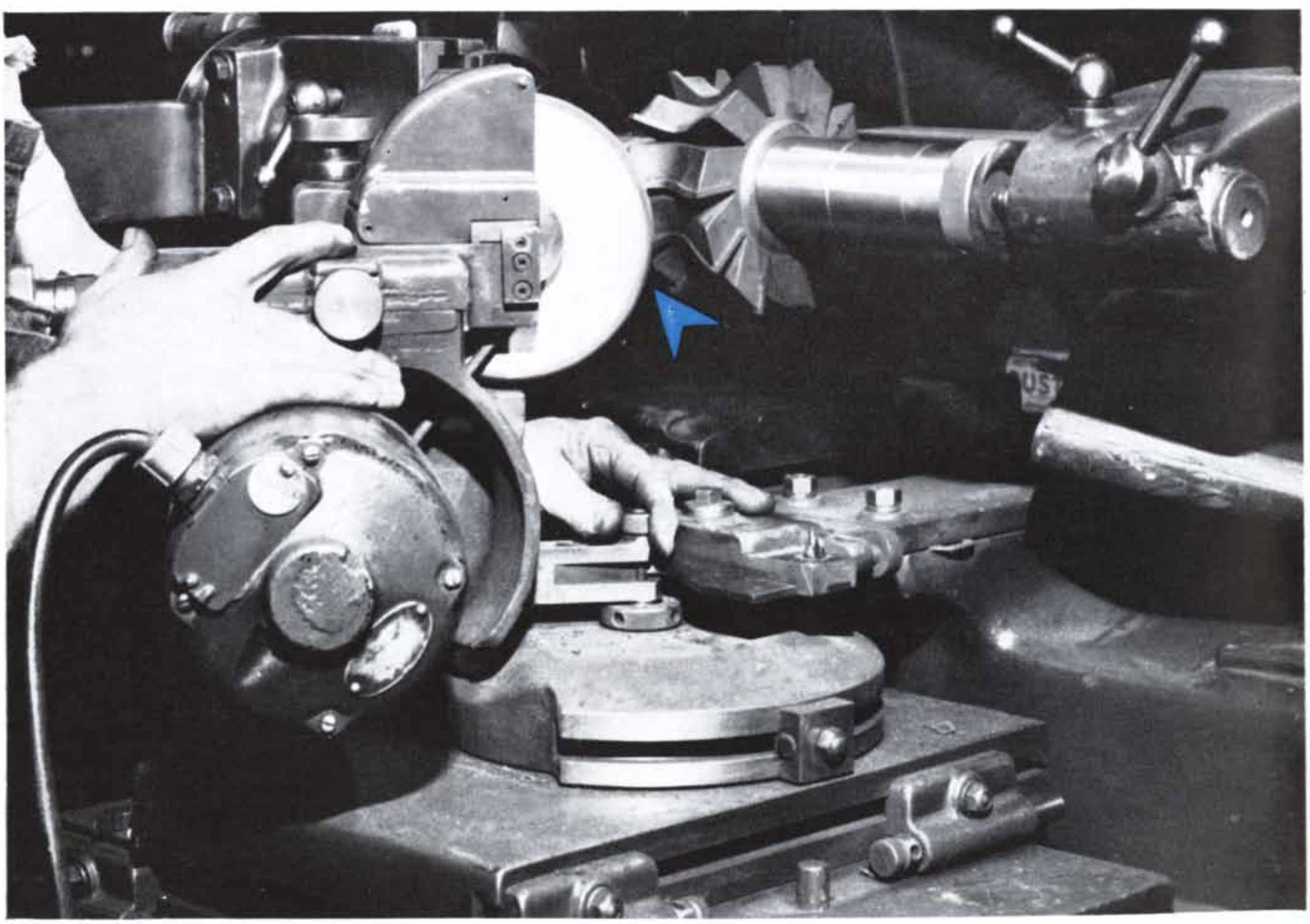
A special impact crushing method for natural diamonds is producing the strongest and most durable grit ever obtained for metal-bond wheels. Your tool and wheel manufacturer is ready to help you select the diamond tool that's right for your job.

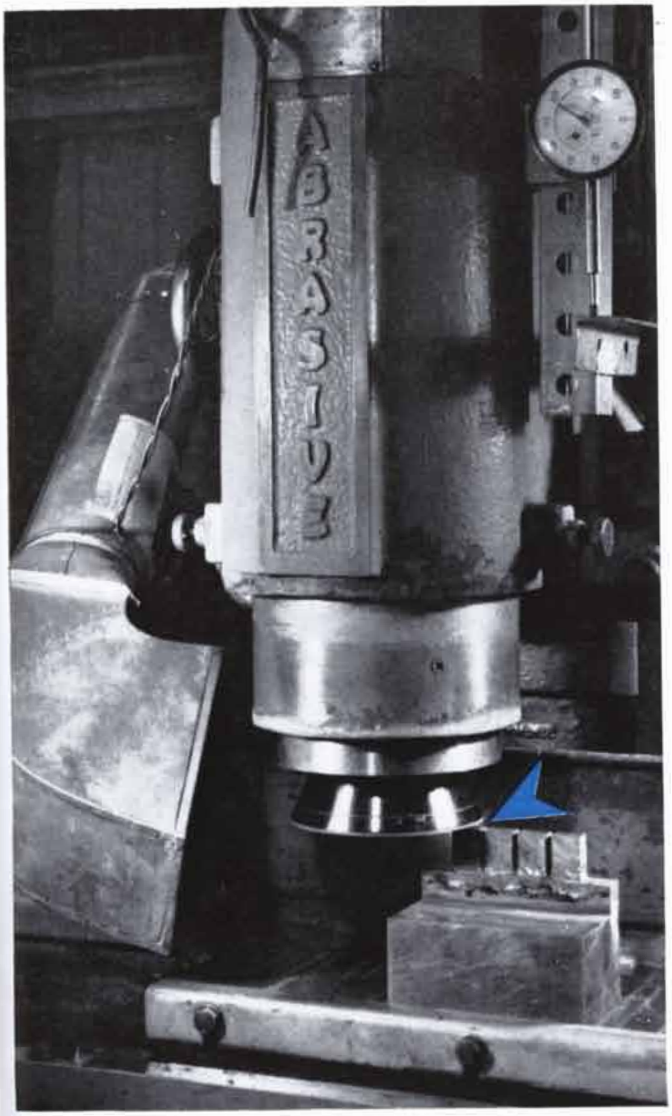
INDUSTRIAL DIAMONDS CUT PRACTICALLY EVERYTHING...ESPECIALLY YOUR PRODUCTION COSTS

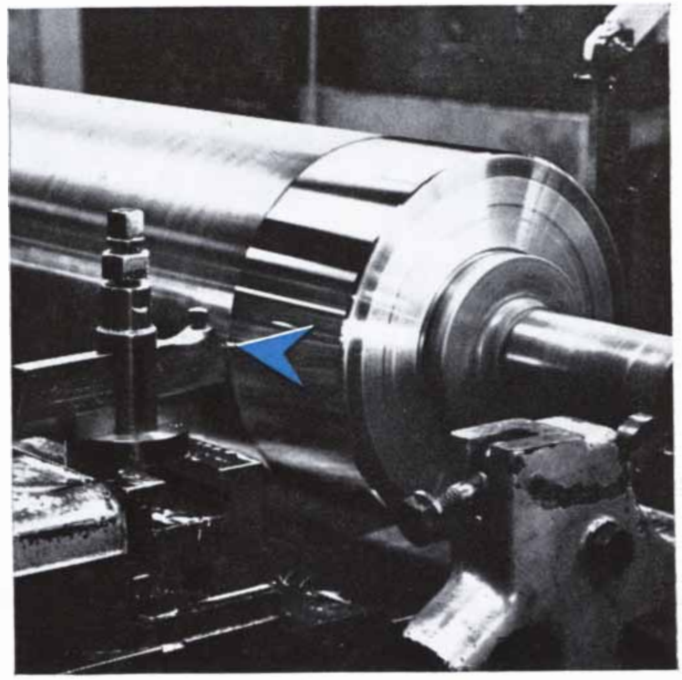
INDUSTRIAL DISTRIBUTORS (SALES), LTD., Johannesburg · London

World's leading supplier of diamonds for industry

Textile Machine Works, Reading, Pa., mounted a vitrified-bond natural diamond wheel on a pivot for grinding shapes on carbide-tipped or solid carbide cutting teeth of milling cutter. This unique setup makes it possible for the wheel to grind complex helical curves with little effort.

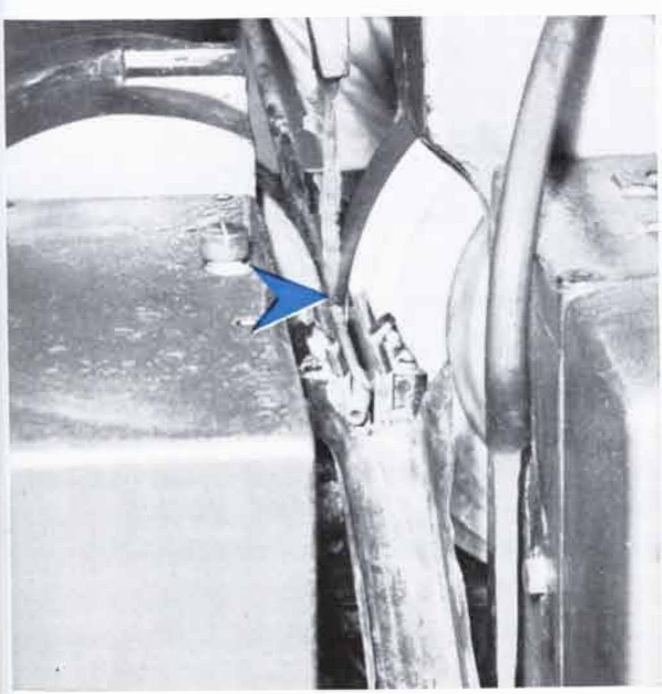






Copper-plated rollers of cast iron, steel or aluminum for gravure printing are smooth-finished in a single pass with natural-diamond lathe tool at Southern Gravure Service, Louisville, Ky. Surface finish of about six micro-inches results. No coolant is required.

Tungsten-carbide is dry-ground experimentally with natural diamond wheel. Vacuum duct at left collects particles removed by the grinding operation, from which diamond dust can be recovered for study or reclamation. Diamond reclamation can normally recover about 7% of the original cost of the grinding wheel.



Sintered alumina ceramic insulators are ground with natural-diamond centerless grinder at Royal Worcester Industrial Ceramics, Ltd., South Wales, England. The 180-mesh-grit wheel has a taper of .003 inch on the first ⅜ inch to facilitate entry of the insulators between diamond wheel (right) and fiber guide wheel (left). Tolerances of ±.0004 inch are achieved. Wheel speed: 3000 surface feet per minute.

Ant and new computer component at left enlarged five times. Actual size shown here. 

Electronic Brawn

There are two powerhouses in this picture: the ant and that tiny wafer he's toting—RCA's new metal oxide semiconductor. Like the ant, this new fundamental computer component is a giant for putting out work. It makes dynamic circuitry possible for miniaturized high-performance computers.

Another result of advanced EDP engineering is RCA's new REALCOM 3301, the first "all-purpose" computer. The 3301 is a super-fast business data processor. It is a scientific system. It is a communications processor. It is a real-time, on-line, system with priority interrupt and fast random access storage. And this new RCA 3301 is in the medium price range.

Brawn? Brains? Service? Support? RCA pinpoints your exact needs, then matches computer to workload to save you money. It's the customer-directed approach to EDP. It centers on you. Call us—and see!

RCA ELECTRONIC DATA PROCESSING, CHERRY HILL, N.J.

RCA® **The Most Trusted Name in Electronics**

They Journeyed into SPACE...

Astronaut
Alan B. Shepard
Suborbital Flight
5 May 1961

FREEDOM 7

Astronaut
Virgil I. Grissom
Suborbital Flight
21 July 1961

LIBERTY BELL 7

Astronaut
John H. Glenn
Three Orbits
20 February 1962

Friendship 7

Astronaut
M. Scott Carpenter
Three Orbits
24 May 1962

AURORA 7

Astronaut
Walter M. Schirra
Six Orbits
3 October 1962

Σ7

Astronaut
L. Gordon Cooper
15-16 May 1963
22 Orbits

FAITH 7

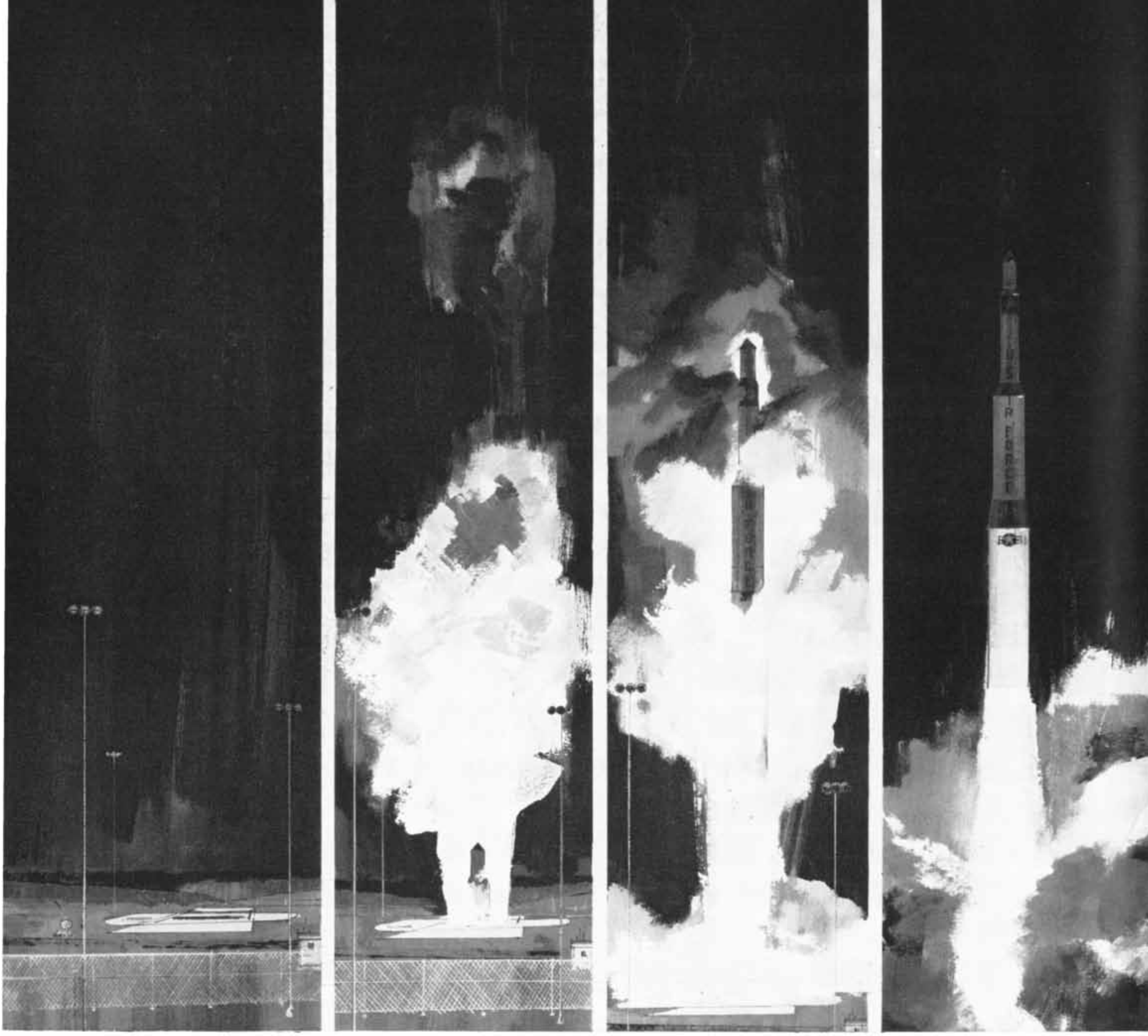
... and Safely Returned in Mercury Spacecraft

FIRST FREE MAN IN SPACE TRADEMARK

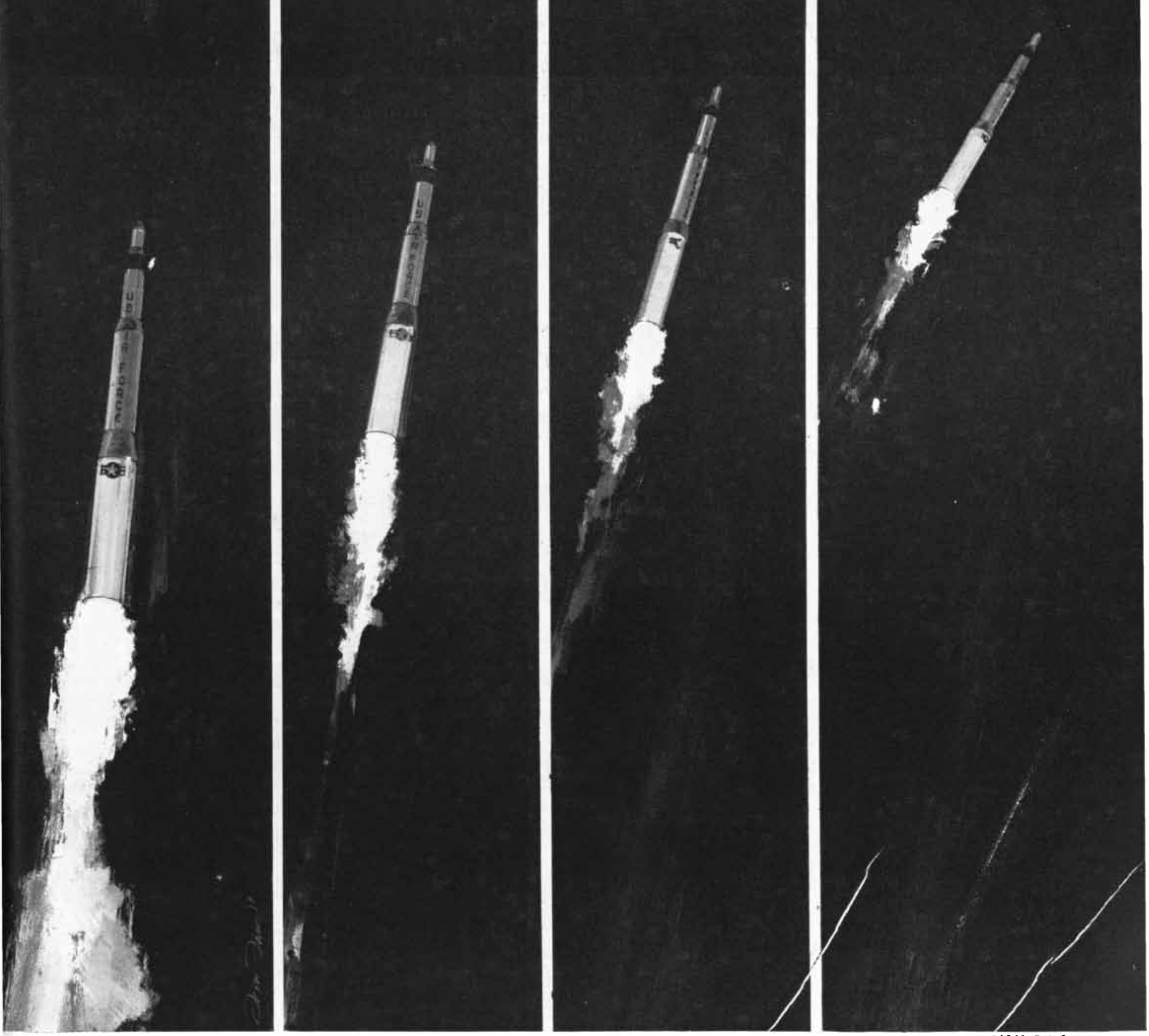
Designed and built under the leadership of the National Aeronautics and Space Administration by

MCDONNELL

America's Experience in Manned Space Flight, and Ours, is the Same.



How do you help keep a Minuteman on the straight



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and narrow? Borg-Warner knows how!

One of our surest persuaders for peace is the Air Force Minuteman missile. Poised in underground silos around the country, it can carry a nuclear warhead more than 6,300 miles with deadly accuracy.

Borg-Warner's Pesco Products Division supplies the hydraulic "muscles" for all three stages to steer Minuteman straight to the bulls-eye.

Borg-Warner makes certain these "muscles"—intricate pumps and motors that power the missile's guidance system—will work every single time. Each unit is hand-assembled in "clean" rooms where environmental control keeps the air more dust-free than in a hospital's operating room, while holding the temperature and humidity constant.

You'll find precision products from Borg-Warner also serving aboard our sleek new fleet of nuclear submarines, roaring into space with our astronauts, and standing guard in supersonic jets and giant ICBM's.

We hope Minuteman's hydraulic power units may never be called upon to help steer to an enemy target. But if they are, Borg-Warner research and engineering will make certain they'll get the job done. Borg-Warner Corporation, 200 South Michigan Avenue, Chicago 4, Illinois.

B-W

BORG-WARNER *where research and engineering work wonders for you*

Established 1845 SCIENTIFIC AMERICAN September 1963 Volume 209 Number 3

Technology and Economic Development

Presenting an issue devoted to the problem of how nations can attain a state of self-sustaining growth. This article outlines the history of development and of the division of nations into "rich" and "poor"

by Asa Briggs

A circumstance new to history stretches the tensions of contemporary world politics. This is the widespread awareness of the division of nations into two classes: "developed" and "underdeveloped" in the parlance of the day or, in plainer words, rich and poor. The contour lines of international economic inequality are easily drawn. To the class of the rich belong the nations of northwestern Europe and those elsewhere in the Temperate Zones that were settled and organized by people of the same stock: the U.S., Canada, Australia and New Zealand. One non-European nation—Japan—should also be counted in the group, and recently another European nation, the U.S.S.R., has joined it. These nations, constituting less than a third of the human population, produce and consume more than two-thirds of the world's goods. Their output is increasing more rapidly than their population, and they boast rising incomes per capita.

Income per capita hardly serves as a measure of the position of the nations of the poor. The overwhelming majority of their populations are occupied in subsistence agriculture and live almost entirely outside the monetary systems of their meager economies. For what the economic indices are worth, they show that between the poorest 1.5 billion people—the bottom half of the human population—and the average standard of living prevailing in the rich countries the disparity is on the order of one to 10. More significantly, the indices show that the disparity between the two classes of nations is widening.

Poverty is not, of course, a new condition in human affairs. Some of the poor nations were once world powers and were held to be rich as well as powerful. But even though they have been placed at a disadvantage in recent years by the unfavorable terms of their relations with the rich nations, the situation in which their peoples live is not much worse than before. The rich nation is the novelty, and the development that makes entire nations rich is itself the pivotal development of modern history. To understand the increasing economic inequality of nations one must look outside the boundaries of economic theory. In the search for the causes, antecedents and "preconditions" of development it is necessary to turn to history, and the historian has his choice of starting points.

In the summer of 1454, one year after the fall of Constantinople to the Ottoman Turks, Enea Sylvio Piccolomini (later Pope Pius II), who has been described as one of the best-informed men in Europe, wrote gloomily that he could not see "anything good" in prospect. Christendom was weak and divided, and internal conflicts as well as external challenges foretold likely destruction. He did not add, as he might have done, that there had also been a downsweep in the medieval economy. This was not the language of the age. His modest humanist hope was that he would be proved entirely wrong and that posterity would call him a liar rather than a prophet.

Within less than 50 years Europeans had pushed out adventurously far beyond the confines of Europe around the coast of Africa, toward India and Southeast Asia and across the Atlantic. An Indian historian has described everything that has happened between then and our own times as the "Vasco da Gama epoch" in world history. The search for wealth outside Europe's boundaries preceded the full mobilization of wealth within. Long before our own times Adam Smith, writing on the eve of the great industrial changes that transformed both society and men's ways of thinking about it, declared that the discovery of America and of a passage to the East Indies via the Cape of Good Hope were the two most important events in the history of mankind.

Within less than 100 years after 1454 the great movements of thought and feeling to which historians long ago attached the labels of "Renaissance" and "Reformation" had further extended and disturbed the horizons of many Eu-

DEVELOPMENT IN NIGERIA is exemplified by the construction of a bridge across the Niger River, the first piers of which are seen in the aerial photograph on the opposite page. The bridge, at Onitsha, will greatly improve communication between Nigeria's Eastern and Western regions.

CHILD APPRENTICE is instructed in the workings of the spinning machine she will tend. This early industrial photograph was made in a U.S. textile mill. Child labor was an important source of the human capital invested in 19th-century industrialization.

ropeans. It is just as easy for 20th-century writers to place the beginnings of "modern times" in 15th- and 16th-century breaks with tradition as it was for Adam Smith. Those breaks now figure, however, less as spectacular events than as phases of processes, "preconditions" of what was to happen later. The invention of the steam engine or the French Revolution, the one carrying with it a universal technology, the other a universal ideology, may today look like even bigger breaks. It is part of the task of the historian to scrutinize old labels carefully, to qualify large-scale generalizations and to expose contradictory tendencies. Much that seems "modern" has origins more remote than the 18th century. Much that was old in the 15th and 16th centuries has survived on a massive scale.

The least modern element in the first predatory phases of discovery was that the underdeveloped countries of today then seemed to be the great centers of wealth: the "gorgeous East" and the South American El Dorado. The 17th-century English writer Thomas Mun, exaggerating and oversimplifying, maintained that the world commerce of his day consisted in the exchange of the mineral wealth of the new Indies in the West for the luxuries and refinements of the old Indies in the East. Francis Bacon referred to South America as "the money-breeder of Europe."

Between the beginnings of the age of world commerce, when new resources and markets were opened up, and the great industrial changes of the 18th and 19th centuries, when new methods of production were introduced, the wealth of nations was determined in large part by the struggle for empire and power. That struggle, which led to the eclipse of Spain and Portugal, the rise of the Netherlands and the protracted contest between England and France, was world-wide in scale. American independence was one aspect of it. Concurrently, within Europe, no less significant but less dramatic changes in economic life were under way, later to culminate in industrial revolutions and the postindustrial division of nations into developed and underdeveloped.

By the early 18th century there were present in parts of Europe many of those economic and social ingredients whose absence is taken today as a sign or a cause of "backwardness." Among them were transport and credit facilities, many deriving from international trade; supplies of relatively skilled labor, some of it employed in industries with scattered and potentially expanding markets, and—not least—well-trained acquisitive attitudes, congenial to both enterprise and capital accumulation. R. H. Tawney is not the only historian of capitalism to go back for his basic evidence not to the age of industrialism but to the shifts of values in the three centuries that preceded it.

It was during the last of these centuries that the "scientific revolution" created new climates of opinion. "The stream of English scientific thought, issuing from the teaching of Francis Bacon and enlarged by the genius of Boyle and Newton," T. S. Ashton has written, "was one of the main tributaries of the industrial revolution." The statement cannot be disputed, even though many of the first inventors who transformed ways of production were men of little science. Practical and empirical, they were more interested in solving an immediate problem than in speculating about nature. The technical ascendancy of science belongs to the 19th century, not the 18th.

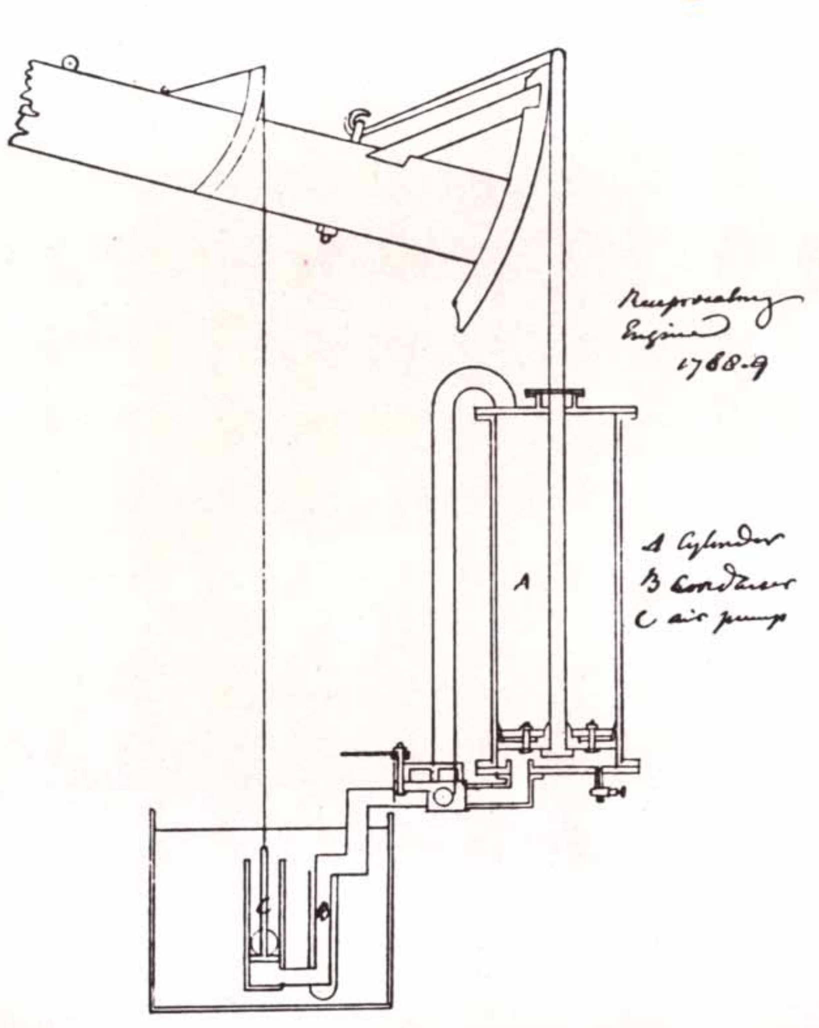
Britain was the center of the first industrial revolution. Throughout the first decades of the 19th century more than half of the world's industrial output was concentrated in an island with only about 2 per cent of the world's population. The British industrial revolution, the first in a sequence, became a classic model, even if it was a misleading model. From it Karl Marx deduced that "the industrially more developed country presents to the less developed country a picture of the latter's future." The forecast, involving as it did both the premise of economic growth and the threat of social conflict, contrasts sharply with Adam Smith's preindustrial forecast of a "stationary state" in which the existing methods of production would have been "improved" as far as they could possibly be improved and economic growth would have ceased.

The "causes" of the British industrial revolution, therefore, have more than local interest. Historians are still arguing about the weighting of the various factors that contributed to the upsurge of growth, particularly in the 1780's. What seems clear is that, in addition to the cumulative build-up of economic power on the high seas and overseas and the social development of a community that encouraged innovation and thrift, there were urgent challenges that had to be overcome before there could be an immense spurt in invention, investment, production and trade. The slowing down of a previous rate of agricultural expansion and the peculiar exigencies of unprecedented population growth may explain difficult questions relating to timing. There are also long-term technical questions, however, in relation to the exploitation of iron and the development of steam power. It has even been argued that Britain had to leap ahead if it was not to lumber back.

Businessmen of the time often gave simple answers. "We want as many spotted Muslins and fancy Muslins as you can make," a Northern cotton spinner was informed by his London agents in 1786. "You have many competitors, we hear, coming forward.... You must give a look to Invention. Industry you have in abundance.... We expect to hear from you as soon as possible, and as the Sun shines let us make the Hay." There were no ways to increase output to meet rising demand without new processes and new forms of organization. As a knowledgeable Manchester man put it in 1783: "No exertion of the manufacturers or workmen could have answered the demands of trade without the introduction of spinning jennies."

Thus at the very time American independence was ratified Britain was finding new sources of economic strength. Between 1781 and 1800 the imports of raw cotton quintupled, pig iron production quadrupled, foreign trade (whether measured in shipping tonnage cleared from the ports or in export and import values) nearly tripled and total industrial production doubled.

A contemporary writer with a precocious statistical sense drew rhetorical conclusions. "An era has arrived in the affairs of the British Empire," wrote Patrick Colquhoun in 1814, just before the last of the great wars between Britain and France came to an end, "when resources have been discovered which have excited the wonder, the astonishment and perhaps the envy of the civilized world." He moved from rhetoric to social generalization. "It is with nations as it is with individuals who are in train of acquiring property. At first, progress is slow until a certain amount is obtained, after which, as wealth has a creative power under skillful and judicious management, the accumulation becomes more and more rapid, increasing often beyond a geometrical ratio, expanding in all directions, diffusing its influence wherever talents and industry prevail, and thereby extending the resources by which riches are obtained by communicating the power of acquiring it to thou-



STEAM ENGINE as modified by James Watt was the basic source of power for the British industrial revolution. In this drawing prepared by Watt for a 1769 patent specification the cylinder is at right and the separate condenser, one of his important contributions, is at the bottom. The downstroke of the piston exerted a downward force on the rocker arm (*top*).

sands who have remained without wealth in countries less opulent."

The term "industrial revolution" seems to have been invented by a French economist, Jérôme Adolphe Blanqui, in 1827. Before this, however, James Watt and Richard Arkwright had already been compared with Mirabeau and Robespierre, and smoke with propaganda. Something more had happened than mere acceleration of existing economic trends. Man's position had changed in relation to nature. Poets and prophets were as fascinated by steam power as millowners and ironmasters. Erasmus Darwin, the grandfather of Charles, wrote in 1792:

Soon shall thy arm, UNCONQUER'D STEAM, afar
Drag the slow barge, or drive the rapid car;
Or on wide-waving wings expanded bear
The flying chariot through the fields of air.
Fair crews triumphant, leaning from above
Shall wave their fluttering kerchiefs as they move;
Or warrior bands alarm the gaping crowd,
And armies shrink beneath the shadowy cloud.

In the first flash of enthusiasm there was immense imaginative appeal in technical discovery, just as there had been in the discovery of America. It was the recognition that nature could be tamed and the environment controlled that distinguished the industrial revolutions of the 18th and 19th centuries from the only comparable revolution in human productivity, that of the neolithic world, when settled agriculture took the place of hunting and food-gathering and a new division of labor transformed social and cultural processes.

The extent of the change can be measured not only in statistics of material progress but also in 19th-century social comment from Jean Charles Sismondi and Claude Henri Saint-Simon to John Stuart Mill and Marx. Saint-Simon wanted to change the words of the *Marseillaise* from "*enfants de la patrie*" to "*enfants de l'industrie*." Politics for him was "the science of production." In 1848, the year of revolution, Mill wrote: "All the nations which we are accustomed to call civilized, increase gradually in production and in population; and there is no reason to doubt that not only these nations will for some time continue so to increase but that most of the other nations of the world, including some not yet founded, will successively enter upon the same career."

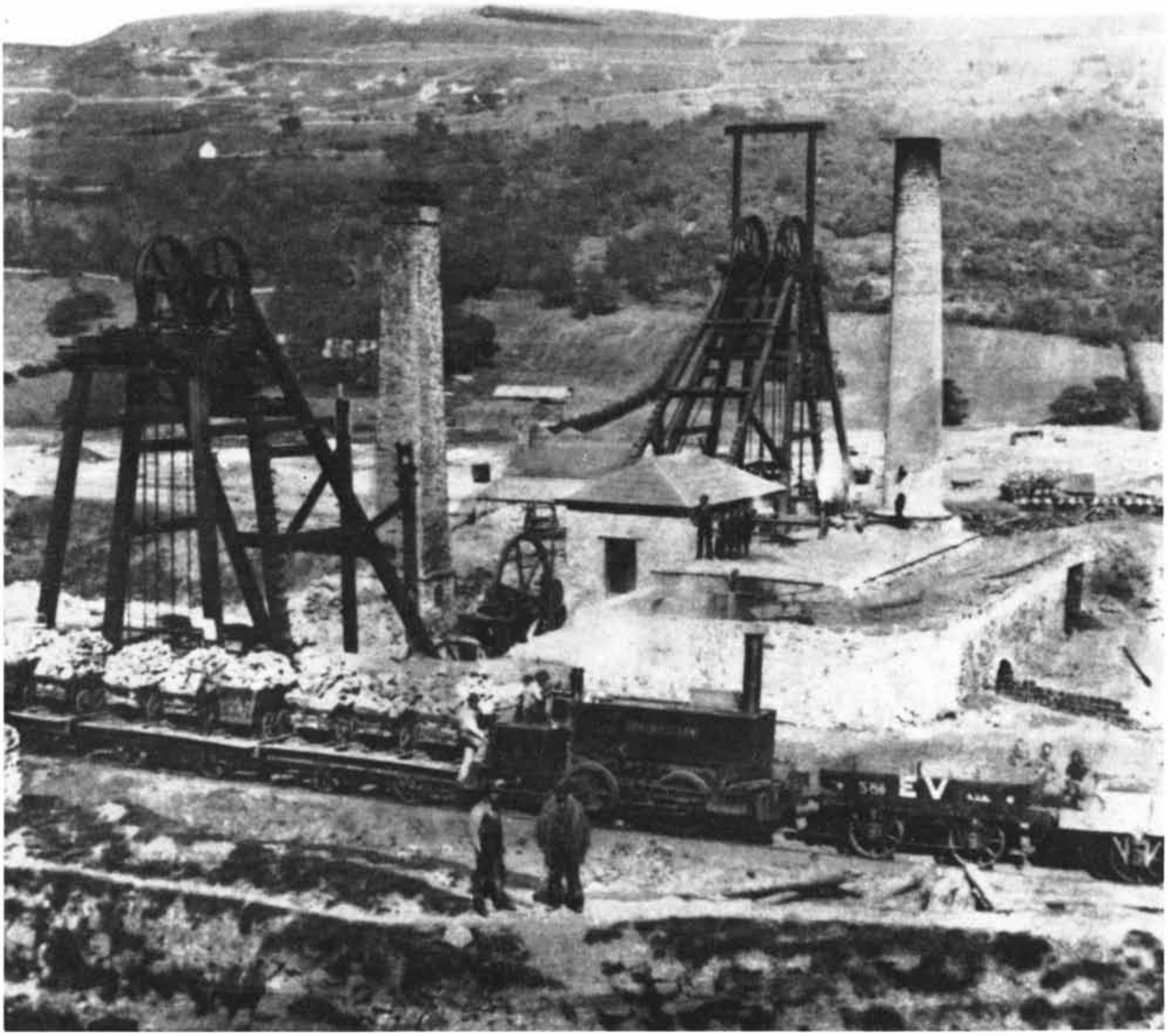
Only the word "gradually" is misleading. Industrialism was to establish itself in sharp bursts, and once established it was to develop unevenly through boom and slump. It was also to create new social conflicts. Later writers emphasized, as the elder Arnold Toynbee did in his pioneer study of the 1880's, *Lectures on the Industrial Revolution of the 18th Century in England,* the social consequence of steam power—its effects on men's relations not with nature but with one another.

Not only were owners of capital often pitted against owners of land—town versus country, competition versus monopoly, progress versus tradition were some of the battle cries—but also there was a new division between "capital" and "labor." It was to this division that Marx turned his attention, maintaining that in the very processes of industrial expansion "classes" were being formed that were inexorably antagonistic. The rich would become richer and the poor poorer. Unlike traditionalist writers who bemoaned the decay of an old social order, Marx welcomed the transformation and the social revolution he thought it would ultimately entail. The melancholy conservative reaction was well expressed by Henri Frédéric Amiel in 1851: "The statistician will register a growing progress and the novelist a gradual decline.... The useful will take the place of the beautiful, industry of art, political economy of religion, and arithmetic of poetry."

These contrasting pictures of the future were painted at a time when Europe was still primarily an agricultural continent with no more than patches of industry. Even these patches were frequently to be found among forests and beside streams rather than in concentrated industrial areas. Marx and the early British socialists before him might talk of a "working class," but in Europe craftsmen far outnumbered factory workers and even in Britain there were far more domestic servants than textile workers. When the Great Exhibition of 1851 was held in the specially built Crystal Palace to illustrate "the progress of mankind," there was no doubt that Britain was a workshop of the world.

During the early stages of industrialization the two master commodities were coal and iron. They took the place of wood, wind and water at the center of the new technology. The two materials were associated both geographically and economically; their close geographical proximity often created "black country." Their economic interdependence was expressed most strikingly in the great symbol of early industrialization: the steam locomotive puffing its way over "iron roads." It is not surprising that contemporaries saw the building of railroads as the beginning of a new world. "We who lived before railways," wrote William Makepeace Thackeray, "and survive out of the ancient world, are like Father Noah and his family out of the Ark. The children will gather round and say to us patriarchs, 'Tell us, grandpa, about the old world.' "

Others saw railroads as sinews of the economy and vitalizing influences on society. Heinrich von Treitschke, the ideologue of German nationalism, believed that railways "dragged the German nation from its stagnation." Count



INDUSTRIAL LANDSCAPE photographed in the Midlands of England about 1855 shows a mine with two shaft hoists and (*center*) a steam-driven water pump. In the foreground is a steam locomotive pulling a string of flatcars carrying loaded mine carts.

Sergei Yulievich Witte, the Russian engineer and exponent of industrialization, set out to make railroads the foundation of a new economy in Russia in the 1890's; economic historians have been unanimous in pointing to Russian railroad building as "the fulcrum round which the industrial level of the country was being rapidly lifted" during that decade.

The identification of industrialization with "carboniferous capitalism," which was simply one phase of industrialization, has had lasting results. Along with a waste of economic resources there was a marked deterioration in the human environment in the new industrial areas. At the very time that science was suggesting that "fate" was really amenable to social control, a new framework of social necessity was being constructed. The mill chimney and the slag heap dominated the horizon and set the scene for the social conflicts that also came to be identified with capitalism—conflicts centering not only on wages but also on status and authority, the length of the working day and the right to security.

Whatever the technology that activates industrial revolutions, the disturbance of old traditions and institutions and the imposition of unfamiliar rhythms of work and leisure are bound to bring social upheavals. But the coal-and-iron technology of the first industrial revolutions accentuated all the human difficulties. It is not surprising that in 19th-century Britain aesthetic and social protest converged in the writings of John Ruskin and William Morris. The same tradition of protest continued to exert a powerful influence, however, even after iron had given way to steel as a master material and electricity had provided a new source of power.

In this next age of technology Britain pioneered new schemes of social welfare but failed to hold its own economically. It was not only that other nations possessed greater physical resources they could develop at lower cost; there was also a withering of enterprise in Britain. The rate of expansion slowed and British industry failed to participate fully in the new developments in steel—even though some of the basic inventions were British—in machine tools, electrical engineering and chemicals.

Germany and the U.S. were the countries that took the lead in these industries of the future. By 1886 the U.S. had replaced Britain as the world's largest steel producer; Germany too was ahead by 1900. In machine tools the U.S. set a new pattern of standardization, the precondition of mass production. In the building of its electrical and chemical industries Germany, with the most advanced European system of scientific and technological education, became a "new model" of industrialization. Output of sulfuric acid and alkalies rose eight times between 1870 and 1900; that of dyestuffs, in which Germany held a near monopoly, rose four times during the same period.

In both the U.S. and Germany the big industrial concern came to dominate manufacturing industry. The resulting concentration of economic power contrasted sharply with the diffusion of economic power during the early stages of the British industrial revolution. There was talk in the U.S. of "titans" and in Germany of "industrial Bismarcks." Many of the great corporations of the 20th century had their origins in the last decade of the 19th.

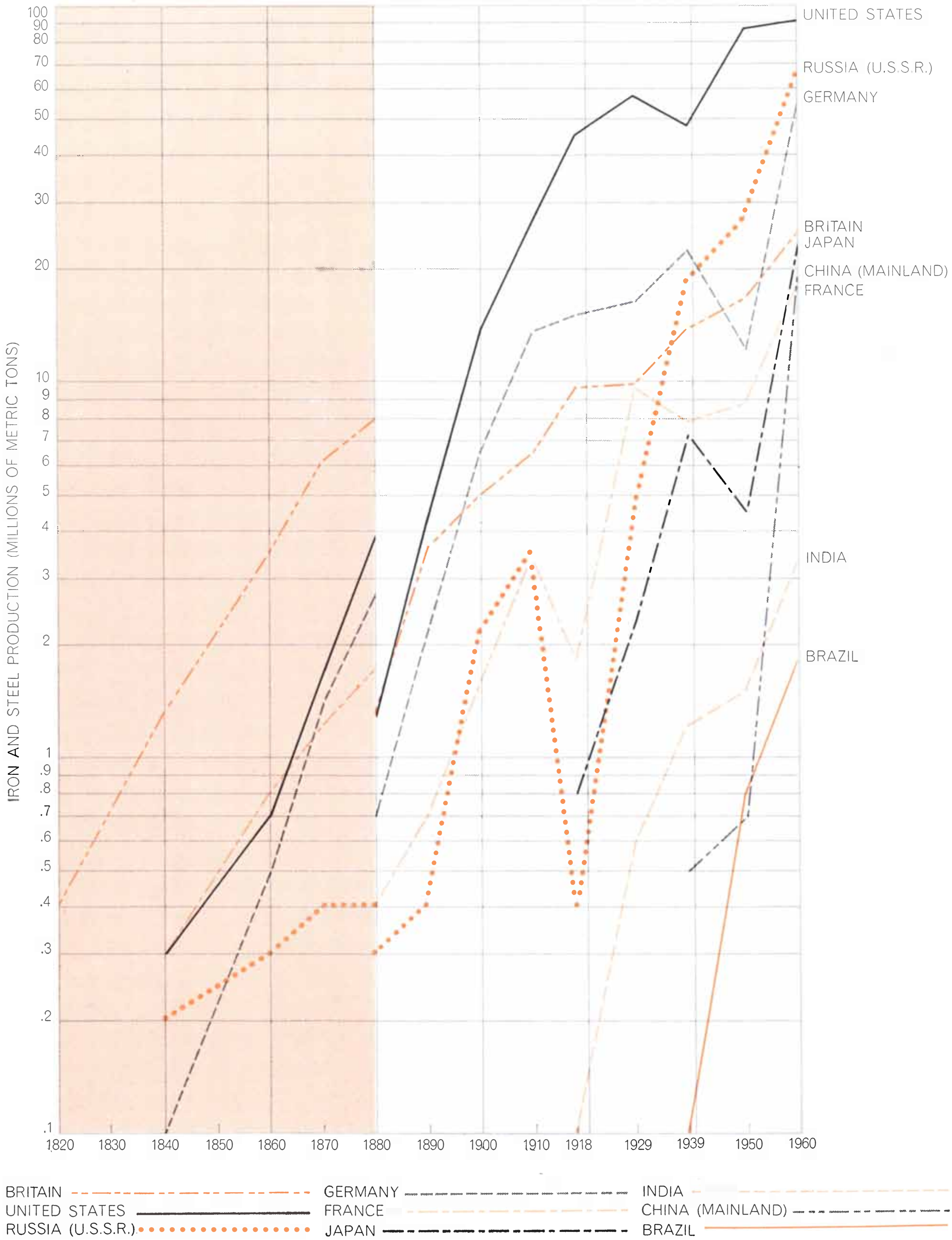
This was not the only difference between the British industrial revolution and the industrial revolutions that followed. In Britain little reliance had been placed on the state; everything had depended on a partnership of inventors and businessmen. The theory of the revolution—if there was a theory—was self-help in the industrial sphere and free trade between nations. In Germany the power of the state was harnessed to assist industrialization. In the U.S. the emerging industrial power enlisted the benevolent patronage of the Federal and state governments in the allocation of the continent's rich resources and the maintenance of a social and political climate congenial to its growth.

There was a traditional sanction for the German reliance on the state, but it was given eloquent new expression in the late 19th century. As Gustav Schmoller, an influential professor of economics, put it in 1884: "It was clearly those governments which understood best how to place the might of their fleets and the apparatus of their customs and navigation laws at the service of the economic interests of the nation with speed, boldness and clear purpose which thereby obtained the lead in the struggle and the riches of industrial prosperity." At the same time the riches of prosperity added to the power of the state. The newly unified German state grew stronger as the industrial economy grew stronger. Dependence on tariffs, the direct intervention by bankers in the structure and control of industry and the encouragement by the courts and the government of cartels and large-scale industrial organizations were all parts of the pattern.

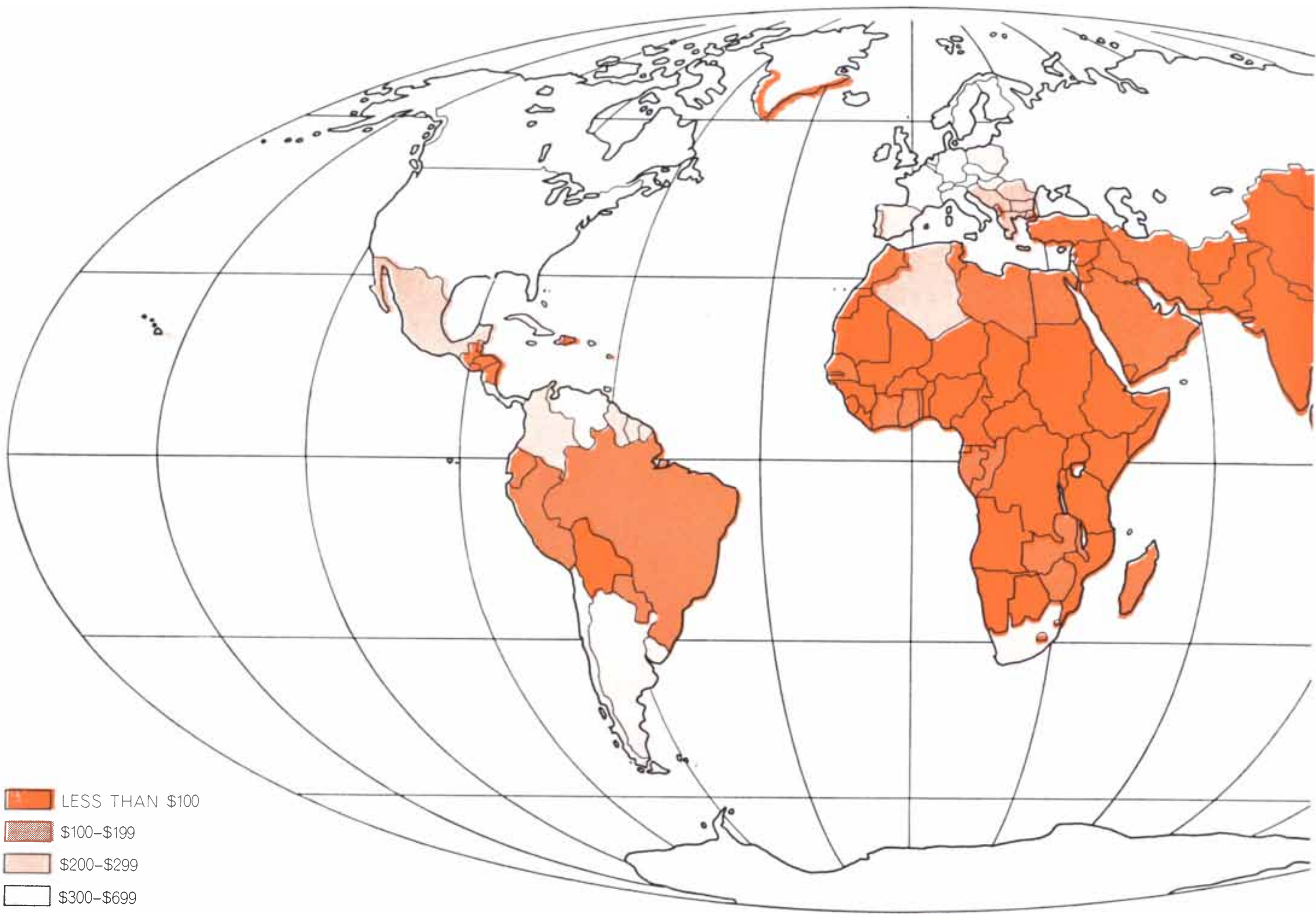
The idea of using political power to hasten industrialization has become a commonplace in the 20th century. Protests against industrialism have been less vociferous than demands for more industrialization. Not only has nationalism come to be closely associated with industrial strength and economic independence, but also socialism, which began with industrial discontent, has dwelt increasingly on economic "planning." Whereas in 19th-century Britain transfers of political power followed industrialization as railroads followed factories and furnaces, in many 20th-century countries the existence of a "progressive" and "dynamic" directing political power has come to be considered a precondition to industrialization, much as Witte held railroads to be. Economic and social historians have spoken increasingly of innovating elites instead of entrepreneurs, the protagonists of classical economics. The more backward the economy, they argue, the more directly the state has had to intervene in the encouragement of industrialization, the greater has been the pressure for large-scale plant and the most up-to-date technology, and the more necessary has it been to proclaim a gospel of industrialism. In the "neoclassic" industrial revolutions the incentive to "get rich quick" has seldom proved a sufficient motive; "development" has had to be advocated in more general terms.

Even before 1914, when industrialization was widening the income gap between the countries now classified as "developed" and "underdeveloped," Japan had joined Germany and the U.S. as a new center of industrial revolution. In Japan, as in Germany, economic and political processes ran together in close harness. As a result of political and social revolutions in the 1860's Japan was able to break with enough of its tradition to carry out a deliberate industrial revolution. Samurai bureaucrats embarked on a sweeping "westernization," although they took care not to destroy existing social structures. The state itself initiated strategic enterprises, facilitated the borrowing of advanced technology from abroad and pursued a fiscal policy that encouraged the businessman and fixed the burden of forced savings on the farmer.

Between 1907 and 1914 Japan achieved an annual growth rate of more than 8 per cent. "By 1914," wrote William W. Lockwood, the historian of



IRON AND STEEL PRODUCTION, charted here, tell the story of industrialization. In the era of iron (*colored part of chart*) Britain led the world. When steel technology supplanted iron, the U.S. and Germany began to move ahead. Over the years other nations developed substantial steel industries, some (notably Communist China) only in the past decade. The logarithmic scale makes it possible to compare rates of growth in production in different countries: parallel segments of the curves show growth at similar rates.



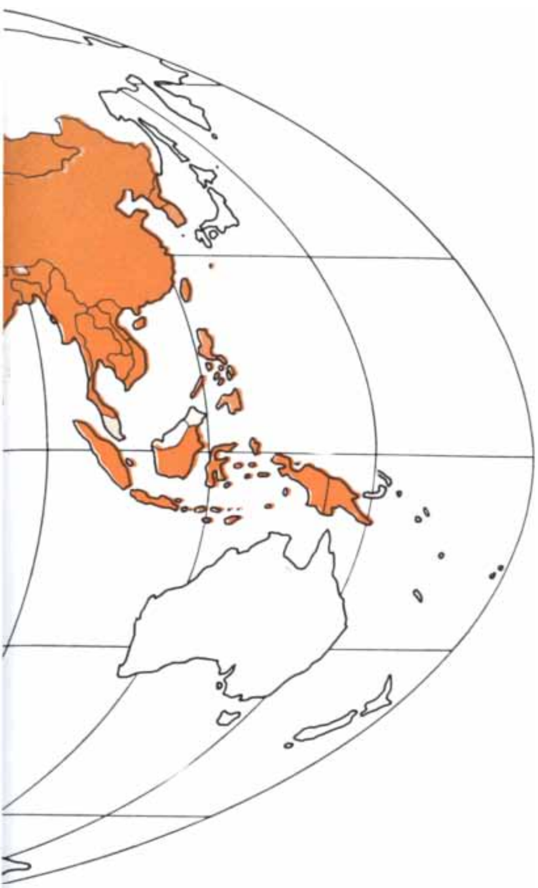
UNDERDEVELOPED COUNTRIES are grouped here according to their average per capita incomes for 1957–1959, based on available UN statistics and some estimates. Income, commonly accepted as a rough gauge of development, does not tell the whole story:

Japan's spectacular development, "Japanese industrial capitalism was still weak and rudimentary by comparison with the advanced economies of the West. But it had now emerged from its formative stage." During and after World War I it was to profit from its industrial lead in Asia as Britain had profited from its lead in Europe 150 years before. It was also to be in the vanguard of the third generation of industrial technology based on plastics, new metals and electronics.

Russia, which also increased its industrial output by 8 per cent per year during its great forward leap of the 1890's, relied on somewhat similar devices, notably fiscal pressure on the peasants and the acquisition of technology from abroad. After the revolution of 1917 and the economic vicissitudes leading up to the promulgation of the first and second Five Year Plans, there evolved a militant ideology of industrialization. In the 18th century Britain and France had offered different, if complementary, revolutions to the world; the first was economic, the second political. The U.S.S.R. sought to offer both in one package. The ideology of industrial change would appeal to "poor nations," it was felt, at least as strongly as socialist ideology had appealed to poor individuals or classes in the stormy years of iron and coal industrialization. Speed and scale were both emphasized. So too was sacrifice—the deliberate concentration on heavy industry and capital investment and the forcible limitation of consumption.

This model, reinforced as it has been with the factual evidence of an exceptionally high growth rate, has probably had more appeal than the ideology of communism itself. The appeal has influenced quite different kinds of society, although the universal applicability of the model is just as much open to question as the universal applicability of the British model was open to question in the 19th century. More recently economists have directed increasing attention to the place in economic growth not of heavy industry but of agriculture. They have also stressed the subtleties of development. Industrial revolutions require more than political enthusiasm. "Economic development is a process," John K. Galbraith, then U.S. Ambassador to India, told an Indian audience in 1961, "that extends in range from new nations of Africa only slightly removed from their tribal structure to the elaborate economic and social apparatus of Western nations. At each stage along this continuum there is an appropriate policy for further advance. What is appropriate at one stage is wrong at another."

In the changing context of argument and action the industrial experience of the richest industrial country in the world—the U.S.—has general relevance. Industrialization in the U.S. proceeded in a number of clearly defined spurts:



Japan, for example, is considered developed although its per capita income is not high.

the first between 1837, a year of depression, and the Civil War; the second in the decade and a half following the end of the war; and the third in the 1890's. Although there was a marked trend in each of these three periods to increase the relative share in production of producers' goods, equipment and machines, emphasis in the 20th century has been increasingly placed on the great expansion of consumers' goods. The U.S., with its huge domestic market, has used the new technology to transform not only the standard of life of all its inhabitants but also their whole pattern of daily living. The consumer was deliberately placed at the center of the industrial complex. The resulting dazzle of affluence contrasts sharply with the grim facts of poverty in underdeveloped countries and with the compelling "puritan" philosophy of sacrifice based on investment for investment's sake.

Beyond doubt the problems centering on development and underdevelopment furnish the principal preoccupation of contemporary political, economic and social theory. Before World War I it was almost taken for granted that there was a natural division in the world between manufacturing countries and primary producing countries—the black and the green. This assumption did not suppose either that relative power within the group of manufacturing countries was fixed for all time or that the gap between the rich countries and the poor countries was destined to go on widening forever. Yet it did close minds to a number of problems that are now felt to be fascinating as well as important.

Within the developed countries the facts of inequality between societies have lately begun to shock. The body of world statistics, gathered for the first time by the technical agencies of the League of Nations and now powerfully amplified by the international civil service of the United Nations, has exposed not only inequality but also the ugly mechanism of the "Malthusian trap" in which two-thirds of mankind is imprisoned. Kingsley Davis shows in the next article in this issue of *Scientific American* ["Population," page 62] how the 20 or so developed nations have made their escape and prays that increase in the rate of production may exceed the rate of population growth elsewhere and make it possible for other nations to follow. As for food, water, energy and minerals, the authors find that supply is a function of the dynamic international variable: technology.

Yet although technology is international, political facts and attitudes remain stubbornly national. The spell of nationalism is strongest in the ex-colonies of "developed" nations with empires. Political independence, it is felt, must be ratified by economic liberation. Any economic gains colonies may have secured through their place in the decaying empires are brushed aside, and the complicity of the rich in the poverty of the poor nations supplies the negative mold that shapes the plans of development. It is the "distortions" of colonialism that count, not its untapping of world resources. As Wassily Leontief shows in his article ["The Structure of Development," page 148], the underdeveloped economies often present a "mirror image" of the developed. Nigeria, for example, exports a few "single crop" products of plantation agriculture and imports the diversity of goods produced by the advanced industrial economies. Other underdeveloped countries are engaged in shipping out their "lifeblood" in the form of irreplaceable mineral resources. Each of these countries in turn, ex-colony or not, now seeks to import the technology necessary to the building of an indigenous, diversified, self-sustaining industrial economy.

Yet in spite of all the brave planning and even the beginnings of industrialization in countries such as India, the inequalities between nations are increasing. More than 90 per cent of the world's industrial output is still concentrated in areas inhabited by people of European origin. Even if underdeveloped countries were to increase their average incomes 10 times faster than the economically advanced countries, the gap would still widen. Given both population pressure and political pressure, is it possible to live peaceably in a world where such inequalities are being aggravated rather than attenuated and where dreams of development are sometimes frustrated?

Development is intimately bound up with 20th-century shifts in power and conflicts of power, with mainland China now taking the stage as well as the U.S.S.R. The dynamic forces of industrialization are as much an element in contemporary international politics as the quest for gold and spices was in the era of mercantile expansion. The countries of the Temperate Zones once turned to the Tropics for riches. Now the Tropics—Brazil, for example, whose gold found its way through Portugal and Spain to finance the industrial revolution of Britain—turn to the temperate countries for know-how that cannot be transported in ships or by formula.

Whether, as Abba Eban of Israel has proposed, the "new nations do not have to tread long and tormented paths . . . and can skip the turbulent phases through which Western industrial revolutions had to pass," depends in decisive part on the politics and social disposition of the developed nations. As Edward S. Mason shows in the concluding article of this issue ["The Planning of Development," page 235], the West is called on not only for "aid" but also for tolerance of the new modes in which the developing nations will assert their liberation from poverty. Attitudes deriving from inequality can help or hinder such tolerance. Consciences can be stirred, but there are also built-in feelings of "inferiority" and "superiority." In balance, a 20th-century Piccolomini might see some good in prospect, provided, that is, that we have imaginations powerful enough to bridge the gulf between the different worlds of our own making.

POPULATION

At the current growth rate the world's population would multiply sixfold in a century. Recent history suggests, however, that the rate will be cut by people acting in their own private interest

by Kingsley Davis

Just as the nation-state is a modern phenomenon, so is the explosive increase of the human population. For hundreds of millenniums *Homo sapiens* was a sparsely distributed animal. As long as this held true man could enjoy a low mortality in comparison to other species and could thus breed slowly in relation to his size. Under primitive conditions, however, crowding tended to raise the death rates from famine, disease and warfare. Yet man's fellow mammals even then might well have voted him the animal most likely to succeed. He had certain traits that portended future dominance: a wide global dispersion, a tolerance for a large variety of foods (assisted by his early adoption of cooking) and a reliance on group co-operation and socially transmitted techniques. It was only a matter of time before he and his kind would learn how to live together in communities without paying the penalty of high death rates.

Man remained sparsely distributed during the neolithic revolution, in spite of such advances as the domestication of plants and animals and the invention of textiles and pottery. Epidemics and pillage still held him back, and new kinds of man-made disasters arose from erosion, flooding and crop failure. Indeed, the rate of growth of the world population remained low right up to the 16th and 17th centuries.

Then came a spectacular quickening of the earth's human increase. Between 1650 and 1850 the annual rate of increase doubled, and by the 1920's it had doubled again. After World War II, in the decade from 1950 to 1960, it took another big jump [*see middle illustration on page 66*]. The human population is now growing at a rate that is impossible to sustain for more than a moment of geologic time.

Since 1940 the world population has grown from about 2.5 billion to 3.2 billion. This increase, within 23 years, is more than the *total* estimated population of the earth in 1800. If the human population were to continue to grow at the rate of the past decade, within 100 years it would be multiplied sixfold.

Projections indicate that in the next four decades the growth will be even more rapid. The United Nations' "medium" projections give a rate during the closing decades of this century high enough, if continued, to multiply the world population sevenfold in 100 years. These projections are based on the assumption that the changes in mortality and fertility in regions in various stages of development will be roughly like those of the recent past. They do not, of course, forecast the actual population, which may turn out to be a billion or two greater than that projected for the year 2000 or to be virtually nil. So far the UN projections, like most others in recent decades, are proving conservative. In 1960 the world population was 75 million greater than the figure given by the UN's "high" projection (published in 1958 and based on data up to 1955).

In order to understand why the revolutionary rise of world population has occurred, we cannot confine ourselves to the global trend, because this trend is a summation of what is happening in regions that are at any one time quite different with respect to their stage of development. For instance, the first step in the demographic evolution of modern nations—a decline in the death rate—began in northwestern Europe long before it started elsewhere. As a result, although population growth is now slower in this area than in the rest of the world, it was here that the unprecedented upsurge in human numbers began. Being most advanced in demographic development, northwestern Europe is a good place to start in our analysis of modern population dynamics.

In the late medieval period the average life expectancy in England, according to life tables compiled by the historian J. C. Russell, was about 27 years. At the end of the 17th century and during most of the 18th it was about 31 in England, France and Sweden, and in the first half of the 19th century it advanced to 41.

The old but reliable vital statistics from Denmark, Norway and Sweden show that the death rate declined erratically up to 1790, then steadily and more rapidly. Meanwhile the birth rate remained remarkably stable (until the latter part of the 19th century). The result was a marked increase in the excess of births over deaths, or what demographers call "natural increase" [*see illustration on page 68*]. In the century from about 1815 until World War I the average annual increase in the three Scandinavian countries was 11.8 per 1,000—nearly five times what it had been in the middle of the 18th century, and sufficient to triple the population in 100 years.

For a long time the population of northwestern Europe showed little reaction to this rapid natural increase. But when it came, the reaction was emphatic; a wide variety of responses occurred, all of which tended to reduce the growth of the population. For ex-

MEXICO CITY, a part of which is shown in the vertical aerial photograph on the opposite page, displays the rapid population growth and the urbanization that characterize much of the world today. In 1940 the population of the metropolitan area of the city was 1,758,000, in 1950 it reached 3,050,000 and by 1960 it had jumped to 4,830,000.

ample, in the latter part of the 19th century people began to emigrate from Europe by the millions, mainly to America, Australia and South Africa. Between 1846 and 1932 an estimated 27 million people emigrated overseas from Europe's 10 most advanced countries. The three Scandinavian countries alone sent out 2.4 million, so that in 1915 their combined population was 11.1 million instead of the 14.2 million it would otherwise have been.

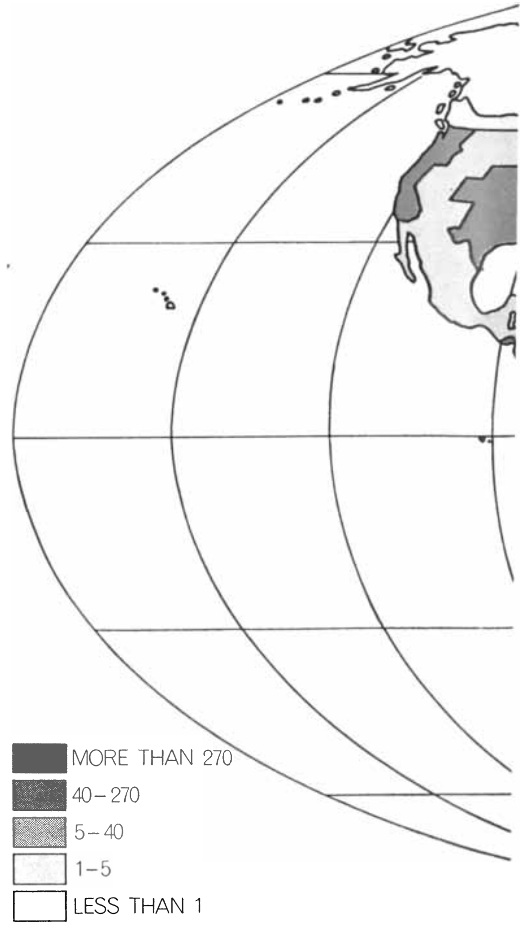
In addition to this unprecedented exodus there were other responses, all of which tended to reduce the birth rate. In spite of opposition from church and state, agitation for birth control began and induced abortions became common. The age at marriage rose. Childlessness became frequent. The result was a decline in the birth rate that eventually overtook the continuing decline in the death rate. By the 1930's most of the industrial European countries had age-specific fertility rates so low that, if the rates had continued at that level, the population would eventually have ceased to replace itself.

In explaining this vigorous reaction one gets little help from two popular clichés. One of these—that population growth is good for business—would hardly explain why Europeans were so bent on stopping population growth. The other—that numerical limitation comes from the threat of poverty because "population always presses on the means of subsistence"—is factually untrue. In every one of the industrializing countries of Europe economic growth outpaced population growth. In the United Kingdom, for example, the real per capita income increased 2.3 times between the periods 1855–1859 and 1910–1914. In Denmark from 1770 to 1914 the rise of the net domestic product in constant prices was two and a half times the natural increase rate; in Norway and Sweden from the 1860's to 1914 it was respectively 1.4 and 2.7 times the natural increase rate. Clearly the strenuous efforts to lessen population growth were due to some stimulus other than poverty.

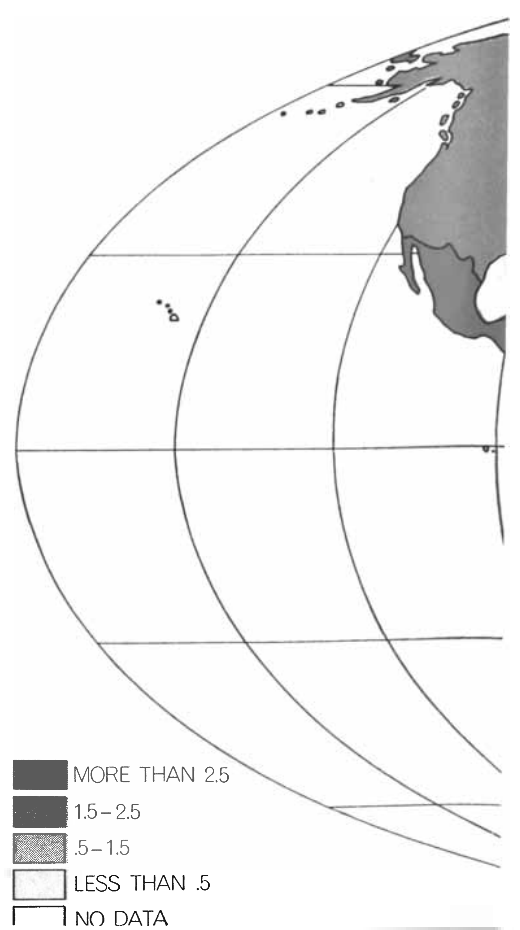
The stimulus, in my view, arose from the clash between new opportunities on the one hand and larger families on the other. The modernizing society of northwestern Europe necessarily offered new opportunities to people of all classes: new ways of gaining wealth, new means of rising socially, new symbols of status. In order to take advantage of those opportunities, however, the individual and his children required education, special skills, capital and mobility—none of which was facilitated by an improvident marriage or a large family. Yet because mortality was being reduced (and reduced more successfully in the childhood than in the adult ages) the size of families had become potentially larger than before. In Sweden, for instance, the mortality of the period 1755–1775 allowed only 6.1 out of every 10 children born to reach the age of 10, whereas the mortality of 1901–1910 allowed 8.5 to survive to that age. In order to avoid the threat of a large family to his own and his children's socioeconomic position, the individual tended to postpone or avoid marriage and to limit reproduction within marriage by every means available. Urban residents had to contend particularly with the cost and inconvenience of young children in the city. Rural families had to adjust to the lack of enough land to provide for new marriages when the children reached marriageable age. Land had become less available not only because of the plethora of families with numerous youths but also because, with modernization, more capital was needed per farm and because the old folks, living longer, held on to the property. As a result farm youths postponed marriage, flocked to the cities or went overseas.

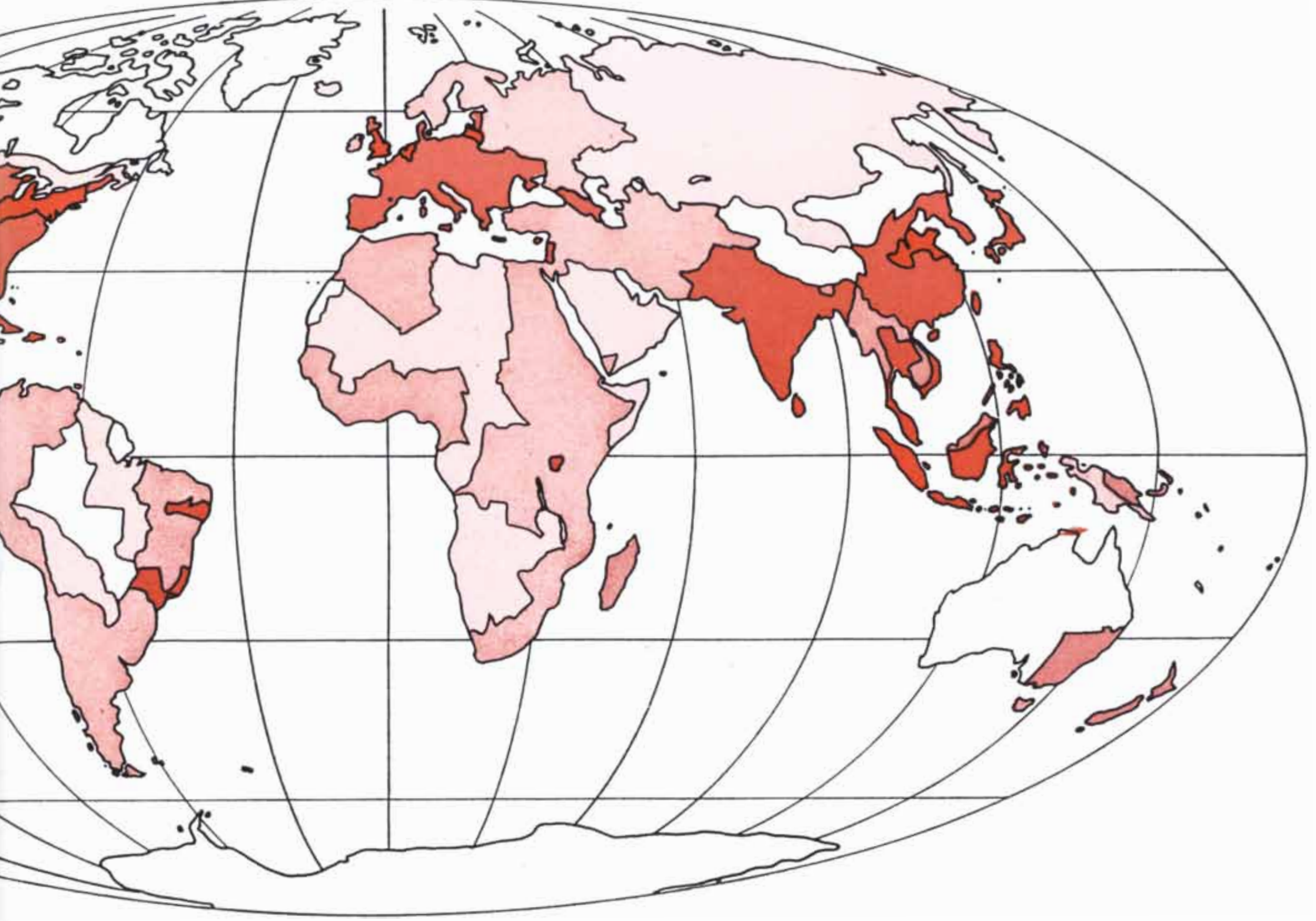
In such terms we can account for the paradox that, as the progressive European nations became richer, their population growth slowed down. The process of economic development itself provided the motives for curtailment of reproduction, as the British sociologist J. A. Banks has made clear in his book *Prosperity and Parenthood*. We can see now that in all modern nations the long-run trend is one of low mortality, a relatively modest rate of reproduction and slow population growth. This is an efficient demographic system that allows such countries, in spite of their "maturity," to continue to advance economically at an impressive speed.

Naturally the countries of northwestern Europe did not all follow an identical pattern. Their stages differed somewhat in timing and in the pattern of preference among the various means of population control. France, for example, never attained as high a natural increase as Britain or Scandinavia did. This was not due solely to an earlier decline in the birth rate, as is often assumed, but also to a slower decline in the death rate. If we historically substitute the Swedish death rate for the French, we revise the natural increase upward by almost the same amount as we do by substituting the Swedish birth rate. In accounting

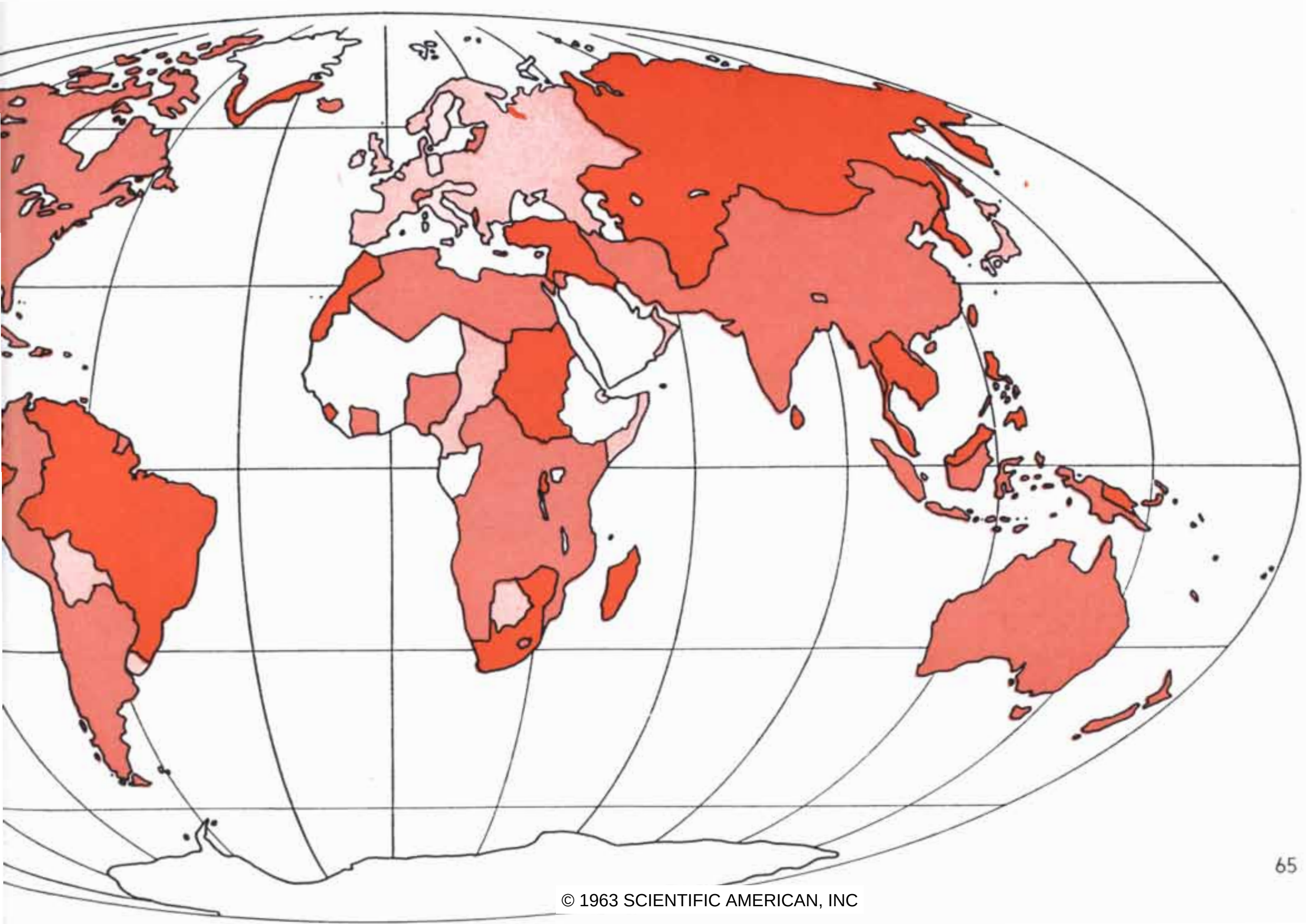


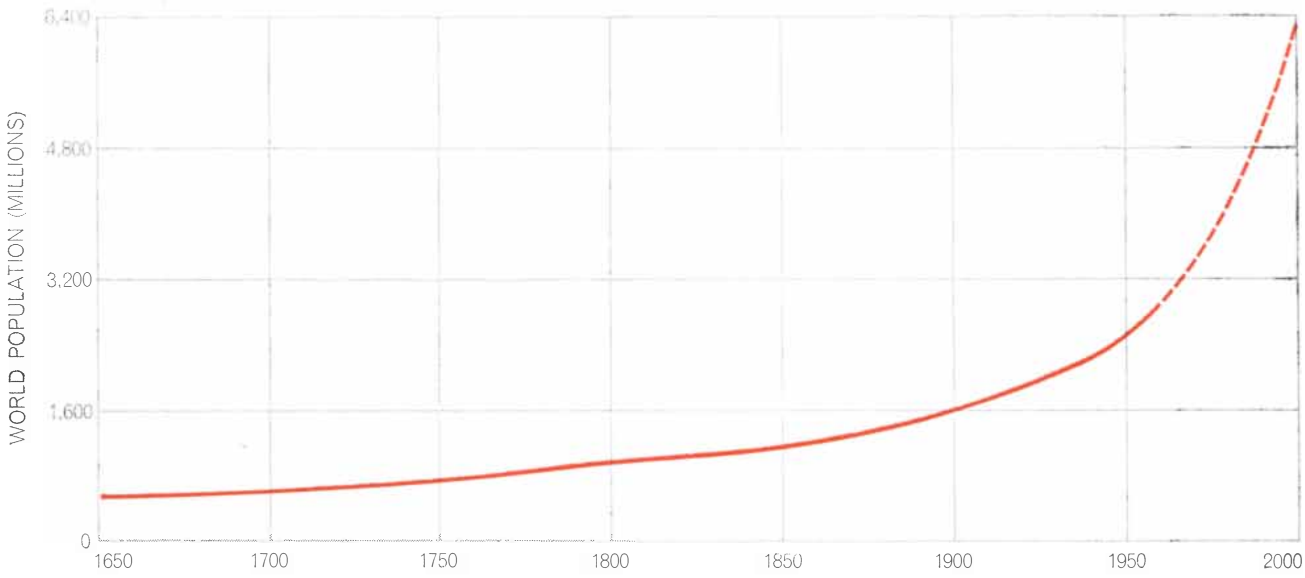
POPULATION MAPS show density (*top*) as of 1961 and per cent increase per year

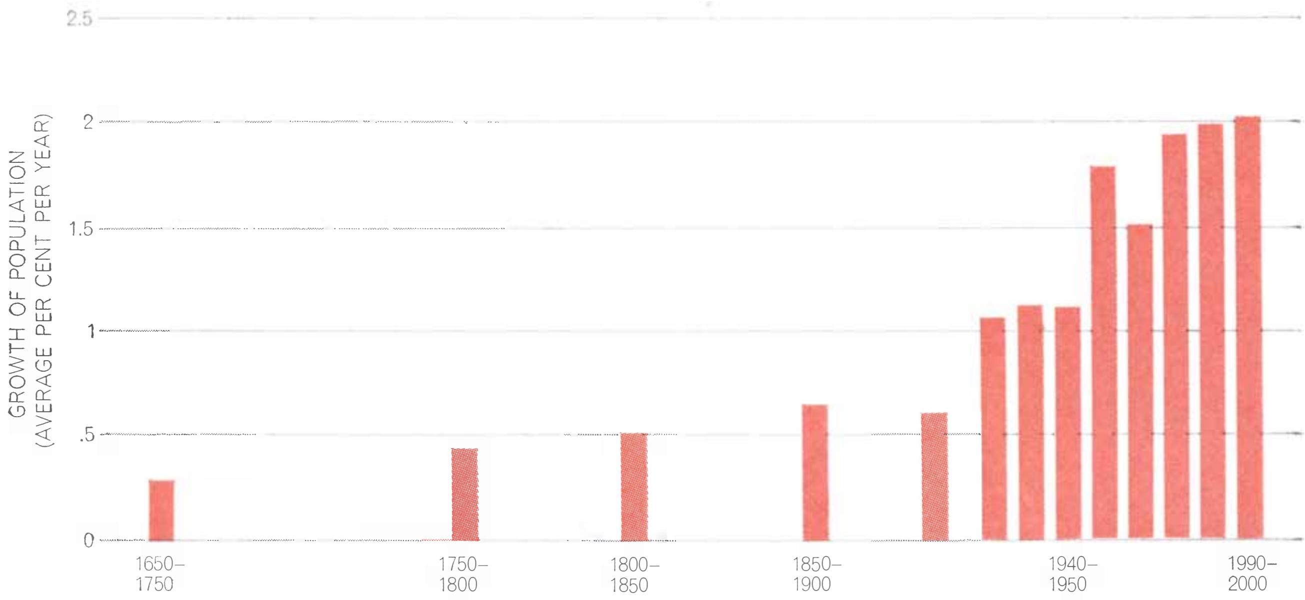


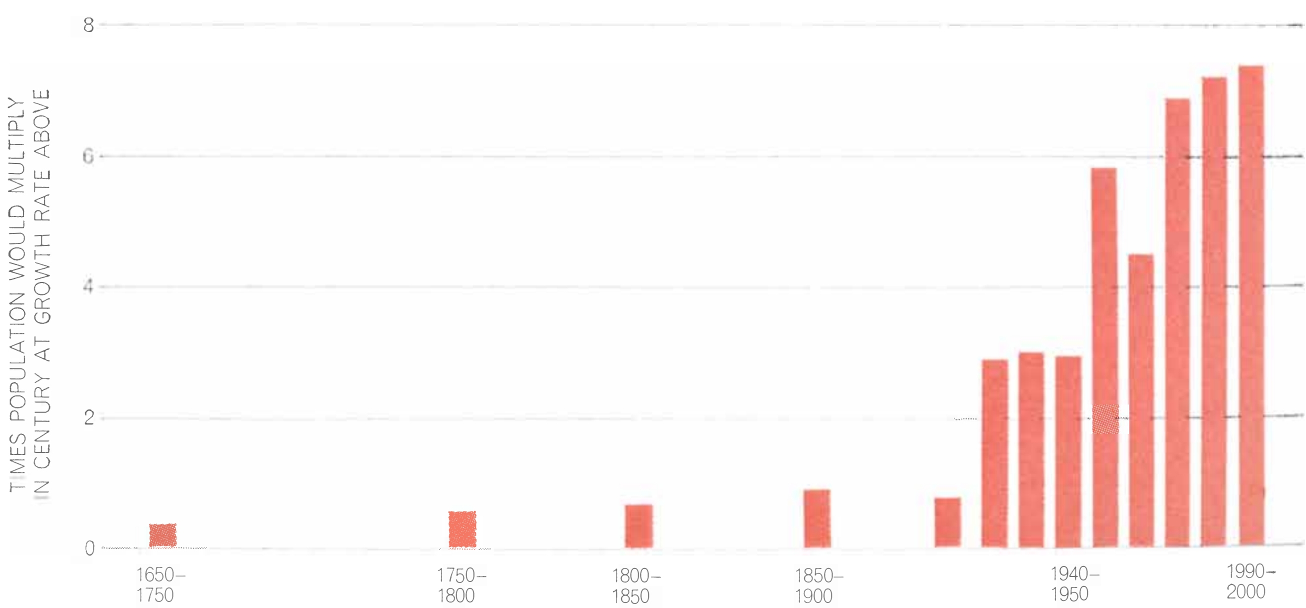


between 1958 and 1961 (*bottom*). Except for the countries of largest area the density has been averaged within the boundaries of each nation. The densities are given in terms of the number of people per square kilometer. The data are primarily from UN publications.




WORLD POPULATION (MILLIONS)
6,400
4,800
3,200
1,600
0
1650
1700
1750
1800
1850
1900
1950
2000


GROWTH OF POPULATION (AVERAGE PER CENT PER YEAR)
2.5
2
1.5
1
.5
0
1650–1750
1750–1800
1800–1850
1850–1900
1940–1950
1990–2000


TIMES POPULATION WOULD MULTIPLY IN CENTURY AT GROWTH RATE ABOVE
8
6
4
2
0
1650–1750
1750–1800
1800–1850
1850–1900
1940–1950
1990–2000

for the early and easy drop in French fertility one recalls that France, already crowded in the 18th century and in the van of intellectual radicalism and sophistication, was likely to have a low threshold for the adoption of abortion and contraception. The death rate, however, remained comparatively high because France did not keep economic pace with her more rapidly industrializing neighbors. As a result the relatively small gap between births and deaths gave France a slower growth in population and a lesser rate of emigration.

Ireland also has its own demographic history, but like France it differs from the other countries in emphasis rather than in kind. The emphasis in Ireland's escape from human inflation was on emigration, late marriage and permanent celibacy. By 1891 the median age at which Irish girls married was 28 (compared with 22 in the U.S. at that date); nearly a fourth of the Irish women did not marry at all, and approximately a third of all Irish-born people lived outside of Ireland. These adjustments, begun with the famine of the 1840's and continuing with slight modifications until today, were so drastic that they made Ireland the only modern nation to experience an absolute decline in population. The total of 8.2 million in 1841 was reduced by 1901 to 4.5 million.

The Irish preferences among the means of population limitation seem to come from the island's position as a rural region participating only indirectly in the industrial revolution. For most of the Irish, land remained the basis for respectable matrimony. As land became inaccessible to young people they postponed marriage. In doing so they were not discouraged by their parents, who wished to keep control of the land, or by their religion. Their Catholicism, which they embraced with exceptional vigor both because they were rural and because it was a rallying point for Irish nationalism as against the Protestant English, placed a high value on celibacy. The clergy, furthermore, were powerful enough to exercise strict control over courtship and thus to curtail illicit pregnancy and romance as factors leading to marriage. They were also able to exercise exceptional restraint on abortion and contraception. Although birth control was practiced to some extent, as evidenced by a decline of fertility within marriage, its influence was so small as to make early marriage synonymous with a large family and therefore to be avoided. Marriage was also discouraged by the ban on divorce and by the lowest participation of married women in the labor force to be found in Europe. The country's failure to industrialize meant that the normal exodus from farms to cities was at the same time an exodus from Ireland itself.

Ireland and France illustrate contrasting variations on a common theme. Throughout northwestern Europe the population upsurge resulting from the fall in death rates brought about a multiphasic reaction that eventually reduced the population growth to a modest pace. The main force behind this response was not poverty or hunger but the desire of the people involved to preserve or improve their social standing by grasping the opportunities offered by the newly emerging industrial society.

Is this an interpretation applicable to the history of any industrialized country, regardless of traditional culture? According to the evidence the answer is yes. We might expect it to be true, as it currently is, of the countries of southern and eastern Europe that are finally industrializing. The crucial test is offered by the only nation outside the European tradition to become industrialized: Japan. How closely does Japan's demographic evolution parallel that of northwestern Europe?

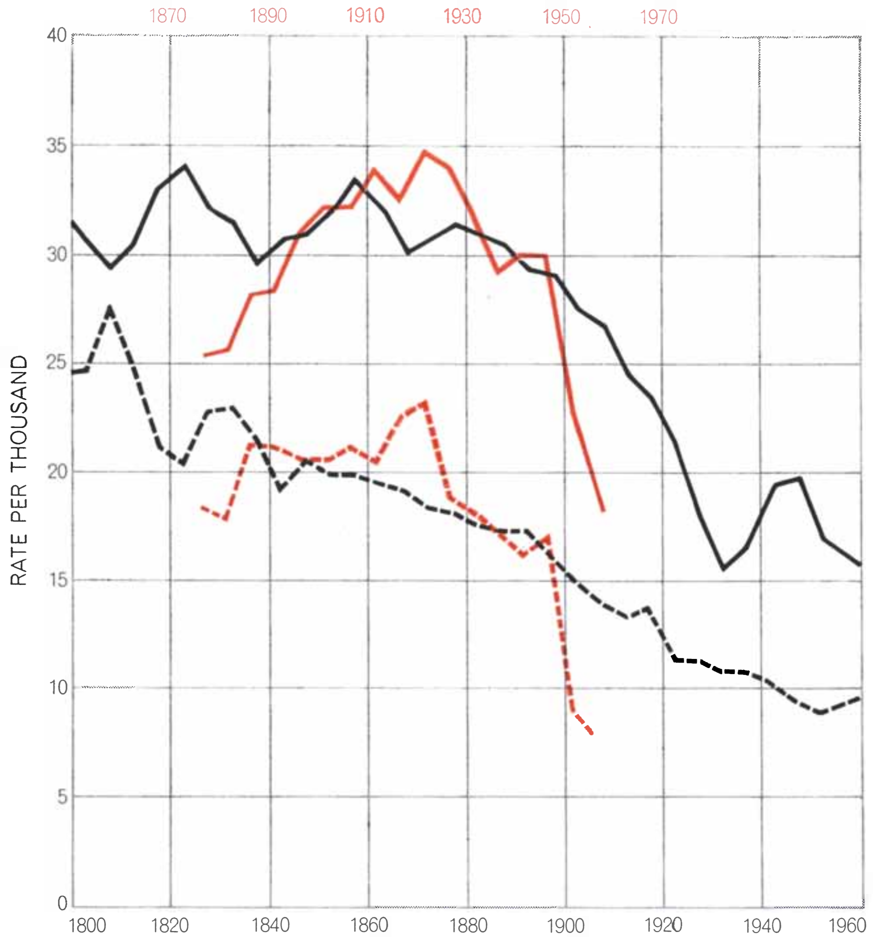
If we superpose Japan's vital-rate curves on those of Scandinavia half a century earlier [*see illustration on next page*], we see a basically similar, although more rapid, development. The reported statistics, questionable up to 1920 but good after that, show a rapidly declining death rate as industrialization took hold after World War I. The rate of natural increase during the period from 1900 to 1940 was almost exactly the same as Scandinavia's between 1850 and 1920, averaging 12.1 per 1,000 population per year compared with Scandinavia's 12.3. And Japan's birth rate, like Europe's, began to dip until it was falling faster than the death rate, as it did in Europe. After the usual baby boom following World War II the decline in births was precipitous, amounting to 50 per cent from 1948 to 1960—perhaps the swiftest drop in reproduction that has ever occured in an entire nation. The rates of childbearing for women in various ages are so low that, if they continued indefinitely, they would not enable the Japanese population to replace itself.

In thus slowing their population growth have the Japanese used the same means as the peoples of northwestern Europe did? Again, yes. Taboo-ridden Westerners have given disproportionate attention to two features of the change—the active role played by the Japanese government and the widespread resort to abortion—but neither of these disproves the similarity. It is true that since the war the Japanese government has pursued a birth-control policy more energetically than any government ever has before. It is also clear, however, that the Japanese people would have reduced their childbearing of their own accord. A marked decline in the reproduction rate had already set in by 1920, long before there was a government policy favoring this trend.

As for abortion, the Japanese are unusual only in admitting its extent. Less superstitious than Europeans about this subject, they keep reasonably good records of abortions, whereas most of the other countries have no accurate data. According to the Japanese records, registered abortions rose from 11.8 per 1,000 women of childbearing age in 1949 to a peak of 50.2 per 1,000 in 1955. We have no reliable historical information from Western countries, but we do know from many indirect indications that induced abortion played a tremendous role in the reduction of the birth rate in western Europe from 1900 to 1940, and that it still plays a considerable role. Furthermore, Christopher Tietze of the National Committee for Maternal Health has assembled records that show that in five eastern European countries where abortion has been legal for some time the rate has shot up recently in a manner strikingly similar to Japan's experience. In 1960–1961 there were 139 abortions for every 100 births in Hungary, 58 per 100 births in Bulgaria, 54 in Czechoslovakia and 34 in Poland. The countries of eastern Europe are in a developmental stage comparable to that of northwestern Europe earlier in the century.

Abortion is by no means the sole factor in the decline of Japan's birth rate. Surveys made since 1950 show the use of contraception before that date, and increasing use thereafter. There is also a rising frequency of sterilization. Furthermore, as in Europe earlier, the Japanese are postponing marriage. The proportion of girls under 20 who have ever married fell from 17.7 per cent in 1920 to 1.8 per cent in 1955. In 1959 only about 5 per cent of the Japanese girls marrying for the first time were under

POPULATION GROWTH of world from 1650 to 1960 is shown by curve at top of opposite page, projected to the year 2000. The middle chart shows the rate of growth, and the bottom chart the number of times the population would multiply in 100 years at that growth rate for various periods.



BIRTH AND DEATH RATES for Denmark, Norway and Sweden combined (*black lines and dates*) are compared with Japanese rates (*colored lines and dates*) of 50 years later. Japan has been passing through a population change similar to that which occurred earlier in Scandinavia. Area between respective birth-rate curves (*solid lines*) and death-rate curves (*broken lines*) shows natural increase, or population growth that would have occurred without migration. In past few years both Japanese rates have dropped extremely rapidly.

20, whereas in the U.S. almost half the new brides (48.5 per cent in the registration area) were that young.

Finally, Japan went through the same experience as western Europe in another respect—massive emigration. Up to World War II Japan sent millions of emigrants to various regions of Asia, Oceania and the Americas.

In short, in response to a high rate of natural increase brought by declining mortality, Japan reacted in the same ways as the countries of northwestern Europe did at a similar stage. Like the Europeans, the Japanese limited their population growth in their own private interest and that of their children in a developing society, rather than from any fear of absolute privation or any concern with overpopulation in their homeland. The nation's average 5.4 per cent annual growth in industrial output from 1913 to 1958 exceeded the performance of European countries at a similar stage.

As our final class of industrialized countries we must now consider the frontier group—the U.S., Canada, Australia, New Zealand, South Africa and Russia. These countries are distinguished from those of northwestern Europe and Japan by their vast wealth of natural resources in relation to their populations; they are the genuinely affluent nations. They might be expected to show a demographic history somewhat different from that of Europe. In certain particulars they do, yet the general pattern is still much the same.

One of the differences is that the riches offered by their untapped resources invited immigration. All the frontier industrial countries except Russia received massive waves of emigrants from Europe. They therefore had a more rapid population growth than their industrializing predecessors had experienced. As frontier countries with great room for expansion, however, they were also characterized by considerable internal migration and continuing new opportunities. As a result their birth rates remained comparatively high. In the decade from 1950 to 1960, with continued immigration, these countries grew in population at an average rate of 2.13 per cent a year, compared with 1.76 per cent for the rest of the world. It was the four countries with the sparsest settlement (Canada, Australia, New Zealand and South Africa), however, that accounted for this high rate; in the U.S. and the U.S.S.R. the growth rate was lower—1.67 per cent per year.

Apparently, then, in pioneer industrial countries with an abundance of resources population growth holds up at a higher level than in Japan or northwestern Europe because the average individual feels it is easier for himself and his children to achieve a respectable place in the social scale. The immigrants attracted by the various opportunities normally begin at a low level and thus make the status of natives relatively better. People marry earlier and have slightly larger families. But this departure from the general pattern for industrial countries appears to be only temporary.

In the advanced frontier nations, as in northwestern Europe, the birth rate began to fall sharply after 1880, and during the depression of the 1930's it was only about 10 per cent higher than in Europe. Although the postwar baby boom has lasted longer than in other advanced countries, it is evidently starting to subside now, and the rate of immigration has diminished. There are factors at work in these affluent nations that will likely limit their population growth. They are among the most urbanized countries in the world, in spite of their low average population density. Their birth rates are extremely sensitive to business fluctuations and social changes. Furthermore, having in general the world's highest living standards, their demand for resources, already staggering, will become fantastic if both population and per capita consumption continue to rise rapidly, and their privileged position in the world may become less tolerated.

Let us shift now to the other side of the population picture: the nonindustrial, or underdeveloped, countries.

As a class the nonindustrial nations since 1930 have been growing in population about twice as fast as the industrial ones. This fact is so familiar and so taken for granted that its irony tends to escape us. When we think of it, it is astonishing that the world's most impoverished nations, many of them already overcrowded by any standard, should be generating additions to the population at the highest rate.

The underdeveloped countries have about 69 per cent of the earth's adults—and some 80 per cent of the world's children. Hence the demographic situation itself tends to make the world constantly more underdeveloped, or impoverished, a fact that makes economic growth doubly difficult.

How can we account for the paradox that the world's poorest regions are producing the most people? One is tempted to believe that the underdeveloped countries are simply repeating history: that they are in the same phase of rapid growth the West experienced when it began to industrialize and its death rates fell. If that is so, then sooner or later the developing areas will limit their population growth as the West did.

It is possible that this may prove to be true in the long run. But before we accept the comforting thought we should take a close look at the facts as they are.

In actuality the demography of the nonindustrial countries today differs in essential respects from the early history of the present industrial nations. Most striking is the fact that their rate of human multiplication is far higher than the West's ever was. The peak of the industrial nations' natural increase rarely rose above 15 per 1,000 population per year; the highest rate in Scandinavia was 13, in England and Wales 14, and even in Japan it was slightly less than 15. True, the U.S. may have hit a figure of 30 per 1,000 in the early 19th century, but if so it was with the help of heavy immigration of young people (who swelled the births but not the deaths) and with the encouragement of an empty continent waiting for exploitation.

In contrast, in the present underdeveloped but often crowded countries the natural increase per 1,000 population is everywhere extreme. In the decade from 1950 to 1960 it averaged 31.4 per year in Taiwan, 26.8 in Ceylon, 32.1 in Malaya, 26.7 in Mauritius, 27.7 in Albania, 31.8 in Mexico, 33.9 in El Salvador and 37.3 in Costa Rica. These are not birth rates; they are the *excess* of births over deaths! At an annual natural increase of 30 per 1,000 a population will double itself in 23 years.

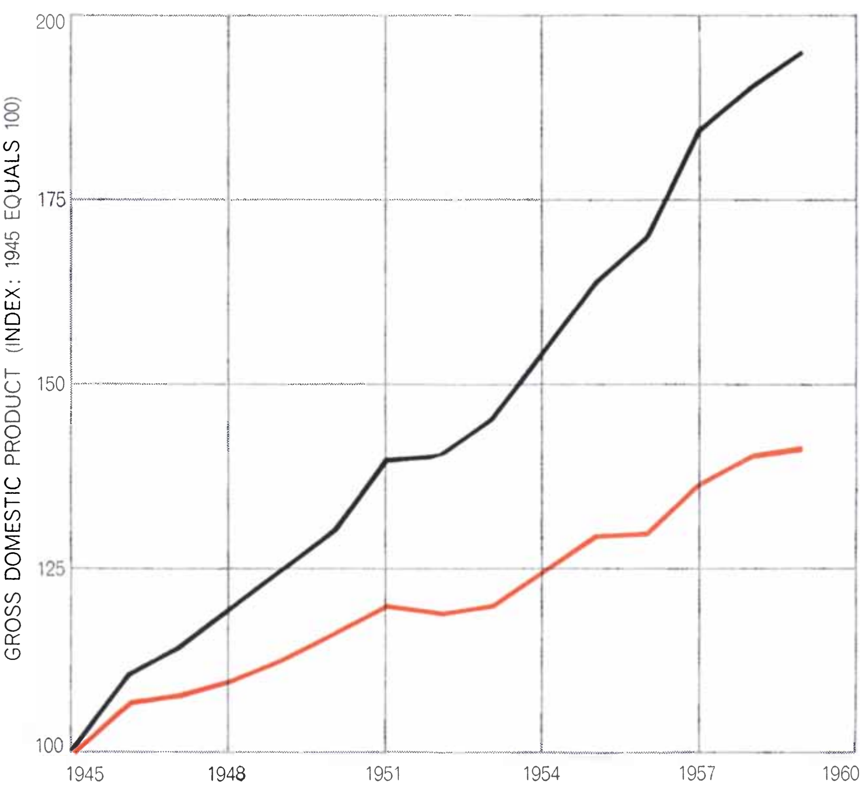
The population upsurge in the backward nations is apparently taking place at an earlier stage of development—or perhaps we should say *un*development—than it did in the now industrialized nations. In Britain, for instance, the peak of human multiplication came when the country was already highly industrialized and urbanized, with only a fifth of its working males in agriculture. Comparing four industrial countries at the peak of their natural increase in the 19th century (14.1 per 1,000 per year) with five nonindustrial countries during their rapid growth in the 1950's (32.2 per 1,000 per year), I find that the industrial countries were 38.5 per cent urbanized and had 27.9 per cent of their labor force in manufacturing, whereas now the nonindustrial countries are 29.4 per cent urbanized and have only 15.1 per cent of their people in manufacturing. In short, today's nonindustrial populations are growing faster and at an earlier stage than was the case in the demographic cycle that accompanied industrialization in the 19th century.

As in the industrial nations, the main generator of the population upsurge in the underdeveloped countries has been a fall in the death rate. But their resulting excess of births over deaths has proceeded faster and farther, as a comparison of Ceylon in recent decades with Sweden in the 1800's shows [*see illustration on next page*].

In most of the underdeveloped nations the death rate has dropped with record speed. For example, the sugar-growing island of Mauritius in the Indian Ocean within an eight-year period after the war raised its average life expectancy from 33 to 51—a gain that took Sweden 130 years to achieve. Taiwan within two decades has increased its life expectancy from 43 to 63; it took the U.S. some 80 years to make this improvement for its white population. According to the records in 18 underdeveloped countries, the crude death rate has dropped substantially in each decade since 1930; it fell some 6 per cent in the 1930's and nearly 20 per cent in the 1950's, and according to the most recent available figures the decline in deaths is still accelerating.

The reasons for this sharp drop in mortality are in much dispute. There are two opposing theories. Many give the credit to modern medicine and public health measures. On the other hand, the public health spokesmen, rejecting the accusation of complicity in the world's population crisis, belittle their own role and maintain that the chief factor in the improvement of the death rate has been economic progress.

Those in the latter camp point out that the decline in the death rate in northwestern Europe followed a steadily rising standard of living. Improvements in diet, clothing, housing and working conditions raised the population's resistance to disease. As a result many dangerous ailments disappeared or subsided without specific medical attack. The same process, say the public health peo-



GROSS DOMESTIC PRODUCT of Latin America doubled between 1945 and 1959 (*black line*) but population growth held down the increase in per capita product (*colored line*).

ple, is now at work in the developing countries.

On the other side, most demographers and economists believe that economic conditions are no longer as important as they once were in strengthening a community's health. The development of medical science has provided lifesaving techniques and medicines that can be transported overnight to the most backward areas. A Stone Age people can be endowed with a low 20th-century death rate within a few years, without waiting for the slow process of economic development or social change. International agencies and the governments of the affluent nations have been delighted to act as good Samaritans and send out public health missionaries to push disease-fighting programs for the less developed countries.

The debate between the two views is hard to settle. Such evidence as we have indicates that there is truth on both sides. Certainly the newly evolving countries have made economic progress. Their economic advance, however, is not nearly rapid enough to account for the very swift decline in their death rates, nor do they show any clear correlation between economic growth and improvement in life expectancy. For example, in Mauritius during the five-year period from 1953 to 1958 the per capita income fell by 13 per cent, yet notwithstanding this there was a 36 per cent drop in the death rate. On the other hand, in the period between 1945 and 1960 Costa Rica had a 64 per cent increase in the per capita gross national product and a 55 per cent decline in the death rate. There seems to be no consistency—no significant correlation between the two trends when we look at the figures country by country. In 15 underdeveloped countries for which such figures are available we find that the decline in death rate in the 1950's was strikingly uniform (about 4 per cent per year), although the nations varied greatly in economic progress—from no improvement to a 6 per cent annual growth in per capita income.

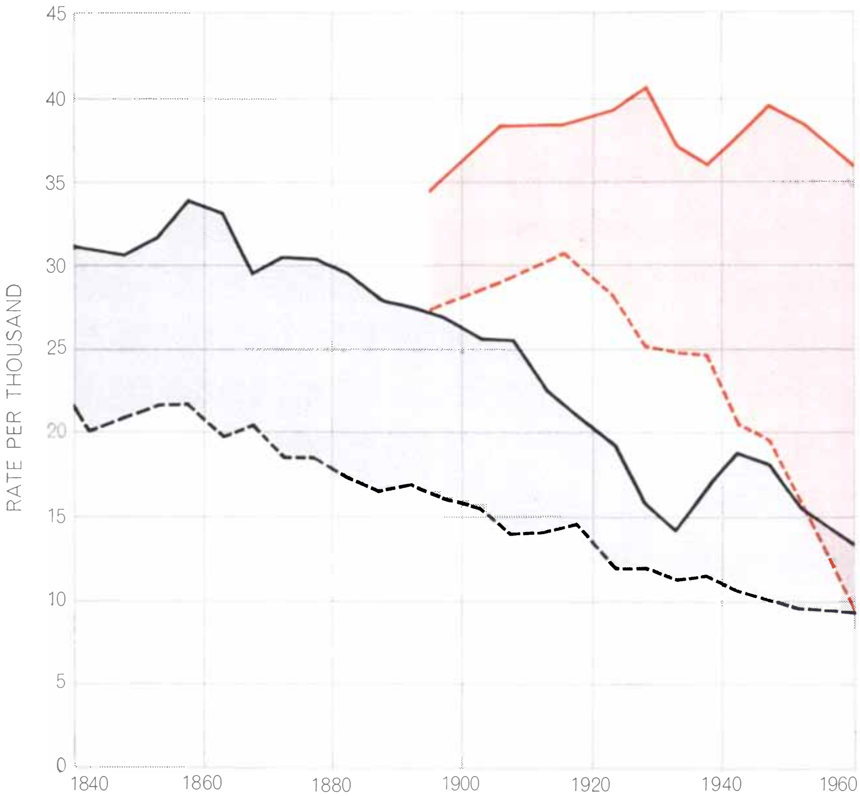
Our tentative conclusion must be, therefore, that the public health people are more efficient than they admit. The billions of dollars spent in public health work for underdeveloped areas has brought down death rates, irrespective of local economic conditions in these areas. The programs instituted by outsiders to control cholera, malaria, plague and other diseases in these countries have succeeded. This does not mean that death control in underdeveloped countries has become wholly or permanently independent of economic development but that it has become temporarily so to an amazing degree.

Accordingly the unprecedented population growth in these countries bears little relation to their economic condition. The British economist Colin G. Clark has contended that rapid population growth stimulates economic progress. This idea acquires plausibility from the association between human increase and industrialization in the past and from the fact that in advanced countries today the birth rate (but not the death rate) tends to fluctuate with business conditions. In today's underdeveloped countries, however, there seems to be little or no visible connection between economics and demography.

In these countries neither births nor deaths have been particularly responsive to economic change. Some of the highest rates of population growth ever known are occurring in areas that show no commensurate economic advance. In 34 such countries for which we have data, the correlation between population growth and economic gain during the 1950's was negligible, and the slight edge was on the negative side: − .2. In 20 Latin-American countries during the period from 1954 to 1959, while the annual gain in per capita gross domestic product fell from an average of 2 per cent to 1.3 per cent, the population growth rate *rose* from 2.5 to 2.7 per cent per year.

All the evidence indicates that the population upsurge in the underdeveloped countries is not helping them to advance economically. On the contrary, it may well be interfering with their economic growth. A surplus of labor on the farms holds back the mechanization of agriculture. A rapid rise in the number of people to be maintained uses up income that might otherwise be utilized for long-term investment in education, equipment and other capital needs. To put it in concrete terms, it is difficult to give a child the basic education he needs to become an engineer when he is one of eight children of an illiterate farmer who must support the family with the produce of two acres of ground.

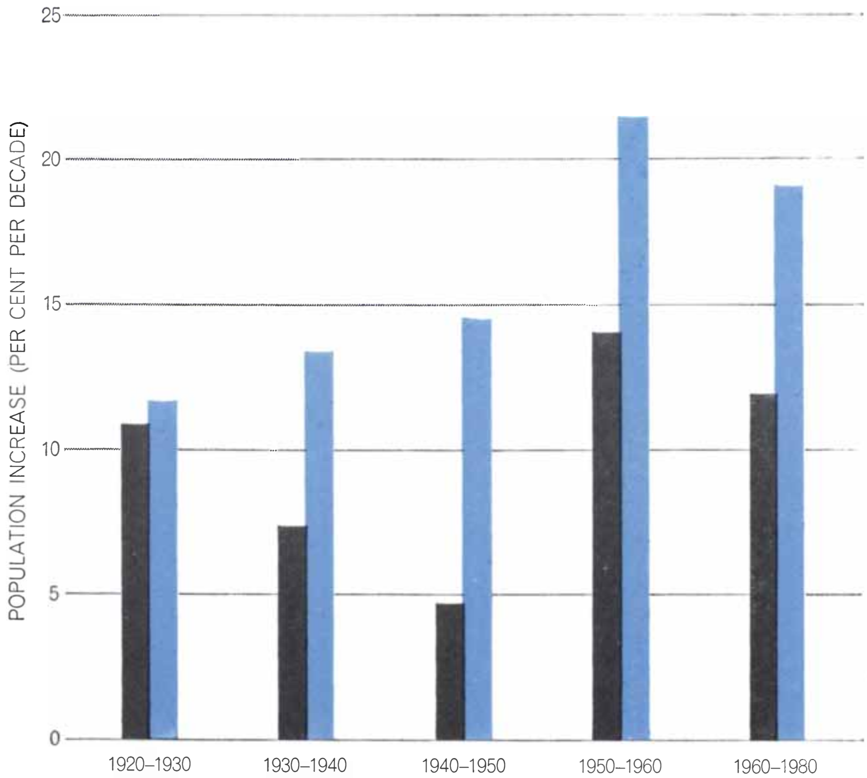
By definition economic advance means an increase in the amount of product per unit of human labor. This calls for investment in technology, in improvement of the skills of the labor force and in administrative organization and planning. An economy that must spend a dispro-



NEW DEMOGRAPHIC PATTERN is appearing in the nonindustrialized nations. The birth rate (*solid line*) has not been falling significantly, whereas the death rate (*broken line*) has dropped precipitously, as illustrated by Ceylon (*color*). The spread between the two rates has widened. In nations such as Sweden (*black*), however, birth rate dropped during development long before death rate was as low as in most underdeveloped countries today.

portionate share of its income in supporting the consumption needs of a growing population—and at a low level of consumption at that—finds growth difficult because it lacks capital for improvements.

A further complication lies in the process of urbanization. The shifts from villages and farmsteads to cities is seemingly an unavoidable and at best a painful part of economic development. It is most painful when the total population is skyrocketing; then the cities are bursting both from their own multiplication and from the stream of migrants from the villages. The latter do not move to cities because of the opportunities there. The opportunities are few and unemployment is prevalent. The migrants come, rather, because they are impelled by the lack of opportunity in the crowded rural areas. In the cities they hope to get something—a menial job, government relief, charities of the rich. I have recently estimated that if the population of India increases at the rate projected for it by the UN, the net number of migrants to cities between 1960 and 2000 will be of the order of 99 to 201 million, and in 2000 the largest city will contain between 36 and 66 million inhabitants. One of the greatest problems now facing the governments of underdeveloped countries is what to do with these millions of penniless refugees from the excessively populated countryside.



DIFFERENTIAL POPULATION GROWTH in underdeveloped regions (*colored bars*) and developed regions (*gray bars*) is plotted. The 1960–1980 projections may turn out to be low.

Economic growth is not easy to achieve. So far, in spite of all the talk and the earnest efforts of underdeveloped nations, only one country outside the northwestern European tradition has done so: Japan. The others are struggling with the handicap of a population growth greater than any industrializing country had to contend with in the past. A number of them now realize that this is a primary problem, and their governments are pursuing or contemplating large-scale programs of birth-limitation. They are receiving little help in this matter, however, from the industrial nations, which have so willingly helped them to lower their death rates.

The Christian nations withhold this help because of their official taboos against some of the means of birth-limitation (although their own people privately use all these means). The Communist nations withhold it because limitation of population growth conflicts with official Marxist dogma (but Soviet citizens control births just as capitalist citizens do, and China is officially pursuing policies calculated to reduce the birth rate).

The West's preoccupation with the technology of contraception seems unjustified in view of its own history. The peoples of northwestern Europe utilized all the available means of birth limitation once they had strong motives for such limitation. The main question, then, is whether or not the peoples of the present underdeveloped countries are likely to acquire such motivation in the near future. There are signs that they will. Surveys in India, Jamaica and certain other areas give evidence of a growing desire among the people to reduce the size of their families. Furthermore, circumstances in the underdeveloped nations today are working more strongly in this direction than they did in northwestern Europe in the 19th century.

As in that earlier day, poverty and deprivation alone are not likely to generate a slowdown of the birth rate. But personal aspirations are. The agrarian peoples of the backward countries now look to the industrialized, affluent fourth of the world. They nourish aspirations that come directly from New York, Paris and Moscow. No more inclined to be satisfied with a bare subsistence than their wealthier fellows would be, they are demanding more goods, education, opportunity and influence. And they are beginning to see that many of their desires are incompatible with the enlarged families that low mortality and customary reproduction are giving them.

They live amid a population density far greater than existed in 19th-century Europe. They have no place to which to emigrate, no beckoning continents to colonize. They have rich utopias to look at and industrial models to emulate, whereas the Europeans of the early 1800's did not know where they were going. The peoples of the underdeveloped, overpopulated countries therefore seem likely to start soon a multiphasic limitation of births such as began to sweep through Europe a century ago. Their governments appear ready to help them. Government policy in these countries is not quibbling over means or confining itself to birth-control technology; its primary task is to strengthen and accelerate the peoples' motivation for reproductive restraint.

Meanwhile the industrial countries also seem destined to apply brakes to their population growth. The steadily rising level of living, multiplied by the still growing numbers of people, is engendering a dizzying rate of consumption. It is beginning to produce painful scarcities of space, of clean water, of clean air and of quietness. All of this may prompt more demographic moderation than these countries have already exercised.

FOOD

The first task of a poor country is to improve both the quantity and the quality of its nutrition. Basically this calls for education, not only in agriculture but also in food economics and technology

by Nevin S. Scrimshaw

Nearly half the world's population is underfed or otherwise malnourished. The lives of the people in the underdeveloped areas are dominated by the scramble for food to stay alive. Such people are perpetually tired, weak and vulnerable to disease—prisoners of a vicious circle that keeps their productivity far below par and so defeats their efforts to feed their families adequately. Because their undernourishment begins soon after birth, it produces permanently depressing and irremediable effects on the population as a whole. Malnutrition and disease kill a high proportion of the children by the age of four; the death rates for these young children are 20 to 60 times higher than in the U.S. and western Europe. Among those who survive, few escape physical or mental retardation or both.

Obviously the first necessity, if the underdeveloped countries are to develop, is more and better food. Much has been said about the need for industrialization of these countries as the quickest and most effective way to raise their incomes and level of living. But they cannot industrialize successfully without a substantial improvement in their nourishment and human efficiency. This must depend primarily on improvement of their agriculture and utilization of food. In these countries from 60 to 80 per cent of the people are engaged in farming, but their productivity is so low that it falls far short of feeding the population. That stands as a roadblock against their advance. Unless they improve their food-producing efficiency, any diversion of their working force to industry will only make their food problem more desperate.

Moreover, during the coming decades their food requirements will rise astronomically, both because of their rapid population growth and because of the demand for a better scale of living that comes with industrialization. The Food and Agriculture Organization of the United Nations has estimated that to provide a decent level of nutrition for the world's peoples the production of food will have to be doubled by 1980 and tripled by 2000.

Can the developing nations make the grade? Is our planet capable of feeding the hungry half of the world and supporting its vast, growing population? This is a complex question that involves many issues other than the volume of food production. Just as important are the conservation of food, the kinds of foods produced and the ways in which food is used. Food supply is not merely a matter of the number of bushels of grain the farmer harvests or the number of chickens he raises. Other vital elements in the equation are the selection, handling, processing, storage, transportation and marketing of the food crops. Each factor allows opportunities for improvement of efficiency that can greatly enhance the food supply.

Let us consider what science and technology have to contribute to the food problem.

The simplest way to increase food production, one might suppose, is to bring more land under cultivation and put more people to work on it. The U.S.S.R. and some of the underdeveloped countries have resorted to this straightforward approach, without notable success. It contains several fallacies. For one thing, it usually means moving into marginal land where the soil and climatic conditions give a poor return. Cultivation may quickly deplete this soil, ruining it for pasture or forest growth. It is often possible, of course, to turn such lands into useful farms by agricultural know-how; for instance, a sophisticated knowledge of how to use the available water through an irrigation system may reclaim semiarid grasslands for crop-growing. But the cultivation of marginal lands is in any case unsuccessful unless it is carried out by farmers with a centuries-old tradition of experience or by modern experts with a detailed knowledge of the local conditions and the varieties of crops that are suitable for those conditions. Such knowledge is conspicuously absent in the underdeveloped countries.

Furthermore, we know that the highly developed countries have not increased the number of acres under cultivation but on the contrary have abandoned their marginal lands and steadily reduced the proportion of the population engaged in farming. Efficient farming calls for concentration on the most efficient lands, and it also results in greater production with fewer people. The U.S., for example, produces a huge surplus of food with only about 10 per cent of its people working on the farms.

The problem of the underdeveloped countries, then, is to increase the productivity of their farms and farmers. This would allow them to industrialize and to feed their people more adequately. It is not easy to accomplish, however. The peasant farmers are conservative and resistant to change in their methods of cultivation. The entire population

CHICAGO STOCKYARDS are a focal point in the distribution of protein in the U.S., handling more than three million head of cattle, hogs and sheep a year. Only a few of its hundreds of pens appear in the aerial photograph on the opposite page. The brown cattle are Herefords; the black, Angus; the white, Holsteins. Green areas are unused pens. Near center men are herding cattle out of a pen through long runway.

FOOD SUPPLIES available (*gray bars*) and needed (*colored bars*) vary widely in four underdeveloped regions, according to studies by the Food and Agriculture Organization (FAO). All the regions suffer from both shortages of food and badly unbalanced diets. The lack of proteins is particularly acute and plays an important role in malnutrition. Pulses include leguminous crops such as peas and beans. The relatively well-fed countries of Paraguay, Uruguay and Argentina are omitted from the Latin America chart.

needs to be indoctrinated in the possibilities offered by scientific agriculture, including the officials who must provide the necessary funds, planning, legislation, training and research programs. The underdeveloped countries are greatly in need of studies and experiments to help them to adapt modern agricultural methods to their own conditions.

During the past two decades some of these countries have increased their food production, but their populations have in the meantime grown faster; therefore they are farther behind than before. Furthermore, the food increase has been gained at the expense of using up marginal lands. In productivity per acre or per man they have not gained at all.

Meanwhile the efficiency of farming in the developed countries has progressed phenomenally. In the U.S. the productivity per farm worker has tripled since 1940 [*see illustration on page 80*]. With a 7 per cent reduction in the total acreage under cultivation, U.S. production of cereal grains has jumped 50 per cent; the increase in the corn output, thanks to hybrid corn, has been even greater.

The "secret" of these improvements can be summed up in a few words: chemicals, mechanization, breeding and feeding.

Fertilizers are an old story to farmers, even in backward countries, but the practitioners of modern farming have raised the use of chemical fertilizers to a high art. To these they have added a pharmacopoeia of chemicals for special purposes: poisons to kill insects, fungi and other pests; plant-growth regulators to control weeds, force early sprouting, stimulate ripening and prevent premature dropping of fruit; soil-conditioners to improve the physical characteristics of the soil. Most of these techniques and materials could easily be introduced on the farms of the underdeveloped areas. They require capital investment, but they would pay for themselves many times over in higher yields.

The mechanization of farming has become so familiar in Western countries that we have forgotten the many changes it has brought about. It has released for human food a great deal of land formerly devoted to growing feed for draft animals. Feeding fuel to a machine is cheaper than feeding a horse, and the machine needs less care and maintenance. The machine not only plows and cultivates but also digs ditches and postholes, loads and handles heavy materials, harvests, threshes, chops forage, cleans vegetables and does many other things the intelligent horse could never do. It does all these things swiftly and virtually at a moment's notice, so that the farmer no longer has to worry about whether or not he can get a job done before threatening weather ruins his planting or his harvest.

The machine has also facilitated the building and development of irrigation systems. It makes easy work of the construction of dams, the digging of water channels and the pumping of water. In the U.S. irrigation has made it possible to increase the crop yield of Western lands by 50 to 100 per cent. In the arid zones of India and the Middle East, which for centuries have been entirely dependent on irrigation for their farming, extension of their systems with machinery would be a great boon. In some areas where enough water could be furnished by irrigation, two or three crops a year could be produced and the crops could be diversified.

Finally, a combination of selective breeding and efficient feeding has generated astonishing bounties in both plant and animal production. For most of the major plant crops, thanks to modern genetics, we have seen the development of new varieties that give a higher yield and are more resistant to disease. The same is true of the animals that supply our meat, milk and eggs. "Hybrid vigor" has become a magic phrase in the U.S. farm belt. Furthermore, the farmer today can buy selected seeds he knows will do certain specific things with high reliability: produce plants that mature faster or are adapted to a wide range of conditions or grow to a uniform height and all ripen at the same time so that they can be harvested by machine.

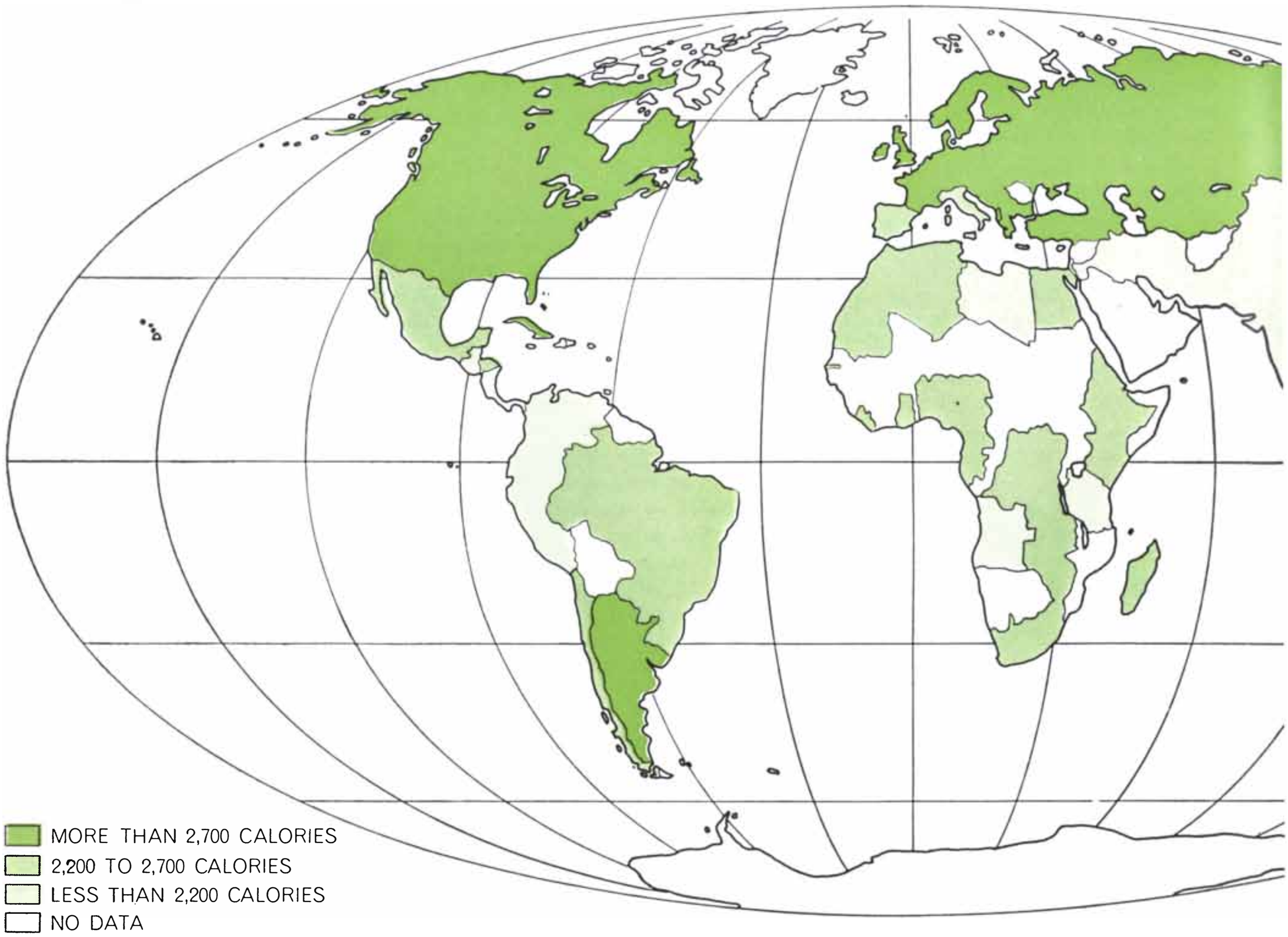
We now have wilt-resisting peas and cabbages, mosaic-resisting snap beans, virus-resisting potatoes, mildew-resisting cucumbers and lima beans, anthracnose-resisting watermelons and leaf-spot-resisting strawberries. We have new cereal grains rich in high-quality protein, special squash rich in vitamin A, cottonseed from which the toxic pigment called gossypol has been bred out. We have cows that give richer milk, hogs that grow exceptionally fast on less feed, hogs with more lean meat and less fat, poultry with a high ratio of lean meat.

To improvement of the animal breeds the advanced countries have coupled scientific husbandry: finely calculated diets and rations, synthetic hormones, pesticides and sanitary stalls, drugs and vaccines to control disease and many other measures that have heightened the efficiency of production. The results are most strikingly shown in poultry raising. There are now breeds of hens that lay more than 200 eggs a year and broilers that grow to a three-pound market size within 10 weeks. Diseases, waste motion and costs have been sharply reduced. Raised in individual cages arrayed in batteries of hundreds or thousands, the chickens minimize the expenditure of energy by themselves and their caretakers and facilitate record-keeping, so that the less productive birds can easily be eliminated.

In general it would not be difficult to apply most of the agricultural improvements to the countries that need them so urgently. The main biological problem would be to select the right plants and animals for transfer to those countries. For instance, Temperate Zone varieties of corn and soybeans do not grow well in hotter areas; prize pigs from mild climates are often unable to nurse their young in the Tropics; plants and animals that are successful in one region may quickly succumb to diseases in another. But analysis of the ecological conditions and testing can resolve these problems. It is known, for example, that certain plants can readily be transplanted from areas in the U.S. to areas in Japan because the climatic conditions are much the same. The identification and classification of such ecological analogues on a world-wide scale would greatly facilitate the transfer of agricultural techniques to the underdeveloped regions.

Aside from more efficient methods, however, those countries need a sounder over-all policy, which is to say, in most cases, more diversification of crops. Many of the underdeveloped nations are enslaved by a single cash crop, such as rubber, hemp, cotton, coffee, tea, sugar or olive oil, with deadly effects on their basic food supply. It is true that the export of the single crop provides cash with which to buy food, but it places the country at the mercy of crop failure and price fluctuations in the world market. There have been periods when it has meant mass starvation for a whole region.

Without giving up its profitable crop, each country should be able to expand its own food production and achieve a better-balanced agricultural economy. In some cases it could improve its food supply immediately without radical changes. For example, the cotton-raising countries usually export the cottonseed-oil meal along with the fiber;



NUMBER OF CALORIES per person per day as estimated by the FAO in 1962 is plotted on a map of the world. Several heavily populated countries, such as India and China, fall into the lowest classification, which means that a large part of the world's

instead they could keep the meal and use it for animal feed and even as human food.

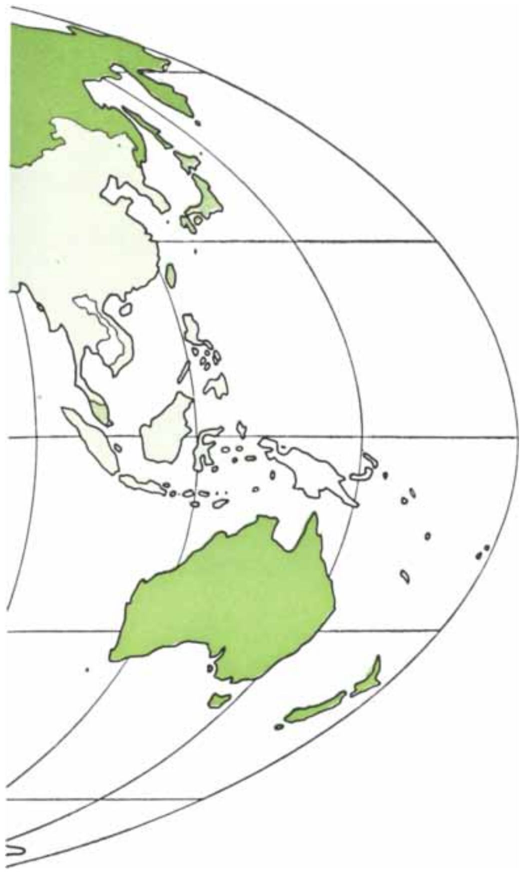
Thus in their campaign against hunger the developing countries need first of all to increase their food production. The second way in which they could make great strides is by better food conservation or preservation. In this field the advanced countries have achieved improvements fully as spectacular as in production.

For food-raising *Homo sapiens* the perishability of foodstuffs has always been a major problem. Gradually he learned that his food supply would go further if he kept it edible longer by smoking, drying or salting it, or by keeping it cool in caves, wells, snow or ice from ponds. With limited effectiveness, these devices have served man for many centuries. But general food conservation on a large scale did not begin until the 19th century, with the arrival of the insulated refrigerator.

Within the past two decades we have seen freezing become a major means of preserving food in the U.S. Still newer is the recent development of freeze-drying—a system of vacuum dehydration of frozen food that makes it possible to store many foods without refrigeration and still retain their fresh flavor and characteristic properties. This method is ideal for keeping food in tropical areas, but it is still comparatively expensive. Vacuum-drying without freezing, however, is less costly and can preserve certain foods with little change in their flavor or texture. Also cheaper than freeze-drying is the new process of foam-mat drying, which is particularly good for fruit juices and purées.

Sterilization of food by ionizing radiation, which once seemed very promising, now looks impractical, because it damages the flavor and nutritional value. But irradiation with smaller doses, in the pasteurization range, may help to prolong the storage life of foods, although they will have to be refrigerated. Bacon preserved by this process has recently been approved for sale in the U.S. Another new technique is dipping the food in an antibiotic bath; this works well for fresh fish and meat. Of course there are also the chemical preservatives and other additives that have been used in food for some time, such as propionates to inhibit molds in bread, antioxidants to slow down the process by which fats become rancid, emulsifying agents, bleaching agents and so on.

In many other ways, some obvious and some subtle, modern food industries have contrived to reduce the attrition of food between its harvesting in the field and its delivery to the consumer. These include scientific storage at the right temperature and humidity with protection from rodents and insects, protective packaging (for which polyethylene and other synthetic wrappings have been particularly useful) and rapid transportation in refrigerated ships, cars and airplanes. Today there is virtually no food that cannot be delivered fresh and



population is undernourished. While production is rising, so is the number of people.

with only minor losses to consumers everywhere.

Better food production and better food conservation are the prime requirements of the ill-fed countries. There is a third modern development that could also help them tremendously—artificial enrichment of their food with vitamins and other substances.

Everyone knows the story of the dramatic conquest of goiter in the U.S. and elsewhere by the simple device of adding iodine to the salt. Iodized salt in the 1920's practically eliminated goiter in the U.S. Middle West and Switzerland, where iodine is missing from the normal inland diet. In recent years Guatemala by the iodization of salt has abruptly reduced the incidence of goiter to less than 10 per cent in areas where it was formerly 30 to 60 per cent, and Colombia has achieved similar results. Salt iodization is now an officially sponsored practice in a number of underdeveloped countries.

Other deficiency diseases, such as pellagra and beriberi, can be eliminated by the simple addition of vitamins to wheat flour and polished rice. Here it is usually a case of restoring valuable food elements that are lost in the processing of the whole grain into the "refined" food. Since 1941 the enrichment of wheat flour with thiamine, riboflavin and niacin has been a general practice in the U.S. and Canada, and it is required by law in Puerto Rico and the Central American countries. Such legislation should be adopted by all countries depending on refined wheat flour as a basic food. The same goes for polished rice. In a test on a large scale in the Philippines from 1948 to 1950 it was shown that enrichment of polished rice with vitamins was very effective in combating beriberi in this rice-eating population. Corn meal also needs to be enriched; a diet consisting mainly of corn may produce pellagra, the disease resulting from a deficiency of the vitamin niacin combined with a diet low in the amino acid tryptophan.

Enrichment of a nation's wheat, corn and rice with the vitamins thiamine, riboflavin and niacin, plus calcium and iron, costs only a few cents per person per year. It would produce significant improvements in the health of most ill-fed populations, and it is strongly recommended by international health organizations.

A great part of the hungry half of the world suffers primarily from a deficiency of protein. In most vegetables and other plant foods the protein content is low in quantity and poor in quality—meaning that it is only partly metabolized by the body. High-quality protein is hard to come by. In many of the underdeveloped countries it would require the relatively wasteful allocation of land to pasture for animals, whereas it is often more efficient at present to devote the land to the direct growing of food for human beings.

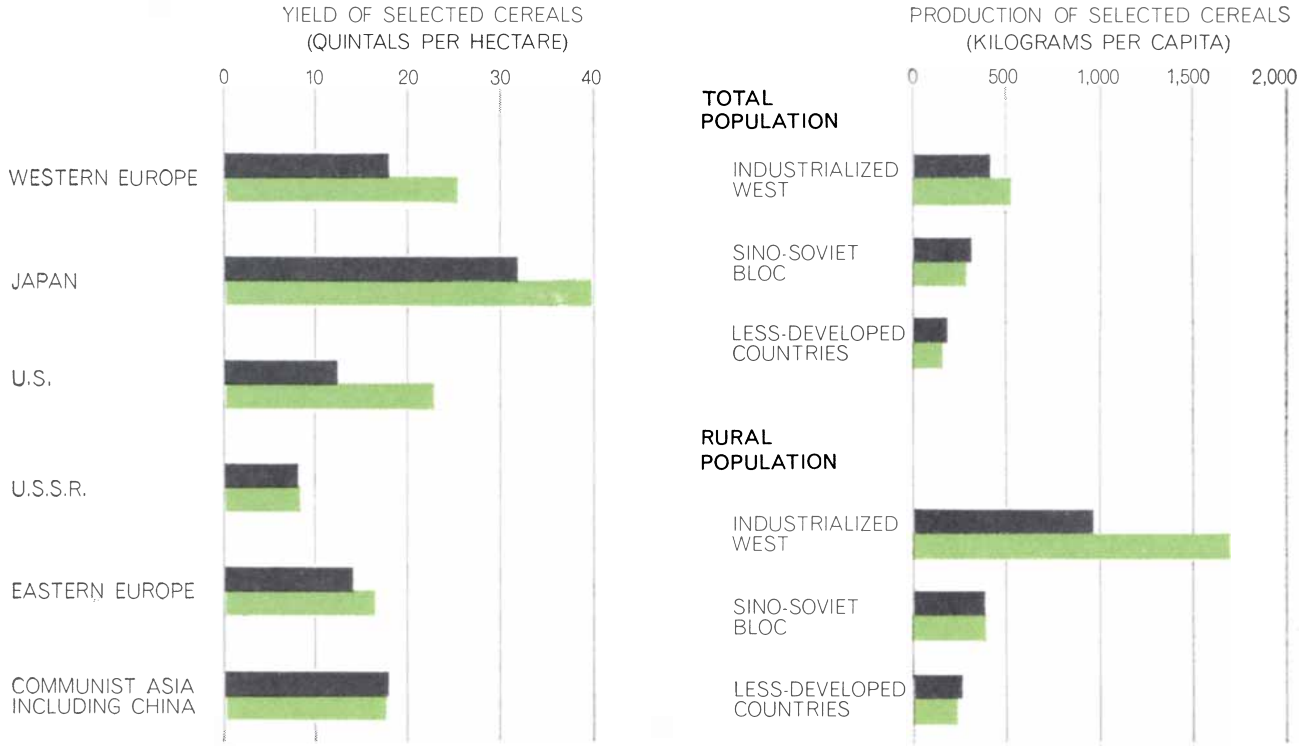
Fortunately, however, low-protein foods can be enriched economically by adding a source of the missing amino acids that are essential to the synthesis of proteins by the body. The nutritive value of corn meal, for example, can be greatly improved by adding to it a supplement of 3 per cent fish flour, 3 per cent egg powder, 3 per cent food yeast, 5 per cent skim milk, 8 per cent soybean flour or 8 per cent cottonseed flour. Any of these supplements will supply material for protein synthesis and also improve the efficiency of utilization of the protein in the corn meal.

A most promising development is the progress that is being made in the artificial synthesis of amino acids themselves. Synthetic methionine is already being fed to animals in the U.S. on a considerable scale. The addition of lysine to wheat flour or bread can raise the proportion of the wheat's usable protein from about a half to two-thirds, and the amino acid threonine could make grain protein almost as fully usable as the proteins of meat and milk. The main problem so far is the cost of the synthetic amino acids. As more of them are synthesized and the price is brought down, these products of laboratory chemistry will make it possible to turn grain into meat for the meatless regions of the world.

Already nutritionists, using only natural sources, have concocted mixtures that can make a purely vegetarian diet richer in protein. The basic ingredients are a cereal grain, such as corn, rice or wheat, and an oilseed meal. This meal, or flour, is made from the cakes that are left when the oil is pressed out of the seed. It is consequently less expensive than comparable animal protein because it is a dividend remaining after sale of the oil. It generally contains about 50 per cent protein. Good sources of oilseed meal are cottonseed, soybean seeds, sesame seeds, sunflower seeds and peanuts.

When a properly processed oilseed meal is mixed with a grain in the ratio of one part meal to two parts grain, the combination contains about 25 per cent protein of meatlike quality. With the addition of a small amount of yeast and vitamin A it makes a highly nutritious food. In tropical and subtropical areas it could serve as a complete basic food lacking only vitamin C (which is supplied in abundance by tropical fruits and vegetables) and sufficient calories. The latter are obtained readily from sugar, starchy vegetables and such fruits as bananas and plantains.

Low-cost mixtures of this kind have been developed by the Institute of Nutrition of Central America and Panama. Under the generic name of Incaparina, they are already being manufactured and sold as basic foods in Guatemala, El Salvador, Mexico and Colombia and will soon be available in other Latin-American countries. Incaparina has been found to be almost as good a protein source for young children as milk, and it has proved to be effective in preventing or curing protein malnutrition in children. Almost every region of the world either has already or can grow the raw materials for this food. The basic formula is about



EFFICIENCY OF AGRICULTURAL PRODUCTION has grown in industrialized areas but has remained static or even declined elsewhere. Gray bars represent years 1935–1939, colored bars the year 1959. Chart at left shows yields of selected cereals. A quintal is 100,000 grams, or about 220 pounds. A hectare is 2.47 acres. Charts at right show production of selected cereals per capita of total population (*top*) and of rural population (*bottom*). The latter includes people living in both rural areas and small villages.

55 per cent grain (corn, sorghum, rice, wheat or whatever other cereal is available locally), 38 per cent oilseed meal, 3 per cent torula yeast, 3 per cent leaf meal (as a source of vitamin A) and 1 per cent calcium carbonate.

Many other schemes for getting more protein from plants have been studied. One on which a great deal of work has been done is the growing in liquid culture of the single-celled alga *Chlorella*. Efforts have also been made to concentrate or extract protein from grass, vegetables, cereals and other plant materials. But so far all these investigations have been disappointing in one way or another: the food produced is either too expensive, unpalatable or low in nutritive value.

Then there is the sea, whose tremendous population of fish and other edibles continues to excite the imagination of those concerned with the world's food problem. The main obstacle here is the cost of storing the catch of fish; such storage requires mechanical refrigeration, not generally available in the underdeveloped countries. The grinding of fish to make a protein-rich flour looks like a promising answer to this problem, but it calls for technical skill and costs more than providing protein in the form of surplus dried skim milk or oilseed meal. Moreover, large quantities of fish flour are not attractive in a basic daily diet. All in all, it must be said that sea food offers possibilities one should not neglect but that it cannot be regarded as a panacea for prompt solution of the world's food problems.

Finally, there is the dream of manufacturing completely synthetic foods at a cost low enough to end all food worries. After all, the essential nutrients man requires are basically chemicals whose formulas are well known. Most of them can be synthesized in the laboratory, either by direct chemical manipulation or with the help of microorganisms. We already have synthetic vitamins, synthetic amino acids, hydrogenated fats, artificial flavoring and coloring agents and so on. From a concentrate of soybean protein the skill of the food chemist can prepare a meatlike product that with proper flavoring, coloring and molding can pass for pressed ham or chicken.

The cost of such creations is still exorbitant. But the progress of chemistry is steadily reducing the cost, and almost certainly we shall eventually have synthetic foods that will compete in cost, palatability and nutritive value with the products of the farm. Although that day is too far away to promise relief of the present food crisis in the underdeveloped regions, it may help to forestall the crises threatened for the future by the growth of the world's population.

Along with modern food technology go modern dangers. As man takes a more active hand in shaping and extending his food supply he introduces new hazards in what he eats—mainly potentially dangerous new food additives. Thus the safety of our food has become a paramount issue in the industrial age.

Indeed, it has always been something of an issue. We tend to overlook the fact that there are toxic substances in most of the plants we use for food, even the common ones. Fortunately they are usually eliminated or reduced to harmless proportions by cooking or other processing.

Many legumes (notably soybeans) contain an inhibitor that interferes with the action of the protein-digesting enzyme trypsin. Some also have substances that clump the red blood cells. Cabbages and several other common vegetables contain materials that deny iodine to the thyroid gland and so tend to produce goiter. Certain vegetables and cereals have high concentrations of oxalates and phytates, which bind iron and calcium and prevent the use of these minerals by the body. There are also common plants that harbor some of the deadliest poisons known to man. The cassava root contains cyanides; lima beans, the common vetch and the broad bean have a glucoside that gives rise to cyanides; the broad bean also contains a compound that causes hemolytic anemia; the chick-pea contains an unknown substance that produces the disease lathyrism (spastic paralysis of the legs). Consequently man has always had to be careful, and still needs to be, in his choice and processing of natural foods.

The new dangers arise from the increasing and necessary use of chemicals at all stages in the production and handling of food, from the planting of the seed to the packaging of the final product. The hazard begins with the pesticides and other poisons used to protect and promote the growth of the plant. (One may hope that another contaminant—radioactive fallout from nuclear tests—will now effectively be eliminated.) After harvesting, grain and legumes become subject to poisoning by molds unless they are properly stored. Then there is the potential toxicity of residues of the hormones and antibiotics that have become a standard part of the feeding of meat animals. Next come the chemicals added to foods during the processing for flavor, color and preservative purposes. Along the way the food may pick up traces of toxic detergents that have been used to clean the tanks or containers in which it is processed. Finally, the wrappings in which the food is packaged may inadvertently add some toxic contamination.

The whole sequence is imperfectly known; no one can be quite sure just where all the dangers lurk. Gradually the advanced countries have awakened to the need for vigilance in all stages of the handling of food. With respect to the chemical treatment of foods, U.S. legislation and the policy of the Food and Drug Administration are now based on the principle that "there are no harmless substances; there are only harmless ways of using them."

If the technically developed countries are concerned about the safety of their food supplies, obviously the less developed ones must be even more so as they attempt a rapid modernization of their food-producing and food-processing methods. The control of food contamination has become a world-wide problem, and the World Health Organization and the Food and Agriculture Organization of the United Nations have initiated conferences, committees and periodic reports on control regulations in the various countries. International research and standards will be helpful, but each country must take the responsibility for guarding the safety of its own food supply.

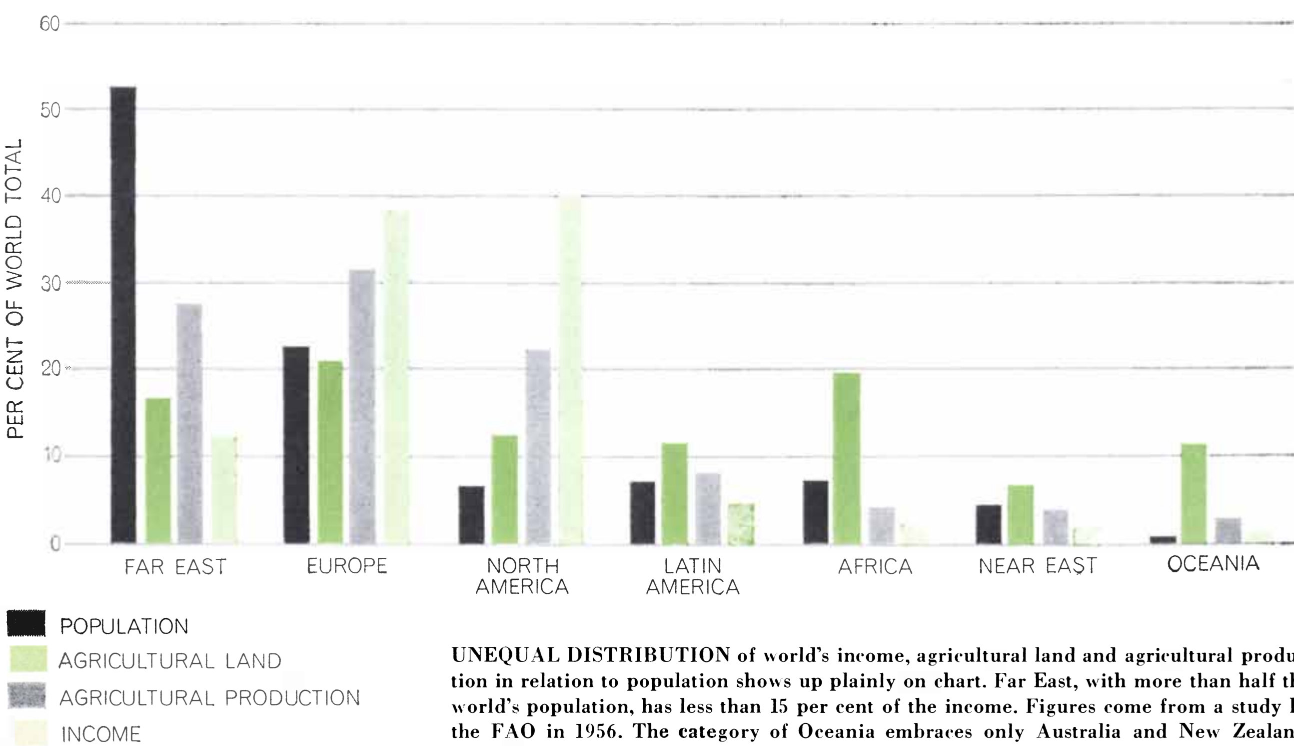
What can be done to help the hungry half of the world pull itself up from its undernourished state and speed up the developments that would enable it to feed itself decently?

Even pessimists must note, first of all, that the prospects of the impoverished peoples are brightened by a most remarkable turn in human history. Whereas in the past men have been concerned only with feeding their own families and have fought long and bitter wars for food, we see today a new and remarkable world-wide concern for feeding the hungry wherever they are. Whether this arises out of advanced humanitarianism, the fears of the well-fed or the contest between the West and Communism is less important than the fact that the wealthy countries are taking an interest in the peoples of the poor countries.

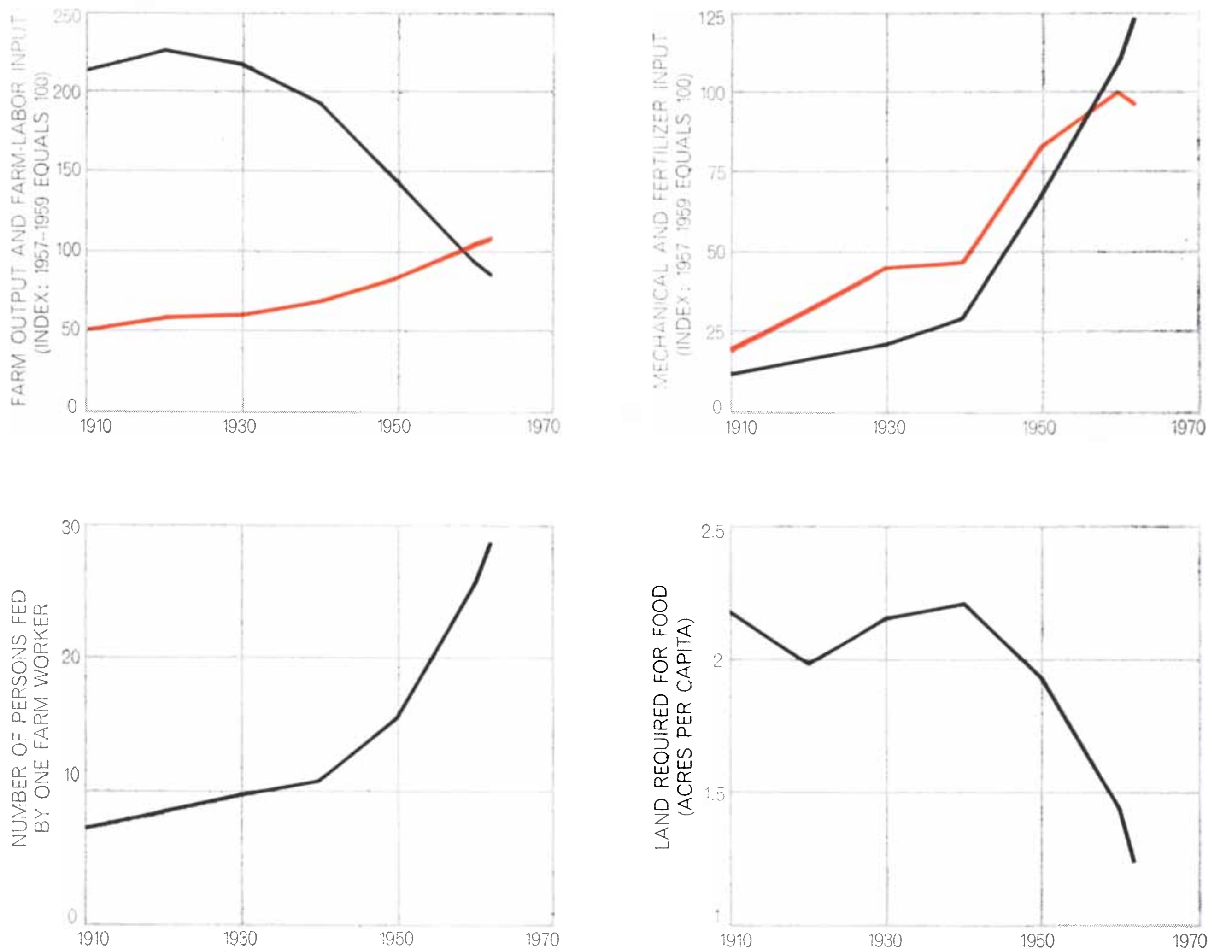
During the past nine years the U.S. has sent more than $12 billion worth of its surplus food to these countries. The Food and Agriculture Organization, at the suggestion of Canada and the U.S., has launched an international effort for the same purpose with a $100 million fund as a starter, and it is now conducting a five-year Freedom from Hunger campaign.

This emergency help is not to be underestimated, and one hopes that it will be continued and even enlarged, preferably under international auspices.

A second way in which the developed countries are helping substantially is by example and by technical advice and assistance to the developing areas. The example, again, is important. The U.S. Department of Agriculture has estimated



UNEQUAL DISTRIBUTION of world's income, agricultural land and agricultural production in relation to population shows up plainly on chart. Far East, with more than half the world's population, has less than 15 per cent of the income. Figures come from a study by the FAO in 1956. The category of Oceania embraces only Australia and New Zealand.



VAST IMPROVEMENT of agricultural production in U.S. demonstrates value of modern techniques. At top left, index of farm-labor input (*black curve*) declined from 212 in 1910 to 85 in 1962, while the farm output index (*colored curve*) rose from 51 to 108. The change was due in great part to increased use of machinery (*top right, colored curve*) and fertilizers and liming materials (*black curve*). The number of persons supplied by one farm worker in 1820 was 4.12. By 1910 it had risen to 7.07 (*bottom left*) and in 1962 it had jumped to 28.57. The number of acres needed to feed one person declined from 2.17 in 1910 to 1.23 in 1962 (*bottom right*).

that at the present rate of progress in agricultural productivity the developed countries will be able to produce almost twice as much food as they need by the year 2000. Such an advance cannot fail to infect and stimulate the backward countries.

Yet when all is said and done, these countries must themselves generate the means for their emancipation from hunger. To do so they will have to change long-established habits and attitudes. Neither well-meant exhortations nor government decrees are likely to persuade them—certainly not in a hurry. Concrete steps may, however, speed reforms by quickly convincing the people of their value.

It is easy to list effective projects that the governments of these countries might undertake. Make available to the farmers the seeds and stocks of improved plant varieties and animal breeds. Build chemical-fertilizer plants. Supply agricultural chemicals for pest control and other special purposes. Provide new implements and machinery suitable for the local types of farming. Extend credit to the farmers for their new seeds and equipment. Pay them subsidies to start urgently needed new crops. And above all, establish training programs that will show them how to handle their new materials and equipment and to farm more efficiently.

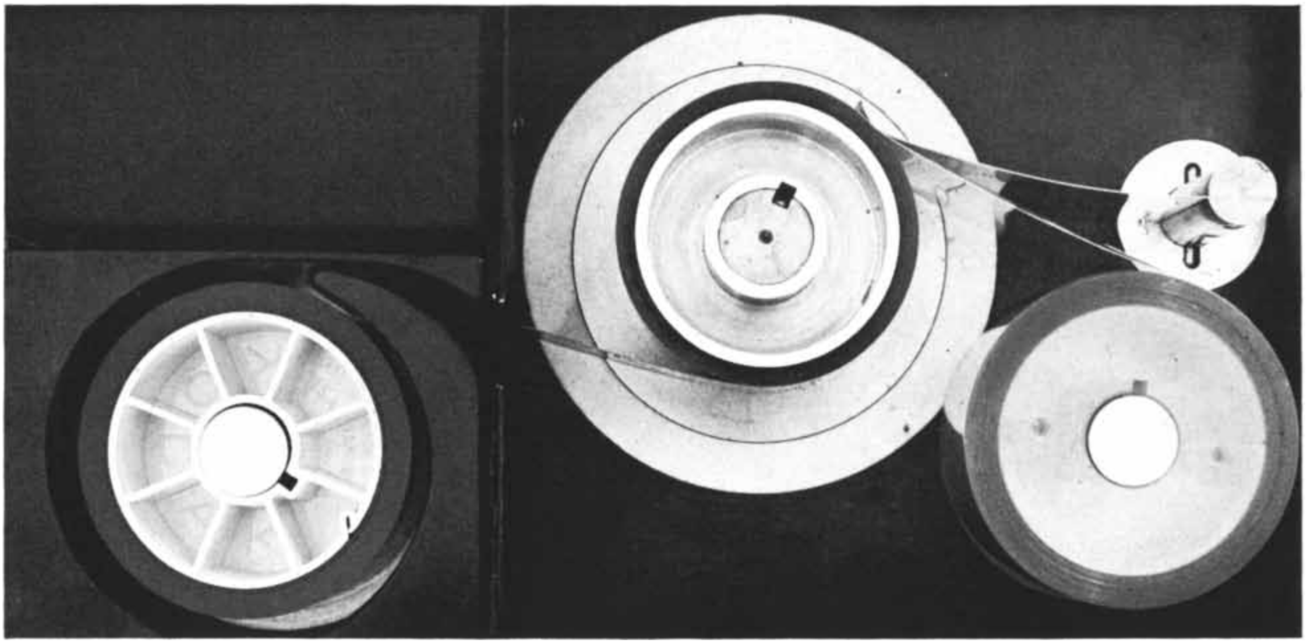
Education must receive the first priority for the advancement of these countries. The development of each one of the Western countries has been founded on the literacy and knowledge of its population. This applies to their progress in agriculture as well as to their achievements in industrial technology and professional services. To raise itself the underdeveloped country requires a population that understands modern agriculture and nutrition, is equipped with teachers and experts in all the fields of food technology and is led by political and administrative officials who appreciate the possibilities of science and technology.

This will be a long and difficult program for some of the poorly educated and ill-fed nations. But investment in education is a far more practical and effective program for them than investment in big buildings, dams, roads and factories that are put up mainly as visible symbols of progress. Just as the strength of the so-called developed countries lies in their educational systems and their culture, so the great hope and promise of the future for the underdeveloped countries resides in the fact that they too will come to share in the full wealth of mankind's knowledge and contribute to it themselves.

Kodak reports on:

processing and printing long film by dampness . . . a nice fluidized bed

Just roll them up together



This represents the principle of either intermittent or non-intermittent processing and printing of long rolls of film by dampness—mere dampness. The principle is quite simple and not quite revolutionary any more. In its new manifestation it delivers not only an immediate positive but a first-class negative for future positives. Perhaps the message will strike right between the eyebrows of some reader who has been struggling hard with the pesky details of apparatus for photographing our too rapidly shrinking planet for the ultimate purpose of making it more livable for our burgeoning species and/or of peace-keeping. (Probably the peskiness of the details has diverted his attention from ultimate purposes.)

We are wide open. We can play guiding angel to this new but well proved technique for broadening the scope and feasibility of photographic surveys, supplying nothing more billable than hospitality and encouragement, hoping that the eventual consumption of our negative materials will reward us for improving the quickness and quality of aerial photography. We can, on a special order basis, supply just the KODAK BIMAT Film, which imbibes solution, applies it to the negative film, and comes away bearing the positive image. We can similarly supply just the KODAK BIMAT Imbibant. We can likewise supply suitable negative films. We can supply the whole works. We can design the hardware, build the hardware, or shake the hand of him who intends to prosper by proving in fair competition that he can outdesign or outbuild us.

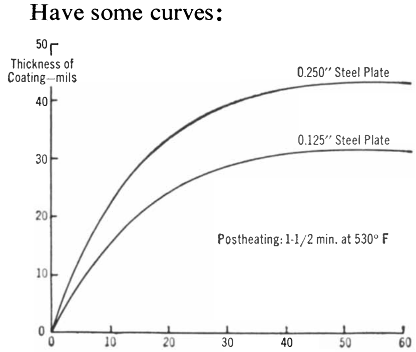
Book an appointment for a preliminary discussion by a letter to Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

Thermoplastic flour

The number of people who know about the fluidized-bed method of coating with plastics is as nothing compared with the number who have never heard of it. If hitherto in the second group, you are hereby switched. To what purpose is for you to determine.

TENITE Butyrate 522G looks like flour, except that in addition to white it can come in any hue you choose. Put some in a double-bottomed container. Make the upper bottom a tight-fitting porous plate of sintered glass or metal, or make it solid and minutely perforated. Pump air into the space between the bottoms. If the pore size and the air pressure are right, seething will commence. "Seethe" hardly belongs in the engineering vocabulary, but it conveys the idea. No dust cloud rises, but the level of the powder does rise. It takes on a ghostly look— a pseudo-liquid, a pseudo-solid, prodigious to behold. All objects sink in it. If the object is hot enough (480° - 570°F), the powder particles hitting it melt to form a coating. Unless the object is very thin or for other reasons loses surface temperature quickly, the coating thickens steadily.

Have some curves:

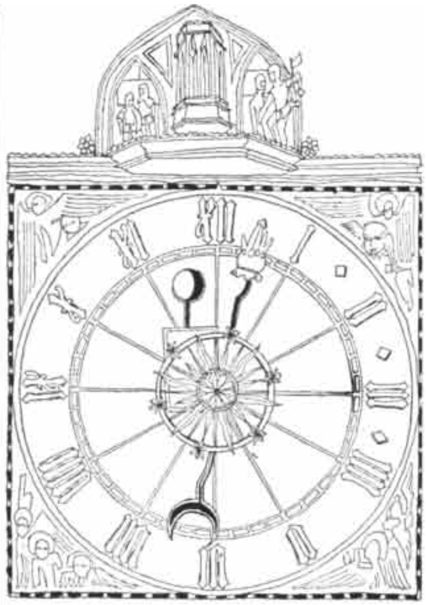


The postheating melts the surface layer and polishes it. Dielectric strength of a .020" coating runs around 16,000 volts.

Note that thick coatings can be made, as compared with lacquers. Note that all openings are entered and all cavity interiors coated. Note where to send for Technical Report TR-12: Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company). Note that though this organization equally prides itself as a marketer of organic solvents, it flinches not at bringing this technique to the attention of the technological public.

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

SCIENCE AND



The Test Ban

The limited nuclear-test-ban treaty signed last month by Great Britain, the U.S. and the U.S.S.R. at the very least promises a sharp reduction in the pollution of the atmosphere with radioactive debris. Beyond that it is, as President Kennedy observed, "an important first step—a step toward peace—a step toward reason—a step away from war." Premier Khrushchev said the treaty should produce "a situation favorable to the long-overdue solutions of international problems." At the level of nuclear power politics the agreement institutionalizes the great-power nuclear stalemate and tends to align the U.S. and the U.S.S.R. against all "*n*th countries" seeking to acquire a nuclear capability—most specifically against Communist China.

Although the treaty curbs tests in the atmosphere, in space and under water (those that produce widespread fallout), it does not stop testing; the long-standing Soviet-U.S. argument on inspection was settled by simply exempting underground tests, the only context in which inspection is an issue. There are still graver reasons why, as President Kennedy said, "the treaty is not the millennium." It does not halt the production of nuclear weapons or of missiles to carry them and, as President de Gaulle pointed out, "nothing is changed in the terrible threat that the nuclear armaments of the two rivals suspends over the world." The treaty is, however, the first fruit of 17 years of on-and-off efforts to control the nuclear arms race, and it capped with almost anticlimactic speed five years of tortuous Big Three negotiations on a suspension of nuclear testing. There is the possibility, President Kennedy said, that "both sides can by this treaty gain confidence and experience in peaceful collaboration."

Aside from pressure to respond to world-wide fears of fallout, the three powers were motivated primarily by a desire to prevent the proliferation of nuclear weapons in the hands of other countries. To abjure atmospheric testing is in effect to agree not to develop fission or fusion weapons. On the first day on which the treaty was opened for accession, representatives of 31 nations signed the copy on deposit in Washington, including Israel and the United Arab Republic, Yugoslavia, Japan, Canada, Australia and several European members of NATO and the Warsaw Pact; about 100 countries are expected eventually to subscribe to it.

Two countries refused to sign. France, which considers a nuclear capability an essential element of an independent foreign policy, has already tested atomic weapons and is reported to be preparing for its first thermonuclear test in the South Pacific. China, which is developing atomic weapons without Soviet assistance, denounced the treaty as a bargain between the U.S.S.R. and the "imperialists" to monopolize nuclear weapons and warned that the monopoly would be broken "in the not too distant future."

The Technical Society

About 2.7 million persons are working in science and technology in the U.S., and the proportion "has increased faster for several decades than has either the population or the labor force," reports a survey published by the National Science Foundation. The foundation describes the survey, entitled *Profiles of Manpower in Science and Technology,* as "a national summary, in broad categories, of numbers of persons working as specialists" in those fields.

Breaking down the total, the survey finds that about 500,000 persons are working as scientists (the category includes social scientists with the exception of historians), nearly a million as engineers, a million as technicians and 250,000 as teachers of science and mathematics in secondary schools. These workers account for about 3.6 per cent of the civilian labor force; the proportion was about 1.5 per cent in 1940 and is expected to increase to 4.7 per cent by 1970.

Among the facts the survey reports are that in 1960 the Government paid for the work of about 60 per cent of the scientists and engineers engaged in research and development, although most of them worked outside the Government; that "the population of scientists and engineers is made up largely of persons in middle brackets [30 to 45] of age," and that half of the scientists and engineers work in six states: California, New York, Pennsylvania, Illinois, Ohio and New Jersey.

No Moon Race?

The British radio astronomer Sir Bernard Lovell, who has just returned from a 12,000-mile tour of Soviet space-tracking stations and radio observatories, has reported that the U.S.S.R. is not planning to send a man to the moon. "The Americans are racing themselves," he told British reporters. Lovell gained the impression that Soviet space experts are not convinced that it is scientifically or otherwise desirable to place a man on the moon in the foreseeable future. They believe they can gain just as much information by sending instruments, and they see two grave obstacles to a manned lunar flight. The first is protecting astronauts from the intense radiation that might be produced by a sudden solar flare. The second is getting them safely back to earth.

What the U.S.S.R. hopes to do within the next five years, said Lovell, is to launch a space observatory that would carry a 36-inch telescope and two astronomers. The vehicle would be kept aloft five or six days at a time. The telescope is the same size as the one the U.S. plans to launch into orbit next year without human observers [see "Observatories in Space," by Arthur I. Berman; SCIENTIFIC AMERICAN, August].

Passamaquoddy Revived

The Kennedy Administration has revived the 44-year-old dream of harnessing the tides of Passamaquoddy Bay to produce electricity. In a report to the President, Secretary of the Interior Stewart L. Udall outlined a $1 billion project that he said would be "economically feasible." The President endorsed the plan and directed the Department of State to begin the negotiations with Canada that will be necessary to advance the project.

Passamaquoddy Bay lies between Maine and New Brunswick. It is an arm of the Bay of Fundy, which has the greatest rise and fall of tides in the world; along the Nova Scotia coast the range between high and low tides is as much as 50 feet. In 'Quoddy the range is 12.7 to 26 feet and the average 18.1 feet. The hydroelectric possibilities arise from the fact that Passamaquoddy and its southerly arm, Cobscook Bay, are almost sealed off from Fundy and from each other by islands. Through the construction of dams and water gates between islands, therefore, each bay could be made into a huge pool and its water levels could, within limits, be controlled. Using such a system, the Udall plan would produce power as follows: A high tide would be trapped in Passamaquoddy, while Cobscook would be kept at a lower level. At the period of peak power demand in the region (5:00 to 6:00 P.M.) the water would be allowed to fall through turbines from Passamaquoddy into Cobscook, producing up to a million kilowatts of electricity.

Dexter P. Cooper, a U.S. engineer, proposed in 1919 the first plan for harnessing the Passamaquoddy tides. The idea was a favorite of President Roosevelt's, who watched the tides from his summer home on Campobello Island. His administration started a Passamaquoddy power project, but the Senate cut off funds in 1935 on the grounds that the venture was economically unjustifiable. Officials involved in the recent study said that a modified design and "an evolution in the power industry" had improved the economics.

If the project materializes (the approval of both Canada and Congress will be necessary), it will be a rarity. France is constructing a tidal power plant in the La Rance estuary off the Gulf of St. Malo, and the U.S.S.R. plans to develop electricity from Arctic Ocean tides. So far, however, there is no tidal power system in operation.

Synchronous Satellite

The communication satellite *Syncom II* was launched July 26 and was successfully guided into a synchronous orbit, the first time this feat has been achieved. The 86-pound craft was placed "on station" over the Atlantic Ocean, where it appears to trace an elongated figure-eight pattern that extends 33 degrees north and south of the Equator along the 55-degree meridian. *Syncom II* was jockeyed into the desired position at an altitude of about 22,800 miles by short bursts of hydrogen peroxide.

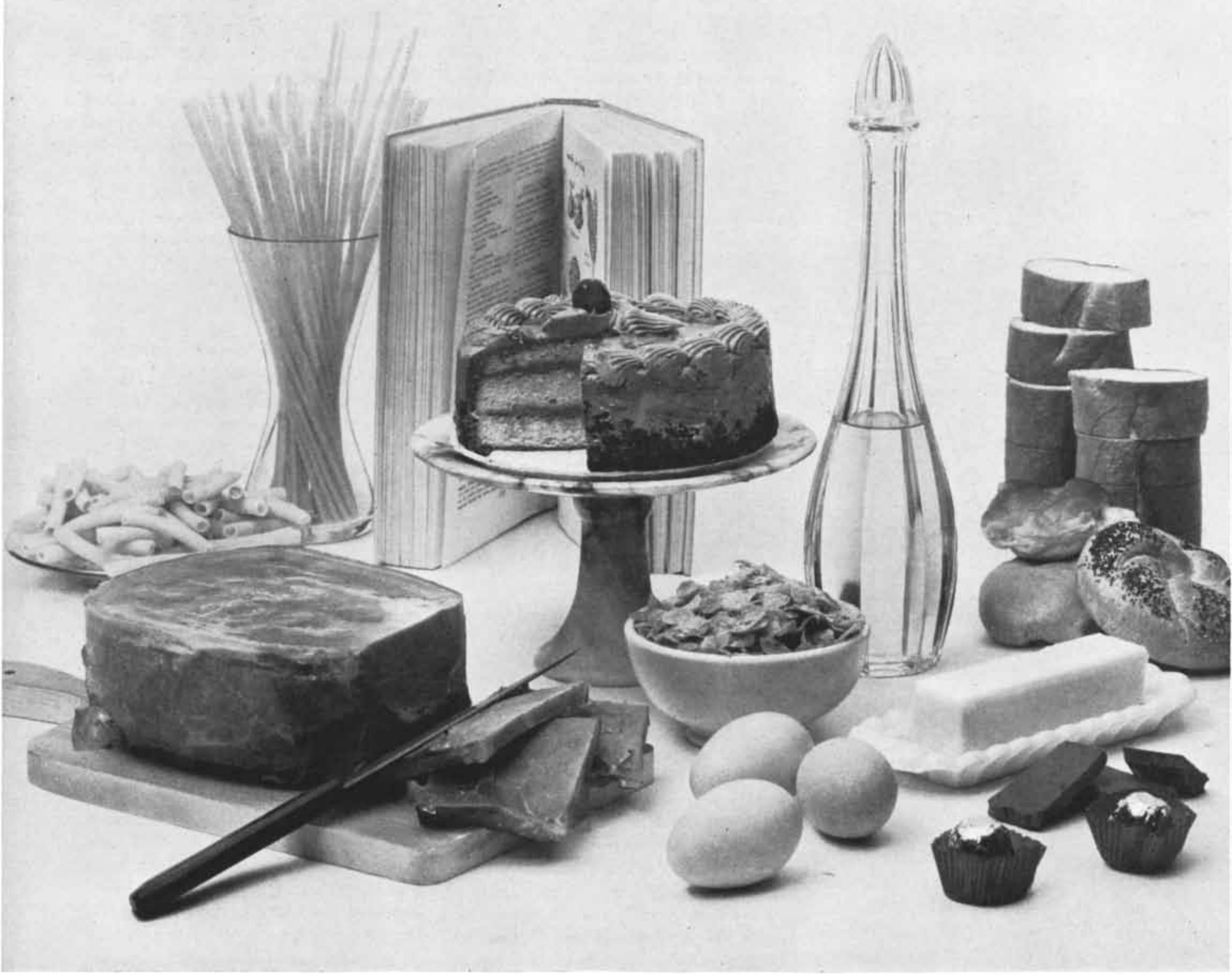
Syncom II, built by the Hughes Aircraft Company for the National Aeronautics and Space Agency, is the third type of communication satellite to be placed in orbit. The first was the aluminum-coated balloon, *Echo I*, launched in 1960, which served simply as a passive reflector for signals from earth. The second type is represented by the "active repeaters" *Telstar* and *Relay*, which travel in fairly low orbits (under 7,000 miles) and relay signals between two points that lie within line of sight as the satellite passes over. The third, the synchronous type, can provide a continuous channel between two line-of-sight points. The initial transmitting and receiving stations for *Syncom II* are Lakehurst, N.J., and the Army communication ship *Kingsport* moored at Lagos in Nigeria. *Syncom II* can transmit one two-way telephone call, teletype messages or facsimile. Unlike *Telstar* and *Relay*, it does not have the capacity to handle television signals.

Relay I, launched in December, 1962, is still in operation. *Telstar I* operated for five months before quitting in February, 1963, apparently damaged by radiation produced by a U.S. high-altitude hydrogen-bomb test. *Telstar II*, more rugged than *Telstar I* and placed in a higher orbit, was launched May 7. It operated for 10 weeks, quit for four weeks and inexplicably started working again.

New Role for Interferon

British workers have found evidence that the substance called interferon, which protects the living cell against virus infection, has the general property of protecting the cell from foreign nucleic acids. Deoxyribonucleic acid (DNA) is the genetic material of living cells, and either DNA or ribonucleic acid (RNA) serves as the genetic material as well as the infective component of viruses. When viral nucleic acid enters a cell it introduces "instructions" for the synthesis of new virus particles. Interferon somehow prevents these instructions from being carried out.

Interferon was discovered in 1957 by Alick Isaacs and Jean Lindenmann at the National Institute for Medical Research



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Isaacs conceived the hypothesis that cells might produce interferon in response to any foreign nucleic acid. He tested the idea by exposing chick and mouse cells to chick and mouse RNA. If chick cells were treated with chick RNA (or mouse cells with mouse RNA), no interferon was produced. But if chick cells were treated with mouse RNA (or mouse cells with chick RNA), interferon appeared. It was shown further that if the "acceptable" RNA was altered chemically, it could be converted into a "foreign" RNA capable of stimulating interferon production. These studies suggest that interferon provides the cell with a generalized defense against foreign nucleic acids that is analogous to the defense that antibodies provide against foreign proteins.

Supersupernova Confirmed?

Optical evidence has been found in support of the hypothesis that the strong radio emission of certain galaxies may have its origin in titanic explosions of "supersupernovae." The possibility of such explosions has been discussed recently by Fred Hoyle and William A. Fowler of the California Institute of Technology. They have postulated an explosion mechanism involving the gravitational collapse of an enormous volume of gas having one million to 10 million times the mass of the sun. Whether or not such a mass can actually exist as a single star is still open to question. Hoyle and Fowler have simply offered the hypothesis as a way of explaining how a strong radio galaxy can emit radio energy equal to the thermonuclear output of all its stars.

Evidence for an explosion of the magnitude postulated by Fowler and Hoyle is reported in *The Astrophysical Journal* by C. R. Lynds of Kitt Peak National Observatory and Allan R. Sandage of the Mount Wilson and Palomar Observatories. The two workers made a photographic and spectrographic study of irregular galaxy M 82, which is a strong radio source, and found that great quantities of luminous gas are streaming outward from the center of the galaxy at velocities about a hundredth the speed of light. The streaming matter shows up as a massive system of bright filaments that appear to be tangled with magnetic lines of force, as if the expanding gas had torn some of the galaxy's magnetic field out of the galaxy's central plane. The filaments have many of the characteristics of those found in the Crab nebula, the remains of an exploding star in our own galaxy that was seen as a supernova in A.D. 1054.

The energy contained in the M 82 filaments, however, is many orders of magnitude greater. Lynds and Sandage calculate that the initial "explosion," which may have taken place about 1.5 million years ago, put about 10^{56} ergs of energy into a great mass of electron gas. The energy is equivalent to the total emission of about a million supernovae. The electrons traveling at high velocity in a magnetic field have radiated radio and optical noise by the synchrotron process ever since the catastrophe. The largest stars are believed to have a mass no more than about 100 times that of the sun; one can only speculate what sort of object might have a mass a million times that of the sun and what it might look like prior to explosion.

Addicted Cells

By inducing addiction to morphine in isolated human cells a University of Michigan investigator has added evidence to dispel the widely held belief that narcotic drugs give rise to physiological dependency in the central nervous system alone. In his experiments at the Michigan Medical Center, Guenter Corssen used a chemically treated culture of cells from a cancer of the cervix. He found that the cells could not grow and function normally without sustained doses of the drug.

When Corssen and his associate Irena Skora cut off the supply of morphine, the cells stopped growing, their uptake of oxygen dropped off, their shape changed and slivers of protoplasm emerged from their formerly smooth walls. Time-lapse photomicrographs revealed that renewed administration of the drug within two or three days after withdrawal symptoms began could restore the healthy functioning of the cells. Corssen has now begun to work with freshly extracted human epithelial cells and will study the effects of morphine withdrawal on respiration and the genetic material.

Other studies of addiction at the cellular level have been made by Eric J. Simon of the New York University School of Medicine. In a recent issue of *Nature* Simon reported that morphine and cer-

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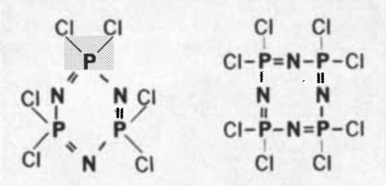

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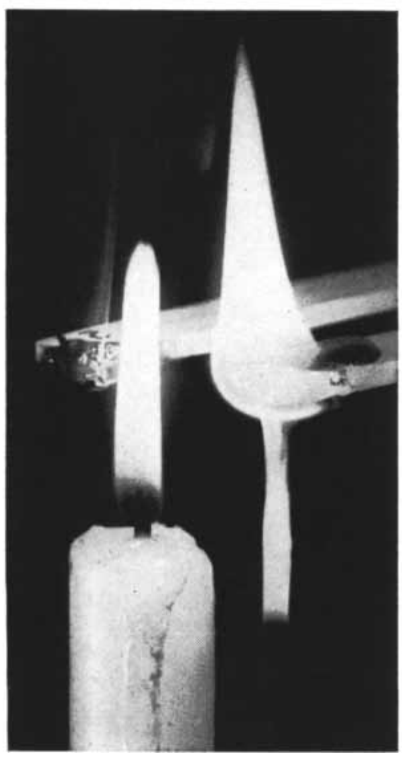

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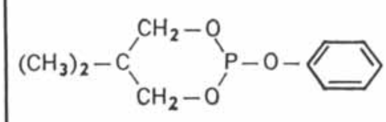

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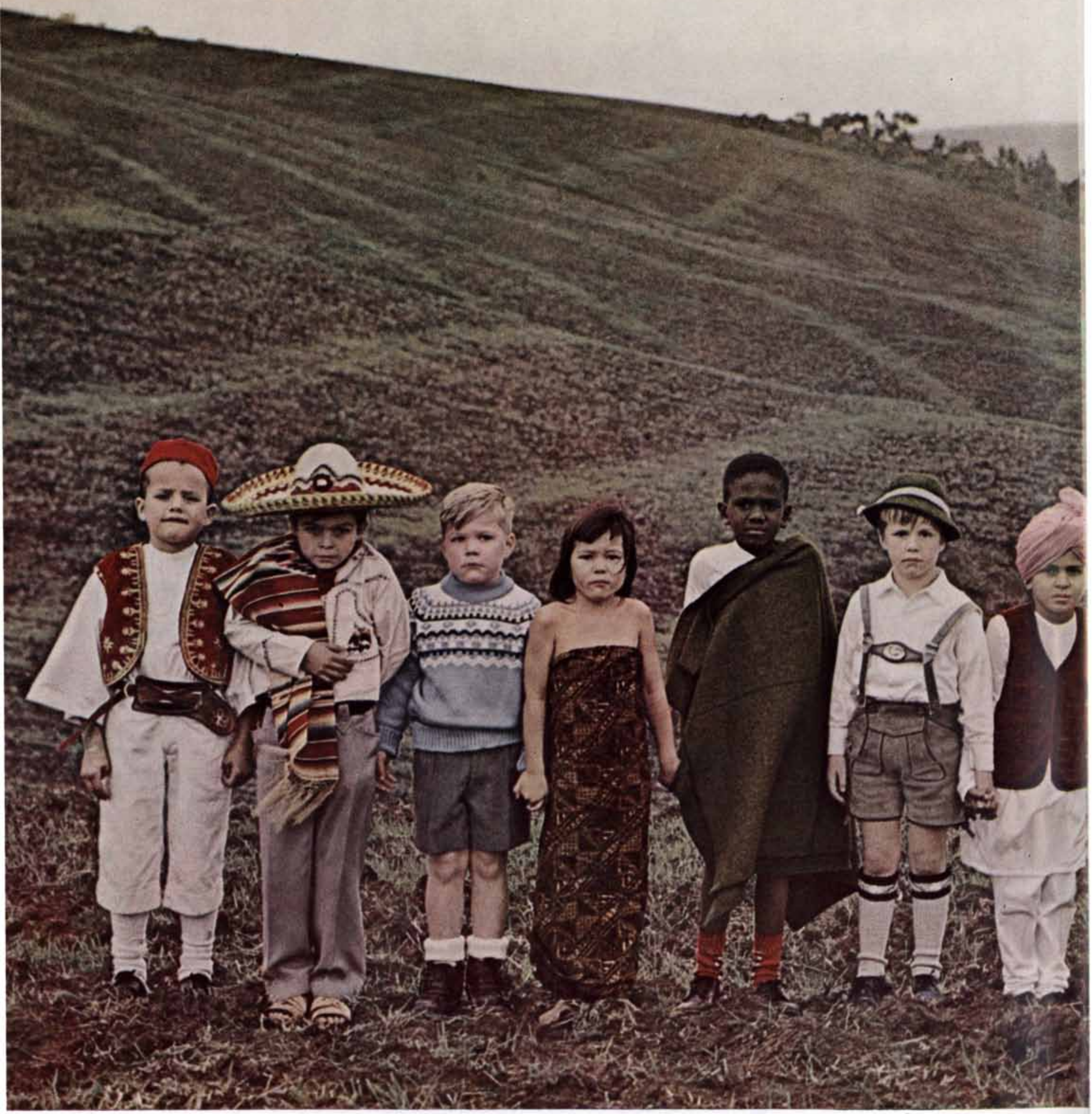
tain of its analogues, notably levorphanol, inhibit the growth of the intestinal bacillus *Escherichia coli.* Treatment with levorphanol, Simon found, reduces the rate at which the bacterium can synthesize ribonucleic acid (RNA).

The Sins of Isaac Newton

Two pages of shorthand notes, discovered in the Fitzwilliam Museum of the University of Cambridge, have provided a rare glimpse into the private life and conscience of Isaac Newton. The notes, composed by Newton in 1662 when he was 19 years old and in his second year as a student at Cambridge, are set down in a shorthand script invented earlier in the 17th century by Thomas Shelton; the same system was used by Newton's contemporary Samuel Pepys in keeping his famous diary. The Newton manuscript consists of a catalogue of sins divided under two headings: those committed "before Whitsunday 1662" and those committed "since Whitsunday 1662."

Writing in a recent issue of *Notes and Records of the Royal Society of London,* Richard S. Westfall of Grinnell College points out that the sins of Newton's youth were "neither salacious nor sensational" and that "anyone who might hope for a Pepysian passage, thinking that Newton's austere figure would be humanized in being besmirched, must be disappointed." Nonetheless the total confession, which comprises 58 items, shows a revealing preponderance of entries involving sins of anger; as Westfall notes, these may be read as a forecast of Newton's celebrated quarrels over priority in many of his discoveries and inventions. The earliest entry in the notes ("Threatening my father and mother Smith to burne them and the house over them") is a fair example of this type. Since Newton's stepfather Barnabas Smith died when the boy was 11 years old, the notes would appear to cover all the sins the 19-year-old student could recall from his past life. Other entries involving Newton's family and friends reveal his own estimation that a quick temper was his most persistent vice: "Wishing death and hoping it to some; Striking many; Beating Arthur Storer; Punching my sister; Putting a pin in John Key's hat to pick him; Calling Dorothy Rose a jade; Peevishness with my mother . . . with my sister . . . at Master Clark . . ." The character that emerges from the notes, concludes Westfall, is that of "a wholly unsophisticated provincial puritan—which is, of course, what we should have expected."



Most of the human race is still poorly fed, and the world is producing people much faster than food. By 1970, world population will have zoomed another half billion. The earth must be helped to do its share.

The earth *is* learning to produce more, partly because of a bold move fifteen years ago. During World War II, the U.S. Government urged the chemicals industry to develop a high analysis fertilizer to boost our farm yield. But there was one hitch. Our farmers were pretty "sot" in their ways; how could they be persuaded to buy the stuff? The Chemicals Division of Olin took on the job. Olin not only developed the new-type fertilizer. (Ammonium phosphate in a pellet form that practically guaranteed even distribution. Half the bulk of ordinary fertilizers. Much easier to apply.) They hit the road to coax the farmers out of their prejudices. Soon this new Ammo-Phos® was helping the U.S. farmer produce more wheat, more corn, more beans per acre than he'd ever thought possible.

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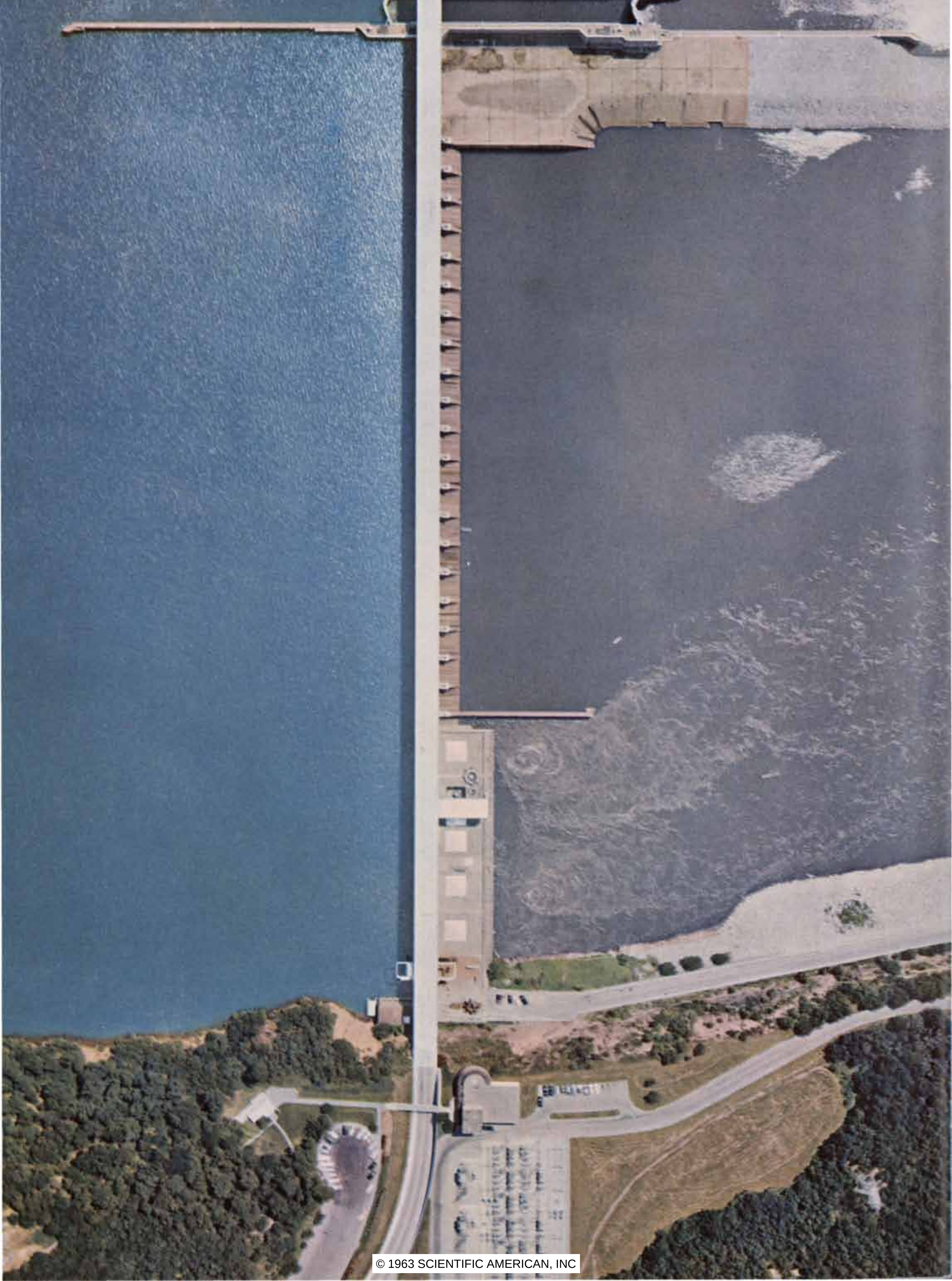


WATER

Men need water to drink and for many other purposes, but by far the largest amount of water they have available must go to agriculture. Again the basic need in the proper utilization of water is education

by Roger Revelle

Did you ever hear of Sweet Betsy
from Pike
Who crossed the wide prairie with her
lover Ike?
The alkali desert was burning and bare
And Ike got disgusted with everything
there.
They reached California with sand
in their eye,
Saying, "Good-by Pike County, we'll
stay till we die."

This bleary and partly unprintable ballad of the 1850's marks the time when most Americans first became aware of the problems of water in national development. In northern Europe, where most of their ancestors had lived, there had always been plenty of water; in the eastern U.S., where they had learned to farm, abundant rain supplied all the water needs of their crops. But when the pioneers crossed the Missouri River, they came to an arid country where water was more precious than land: its presence meant life, its absence death.

Today water problems are part of the national consciousness, and most Americans are aware that the future development of their country is intimately related to the wise use of water resources. The same obviously holds true for the less developed countries. The water problems of the U.S. and the poorer countries are fundamentally similar, but they also differ in significant ways.

Water is both the most abundant and the most important substance with which man deals. The quantities of water required for his different uses vary over a wide range. The amount of drinking water needed each year by human beings and domestic animals is of the order of 10 tons per ton of living tissue. Industrial water requirements for washing, cooling and the circulation of materials range from one to two tons per ton of product in the manufacture of brick to 250 tons per ton of paper and 600 tons per ton of nitrate fertilizer. Even the largest of these quantities is small compared with the amounts of water needed in agriculture. To grow a ton of sugar or corn under irrigation about 1,000 tons of water must be "consumed," that is, changed by soil evaporation and plant transpiration from liquid to vapor. Wheat, rice and cotton fiber respectively require about 1,500, 4,000 and 10,000 tons of water per ton of crop.

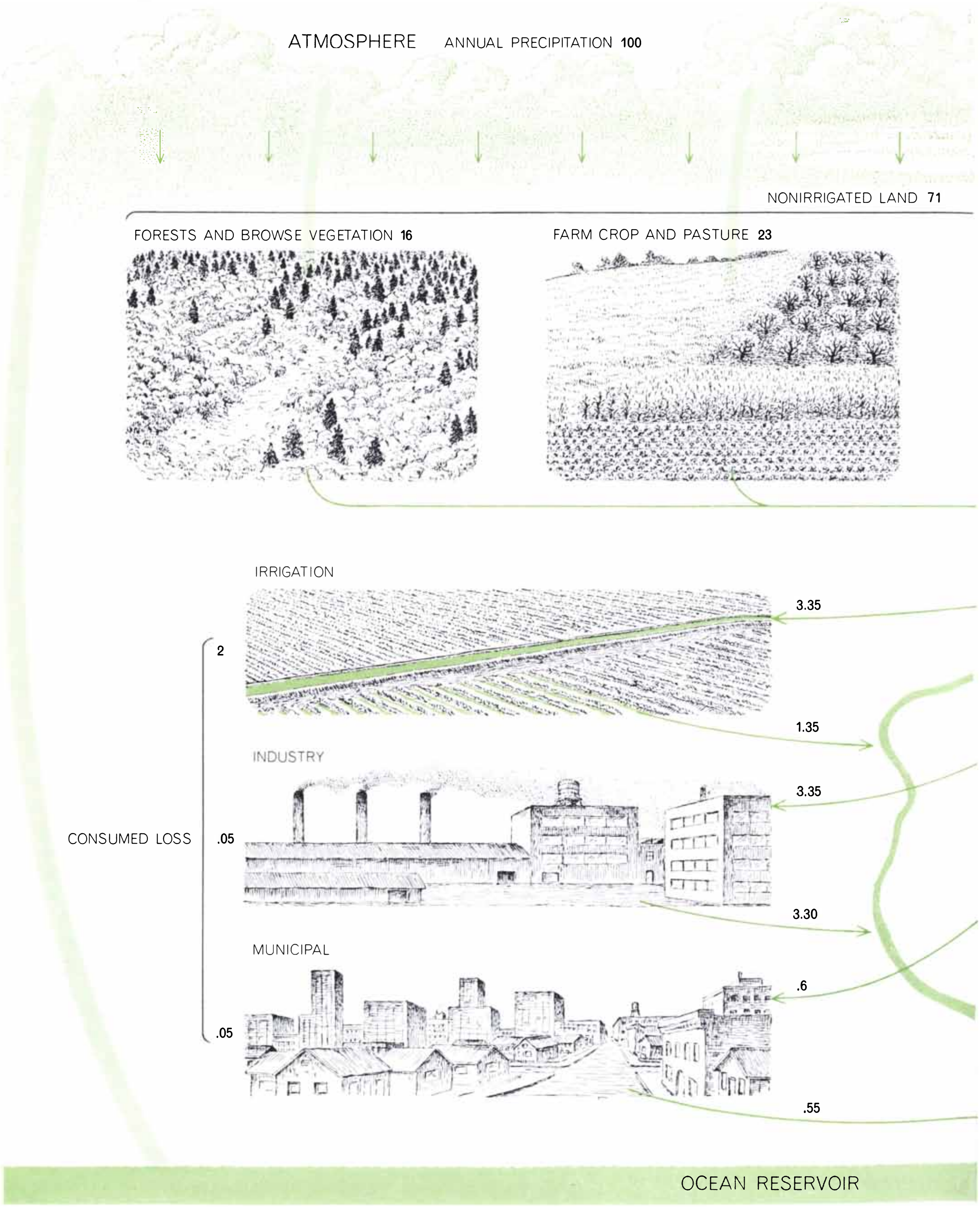
When we think of water and its uses, we are concerned with the volume of flow through the hydrologic cycle; hence the most meaningful measurements are in terms of volume per unit time: acre-feet per year, gallons per day, cubic feet per second. An acre-foot is 325,872 gallons, the amount of water required to cover an acre of land to a depth of a foot. Eleven hundred acre-feet a year is approximately equal to a million gallons a day, or 1.5 cubic feet per second. A million gallons a day fills the needs of 5,000 to 10,000 people in a city; 1,100 acre-feet a year is enough to irrigate 250 to 300 acres of farmland.

The total amount of rain and snow falling on the earth each year is about 380 billion acre-feet: 300 billion on the ocean and 80 billion on the land. Over the ocean 9 per cent more water evaporates than falls back as rain. This is balanced by an equal excess of precipitation over evaporation on land; consequently the volume of water carried to the sea by glaciers, rivers and coastal springs is close to 27 billion acre-feet per year. About 13 billion acre-feet is carried by 68 major river systems from a drainage area of 14 billion acres. Somewhat less than half the runoff of liquid water from the land to the ocean is carried by thousands of small rivers flowing across coastal plains or islands; the area drained is about 11 billion acres, but part of this is desert with virtually no runoff.

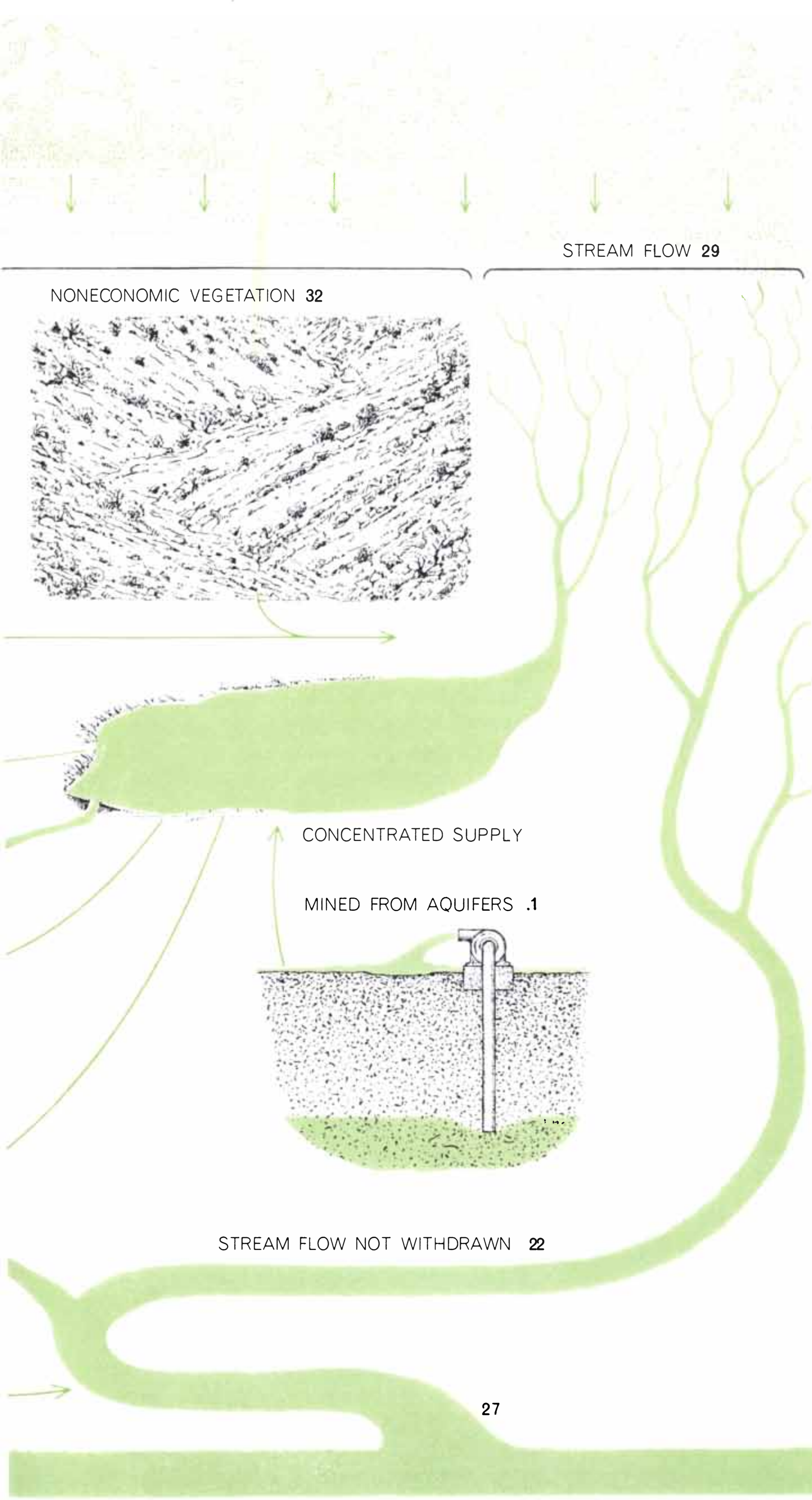
Eight billion acres on the continents drain into inland seas, lakes or playas. This includes most of the earth's six billion acres of desert and also such relatively well-watered areas as the basins of the Volga, Ural, Amu Darya and Syr Darya rivers, which transport several hundred million acre-feet of water each year into the Caspian and Aral seas. The remainder of the land surface, about four billion acres, is covered by glaciers.

Even agriculture, man's principal consumer of water, takes little of the available supply. A billion acre-feet per year—less than 4 per cent of the total river flow—is used to irrigate 310 million acres of land, or about 1 per cent of the land area of the earth. Roughly 10 billion acre-feet of rainfall and snowfall is evaporated and transpired each year from the remaining three billion acres of the earth's cultivated lands and thus helps to grow mankind's food and fiber. Most river waters flow to the sea almost unused by man, and more than half of the water evaporating from the continents—

MULTIPURPOSE DAM at Watts Bar, Tenn., appears in the aerial photograph on the opposite page. The blue lake at left is formed where the dam halts the Tennessee River. Spilled back to river depth beyond the dam, the water regains a slate-gray hue. The turbulent area at lower right is caused by the flow of water through the square-capped hydroelectric generators. At bottom center is a power-distribution station. At top is the lock that enables shipping to pass the dam. The ribs in the dam are spillways, which here are closed. They can adjust the lake level to help control flooding.



HYDROLOGIC CYCLE for the U.S. shows the fraction of annual precipitation used in a highly developed nation. Twenty-nine per cent of the rainfall arrives at the oceans (*bottom*) via stream flow; 71 per cent falls on various types of nonirrigated land, returning



directly to the atmosphere (*top*) by transpiration and evaporation. Water withdrawn for irrigation, industry and municipal use is shown at left to constitute only 7.3 per cent of total.

particularly that part of the evaporation taking place in the wet rain forests and semihumid savannas of the Tropics—plays little part in human life.

Although it is not usually reckoned as such in economic statistics, water can be considered a raw material. In the U.S. the production of raw materials has a minor role in the total economy, and water costs are small even when compared with those of other raw materials. The cost of all the water used by U.S. householders, industry and agriculture is around $5 billion a year: only 1 per cent of the gross national product. The less developed countries, where raw materials are a major component of the economy, cannot afford water prices that would be acceptable in the U.S.

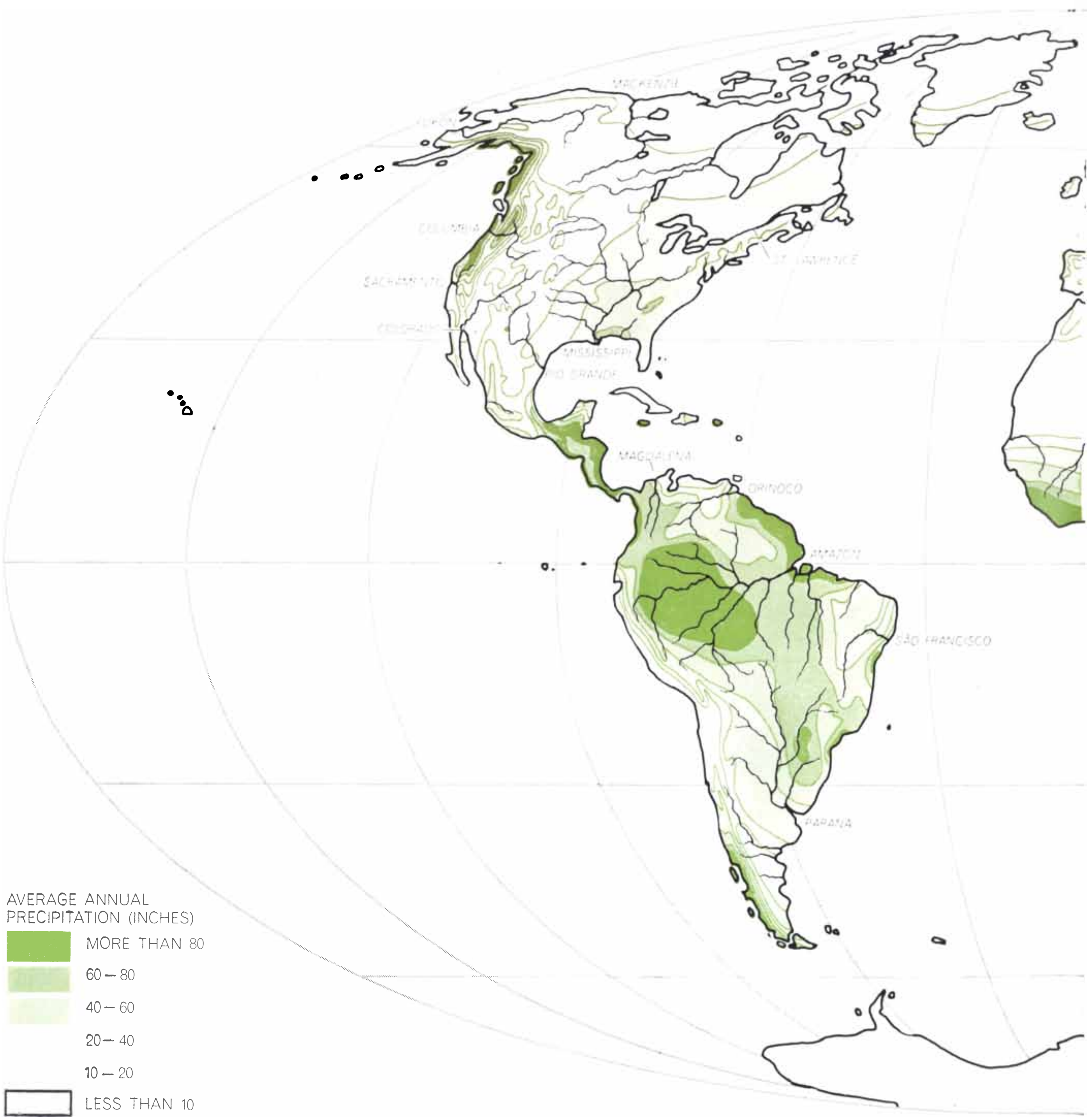
In the U.S. water costs $10 to $20 an acre-foot, compared with wholesale prices of $22,000 an acre-foot for petroleum, $100,000 an acre-foot for milk and $1 million an acre-foot (not counting taxes) for bourbon whiskey. The largest tanker ever built can hold less than $1,000 worth of water. Yet Americans use so much water—about 1,700 gallons a day per capita—that capital costs for water development are comparable to other kinds of investment. Although the water diverted from streams and pumped from the ground is equivalent to only about 7 per cent of the rain and snow falling on the U.S., this is still an enormous quantity: 200 times more than the weight of any other material used except air. The annual capital expenditure for water structures in the U.S.—dams, community and industrial water works, sewage-treatment plants, pipelines and drains, irrigation canals, river-control structures and hydroelectric works—is about $10 billion.

One of the most critical water problems of the U.S. is represented by the vast water-short region of the Southwest and the high Western plains. In some parts of the Southwest water stored underground is being mined at an alarmingly high rate, and new sources must soon be found to supply even the present population. The average annual supply of controllable water in the entire region is 76 million acre-feet. If agriculture continued to develop at the present rate, 98 to 131 million acre-feet would be required by the year 2000. Provided that the neighboring water-surplus regions could be persuaded to share their abundance, this deficit could be met by long-distance transportation of 22 to 55 million acre-feet per year. But the annual cost would be $2 billion to $4 billion, or

$60 to $100 per acre-foot of water, including amortization of capital costs of $30 billion to $70 billion. The cost per acre-foot would be too high for most agriculture, although not too high for municipal, industrial and recreational needs.

Nathaniel Wollman of the University of New Mexico and his colleagues have shown that the average value added to the economy of the Southwest through the use of water in irrigation is only $44 to $51 an acre-foot, whereas the value gained from recreational uses could be about $250 an acre-foot and from industrial uses $3,000 to $4,000 an acre-foot. Because the quantities of water consumed by city-dwellers and their industries are much less than those in agriculture, the arid Western states would not require such a vast increase in future supply if they shifted from a predominantly agricultural to a predominantly industrial economic base.

The value of water in the water-short regions of the U.S. that are in a phase of rapid economic development increases more rapidly than the cost. Even high-cost water is a small burden on the gross product of a predominantly industrial and urban economy, and high water costs are only a small economic disadvantage. This is easily overcome if other

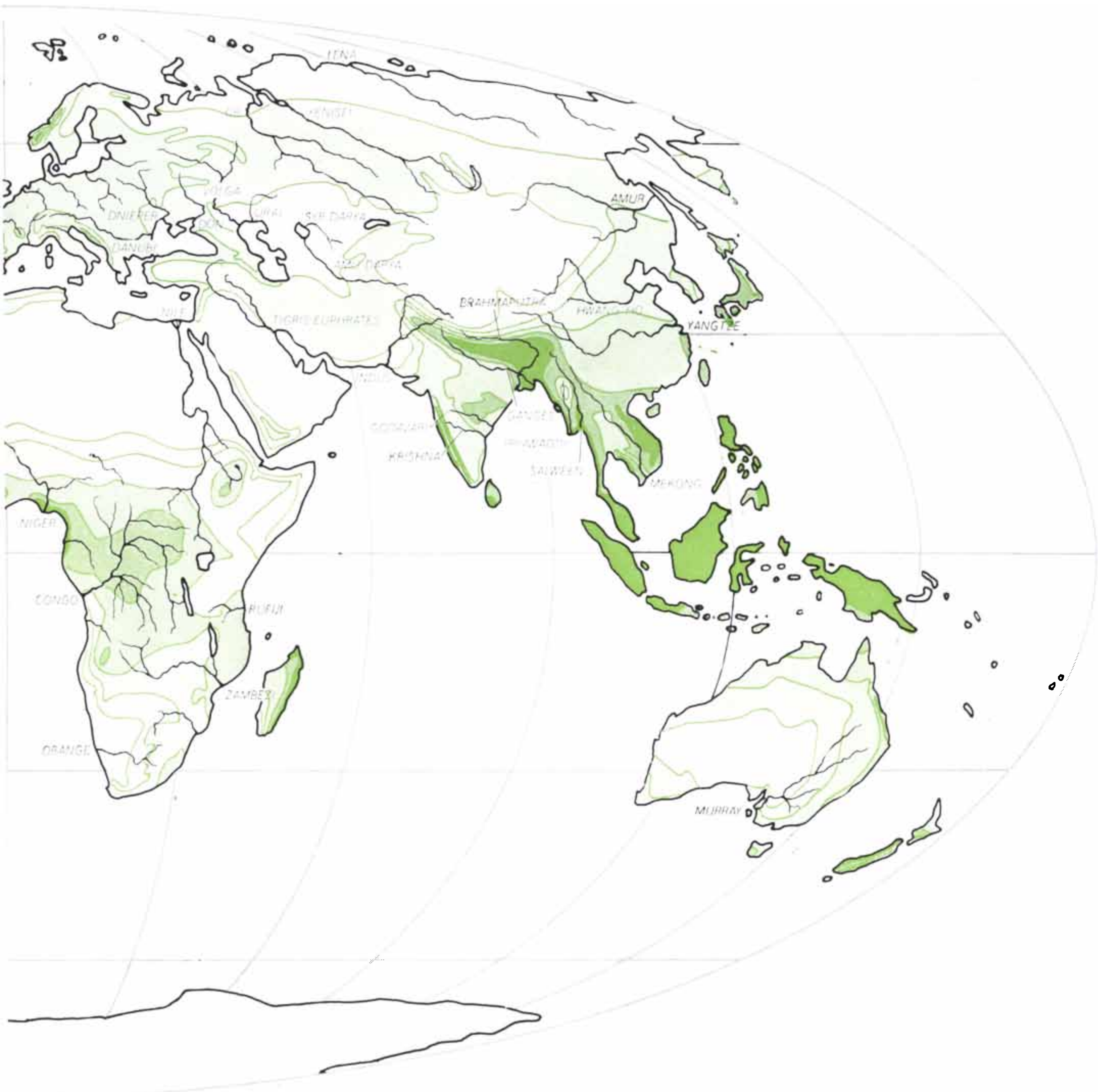


MAJOR RIVERS carry water to the oceans at rate of more than 11 billion acre-feet every year, but even in the U.S. less than a quarter of this flow is diverted by man for his own purposes. Key at lower left distinguishes areas by amount of precipitation they conditions, such as climate, happen to be propitious.

Throughout the country favorable benefit-to-cost ratios can usually be attained from relatively high-cost multipurpose water developments for city residents, industry, irrigation agriculture, the oxidation and dispersal of municipal and industrial wastes, the generation of hydroelectric power, pollution control, fish and wildlife conservation, navigation, recreation and flood control.

In the less developed countries water development by itself does not produce much added value for the present economy. Municipal and industrial water requirements are much smaller than they are in the U.S., and the immediate water needs are chiefly for agriculture, which calls for about the same amount of water in any warm region. Most of these countries have a low-yielding subsistence agriculture that brings in very little cash per acre-foot of water, and their farmers can afford to pay only a few dollars per acre-foot. Development of water resources must be accompanied by other measures to raise agricultural yields per acre-foot and per man-hour, and in general to increase the economic value of water.

One means of coping with water problems in both the U.S. and the less de-



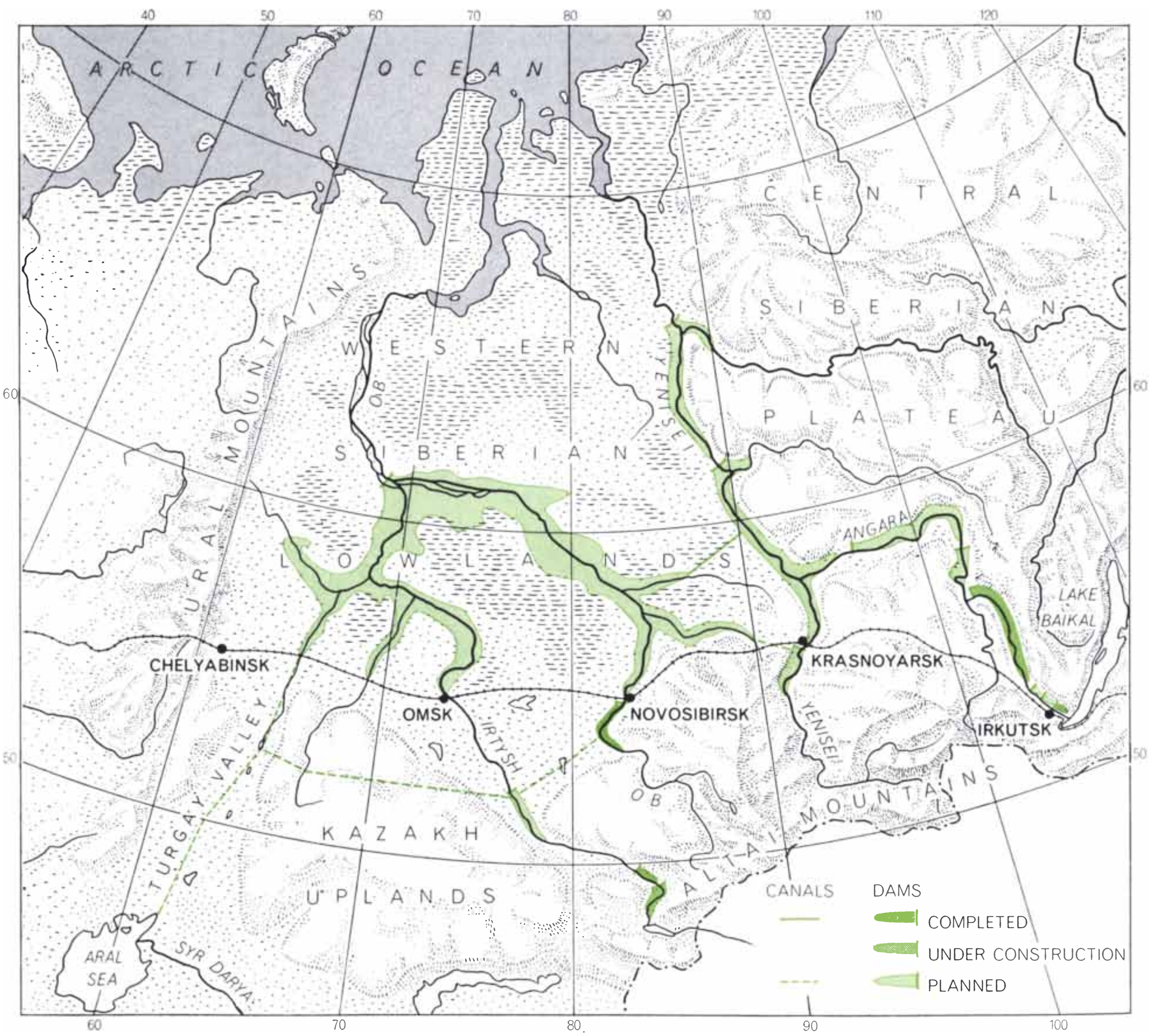
receive each year. Several regions where the average annual precipitation is less than 10 inches (*white*) can be seen to lie close to large rivers. Plans for overcoming the aridity of Egypt and central Russia call for giant dams on the Nile and the Ob.

veloped countries is to improve the present rather low efficiency of water use. Here much could be done by effective research. For example, about half the water provided for irrigation is lost in transport, and less than half the water that reaches the fields is utilized by plants.

New mulching methods are already being applied to reduce evaporation from soil surfaces, thereby making more water available for transpiration by the plants. Through research on the physiology of water uptake and transport in plants, and on plant genetics, transpiration could probably be lowered without a proportional reduction in growth. Development of salt-tolerant crops would reduce the amounts of irrigation water needed to maintain low salt concentrations in the solution around the plant roots. The loss of water by seepage from irrigation canals and percolation from fields would be lowered by the development of better linings for canals and better irrigation practices. Losses from canals would also be reduced if we could learn how to control useless water-loving plants that suck water through the canal banks and transpire it to the air.

In arid regions the runoff from a large area must be concentrated to provide water for a relatively small fraction of the land, and techniques are needed to increase the proportion of total precipitation that can be concentrated. Development of such techniques requires research on means of increasing the runoff from mountain areas (for example, by reducing evaporation from snow fields and modifying the plant cover in order to reduce transpiration) and on methods for accelerating the rate of recharge of valley aquifers.

Finally, water problems could be dealt with by steps that—in contrast to those seeking to make better use of existing supplies—sought to increase the total volume of fresh water. Here research moves on two fronts: attempts to modify precipitation patterns by exerting control over weather and climate, and development of more economical methods of converting sea water or brackish water to fresh water. The ability to control weather and climate, even to a small degree, would be of the greatest importance to human beings everywhere. Whether or not a measure of control can be obtained will remain uncertain until we understand the natural proc-



OB-YENISEI PROJECT calls for huge dam on the Ob, creating an inland sea five-sixths the size of Italy. Canal would link Ob and Yenisei rivers so that 12.5 per cent of the water now flowing unused to the Arctic would irrigate the central Soviet steppes.

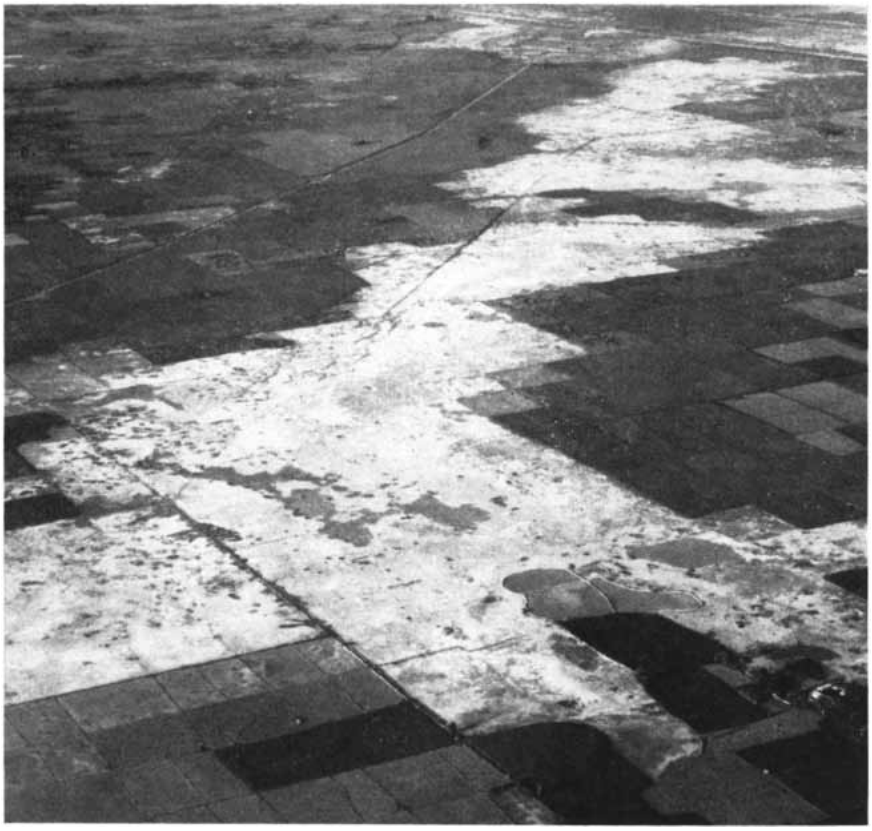
esses in the atmosphere much better than we do now. As for desalination, this could be accomplished more economically than at present if the amount of energy required to separate water and salt could be reduced or the cost of energy lowered. Research on the properties of water, salt solutions, surfaces and membranes is fundamental to the desalination problem. So is research aimed at lowering energy costs.

We know too little to be able to make more than a rough appraisal of the potentialities of water-resources development for agriculture in the less developed countries. The modern technology of irrigation engineering, drainage, sanitation and agricultural practice is quite different from that which determined patterns of land and water use in the past. At the same time technology is almost completely lacking for expanding productive agriculture in the areas of most abundant water and almost unused land: the humid Tropics. Our concern should be not only to find ways of increasing total production in order to feed and clothe the world's expanding human population but also to raise production per farm worker, that is, to raise living standards. A world-wide strategy for development of land and water will require a careful analysis of existing knowledge, region by region, together with field surveys and experimental research in each region by experienced and imaginative specialists.

In humid areas agriculture is limited only by the extent of good land; in arid lands water is the absolute limiting factor. Unless climates can be modified or sea water can be cheaply converted and economically transported, the area of arable land in the arid zone will always exceed the available water. At present, however, neither surface nor underground waters are fully utilized, either for double-cropping in presently cultivated lands or for bringing new land under cultivation.

In addition to improving the utilization of water and increasing agricultural yields other problems that contributed to the destruction of desert civilizations in the past must still be overcome in arid land development. Among them is the fact that the spreading of water over large areas provides a fertile ground for human diseases, such as malaria and bilharzia, and for plant pests. Egyptian records show an average of one plague every 11 years. Uncontrollable malaria might well have been the cause of the mysterious disappearance of the great civilization of the cities Mohenjo-Daro and Harappa, which flourished 4,500

WATERLOGGED FIELDS near Sargodha in Pakistan reflect leaky canal system and inadequate drainage. Cultivated plots can be seen under water in center of photograph. When it evaporates, the water will deter renewed cultivation by leaving salts in topsoil.



SALINE FIELDS stand out against darker cultivated land in this aerial photograph. The related problems of waterlogging and salt accumulation in the soil have made five million acres of West Pakistan's irrigated farmland either impossible or unprofitable to cultivate.

years ago in the Indus valley of Pakistan.

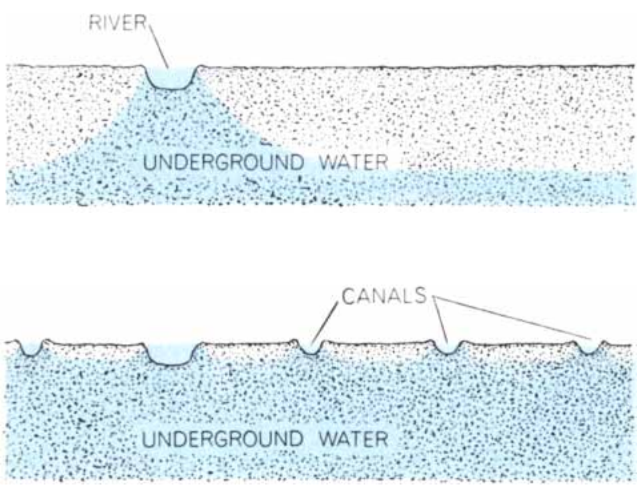
Soil drainage in a nearly level flood plain is very difficult and is usually neglected, with the result that the water table comes close to the surface and drowns the roots of most crop plants. Water rises through the soil by capillary action and evaporates, leaving an accumulation of salt that poisons the plants. The related disasters of waterlogging and salinity may have caused the ruin of the Babylonian civilization in the valley of the Tigris-Euphrates, and they are a frightening menace today in West Pakistan.

Another threat is the conflict between the sedentary farmers of the plain and nomadic herdsmen. The present-day Powindahs of West Pakistan remind us of this ancient conflict. In our own West the feuds between cattlemen and farmers are still a vivid memory.

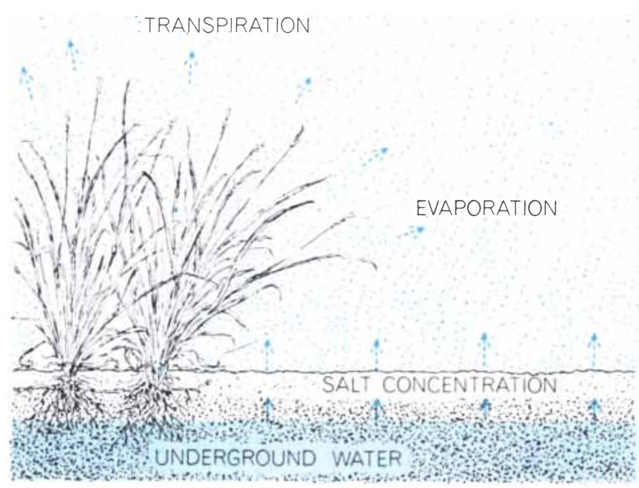
In considering the possibilities of agricultural development in the world's arid lands one thinks first of the famous rivers that have played so large a role in human history: among them the Nile, the Indus and its tributaries and the Tigris-Euphrates.

For thousands of years the Egyptians carried out irrigation by allowing the Nile waters during flood stage to spread in ponded basins broadly over the delta and the valley. When the flood subsided, the basin banks were cut and the ponded water flowed back to the river. The Nile and the sun were said to be the prime farmers of Egypt. It was thought that the river's silt, deposited during the annual flood, fertilized the soil. Sun-drying and -cracking, during the fallow season before the flood, deeply furrowed the soil and killed off weeds and microorganisms, making plowing unnecessary. The flood arrived in July, reached its height in September and subsided quickly. The fields were sown in early winter with wheat, barley, beans, onions, flax and clover. Summer crops were grown only on the river levees and in areas that contained a shallow water table, where water could be lifted by hand from the river banks or from wells. High floods left the basins pestilential morasses that brought plagues and epidemics. Low floods brought famine.

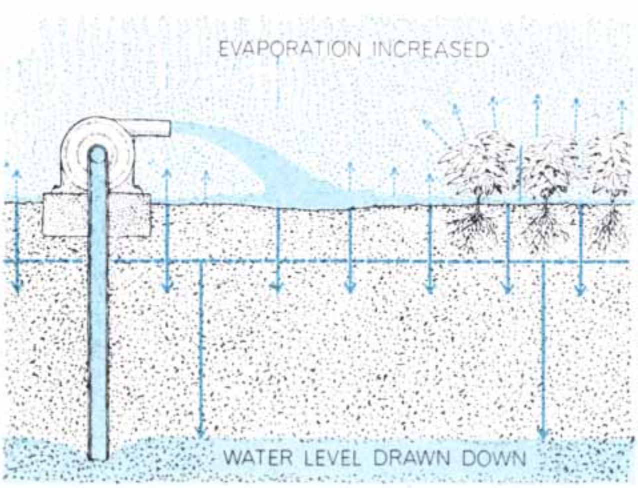
During the past 140 years this ancient system has been transformed. In 1820 Egypt had reached a nadir, with a population of only 2.5 million and with three



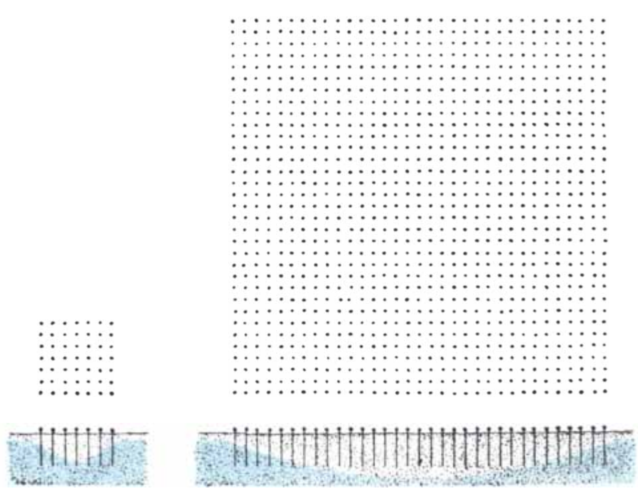
LACK OF DRAINAGE has caused the underground water table to rise disastrously in parts of Pakistan. Before construction of leaky canals, water approached ground level only near rivers. Now water table in many areas is high enough to drown crop roots.



SALT ACCUMULATES on topsoil in two ways. Underground water rises by capillary action, lifting dissolved salts that will be left behind after evaporation. If farmer uses thin layer of water to irrigate topsoil, it will evaporate before percolating down.

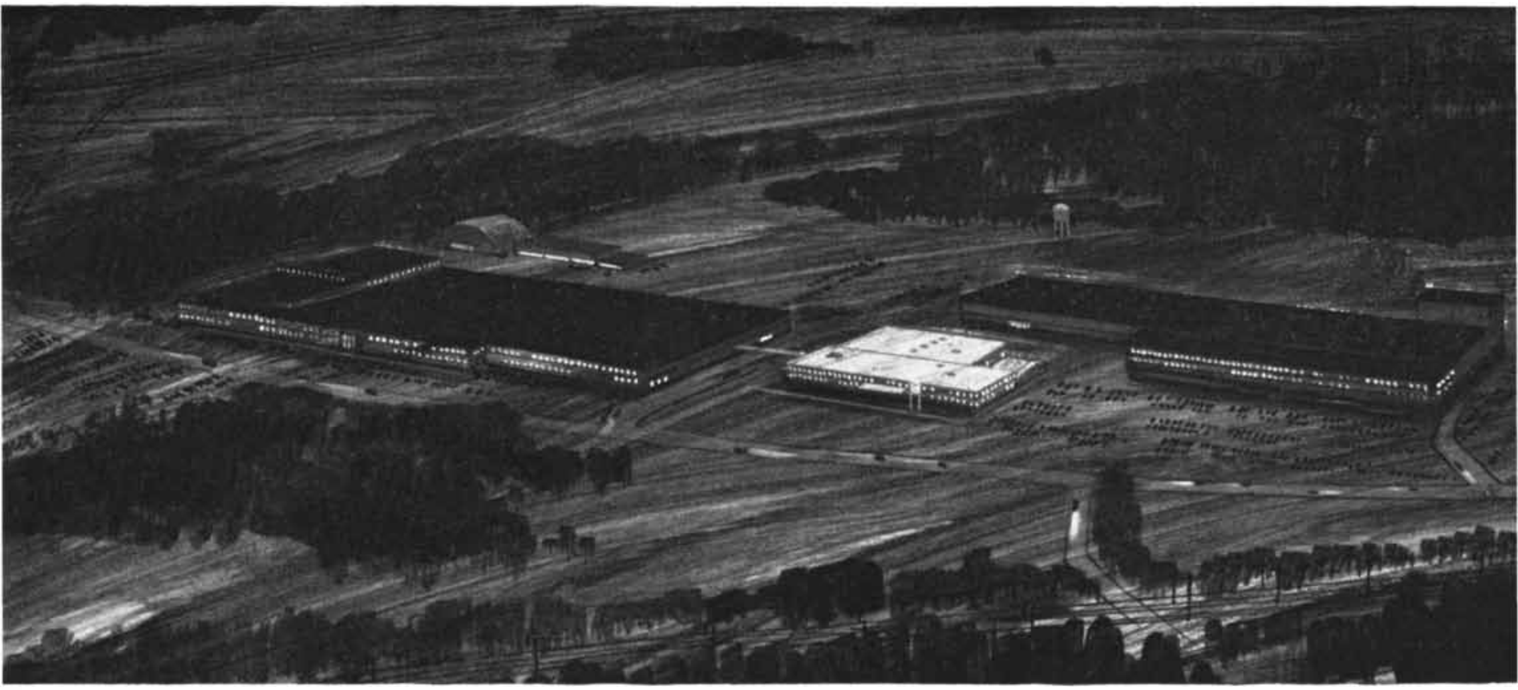


VERTICAL DRAINAGE might solve related problems of salinity and waterlogging. Pumped through cased well from underground table, as illustrated here, enough water could reach surface for salts to percolate down beneath topsoil before full evaporation occurs.



LARGE-SCALE PROJECT will be required to lower the water table. Drainage of a field of one million acres (*right*) could negate seepage from adjacent land. But pumping out a small field (*left*) would have no appreciable effect on underground water level.

Defense Center



Defense Center

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million cultivated acres. This date marked the beginning of perennial canal irrigation and widespread planting of summer crops, including cotton, corn, rice and sugar cane as well as the traditional winter crops. Low dams called barrages were built across the river; the water backed up behind these structures was diverted through large new canals that flowed the year round. By 1955–1956 the cultivated area had increased to 5.7 million acres and the intensity of cultivation to 177 per cent; that is, more than 10 million acres of crops were harvested. Salinity and waterlogging became serious menaces in the early part of this century, but they have been fairly well controlled by an extensive drainage system. Chemical fertilizers are used in large amounts and crop yields per acre are high, even though the Nile silt no longer settles on the fields but is deposited back of the barrages. Sufficient food is grown to feed the present population of 27 million. From the standpoint of crop yields per acre, although not per man, Egypt is a developed country.

The average annual flow of the Nile is 72 million acre-feet, but it is occasionally as high as 105 million acre-feet or as low as 36 million. If all the average flow could be utilized, it would be enough to irrigate 12 to 15 million acres on a year-round basis. At present the area of irrigated land in Egypt is less than half that. During the flood season much of the water flows to the sea unused, and during the rest of the year a shortage of surface and underground water limits the size of the cultivated area.

Now the construction of the Aswan High Dam promises to bring the river under complete control. The dam will have a storage capacity of 105 million acre-feet, equal to the highest annual flow during the past century. There will no longer be a Nile flood; the tamed river will become simply a huge feeder canal for irrigation. With the average of 55 million acre-feet per year available to Egypt (17 million acre-feet from the reservoir is allocated to the Sudan), it will be possible to increase the cultivated area in the delta and the valley floor by 2.2 million acres, or nearly 40 per cent, and to convert .7 million acres from flood to perennial irrigation. Hydroelectric power generation of more than a million kilowatts will make power available for pump drainage, which may increase crop production by 20 per cent, and for the manufacture of chemical fertilizers. The electric power will also be used to lift water to the desert margins of the valley, where it is hoped that an additional one to two million acres can be brought under the plow. If all these benefits can be realized, total agricultural production in Egypt can be increased by 90 per cent, enough to feed almost twice the present population and at the same time provide crops for export.

When Alexander the Great pushed his tired armies eastward some 2,300 years ago, they came at last to an old desert civilization on the banks of the mightiest river they had ever seen. The Aryans, who had preceded Alexander by 1,000 years, did not give the river a name; they called it simply the Indus, which was their word for river, and they named the subcontinent they had invaded "India": the land of the river.

The Indus and its five tributaries of the Punjab, together with the flat plain through which they flow, are one of the major natural resources of the earth. In the Punjab and Sind regions of West Pakistan 30 million persons dwell on the plain; 23 million make their living from farming it. They produce most of the food and fiber that feed and clothe nearly 50 million people.

The rivers carry more than twice the flow of the Nile. Half this water is diverted into a highly developed system of irrigation canals and is used to irrigate some 23 million acres—by far the largest single irrigated region on earth. Underneath the northern part of the plain lies a huge reservoir of fresh ground water, equal in volume to 10 times the annual flow of the rivers.

In spite of the great potentialities of the plain, the fact is that poverty and hunger, not well-fed prosperity, are today the common lot of the people of West Pakistan. These afflictions are nowhere more desperately evident than in the farming villages of the countryside. In a country of farmers food must be imported to provide the most meager of diets; the gap between food production and the number of mouths to be fed is widening.

The problem of agriculture in West Pakistan is both a physical and a human one. It is a problem of land, water and people and of the interactions among them. One of its aspects is the waterlogging and salt accumulation in the soil, caused by poor drainage in the vast, nearly flat plain, that are slowly destroying the fertility of much of the irrigated land. The area of canal-irrigated and cultivated land already seriously damaged by waterlogging and salinity is close to five million acres, or about 18 per cent of the gross sown area. Three

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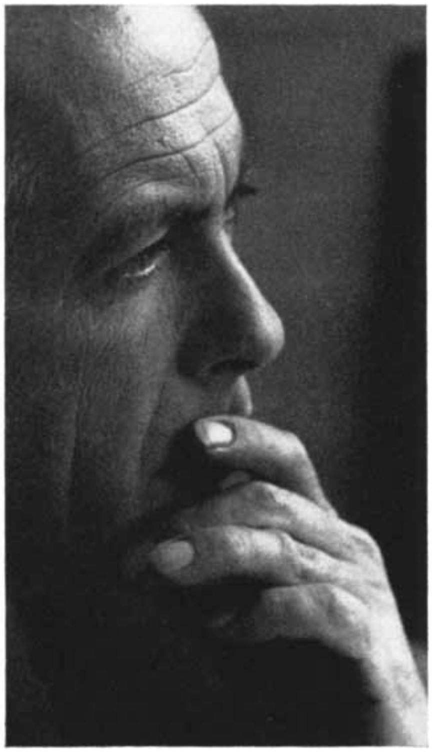

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other difficulties also beset agriculture: shortage of irrigation water, problems of land tenure and poor farming practices.

Although crops can be grown throughout the year, and both a winter and a summer growing season are traditional, the irrigation canals lose so much water by seepage that the amount carried to the fields is sufficient to irrigate only about half the land during each season. Even so, the crops are inadequately irrigated, particularly in summer. Much of the cropped area receives insufficient water to prevent salt accumulation.

Many of the farmers are sharecropping tenants who have little incentive to increase production. Nearly all of them struggle with small and widely separated plots that multiply the difficulties of efficient use of irrigation water and farm animals and gravely inhibit change in traditional practices.

In West Pakistan we have the wasteful paradox of a great and modern irrigation system pouring its water onto lands cultivated as they were in the Middle Ages. Plowing is done by a wooden plow of ancient design, pulled by undernourished bullocks. Unselected seeds are sown broadcast. Pakistan uses only a hundredth as much fertilizer per acre as Egypt.

Careful investigation shows that in most of the Punjab the problems of waterlogging and salinity could be cured, and at the same time adequate water could be supplied to the crops, by sinking fields of large wells to pump the underground water and spread it on the cultivated lands. Part of the pumped water would be carried off by evaporation and transpiration and part would percolate back into the ground, in the process washing the salt out of the soil.

If the well fields are too small in area, lateral infiltration of underground water from the surrounding land will be large compared with the rate at which the pumped water can evaporate, and the process of dewatering will be retarded or completely inhibited. For this and other reasons each Punjab project area should be about a million acres in size.

Removal of salt and provision of additional water are necessary, but by no means sufficient, measures to raise agriculture in West Pakistan from its desperate poverty. Equally essential are chemical fertilizers, higher-yielding seeds, pest control, credit and marketing facilities, and above all incentives and knowledge to adopt better farming practices. The job cannot be done all at once; it is necessary to concentrate on project areas of manageable size. Initial capital costs for a million-acre project in the Punjab would be of the order of $55 million, including costs of wells and electrification, nitrogen-fertilizer plants, pest-control facilities and filling of administrative, educational and research pipelines.

In the Sind region initial capital costs would be considerably higher, probably between $130 million and $165 million per million acres. That is largely because the underground water in most of the Sind is too salty to be used for irrigation, and drainage is therefore a more difficult matter than in the Punjab.

After a few years the minimum net increase in crop value in each million-acre project in the Punjab could be $55 million to $60 million a year, equal to the capital costs and to twice the present gross production, excluding livestock. In the Sind the net increase, including livestock, could probably be at least equal to the present output.

The same interrelated problems of water, land and people that afflict the Indus plain also exist in the valley of the Tigris-Euphrates, but on a much smaller scale. Salty soil is found over large areas; because of waterlogging it is possible to cultivate only about a third of the seven million acres of irrigated land each year. The remainder is left fallow and unirrigated to dry out the subsoil and to build up a little soil nitrogen. Great damage was done long ago when the ancient canal systems were destroyed and the land was depopulated by waves of nomadic invaders. But the nomads merely hastened the salt accumulation and waterlogging that were the seeds of destruction. These had begun centuries earlier as a result of inadequate drainage and inability to control floods.

If the flow of the Tigris-Euphrates could be fully utilized, through combined development of surface and ground water, and if the soils were adequately leached and drained, the irrigated area cultivated each year could be increased to 10 to 12 million acres. If greater water usage were combined with perennial cropping, better farming practices and the application of chemical fertilizers, total agricultural production could be raised at least fivefold.

The largest opportunities for expansion of the area of irrigated arid and semiarid lands exist in the U.S.S.R. Between 1950 and 1960, 15 million acres in the neighborhood of the Black and Caspian seas were provided with irrigation water from the Volga, Dnieper, Amu Darya and Syr Darya rivers. The total flow of these rivers is more than 300 million acre-feet, sufficient, under the cold-winter and warm-summer cli-

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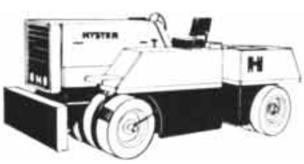
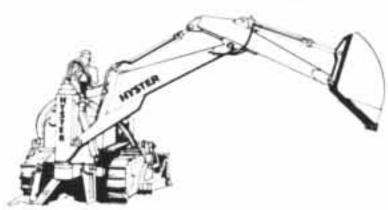
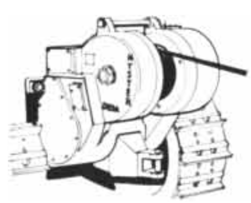


C500A Pneumatic Compacter, one of five types of Hyster earth compaction machines.



D4B Hydraulic Backhoe—mounts on Cat tractors, Traxcavator Loaders.



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Another Hyster® characteristic is engineering leadership. As technology improves throughout the world, and economic development advances with it, the role of Hyster machines will be increasingly strong, since we intend to match or exceed the demand for increasingly versatile machines.

Unique problem . . . simple solution

Although most Hyster machinery is basic, it is the special features introduced by imaginative Hyster engineers which make this equipment technologically advanced. A good example is the Monotrol® control system for lift trucks which puts forward, reverse and acceleration controls in one pedal under the driver's right toe.

Monotrol adds speed, safety and total efficiency to lift truck operation. The key to its need is the fact that a lift truck, unlike an automobile, spends nearly as much time in reverse as it does in forward, and that the driver needs his hands free for steering and lift controls.

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Because of the relatively advanced economic level of the country, large multipurpose water developments in the U.S.S.R. are economically feasible, and a high percentage of the capital invested goes for power, transportation, industrial water supplies and flood control.

Soviet engineers have outlined a plan to build an immense dam on the Ob River, creating an inland sea five-sixths the size of Italy, and to dig a canal connecting the Yenisei with the Ob above the dam [*see illustration on page 98*]. The impounded waters would be transported through a giant system of canals, rivers and lakes to the Aral Sea and thence by canal to the Caspian Sea. Several hundred million acre-feet of water that now goes to waste each year in the Arctic Ocean would be conserved. This water would be used to irrigate 50 million acres of crop lands and a somewhat larger area of pasture in arid western Siberia and Kazakhstan. Accompanying hydroelectric power installations would have a capacity of more than 70 million kilowatts. Major storage, irrigation and hydroelectric works are also under construction or planned in the northern Caucasus and in the Azerbaijan, Georgian and Armenian Soviet Socialist republics. These will bring additional tens of millions of acres under irrigation.

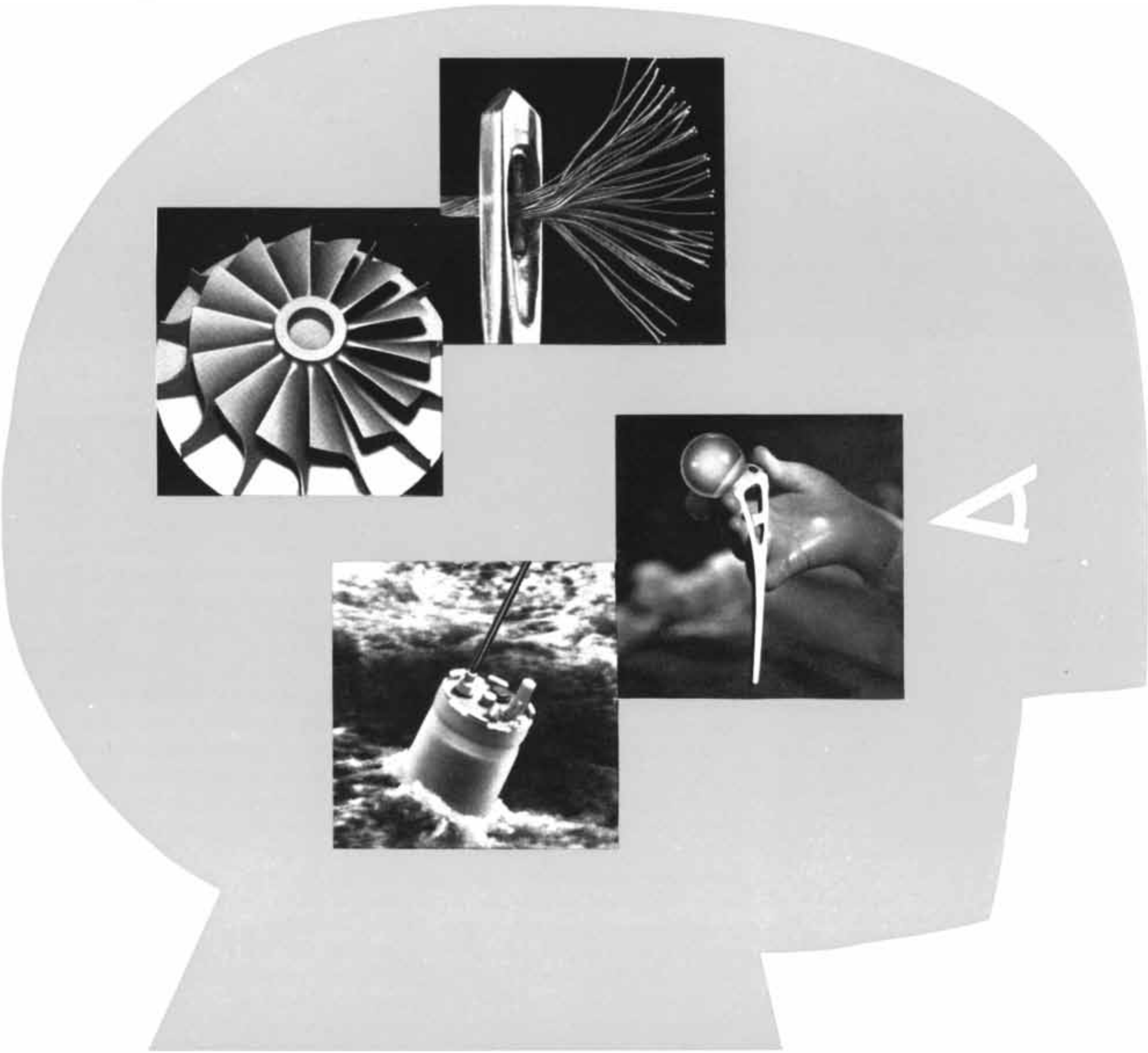
In some parts of the arid zone both surface and ground water are so scarce that it is difficult to see how irrigation agriculture can be developed to support the rapidly expanding population. In the Maghreb countries of North Africa—Tunisia, Algeria and Morocco—there is probably not enough water in the region north of the Sahara to irrigate more than 3.5 million acres of land, yet the combined population of these three countries is already 26 million (equal to Egypt's) and will double in 20 to 25 years. Elaborate systems of dry farming have been developed in the Maghreb; for example, the planting of olive trees far apart in light, sandy soils that catch and hold the nighttime dew. With this technique it has been possible to grow olive and other fruit trees on more than a million acres in Tunisia. In the long run it may be necessary to employ most of the available water in the Maghreb countries for industrial purposes, because these can provide a tenfold to hundredfold higher marginal value for water than agriculture can.

A new possibility for water development has recently been opened, however. During the past few years evidence has been obtained that large areas in the Sahara may be underlain by an enormous lake of fresh water. In some places the water-bearing sands are 3,000 feet thick, and they appear to extend for at least 500 miles south of the Atlas Mountains and perhaps eastward into Tunisia and Libya. If this evidence is correct, the amount of useful water may be very large indeed—of the order of 100 billion acre-feet, sufficient to irrigate many millions of acres for centuries.

In general the possibilities of expanding the area of irrigated land in the arid zone outside the U.S.S.R. are not large when measured in numbers of acres. But crop yields under irrigation in the arid lands are high and assured if all the factors of agricultural production are properly applied. In fact, irrigation agriculture in arid regions can be successful only if it is intensive and high-yielding; it is costly to construct and maintain drainage systems that will keep the water table from rising too close to the surface, and to provide enough water on each acre to leach the salts out of the soil. In hot, arid lands some kinds of irrigation agriculture can be so productive that very expensive irrigation water, such as could be produced by sea-water desalination, may soon become economical.

Much greater possibilities (and also greater difficulties) exist for agricultural expansion in the regions of savanna climate, which are characterized by an annual cycle of heavy rainfall during one season, followed by drought the remainder of the year, and by warm weather at all seasons. In Africa, for example, many millions of what are now barren acres could be brought under irrigated cultivation, provided that interested farmers could be found, in the neighborhood of the great bend of the Niger River in former French West Africa, in the basin of the Rufiji River of Tanganyika and near Lake Kyoga in Uganda. Similarly, in the area extending from India east through Burma, Thailand and Vietnam to the northern Philippines, air temperature and solar radiation are suitable for year-round crop growth, and water and land are the limiting factors [see "The Mekong River Plan," by Gilbert F. White; SCIENTIFIC AMERICAN, April].

In the lower basin of the Ganges and Brahmaputra rivers, comprising East Pakistan and the Indian states of Bengal, Bihar and Assam, some 140 million people live on 70 million cultivated acres. The basic resources of soil and water are grossly underutilized in this land



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DIVISIONS: ROLLING MILLS • DENTAL/SURGICAL • SUPERALLOY PRODUCTS • METALLURGICAL/REFRACTORIES • PRECISION PRODUCTS/TESTING of ancient civilization, extreme present poverty and strong population pressure. Each year the rivers carry about a billion acre-feet to the Bay of Bengal, and in the process they flood most of the countryside. Yet only one crop is grown a year. The land is left idle half the year because of the shortage of water and there is a lack of useful occupation for the people six to eight months of the year. Agricultural practices are adjusted to the rhythm of the monsoon.

The opportunities for increasing production are enormous in this region of land shortage and overabundant water. Through surface and underground storage of a portion of the flood waters, water could be provided for three crops each year over more than half of the cultivable area in the alluvial plain, and a considerable additional area could receive sufficient water for two crops. An assured year-round water supply would also provide favorable conditions for intensive use of fertilizers, higher-yielding plant varieties and better farming practices, which could result in a tripling of yields per crop and per acre for cereals, pulses (the edible seeds of leguminous plants such as peas and beans) and oilseeds.

A well-fed livestock industry could be developed in addition to improvements in field crops, and a balanced diet, instead of the present completely inadequate one, could be provided for twice the present population. Expansion of agricultural production here, based on irrigation, would raise few basic problems of land and settlement, but it would require a reorientation of thinking regarding patterns of land and water use. Because of the enormous volumes of water involved and the flatness of the alluvial basin, the cost of water storage and distribution and of flood control and drainage would be high, but the returns through increased farm and livestock production could be several times higher than the cost. The yields per worker must also be increased, however, and a large degree of industrialization accomplished if the project is to finance itself.

Development of water resources is not an end in itself. The investment can be justified only if it leads to higher agricultural or industrial production, or in other ways to an increase of human well-being. To gain these objectives water development must be accompanied by other actions needed to use the water effectively. This is well illustrated in agriculture. One of the basic principles of agricultural science is the principle of interaction: the concurrent use of all the factors of production on the same parcel of land, which will give a much larger harvest than if these factors are used separately on different parcels. Adequate water and water at the right time are essential if seeds of a particular crop variety planted in a given soil are to yield a good crop. But a much larger crop is possible if seeds of a higher-yield variety are planted. This potential increase in the harvest will be realized, however, only if the soil contains sufficient plant nutrients. Usually nitrogen fertilizers and phosphate fertilizers must be added in large amounts to provide the maximum yield. Increased soil fertility will be drained off by weeds unless these are rigorously controlled, and an eager host of insect pests and plant diseases will fight to share the crop with the farmer unless he can combat them with pest-control measures. Improved seed varieties planted without adequate water, abundant fertilizer and rigorous pest control may not do even as well as the traditionally planted varieties. The potentialities for double- or triple-cropping in a perennial irrigation system cannot be achieved if the farmers do not have tractors and efficient tools to enable them to prepare their fields in the short interval between harvest and planting.

To meet the cost of new irrigation systems the farmer must produce much more per acre-foot of water than he has in the past, and this can be done only if all the factors of production are made available to him and if he is taught how to use them effectively. The human, educational, social and institutional problems of bringing the necessary knowledge to millions of farmers are immense. The task of remaking methods of production that are intimately tied to ways of living and of overcoming institutional and political resistance to change is more difficult than any of the engineering problems. Illiteracy, malnutrition and disease; poverty so harsh that the farmer does not dare risk innovation because failure will mean starvation; small and fragmented farm holdings; land-rental and taxation systems that destroy incentive; extreme difficulties in obtaining a farm loan promptly at a reasonable interest rate; poor marketing and storage systems; administrative inefficiency and corruption; the shortage of trained teachers and farm advisers; inadequate government services for agricultural research, education and extension and for control of water-borne diseases—all must be overcome if investments in water resources in the developing countries are to produce really beneficial results.

ENERGY

Modern man has made himself largely by burning fuel. The supply of fuel appears to be almost inexhaustible, and a high level of fuel consumption is not a prerequisite of development but a result of it

by Sam H. Schurr

There is an obvious connection between economic development and the increased use of energy from mineral sources. According to plausible estimates world consumption of mineral fuels between now and the end of the century will equal about three times the amount consumed in all previous history. Since mineral fuels are depletible resources unequally distributed around the world, it is easy to see why there should be a nagging concern about the ability of the world's resources to meet estimated future consumption.

In this article estimates of future world energy consumption will be compared with the availability of the natural resources from which the supplies must come. Some of the uncertainties that enter into estimates of fuel resources will be examined, and it will be indicated why some estimates are higher than others. Regardless of the discrepancy between particular estimates there is reason to be optimistic about the world outlook for fossil-fuel supplies. The outlook is made even more promising, of course, by the advent of nuclear power. Moreover, the enormous energy yield of nuclear fuels per unit of weight suggests that unique economic effects will result from the exploitation of nuclear power.

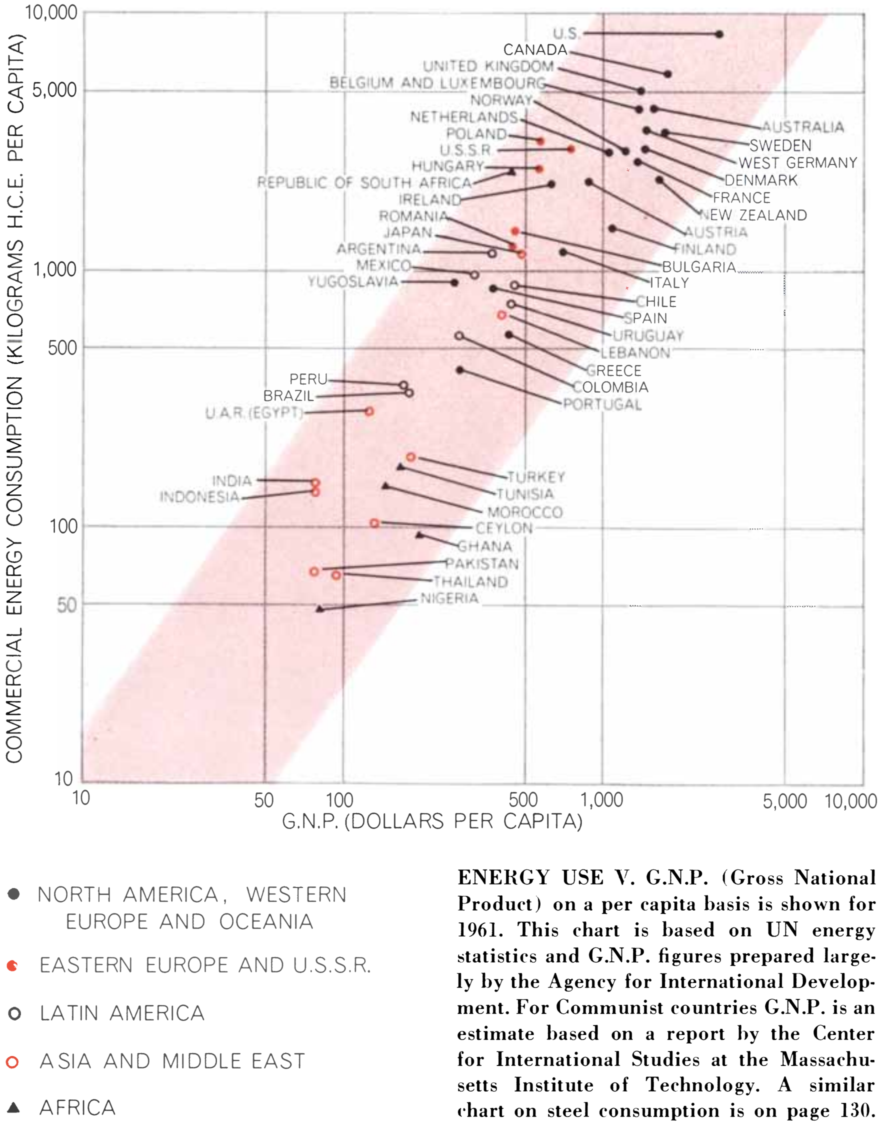
For the purpose of adding together the different energy sources their inherent energy value can be translated into various common denominators, such as kilowatt-hours, calories or British thermal units. This article will follow the practice used by the United Nations and convert the various energy sources into "hard-coal equivalents" (h.c.e.). In making this conversion for crude oil, refinery losses are taken into account and certain nonfuel products, such as asphalt and lubricating oil, are subtracted. Hydroelectric energy is converted to h.c.e. according to the actual energy content of a kilowatt-hour. (Prior to 1955 UN statistics used a conversion factor that reflected how much coal would be needed to produce a kilowatt-hour of electricity. This gave an h.c.e. three or four times higher than the h.c.e. now used for hydroelectric power.)

The chart on page 113, based on UN statistics, shows that in 1960 the world's consumption of mineral fuels and hydroelectric power was 4,235 million metric tons h.c.e. (A metric ton is 1,000 kilograms, or 2,205 pounds.) On a per capita basis this amounts to about 1,400 kilograms h.c.e. The world average conceals an enormous variation among countries. At one extreme the U.S., with only 6 per cent of the world's population, consumed more than a third of the world's total commercial energy supplies. Toward the other end of the range India, with almost 15 per cent of the world's population, used only about 1.5 per cent of the world's commercial energy. (The figures exclude such "noncommercial" energy sources as wood, animal power and dung, which constitute a significant fraction of all the energy used in India and other underdeveloped countries.) Translated into per capita terms, the average American consumed the equivalent of about 8,000 kilograms (eight metric tons) of coal per year, or more than 50 times the Indian per capita consumption.

In the chart on page 113 the nations are divided into three major groups. The first group consists of the most highly developed non-Communist nations: those of North America, western Europe and Oceania (essentially Australia and New Zealand). The second group is made up of the U.S.S.R. and the other European Communist-bloc countries. The third group, composed overwhelmingly of the less developed lands, consists of the nations of Asia, Africa, Latin America and the Middle East. Half of all the energy consumed in 1960 by the third group is accounted for by Communist Asia (chiefly mainland China). The reported per capita energy consumption of 600 kilograms h.c.e. for Communist Asia seems rather high in the light of earlier Chinese figures. If China is excluded, the per capita consumption for the third group is about 315 kilograms h.c.e., compared with about 415 kilograms when China is included. For the second group the per capita energy consumption is about 2,900 kilograms h.c.e., and for the first group (which includes the U.S.) the figure is about 4,500.

It is scarcely surprising that there is a strong positive correlation between per capita energy consumption and per capita share of gross national product (G.N.P.). This correlation for 47 nations in 1961 is shown in the chart on the next page. It extends and brings up to date a chart that Edward S. Mason of Harvard University originally prepared with 1952 figures. In presenting his chart, which used national income rather than G.N.P., Mason pointed to the inadequacies of energy statistics in many countries and to the difficulties involved in trying to reduce the per capita income figures of different countries to their equivalent in U.S. dollars. He concluded nevertheless that "large differences in income are associated with large differences in energy intake, and we may take it for granted that no country at this stage of history can enjoy a high

OIL TANKERS, together with pipelines, have transformed the fuel-consumption habits of the world. The tankers on the opposite page are docked at the Sun Oil refinery on the Delaware River at Marcus Hook, Pa.



ENERGY USE V. G.N.P. (Gross National Product) on a per capita basis is shown for 1961. This chart is based on UN energy statistics and G.N.P. figures prepared largely by the Agency for International Development. For Communist countries G.N.P. is an estimate based on a report by the Center for International Studies at the Massachusetts Institute of Technology. A similar chart on steel consumption is on page 130.

per capita income without becoming an extensive consumer of energy."

Over the past three decades there has been a striking shift in the relative importance of various energy sources. In 1929 solid fuels supplied almost 80 per cent of the world's commercial energy. In 1960 the solid-fuel fraction had declined to barely half [*see illustration on page 114*]. In the same period the share supplied by liquid fuels more than doubled, from about 15 to 31 per cent. The biggest gain of all was made by natural gas, which soared from 4.5 to 14.6 per cent of the total. The share supplied by hydroelectric power more than doubled during the period, but it continued to be a small fraction of the total.

The U.S. led the way in the shift from solid to liquid and gaseous fuels and strongly influenced world totals. In the U.S. oil and natural gas now supply nearly 75 per cent of all the energy consumed. In western Europe, where coal is still pre-eminent, the rise in oil consumption has been comparatively recent. In 1929 only 3.8 per cent of Europe's energy came from oil; by 1960 the figure had climbed to 30.2 per cent. The less developed part of the world depends on oil for more than half of its total commercial supplies compared with about 30 per cent in 1929. In good part the world-wide swing to liquid fuels reflects the fact that oil can be transported much more cheaply than coal over long distances. The rapidly increasing consumption of oil makes it more urgent than ever to have good estimates of world reserves of petroleum, traditionally regarded as far below coal in abundance.

If energy consumption in the future merely maintained the per capita rate of 1960, it would place a tremendous drain on the world's energy resources. The present world population is about three billion. By the year 2000 the population is expected to more than double, reaching a figure of six or seven billion. Obviously energy consumption is destined to climb even more steeply as per capita consumption continues to rise in the highly developed regions of the world, and even more swiftly in the developing ones. The job of producing a reasonable estimate of world energy consumption over the next 40 years is both formidable and hazardous.

In my opinion the most satisfactory technique for estimating world totals would be to project for each country (or region) the anticipated growth of each energy-consuming sector of the economy: industry, transportation, households, agriculture and so on. Unfortunately the data needed to make such a detailed projection are available only for the highly developed countries.

Under the circumstances one must fall back on less satisfactory methods of estimating the world's energy needs. Of the various projections available I prefer to use those prepared for the U.S. Atomic Energy Commission by Milton F. Searl. His estimates are reasonably detailed and allow for different rates of growth in different regions of the world. Moreover, Searl's projections of world energy consumption through the remainder of this century are the highest made by any serious student of the problem. It seems desirable to use a reasonably high estimate because it offers a severe test for the measurement of the adequacy of resources.

Searl's projections of world energy consumption and population in 1980 and 2000 are compared with 1960 figures in the charts on page 116. By the year 2000 a world population twice that of 1960 will consume about five times more energy. At that date the countries of North America, western Europe and Oceania will account for only 45 per cent of the world total, compared with almost 60 per cent in 1960. Over the same period the share of the U.S.S.R. and eastern Europe will decline slightly from about 21 per cent to 19. Meanwhile energy consumption in the rest of the world will have climbed from about 20 per cent of the world total in 1960 to about 35 per cent in the year 2000.

Part of the energy rise in Asia, Africa, Latin America and the Middle East will be accounted for by a rise in population from about 72 per cent of the world total in 1960 to about 77 per cent in 2000. In the main, however, the underdeveloped countries' increased share of projected world energy is accounted for by the assumption that they will be building up an industrial base between 1960 and 2000.

The experience of the U.S. in energy

consumption provides support for this assumption. In five of the six decades from 1850 to 1910—a period during which this country was building its industrial base—the average annual increase in the per capita consumption of mineral fuels and hydroelectric power was around 5 per cent, whereas in subsequent decades the rate fell substantially. Per capita consumption of commercial energy in the underdeveloped world in 1960 (414 kilograms h.c.e.) is about the level reached in the U.S. somewhere between 1850 and 1855—more than 100 years earlier. The per capita energy consumption estimated for the underdeveloped world in 2000 (about 1,500 kilograms h.c.e.) was reached in the U.S. around 1880. It happens that Searl's projections for the year 2000 were made without special reference to the U.S. record in the 19th century. It is interesting to note, therefore, that his estimates for the progress to be made in the underdeveloped world in the last part of the 20th century closely parallel the U.S. experience in the latter part of the 19th century.

There is another parallel in energy consumption between the U.S. of 100 years ago and the underdeveloped world of today: the heavy consumption of noncommercial fuels. As late as 1870 wood accounted for about three-quarters of the total U.S. energy consumption. By 1910 wood's share had fallen to about 10 per cent of the total. In a careful study of India's energy consumption in 1959 it was found that noncommercial fuels (excluding animal power) accounted for about 70 per cent of the country's total energy supply. Almost all the noncommercial fuels were consumed in households. The transformation in energy use that took place in the U.S. in the second half of the past century can be expected to take place in India and elsewhere during the latter half of this one.

Are world energy resources adequate to the expected demand? According to Searl's estimates, between 1960 and 2000 the world will have consumed the equivalent of about 435 billion metric tons of coal. More than half of the total, about 225 billion tons, will have been consumed in North America, western Europe and Oceania; more than a quarter, about 120 billion tons, in the less developed countries; the remainder, about 90 billion tons, in the U.S.S.R. and eastern Europe. The cumulative total is slightly more than 100 times the world's 1960 rate of consumption, which means in turn that over the 40-year period the world's energy resources will be depleted at an average annual rate 2.5 times that of 1960.

In appraising the adequacy of world resources one can neglect hydroelectric power because of its surprisingly small importance. It can be significant, however, in the energy supply of particular countries. Solar radiation, although it is a vast and for all practical purposes an inexhaustible source of energy, will be omitted from this discussion because no way has yet been found to use it as an

REGION	ENERGY CONSUMPTION (MILLIONS OF METRIC TONS H.C.E.)	PER CENT OF WORLD TOTAL	POPULATION (MILLIONS)	PER CENT OF WORLD TOTAL	PER CAPITA ENERGY CONSUMPTION (KILOGRAMS H.C.E.)
WORLD TOTAL	4,235	100.0	3,017	100.0	1,404
NORTH AMERICA, WESTERN EUROPE AND OCEANIA	2,432	57.5	540	17.9	4,504
NORTH AMERICA	1,549.3	36.6	199	6.6	7,785
U.S.	1,447.8	34.2	181	6.0	7,999
CANADA	101.5	2.4	18	0.6	5,639
WESTERN EUROPE	837.3	19.8	326	10.8	2,568
"COMMON MARKET"	440.9	10.4	169	5.6	2,609
UNITED KINGDOM	259.0	6.1	53	1.8	4,887
OTHER	137.4	3.3	104	3.4	1,321
OCEANIA (AUSTRALIA. AND NEW ZEALAND)	45.6	1.1	15	0.5	3,040
U.S.S.R. AND EASTERN EUROPE	907	21.4	313	10.4	2,899
U.S.S.R.	610.6	14.4	214	7.1	2,853
EASTERN EUROPE	296.9	7.0	99	3.3	2,999
LATIN AMERICA, MIDDLE EAST, AFRICA AND ASIA	896	21.1	2,164	71.7	414
CARIBBEAN AMERICA	78.0	1.8	88	2.9	886
OTHER LATIN AMERICA	61.3	1.4	122	4.0	502
MIDDLE EAST	36.9	0.9	138	4.6	267
AFRICA	59.3	1.4	190	6.3	312
ASIA	660.3	15.6	1,626	53.9	406
INDIA	60.7	1.4	433	14.3	140
JAPAN	108.5	2.6	93	3.1	1,167
COMMUNIST ASIA	446.8	10.6	745	24.7	600
OTHER	44.3	1.0	355	11.8	125

WORLD ENERGY CONSUMPTION, population and per capita consumption are shown for 1960. Only commercial energy sources are included; the various kinds of mineral fuel and hydroelectric power are converted, according to energy content, to their hard-coal equivalents (h.c.e.). Oceania, grouped with North America and western Europe, is made up chiefly of Australia and New Zealand. Caribbean America includes Colombia and Venezuela plus all of Central America and the Caribbean islands. The data used in this and subsequent charts in this article (unless otherwise noted) were prepared by Resources for the Future, Inc., from UN statistics.

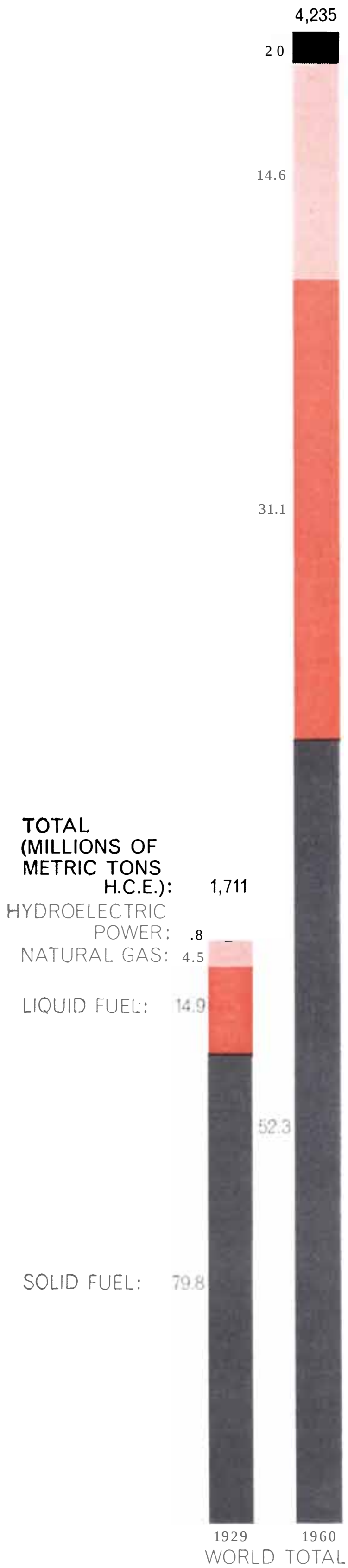
economic substitute for commercial fuels on a major scale. Its greatest promise appears to lie in small-scale applications, such as household cooking and water-heating—the very applications in which noncommercial fuels are so widely used today in the underdeveloped regions. Other unconventional energy sources such as geothermal and tidal power and the wind are also omitted for lack of evidence that they can add significantly to the world's energy supply over the next several decades.

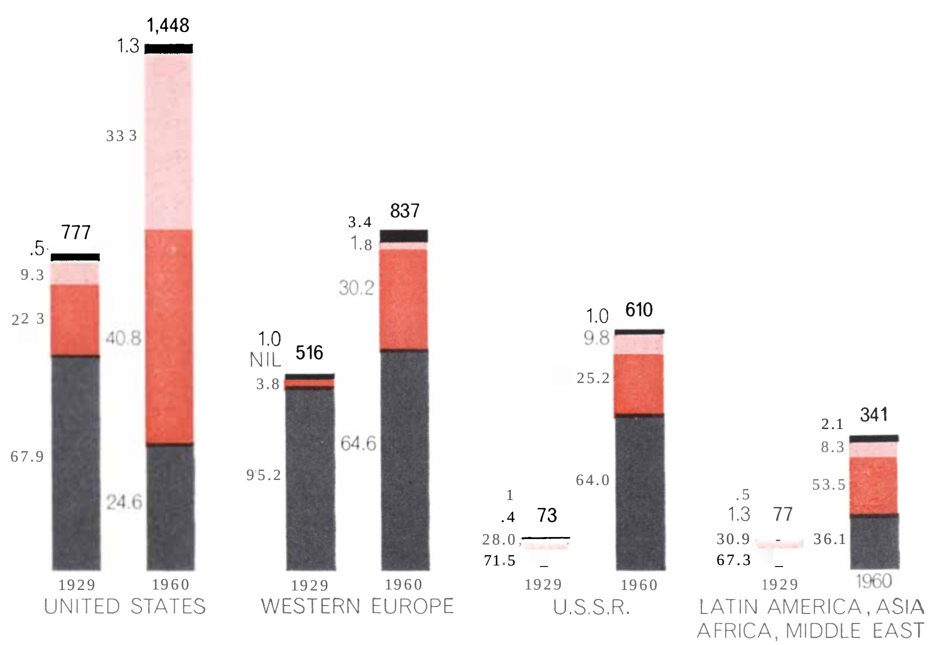
One might think that in turning from estimates of energy demand to the question of the adequacy of resources one would be leaving conjecture behind and entering the realm of hard geological fact. Actually there is no true measure of the world's endowment of energy resources, nor, in the nature of things, is there ever likely to be one. Cost alone would prohibit a comprehensive probing of the earth's crust to provide anything approaching a true measure of resources. More to the point, society's interest is confined to resources that are exploitable now or seem likely to be in the future. As time passes the standards of exploitability keep changing, mainly as a result of advances in technology and changes in economic circumstances. Consequently resource-supply estimates are subject to at least as many uncertainties as energy-demand estimates. Although resource estimates embody some actual measurements of the contents of known deposits, they are based chiefly on geological inference.

Let us first consider coal. Estimates of total resources will differ, depending on such factors as the maximum depth of coal beds to be included, their minimum thickness and whether or not the estimator is willing to include undiscovered deposits whose existence can be inferred. Fortunately the differences in recent estimates are not crucial because even the most conservative ones indicate that world coal resources are enough to meet world energy needs far into the future.

The estimate of world coal resources that will be used here was compiled recently by Paul Averitt of the U.S. Geological Survey. It shows a world total of 2,320 billion metric tons of recoverable coal in known deposits with seams 14 inches or more thick and lying within 3,000 feet of the surface. Recoverability is estimated at 50 per cent of the coal in place, which is more or less consistent with current underground mining experience in the U.S.

This is a conservative estimate in terms of its depth limitations and also in that it makes no allowance for undiscovered deposits, even within these limitations. Nevertheless, it includes far more





RISE IN ENERGY USE from 1929 to 1960 is plotted for the world as a whole and for selected geographical subdivisions. (Figures for Japan and Communist Asia are omitted from the Asian fraction. The numerals to the left of the bars show per cent composition.) Within this period the total amount of energy supplied by oil and natural gas expanded about 480 per cent, whereas the amount supplied by solid fuels rose only about 60 per cent. The biggest rise in solid-fuel consumption, 650 per cent, took place in the U.S.S.R.

Artist's rendition of a water model in operation.

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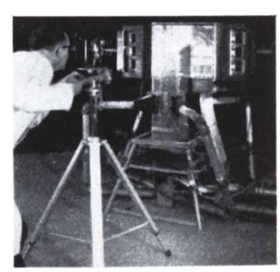

Moving pictures of operating water models enable designers to study gas flow patterns. The models duplicate the shape and interior structure of the steam generator being studied.

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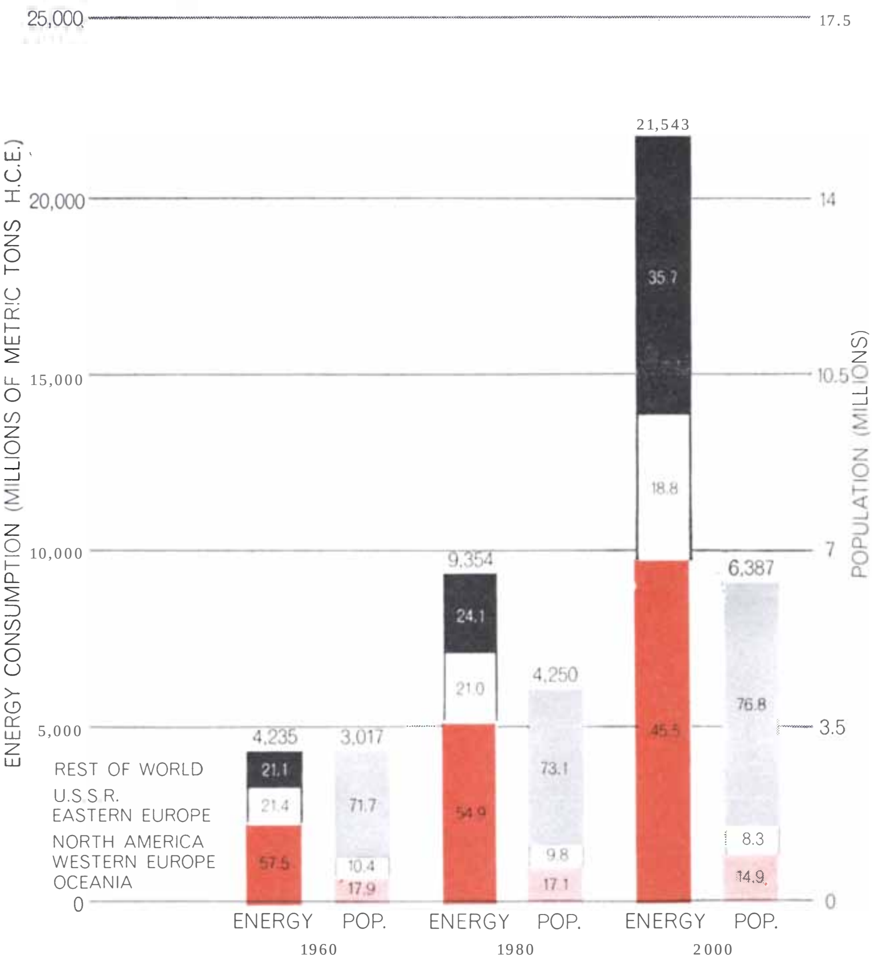
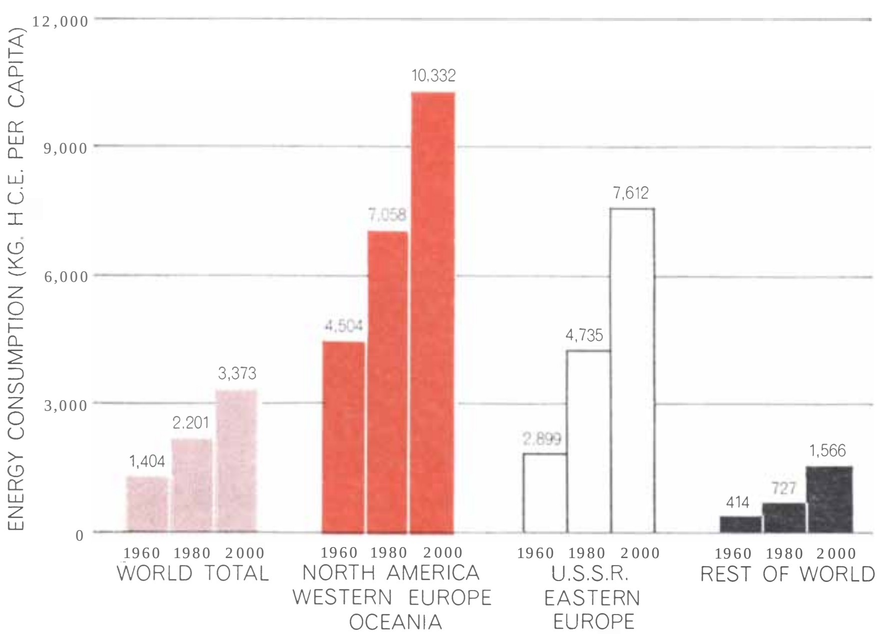


ENERGY CONSUMPTION AND POPULATION projected for 1980 and 2000 are compared with 1960 figures. Over this period energy consumption will rise more than twice as fast as population, with the steepest per capita increase in the non-Western world (*see below*).



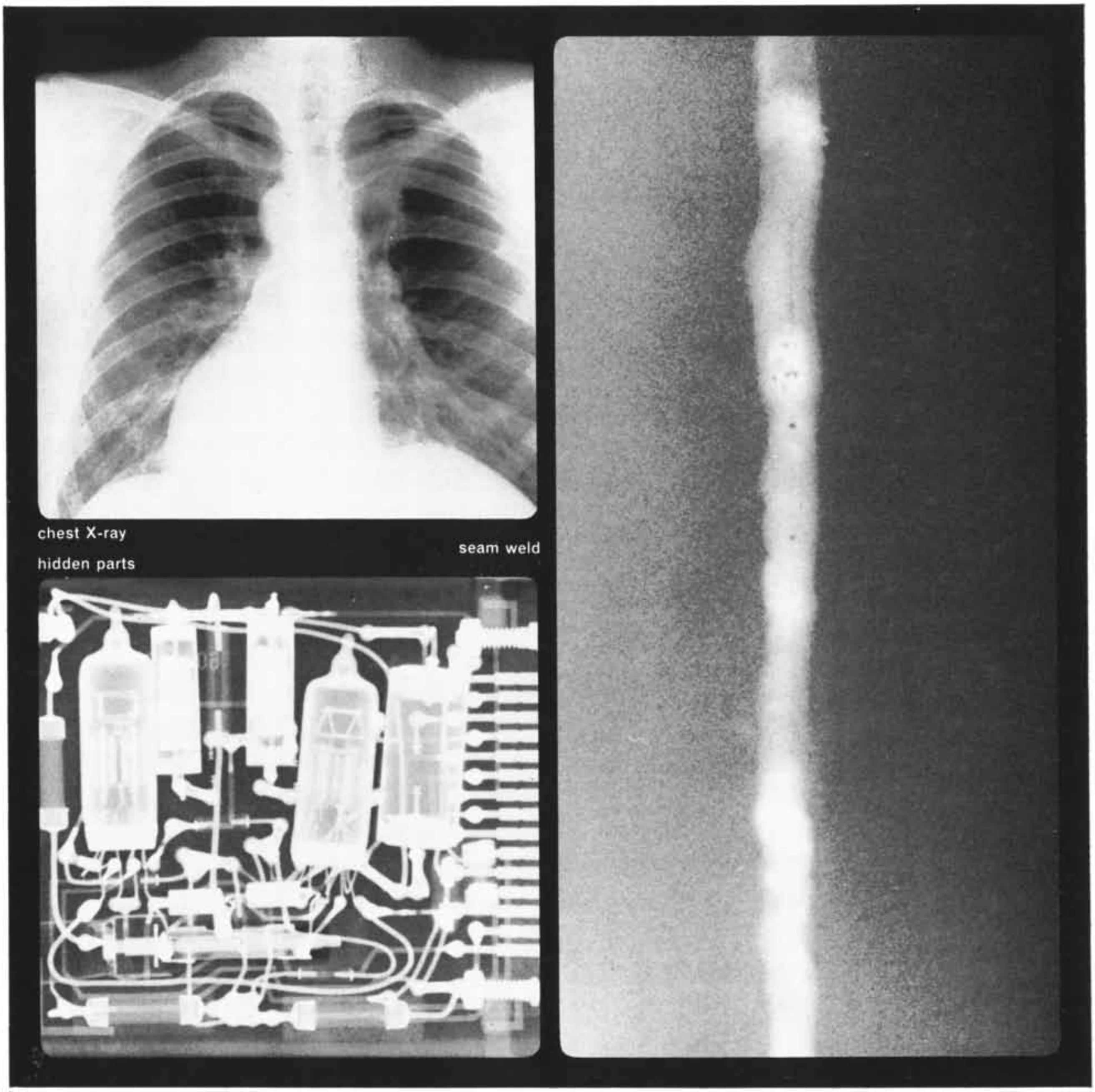
PER CAPITA ENERGY CONSUMPTION will rise sharply between now and the year 2000 in the world as a whole and in all major regions. The energy projections in these two charts were made by Milton F. Searl in a recent report for the U.S. Atomic Energy Commission.

coal than has actually been measured and great quantities of coal in deposits that would not be considered economic by current standards. Stated briefly, it is a conservative measure of the coal that is available in the earth for man to extract, if needed, by employing suitable technical and managerial ingenuity. For the purpose of comparison, a less conservative estimate made by other workers of the U.S. Geological Survey yields a world total that is seven times Averitt's estimate. The higher estimate employs the same depth and thickness limitations but allows for the discovery of new coal deposits.

If Averitt's estimate is accepted, coal could supply the entire 435 billion tons of coal equivalent the world is expected to consume between 1960 and 2000 and enough coal would still remain in the ground at the end of the period to satisfy the world's total demands for energy for almost another century at the estimated annual level of consumption in the year 2000. If present trends continue, of course, coal will be wanted for considerably less than half of the world's energy consumption in the years ahead. The huge coal reserve is reassuring, nevertheless, because with few exceptions coal, used as such or in the generation of electricity, could be satisfactorily substituted for oil and gas in most applications, although perhaps at some added cost. And if a serious pinch were to develop in oil supplies, coal could be converted, at a price, into liquid motor fuels. However, in the U.S. at least, oil shale would probably be used rather than coal as a substitute oil source.

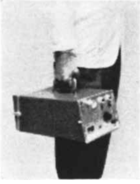
In considering resources of oil and gas one encounters a category that has no exact counterpart in world coal statistics: the concept of "proved reserves." The term refers to discovered and well-delineated reserves that can be extracted by available techniques at current costs and sold at current prices. Present proved reserves of oil are nearly 320 billion barrels, equivalent to 56 billion tons of hard coal, or more than 40 times the world-wide consumption of oil in 1960.

Proved-reserve figures, however, do not begin to provide a full accounting of oil and gas resources even in well-established oil regions. The reason is that reserves cannot be proved without drilling wells, and wells are costly. Reserves are only proved, therefore, in response to explicit commercial needs. In the U.S., for example, proved reserves are essentially a working inventory of natural stocks. Consequently proved-



These X-rays hide one important fact

They were taken with a camera that weighs only 48 pounds complete.



This means that it is now possible to take radiographs in the jungle, on an assembly line, or in an airplane. You can use it anywhere in the hospital, instead of trundling patients to the X-ray room. You can survey for tuberculosis miles from town, as was done last spring in rural Haiti, where a FExitron 845 took 2,312 chest X-rays. Note how compact the camera is. You can examine welds. Airplane stress points. Hidden parts, even certain enclosed parts moving at high speeds, such as valves. High resolution: 1.5 mm X-ray source size. There's a selector switch for 100 KV or 150 KV. A new electronic principle is used to deliver a burst of X-rays for a very short time (.05 microsecond). The short exposure time avoids motion blur on objects which can be exposed with a single pulse (child's chest or 2 inches of aluminum). For thicker objects dial 1 to 25 pulses at seven or 14 pulses per second. Radiographs any part of the body. Both X-ray dose and spectrum are independent of line voltage. Operates off any house circuit or with portable generator. This new instrument extends diagnostic radiography into formerly inaccessible places. Perhaps it can find facts that are now hidden from you. Write; we'll answer immediately.

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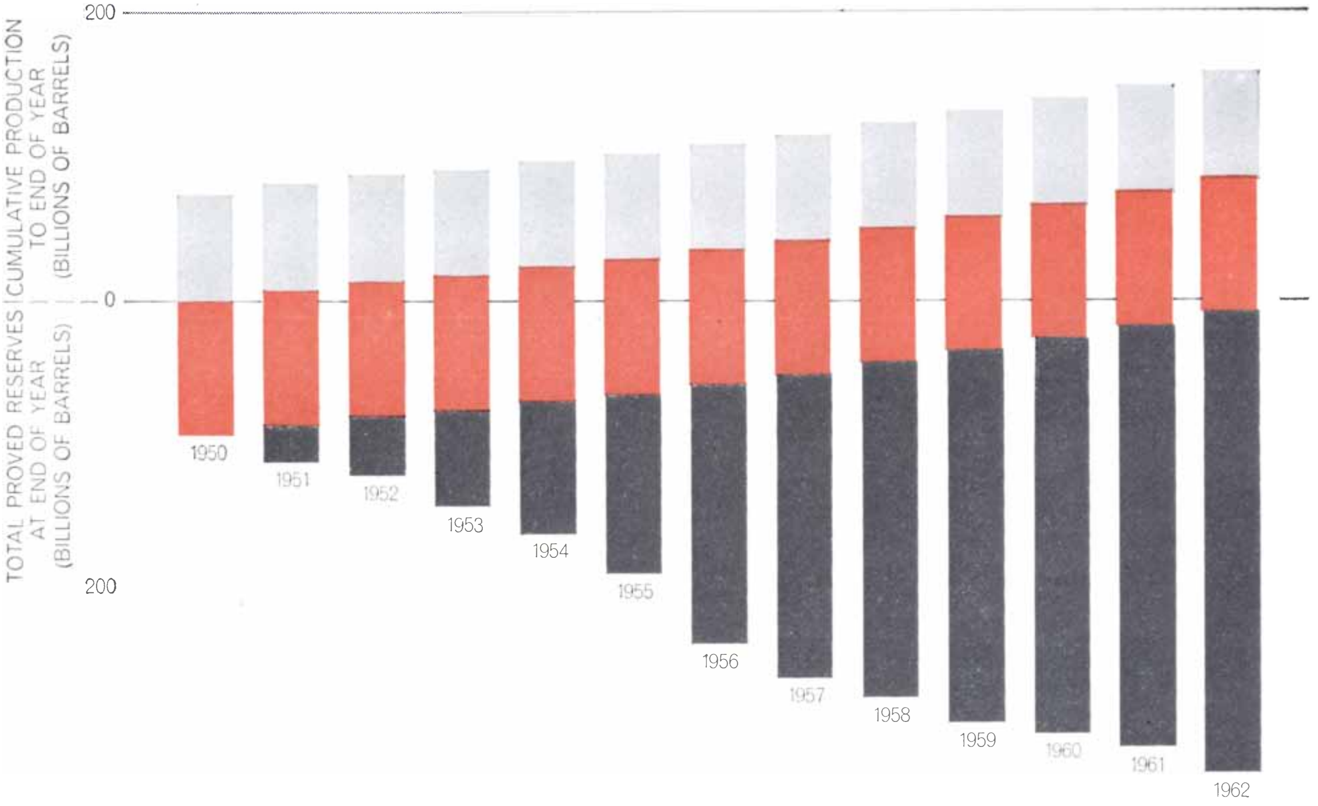


PROVED WORLD RESERVES OF CRUDE OIL increased enormously in the past decade. The upper segment of the bar in 1950 represents total world crude-oil production between 1859 and 1950. That volume was slightly exceeded by the proved reserves at the end of 1950. Between 1950 and 1962 total crude production almost equaled the reserves of 1950, as indicated by the upward shift of colored segment of bars. Meanwhile reserves more than tripled. Chart is based on one by the British Petroleum Company Limited.

reserve figures—which indicate that U.S. reserves will last for perhaps 12 years—are virtually useless for an analysis of the long-term adequacy of resources.

The relation between world oil production, proved reserves and addition to reserves over the period from 1950 to 1962 is indicated in the chart above. The chart shows that cumulative oil production over the 12-year period practically equaled the proved reserves existing at the start of the period but that in the meantime much larger quantities of oil resources were added to proved reserves.

For both oil and natural gas, therefore, it is necessary to estimate "unproved" resources to obtain a figure comparable to that presented for world coal resources. Estimates of such unproved resources have generally been revised upward over the years, but even today there are wide differences on the subject.

The extremes among responsible authorities are represented by the estimates of M. King Hubbert of the Shell Development Company, who recently completed a study of energy resources for the National Academy of Sciences, and those of Alfred D. Zapp of the U.S. Geological Survey. Hubbert's estimate of ultimate world reserves of crude oil is 1,250 billion barrels; Zapp's estimate of potential oil resources is about 3.5 times that, or more than 4,000 billion barrels.

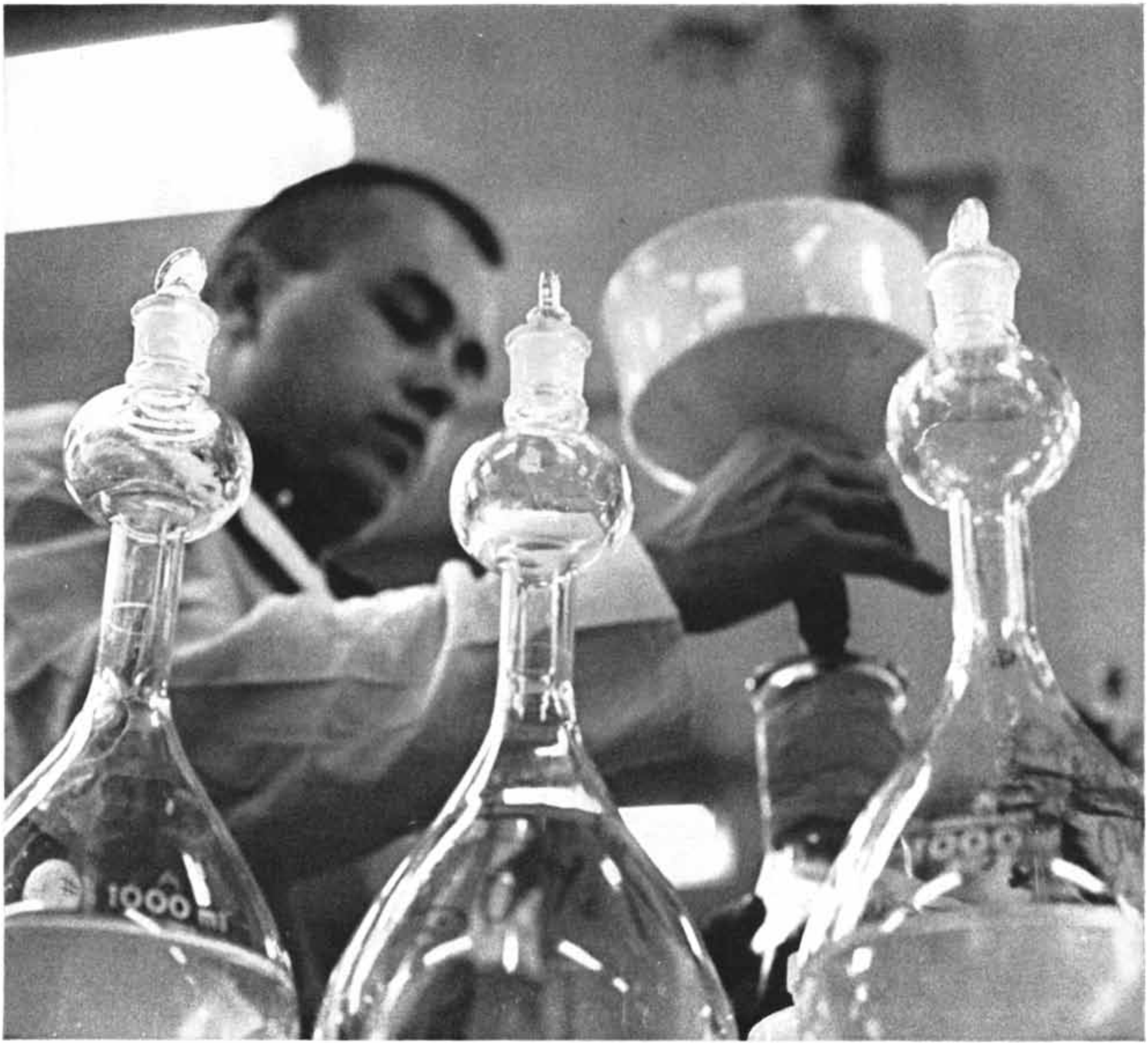
The difference in these two estimates results wholly from the widely different estimates made by the two men of the potential oil resources of the U.S. Hubbert's figure for the U.S. is 175 billion barrels of ultimate reserves, whereas Zapp's estimate is between 500 billion and 600 billion barrels. In each case the world figure is derived from the U.S. estimate by applying certain factors indicating the relative geological favorability of oil occurrence in the U.S. and other parts of the world.

The wide gulf separating the Hubbert and Zapp evaluations of the potential oil resources of the U.S. (and, by extension, the world) results essentially from the different views they hold concerning the relevant variables for assessing unproved oil resources. Hubbert's approach yields an estimate that is shaped by existing economic, technical and political factors affecting the actual production of oil in the U.S. Zapp's approach yields an estimate that admittedly includes deposits that are submarginal by today's standards and whose exploitation would depend on significant improvements in exploration and production technology and perhaps increases in the price of oil.

On the basis of their estimates for oil Hubbert and Zapp were also able to make estimates of the unproved resources of natural gas (and natural-gas liquids). The resulting totals for the world's potential resources of oil and gas, expressed in hard-coal equivalents, are about 535 billion metric tons (Hubbert) and about 1,620 billion metric tons (Zapp).

These various estimates are not to be taken literally. No one really knows what the world's potential resources of coal, oil and gas are. My own guess is that the estimates will be revised upward in the future if the demand for these energy sources continues to justify the search for new deposits and the development of new technology. Improved recovery technology alone could raise the figures by a considerable percentage. For example, only about a third of the oil contained in underground reservoirs in the U.S. is now recovered, and this low recovery factor is built into Hubbert's estimate of ultimate reserves.

In addition to coal, oil and natural gas the earth's crust contains vast potential resources of oil shale and oil-



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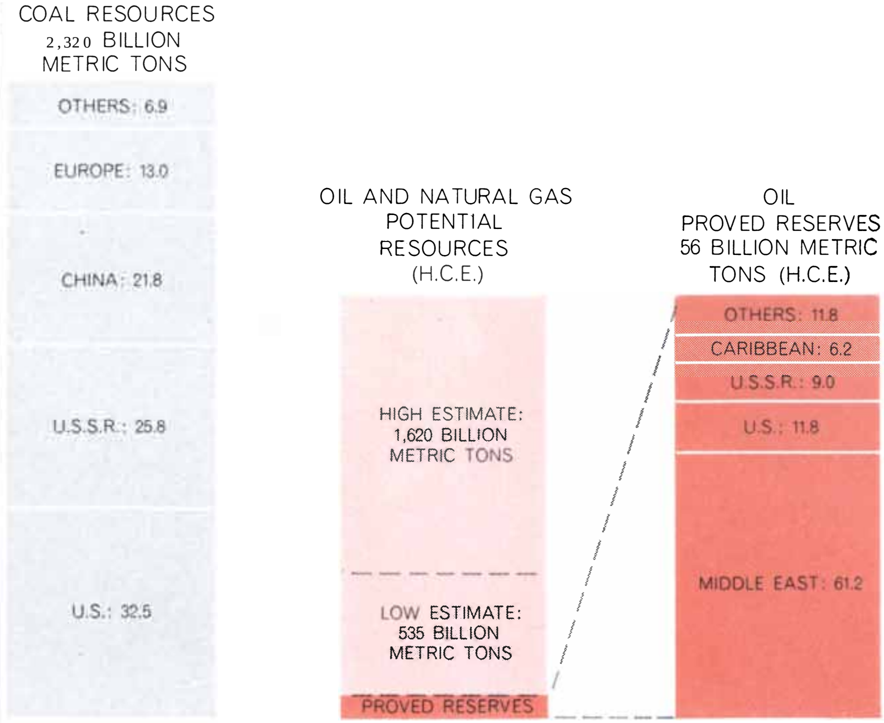

WORLD COAL RESOURCES far exceed estimates of potential oil resources. The coal estimate was compiled by Paul Averitt of the U.S. Geological Survey. The high estimate for oil and natural gas was made by Alfred D. Zapp of the same organization, the low estimate by M. King Hubbert of the Shell Development Company. Data on the proved reserves of oil are from British Petroleum. (The U.S. fraction includes natural-gas liquids.) The bases of the various estimates are explained in the text. In the U.S. alone it is estimated that potential uranium resources are more than 2,000 billion metric tons h.c.e. Between 1960 and 2000 the total world energy consumption may well exceed 400 billion metric tons h.c.e.

bearing tar sands. The U.S. Geological Survey has estimated, for example, that the recoverable energy content of U.S. oil-shale resources is about a third of the total energy content of the known and inferred coal resources of the U.S. There is, therefore, reason to believe that even without atomic energy the world resource base of fossil fuels would be ample into the quite distant future.

Unfortunately a particular country may find small comfort in estimates of vast world resources of fuels if the supply inside or near its own borders is scanty or nonexistent. A striking aspect of the distribution of both coal and oil is their high concentration in just a few of the world's regions [*see illustration above*]. In the case of coal the U.S., the U.S.S.R., China and Europe account for more than 90 per cent of the world's estimated recoverable resources; all the other regions of the world combined—which includes all the underdeveloped world except China—contain only 7 per cent of known resources. For oil, four regions—the Middle East, the U.S., the U.S.S.R. and Caribbean America—also possess about 90 per cent of the world's proved reserves. Most of Africa (outside of North Africa), most of South America and India contain neither coal resources nor proved oil reserves in sizable amounts. It is clear that the distribution of coal and oil is far from evenly matched with the distribution of the population.

Of course, the location of today's known deposits is not identical with what may be found in the future, particularly as the search for fuel resources is widened. But even if important new discoveries are made, international trade in coal and oil will continue to be important in the years ahead, and to expand in volume. The present pattern of major interregional shipments of coal and liquid fuels is illustrated on page 122. The overwhelming importance of western Europe as a fuel-importing area and of the Middle East as an exporting area is clearly apparent, each accounting for about 50 per cent of the world's gross interregional imports and exports respectively. This is a comparatively recent development associated with the postwar shift toward oil in western Europe's energy consumption.

In looking to the future it is apparent that the quantitative preponderance of the developed countries as importers will continue. But as the years pass the

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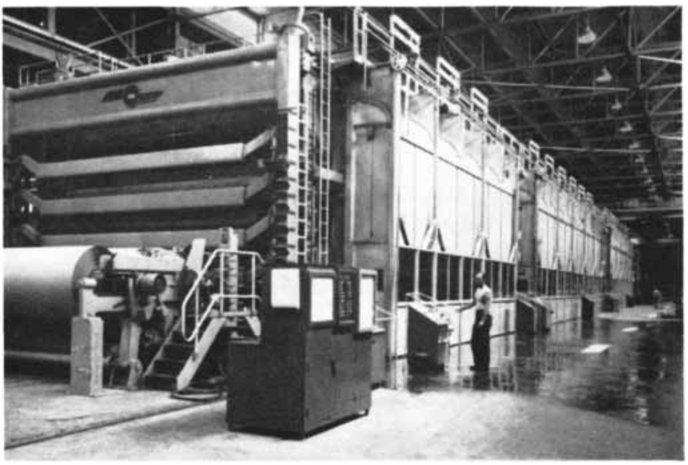

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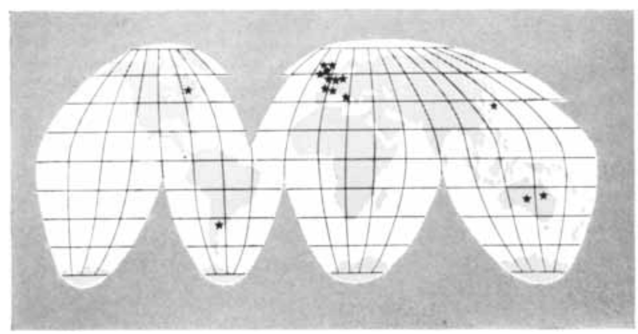

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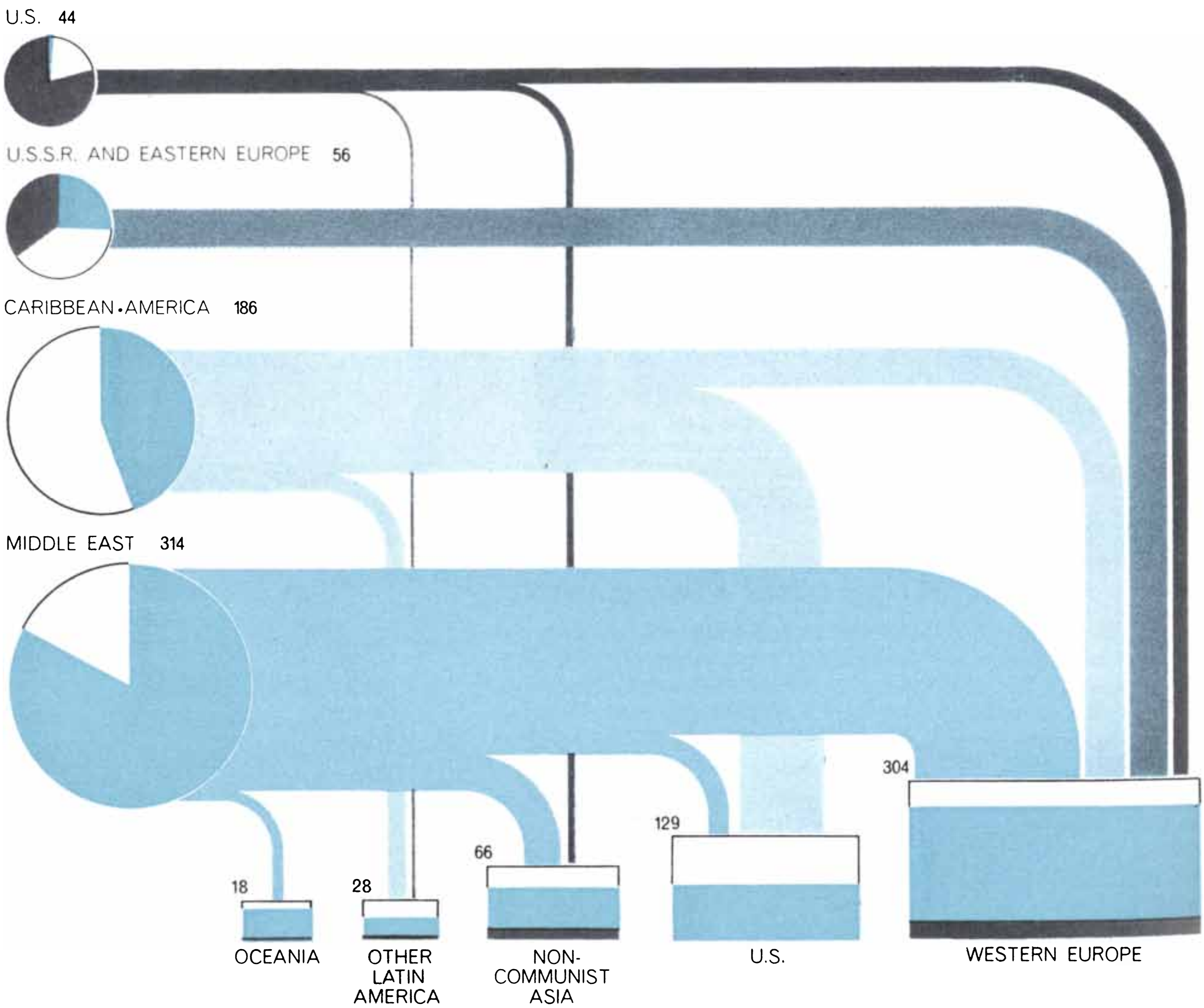
less developed areas of the world will be forced to increase their imports of fuels at a rapid rate. Barring discovery of local energy sources, many countries will find themselves faced with staggering bills for imported fuels.

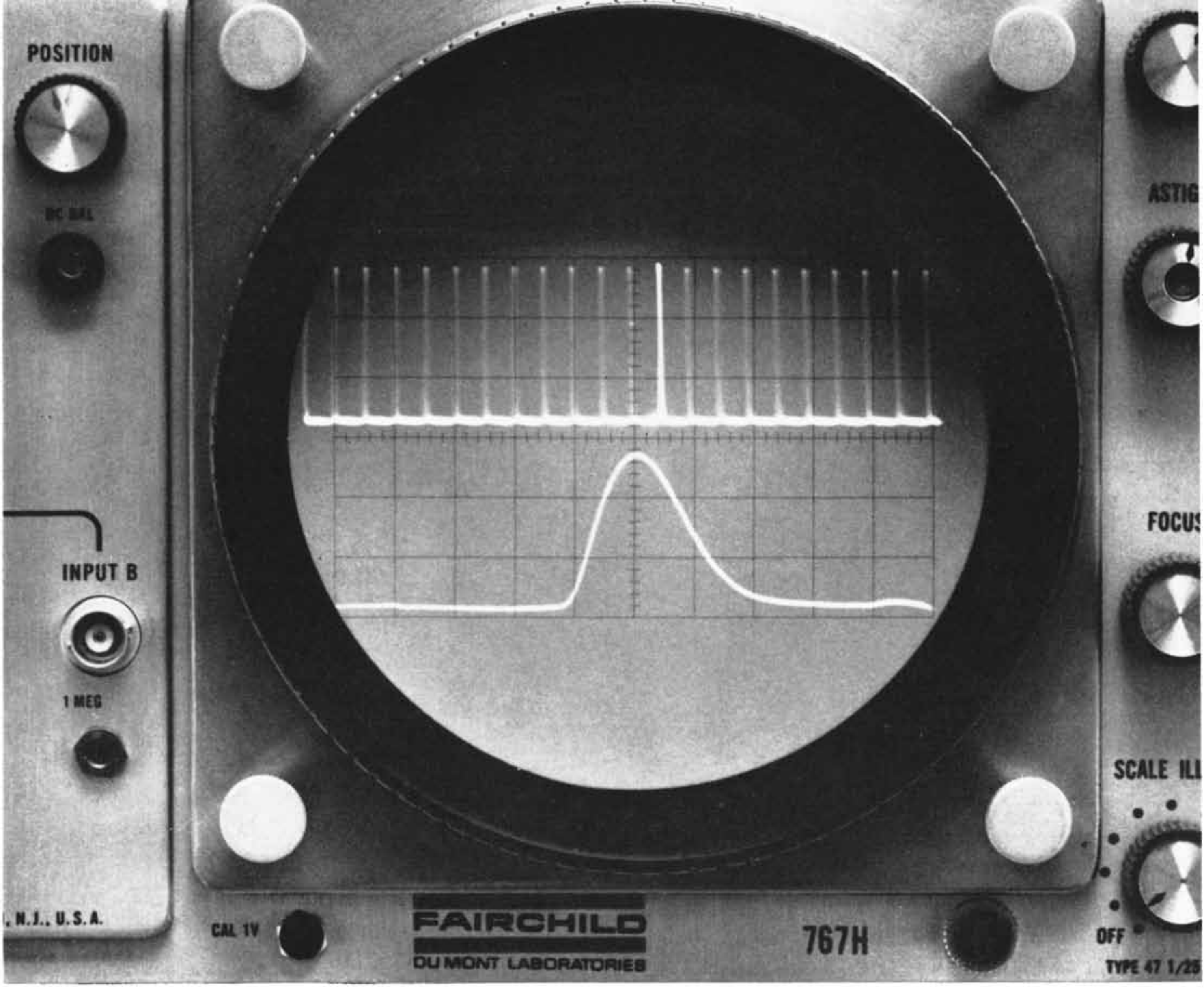
In order to ascertain how big these bills may be my associates and I have made a rough estimate of the volume of imported fuel that will be needed in the year 2000 by underdeveloped non-Communist countries not now self-sufficient in energy. Coal imports were omitted from the calculations because oil is the preferred imported fuel of underdeveloped regions. In 1960 imported oil accounted for about 55 per cent of the total energy consumption of the non-self-sufficient countries of Latin America and Africa and for about 25 per cent in Asia. We assumed that imported oil would constitute the same percentage of energy needs in the year 2000. This estimated volume was then multiplied by current prices of crude oil (even though refined oil products would presumably account for much of the importation).

The conservative figure that resulted from this calculation was an imported-oil fuel bill in the year 2000 of about $10 billion (at today's prices). In 1960 the same group of countries paid out only $17 billion for imported commodities of all kinds, of which oil imports (calculated as crude oil) would have cost less than $1 billion. It is evident from these rough figures that paying for imported fuel supplies in 2000 may pose a difficult problem for developing countries. Although these countries can expect a growing income from exports, export earnings still may not be sufficient to pay for sharply enlarged energy imports along with imports of other necessities. International arrangements for easing the foreign-exchange burden may be needed if energy-consumption levels such as those estimated here are to be achieved.

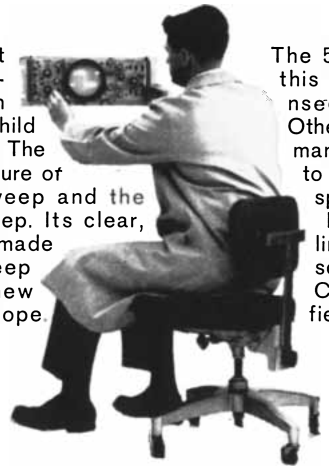
Finally we come to the role that may be played by nuclear power in satisfying the world demand for energy. From the estimates of fossil-fuel reserves already presented it is clear that during the rest of this century and well into the



MAJOR WORLD FUEL SHIPMENTS, excluding intraregional trade, are shown for 1960. Circles represent exporting regions, rectangles importing regions; they are proportional in size to the weight of fuel shipped or received. Figures beside the various regions show gross exports or imports in millions of metric tons h.c.e. Gray areas in circles and rectangles represent solid fuels, colored areas crude oil and white areas refined liquid fuels. The width and color of the bands indicate weight and general nature of shipments. The four exporting regions that are shown in the chart supply more than 90 per cent of all interregional shipments. The five importing regions account for about 85 per cent of all imports, that is, they do not account for all exports from regions shown.



What's the delay here?



The delay here is what happened to a 10-nano-second radar pulse on its way through a Fairchild Type 767H Oscilloscope. The trace is a multiple exposure of a strobed delaying sweep and the magnified delayed sweep. Its clear, "locked in" display was made with the Delaying Sweep Plug-In unit of this new Fairchild solid state scope.

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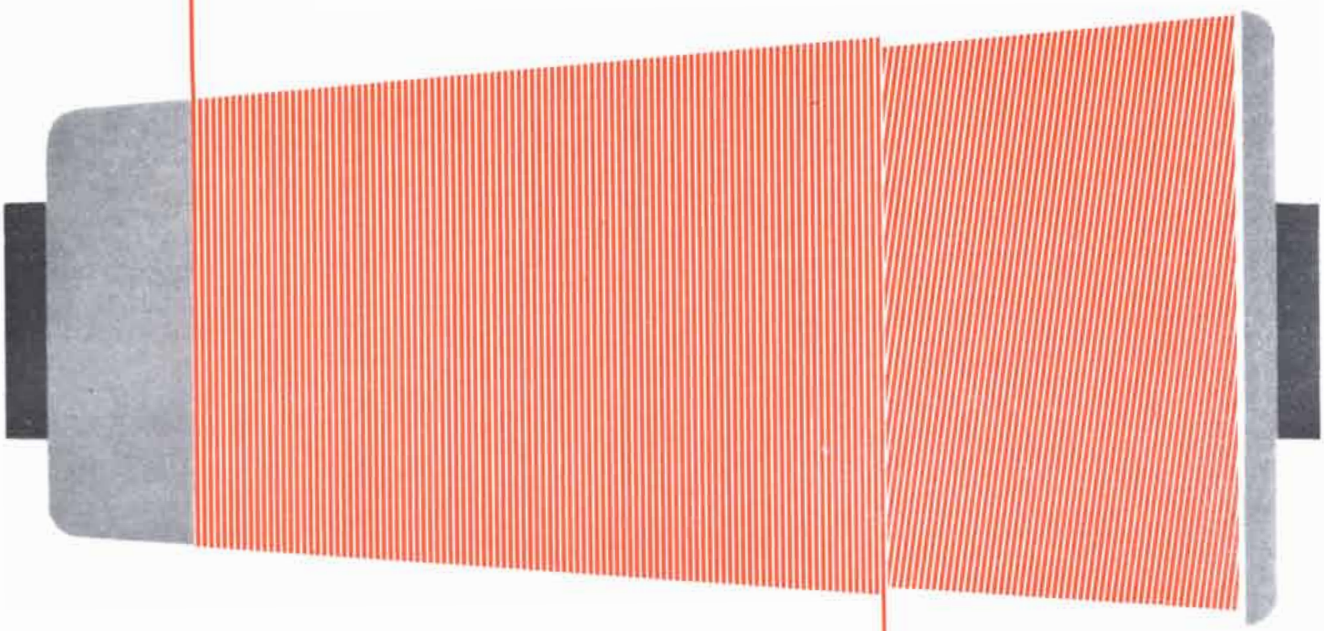
next the world could get along quite well without atomic energy. Nevertheless, as nuclear power costs decline, nuclear fuels will compete increasingly with fossil fuels.

In the U.S. alone the potential (known and unknown) uranium resources, comparable in quality to ore now being mined, are estimated by workers of the U.S. Geological Survey to range from 2,100 billion to 6,900 billion tons of coal equivalents. The larger figure is substantially greater than the combined total of the world's known resources of recoverable coal and potential resources of oil and natural gas. It can be inferred from the U.S. figures that the world resources of uranium (and of thorium, which is probably more abundant than uranium) are greater than the resources of fossil fuels by an enormous margin. If much-lower-grade resources—including ordinary granite—are taken into account, man can be said to have within reach an almost unlimited supply of energy. Underlying these calculations is the assumption that through the development of the "breeder" reactor it will be possible to convert the "fertile" materials uranium 238 (the abundant isotope of natural uranium) and thorium 232 respectively into fissionable uranium 235 and thorium 233.

It is difficult to estimate what effects commercial atomic energy will have on the market for conventional fuels in the years ahead. Within the past year estimates pertaining to the U.S. have appeared in a report to the President prepared by the Atomic Energy Commission. This report predicted that atomic power would become competitive with conventional sources of power throughout most of the U.S. in the 1970's and by 1980 would generate nearly 10 per cent of the nation's electricity. It predicted further that by the end of the century all new electric power plants, and half of all the electricity then being generated in this country, would be nuclear. But it should be kept in mind that these estimates were contained in a report attempting to justify a program of research, development and construction that is designed to improve nuclear technology and to bring down costs. Moreover, the report made assumptions about the future costs of fossil fuels that seem unreasonably high.

But even with these reservations it is apparent that nuclear fuels will emerge as a formidable competitor of the fossil fuels, both at home and abroad. It is therefore worth speculating about the broader economic significance of atomic energy, particularly for the underde-

OPPORTUNITY



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veloped countries. The unique promise of atomic energy is inherent in the fact that nuclear fuels contain an enormous concentration of energy per unit of weight. One pound of nuclear fuel, fully consumed, is the energy equivalent of about three million pounds of coal. Several unusual economic characteristics follow from this fact. Nuclear fuels, for one thing, are essentially weightless and thus freight-free. Their employment should therefore lead toward the geographic equalization of energy costs. This may make it possible for underdeveloped countries to undertake a new pattern of economic development in which certain industries are located near existing agricultural settlements instead of being concentrated in a few large urban centers. Because nuclear fuels are freight-free they might also reduce the need for investment in railroads or pipelines, thereby conserving scarce capital. Finally, there is the long-run promise that nuclear fuels will help to reduce the foreign-exchange burden faced by fuel-poor countries.

Unfortunately the inherent advantages of nuclear fuels are counterbalanced by the present need for very-large-scale installations if power is to be produced at a reasonable cost. Installations of the size needed require the prior existence of a highly concentrated market for power. Moreover, nuclear power plants cost more per kilowatt of installed capacity than conventional power plants do. Hence for the foreseeable future the capital costs of nuclear power plants will offset such advantages of nuclear fuel as cheapness and mobility.

The foregoing conclusions for both the developed and the underdeveloped countries rest on present-day expectations regarding the use of atomic energy. It is impossible to say whether or not the inherent promise of nuclear fuels—abundance, mobility and economy—will begin to be realized within the 40-year time horizon of this analysis, but in the long run it seems almost certain that these intrinsic advantages will be captured in the technology developed to make use of atomic energy.

Author's Note

The following staff members of Resources for the Future, Inc., helped in the preparation of this article: Perry D. Teitelbaum, Jaroslav G. Polach and David B. Brooks.

MINERALS

Deposits of important minerals that can be economically mined are poorly distributed over the surface of the earth. Modern substitutions may, however, alleviate some of this imbalance

by Julian W. Feiss

Although it is widely recognized that an industrial society requires a broad mineral-resource base, the extent to which modern production technology depends on mineral raw materials is seldom appreciated. It is easy to comprehend the needs for and the application of the traditional common metals: iron, copper, lead, tin and the newer metal aluminum; but it is more difficult to comprehend the changes in technology that influence their quality, fabrication and end use in world markets. The increased demand for new alloys requiring special additives, some of which a generation ago were hardly more than names in the periodic table, tremendously complicates the supply requirement. As a result the creation of an integrated minerals or metals industry even where local mineral supplies exist will greatly strain the technological resources of underdeveloped countries.

On the other hand, even countries without mineral wealth of their own should not find it too difficult to import the needed mineral supplies. The total estimated value of the world's mineral production in 1960 was approximately $50 billion, of which fuels represented about $37 billion. The value of all other minerals, including construction materials such as sand and gravel, came to only $13 billion. Of this sum U.S. production for its own consumption and U.S. imports from other countries added up to approximately $7 billion, leaving only about $6 billion worth of nonfuel minerals to be consumed by the rest of the world. This translates into a world consumption, outside the U.S., of only about $2 a head. In comparison, U.S. consumption in 1960 was roughly $40 a head. If allowance is made for a consumption of perhaps $10 to $30 a head in other well-developed countries, the per capita mineral consumption in the underdeveloped regions of the world is reduced to well below $1.

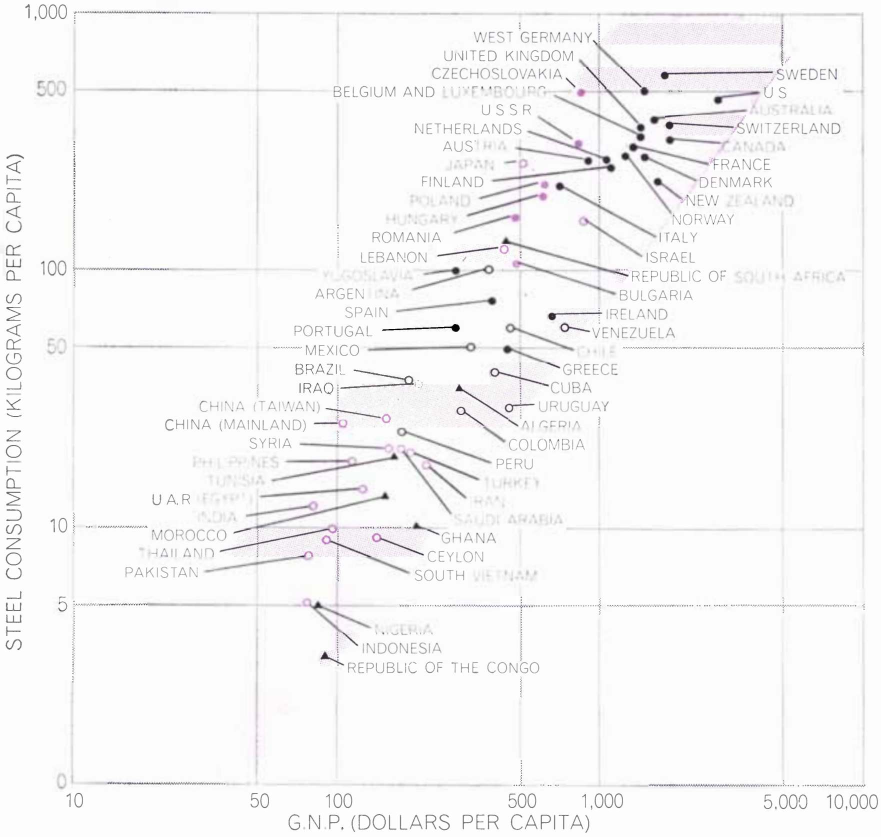
These figures can be viewed both optimistically and pessimistically. The pessimistic aspect is simply that more than two billion of the world's people consume nonfuel minerals at an annual rate measured in pennies and that if their consumption were ever to approach the consumption enjoyed in the more privileged countries, the drain on the world's mineral resources would be staggering. The optimistic aspect is that even those underdeveloped countries that are poor in minerals should be able to double and triple their present tiny rates of mineral consumption at a comparatively small cost in raw materials. This is in marked contrast to the prospect faced by fuel-poor countries in meeting their fuel requirements, as described in the preceding article, "Energy," by Sam H. Schurr. He estimates that in 1980 the underdeveloped countries of Asia, Africa, Latin America and the Middle East will consume about two and a half times more fuel than they did in 1960. If it is estimated that these countries spent $7 billion for fuel in 1960, their 1980 bill, at current prices, will be more than $17 billion. It is doubtful that the same countries consumed as much as $1 billion worth of nonfuel minerals in 1960, so that a comparable doubling or tripling of their consumption by 1980 would represent relatively little money.

Many of the underdeveloped nations of course count on exports of indigenous minerals to provide the foreign exchange needed for industrial development. Such countries can look forward to a steadily rising demand for ores and minerals from the U.S. and other well-developed countries of the world. The U.S., for example, imports all its tin; more than 90 per cent of its manganese, antimony, beryllium and chromium ores; more than 85 per cent of its nickel; about 75 per cent of its bauxite, and about 55 per cent of its zinc and lead. Across the board the U.S. consumes roughly 25 per cent of the world's total production of metals.

Estimates of U.S. metal consumption in 1975, made recently by the U.S. Bureau of Mines, project an increase of 50 to 65 per cent for zinc and copper, 135 per cent for lead and more than 250 per cent for aluminum and tungsten. Originally the increase for steel was estimated at 80 per cent, but it was subsequently cut to 60 per cent.

The reduction in the steel estimate is noteworthy because it reflects a basic shift in the pattern of metals use that has developed almost entirely since the end of World War II and has been accelerating. For years steel production was the great bellwether of the economy. What has happened, very simply, is that steel is losing its historic role as the symbol of economic potency. U.S. steel output reached a peak of 117 million tons in 1955, dropped below 100 million tons in 1958 and has stayed there since. As the chart on the next page indicates, U.S. per capita consumption of steel in 1961 (488 kilograms) was exceeded by Sweden (544 kilograms), Czechoslovakia (493 kilograms) and West Germany (490 kilograms). In its revised projec-

OPEN-PIT IRON MINE, operated by the Jones & Laughlin Steel Corporation in northern New York, is the second largest producer of high-grade iron-ore agglomerates in the eastern U.S. Its annual capacity is 1.5 million tons. The edge of the mine is at the top left of the picture on the opposite page. Ore is crushed in the gray buildings at far left and carried by conveyer to group of buildings at lower right, where it is concentrated and sintered. The beneficiated ore is then shipped to the Pittsburgh area.



- ● NORTH AMERICA, WESTERN EUROPE AND OCEANIA
- ● EASTERN EUROPE AND U.S.S.R.
- ○ LATIN AMERICA
- ○ ASIA AND MIDDLE EAST
- ▲ AFRICA

STEEL CONSUMPTION V. G.N.P. (Gross National Product), per capita, is shown for 1961. The chart is based on UN steel statistics and G.N.P. figures prepared largely by the Agency for International Development. For Communist countries G.N.P. is an estimate based on a report by the Center for International Studies at the Massachusetts Institute of Technology. Sweden, Czechoslovakia and West Germany now exceed the U.S. in per capita steel consumption. A similar chart for energy is given on page 112.

tion for 1975 the Bureau of Mines is providing for a per capita increase in U.S. steel consumption of only about 10 per cent.

In the U.S., probably more than in other countries, steel has run into increasing competition from aluminum, magnesium, titanium, structural concrete and a variety of strong, tough plastics. Steel is also meeting competition from itself: common steels are being replaced by steel alloys that are stronger and do a given job with less weight [see "The Strength of Steel," by Victor F. Zackay; SCIENTIFIC AMERICAN, August]. Last November the changing outlook for steel received documentation from an unexpected source. Speaking to an assemblage of economists and industrial managers in Moscow, Premier Khrushchev said: "There was a time when the power of a state was measured in terms of the amount of steel it could produce.... But now, when there are other materials competing with steel, such a criterion is no longer adequate." He went on to say that some party officials "have put on 'steel blinkers' and now look and act as they were once taught. We now have a material that surpasses steel and costs less, and they still cry 'Steel! Steel!'" Presumably he was referring to new plastics such as polyethylene and polypropylene. In any event, during the next 20 years the U.S.S.R. intends to expand plastics output 20 times and steel production only four times.

This is not to say, of course, that substantial steel capacity will not be needed in the emerging nations. Underdeveloped nations should, however, weigh various alternatives carefully before each new addition to steel output. They probably should not aspire to approach the West in per capita steel capacity.

A capsule history of changing materials technology can be found in the design of bridges. Early bridges were made of wood and stone. The first use of iron on a large scale began about 150 years ago in bridges designed by Thomas Telford in England and Scotland. Steel remained almost unchallenged as a structural metal for bridges until the first all-aluminum bridge span was built over the Grass River at Massena, N.Y., in 1946. Four years later an all-aluminum highway bridge was completed across the Saguenay River at Arvida in the Canadian province of Quebec. The bridge contains a center arch of 290-foot span that weighs only 200 tons—half the weight of an equivalent steel arch. Meanwhile European bridge builders have been reducing the amount of steel needed in bridges by using large members of prestressed concrete. These are concrete beams and slabs in which embedded steel cables or rods are held in tension.

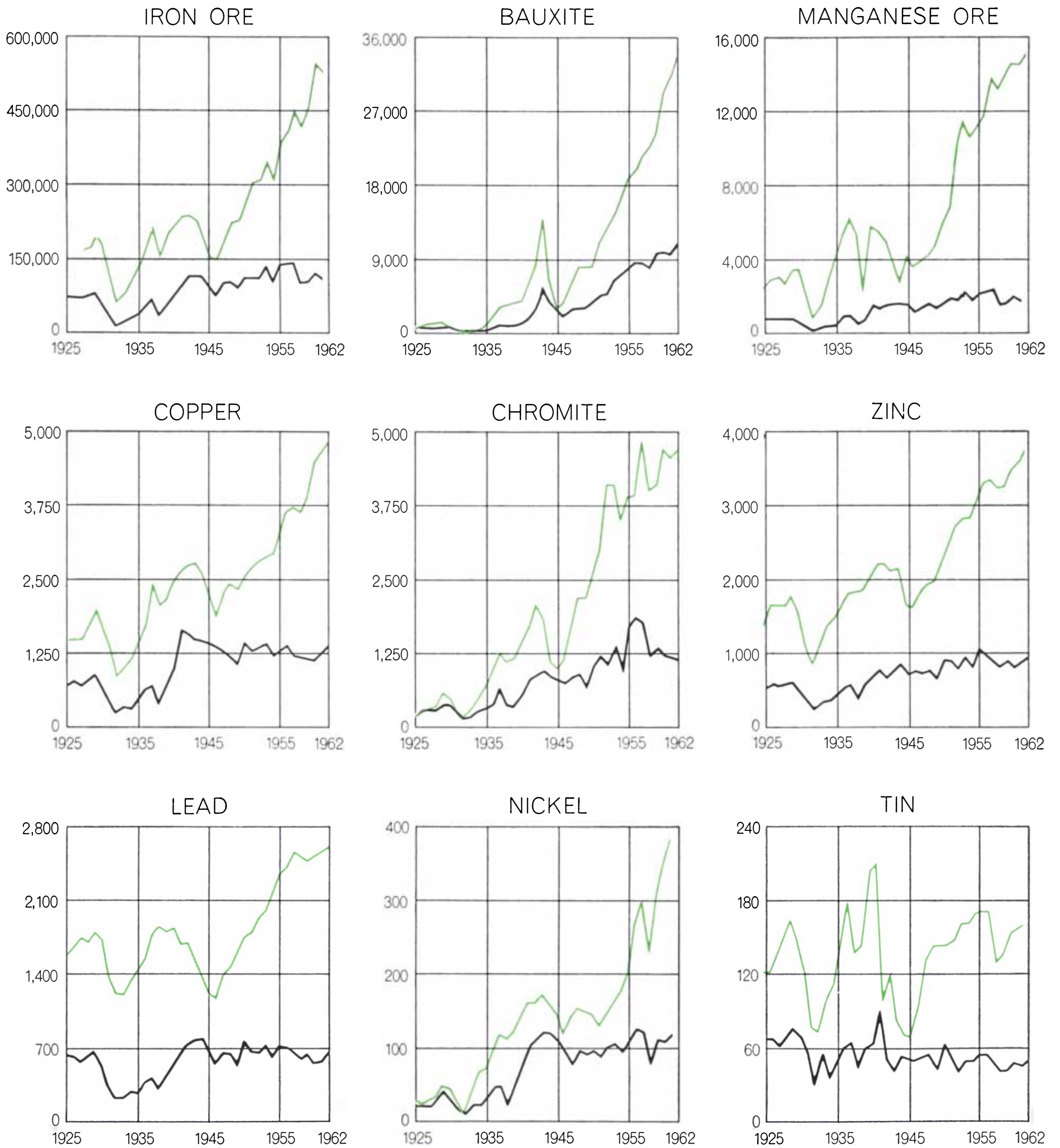
The use of aluminum in bridges is symbolic of the growing competition it offers to steel in construction jobs of many types. In 1961, for example, aluminum curtain walls were used for 18 per cent of the total wall area of nonresidential buildings erected in the U.S. Tens of thousands of tons of aluminum were also used in barges, truck trailers, railroad cars and automobiles.

For underdeveloped countries an important role for aluminum is in replacing copper as a carrier of electric current. Even though aluminum is not so good a conductor as copper, its use can often be justified on other grounds. For example, in high-tension power lines aluminum, because it is lighter than copper, requires fewer supporting towers, with a consequent saving in steel. Asia is particularly deficient in copper ores but has at least 45 million tons of proved reserves of bauxite, the chief aluminum ore, and more can doubtless be found. As recently as 1960 only three Asian countries produced aluminum: China (both mainland and Taiwan), India and Japan. Their total output, about 10 per cent of that of the U.S. and Canada combined, was not insignificant. Indonesia and the Philippines are now planning to build aluminum refineries. The principal obstacle to expanding production is finding adequate electric power.

The depletion of mineral resources, both in the U.S. and elsewhere, became a matter of serious concern immediately after World War II. Some pessimists felt that most of the world's high-grade ore deposits had already been discovered and that the minerals industry must be resigned to working ores of lower and lower grade. With the depletion of high-grade iron-ore deposits in the Lake Superior district, which has traditionally supplied more than 75 per cent of the U.S. total, steel companies began an intensive and costly program to mine the lower-grade taconite and jaspilite ores, and to produce from them concentrated pellets suitable for the blast furnace. The cost of this program to date has been more than $1 billion, and in 1961 taconite and jaspilite pellets accounted for about 12 per cent of the iron in U.S. pig production.

But while the taconite program was still in its early stages some of the world's largest high-grade deposits of iron were being found in Labrador, Ontario, Venezuela, Brazil, Liberia and other parts of West Africa. The iron-ore content of Cerro Bolivar in Venezuela has been placed at 500 million tons, or about 25 per cent of the ore thus far extracted and shipped directly from the great Mesabi Range of Minnesota. In the past few years another extensive deposit of iron ore has been found in the Hamersley Range of northwestern Australia.

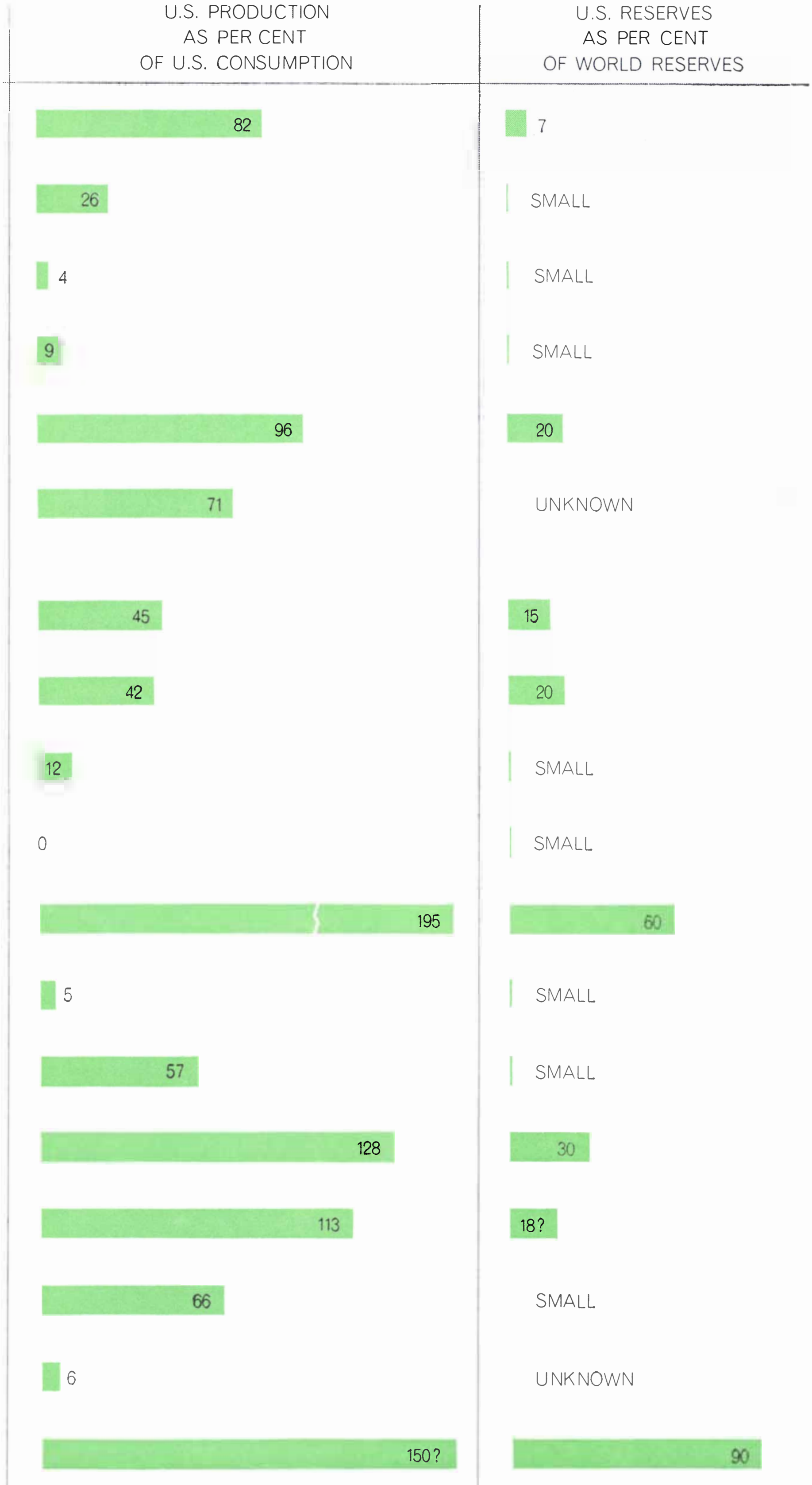
The result of all these new finds has been to raise the known world reserves of iron ore to more than 132 billion tons of iron recoverable by present methods, a minimum increase of 60 per cent over estimated reserves in 1955.



RISING USE OF METALS is shown by charts comparing U.S. consumption (*black*) and world production (*color*) of nine metals or ores in heaviest metallurgical demand. Figures are thousands of short tons. Growth in bauxite demand is most spectacular.

METAL, ORE, OR MINERAL	LEADING WORLD PRODUCER (PER CENT OF WORLD TOTAL)	SITE OF BIGGEST RESERVE (PER CENT OF WORLD TOTAL)	U.S. CONSUMPTION AS PER CENT OF WORLD PRODUCTION
IRON ORE	20 U.S.S.R.	? BRAZIL, INDIA AND U.S.S.R.	21
BAUXITE	23 JAMAICA	35 AUSTRALIA	29
MANGANESE	43 U.S.S.R.	65 U.S.S.R.	14
CHROMITE	20 U.S.S.R.	75 REPUBLIC OF SOUTH AFRICA	25
COPPER	23 U.S.	22 CHILE	26
TITANIUM	ILMENITE 35? U.S.; RUTILE 87 AUSTRALIA	? U.S., CANADA, REPUBLIC OF SOUTH AFRICA	48
ZINC	12 U.S.	22 CANADA	28
LEAD	13 AUSTRALIA	25 AUSTRALIA	25
NICKEL	60 CANADA	40 CUBA; 40 CANADA	31
TIN	29 MALAYA	70 MALAYA	29
MOLYBDENUM	76 U.S.	60 U.S.	47
ANTIMONY	31 CHINA	90? CHINA	21
TUNGSTEN	32 CHINA	? CHINA	18
PHOSPHATE ROCK	43 U.S.	45 MOROCCO (FRENCH)	33
SULFUR	62 U.S.	? UNKNOWN	33
POTASSIUM COMPOUNDS	33 U.S.	? GERMANY	40
ASBESTOS	45 CANADA	? CANADA	30
BORATES	95 U.S.	90 U.S.	65

U.S. DEPENDENCE ON WORLD RESOURCES is evident from this table of mineral production and reserves, based on data from the U.S. Geological Survey. The U.S. is the leading mine producer of only four of the 14 metals or metallic ores at the top of the list (if ilmenite and rutile are counted separately). It is, however, the leading producer of four of the last five minerals at the bottom. For the list as a whole the U.S. consumes about 30 per cent of world production and produces about 60 per cent of U.S.



consumption. There are great uncertainties with regard to reserves, hence the data in the third and sixth columns must be treated with caution. Ores vary greatly in type, quality, accessibility and ease of refining. For example, a deposit of copper ore that would be considered an industrial reserve in Arizona would not be considered one if it were in Alaska.

Nobody can say today which country has the biggest single reserve of iron ore because economics and technology related to local factors determine whether material of a given grade is or is not ore. India has perhaps 21 billion tons; Brazil may have even more, and Canada and West Africa are not far behind. The U.S.S.R. has recently disclosed that its iron-ore resources are slightly more than 30 billion tons. It is clear, in short, that the world's total known resources of iron ore are many times greater than the world's possible needs through the year 2000.

The iron-ore discoveries in Ontario and Venezuela are outstanding instances of what has been achieved with new exploration techniques using air-borne instruments. These instruments include, in addition to the aerial camera, the air-borne magnetometer, the scintillometer and electromagnetic induction devices. The air-borne magnetometer measures anomalies, or irregularities, in the earth's magnetic flux attributable to buried mineral deposits. The scintillometer measures the emanations from radioactive ores and is also widely used in oil prospecting because the radiation flux above oil pools is often less than that in the normal earth background. The electromagnetic-induction technique employs the principle used by wartime mine detectors.

The Marmora iron deposit in Ontario was first spotted by air-borne magnetometer. Cerro Bolivar was identified as a promising site from inspection of aerial photographs and the presence of ore was confirmed by air-borne magnetometer. The big iron deposit of the Nimba Mountains in Liberia was located by air-borne magnetometer. And in the U.S., which had already been prospected intensively for iron ore, the air-borne magnetometer has helped to locate large deposits on Pea Ridge in Missouri and near Morgantown, Pa.

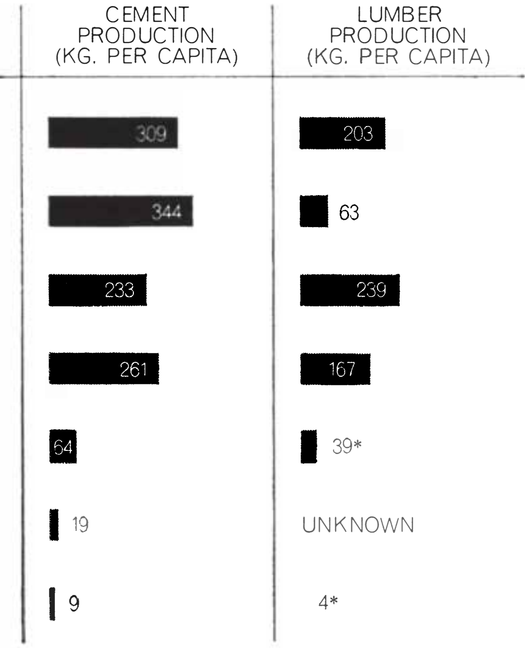
The air-borne magnetometer can also indicate the possible location of minerals other than iron. The presence of nonmagnetic ores, such as copper and bauxite, may be signaled by a magnetic reading that is below the normal background level. Thus the air-borne magnetometer was responsible for locating the New Hosko copper deposit in Quebec, a lead deposit in southeastern Missouri and large bauxite deposits in Surinam and Venezuela.

Electromagnetic surveying from the air has led to the discovery of a new

NATIONS	1961 G.N.P. (DOLLARS PER CAPITA)	ENERGY CONSUMPTION (KG. H.C.E. PER CAPITA)	STEEL CONSUMPTION (KG. PER CAPITA)	FERTILIZER PRODUCTION (KG. PER CAPITA)	SULFURIC ACID PRODUCTION (KG. PER CAPITA)
U.S.	2,823	8,042	488	39.9	88.1
WESTERN EUROPE	1,097	2,699	299	31.8	46.7
U.S.S.R.	816	2,921	314	11	26.3
JAPAN	502	1,298	274	17.4	49.8
BRAZIL	186	345	37	3.4*	1.9*
INDIA	80	150	12	.8*	.9
NIGERIA	82	47	5.1	UNKNOWN	UNKNOWN

RELATION OF G.N.P. to consumption of energy and five basic materials, based on UN statistics, is shown for the U.S., western Europe (the O.E.C.D. nations), the U.S.S.R., Japan, Brazil, India and Nigeria. U.S. bars for income, energy consumption and steel consumption have arbitrarily been made the same length. Consumption of materials other than steel have been scaled to the U.S. bar for steel. Asterisks indicate that values are not for 1961 but for the most recent year available. Fertilizer consumption is the sum of three common types, phosphatic, nitrogenous and potash, which are used in roughly equal amounts. Although figures for

MAJOR MINERAL DISCOVERIES have been made in every continent except Antarctica since the end of World War II. Those listed here represent a fair selection, except for discoveries in the Communist countries, where information is scanty. Many of the



sulfuric acid, cement and lumber refer to production, they reflect consumption quite closely. Lumber figures, which have been converted from a volume measure, show least correlation with G.N.P. per capita.

Ag	SILVER	Li	LITHIUM
Al	BAUXITE	Mn	MANGANESE
Asb.	ASBESTOS	Mo	MOLYBDENUM
Au	GOLD	Nb	COLUMBITE
B	BORON	Ni	NICKEL
Be	BERYLLIUM	Pb	LEAD
Cd	CADMIUM	Phos.	PHOSPHATES
Co	COBALT	S	SULFUR
Cr	CHROME	Ti	TITANIUM
Cu	COPPER	U	URANIUM
Fe	IRON ORE	V	VANADIUM
Fluor	FLUOR SPAR	W	TUNGSTEN
Ge	GERMANIUM	Zn	ZINC
K	POTASH		

new finds have been made with the help of new air-borne geophysical instruments, such as the magnetometer. The aerial methods are ideally suited for prospecting in remote regions.

copper deposit at Mattagami in Ontario and a huge new nickel deposit in Manitoba. The nickel deposit, known as the Thompson ore body, may be the most important find that has been made with the new air-borne geophysical methods.

Another new prospecting tool of growing importance is geochemistry. In this method sensitive chemical indicators are used to find traces of sought-for metals in soils, streams and vegetation. These trace materials are then used as clues for locating a hidden ore body.

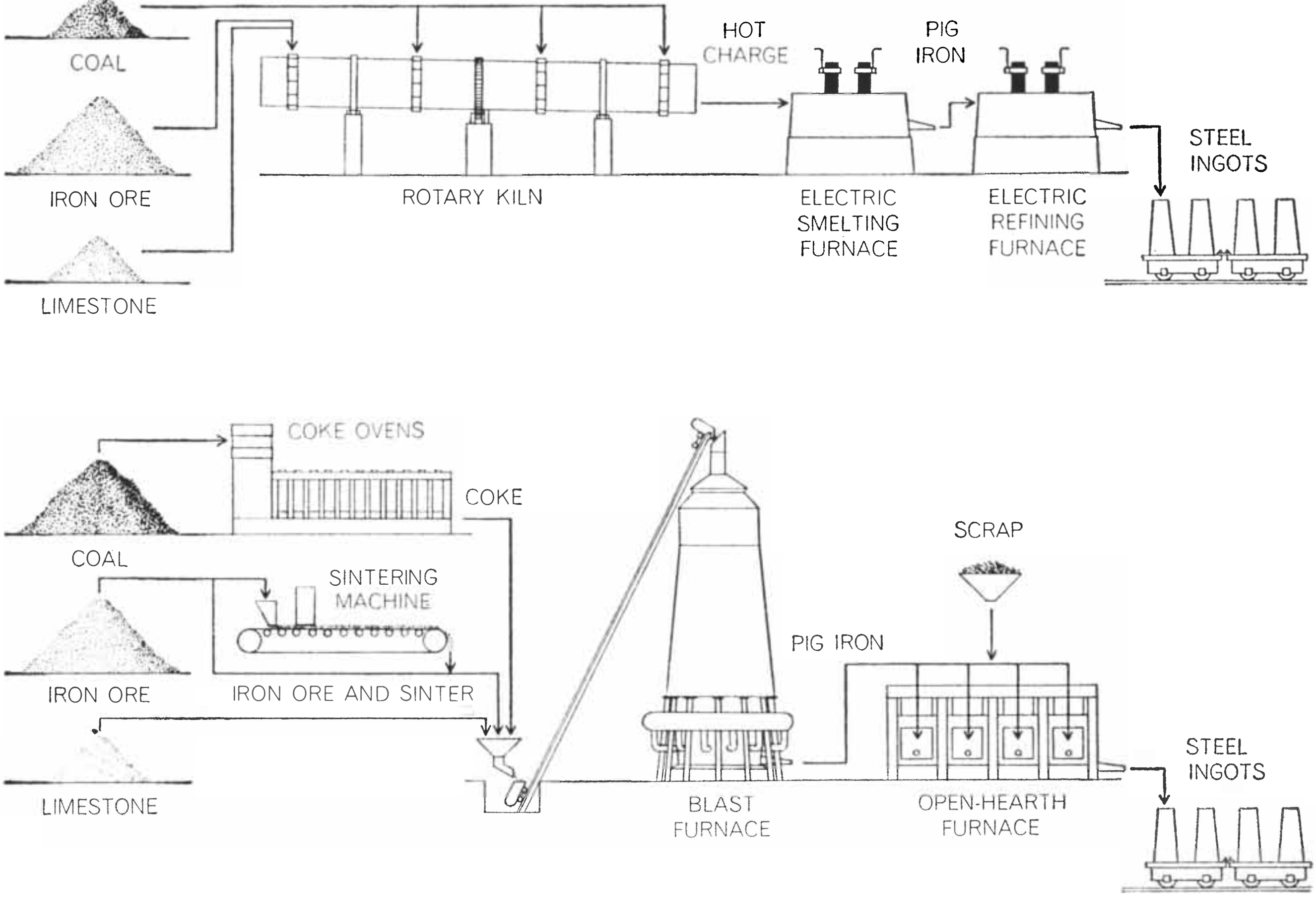
Air-borne geophysical methods are particularly well suited to underdeveloped regions where territories are large, ground surveying is difficult and topographic maps are often nonexistent. In the past 10 years millions of square kilometers of Latin America, Africa and Asia have been mapped photographically from the air and have been surveyed by one or more of the air-borne geophysical instruments. Although costs are high, they are orders of magnitude less than what it would cost to do the same job from the ground. An air-borne survey combining the magnetometer and scintillometer costs about $7 per linear kilometer, or about $6,000 per 1,000 square kilometers. If electromagnetic induction is added, the total cost is $15,000 to $20,000 for the same area. Obviously it will take many years and many millions of dollars to survey the world in reasonable detail. Today only 65 per cent of the U.S. has been topographically mapped and only 20 per cent has been mapped geologically.

Even after an underdeveloped country (or a developed one, for that matter) has discovered a deposit of ore worth mining, the job has only begun. Unless the ore is exceptionally rich, accessible and convenient to transportation, a heavy capital investment is usually required to dig it out, process it and move it to market. Usually technical and financial assistance from one of the developed nations will have to be sought. And gauging the proper capital investment may be difficult. It is often a mistake, for example, to mechanize a mine in an underdeveloped land as fully as a comparable mine in a more advanced nation. Frequently the capital needed for high mechanization could be better spent elsewhere in the economy. Since most underdeveloped lands have a labor surplus it may be better to employ many workers at a modest wage than to employ a few skilled machine operators at a wage disproportionate to that prevailing in other fields.

Another difficult question is whether to sell the crude ore as it is mined or to beneficiate it and thereby obtain a higher market price and lower freight rates. Again, the cost of a beneficiation plant must be weighed against other demands for capital. Whatever the decision, a poor country lucky enough to find a sizable ore deposit must recognize that it has found an important capital asset. To hoard it and leave it unmined would be folly. Last spring at Geneva, Harrison S. Brown of the California Institute of Technology spoke on this point at the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas. Funds derived from the sale of mineral resources, Brown said, "should be converted to other forms of capital, which are of equal or greater value, particularly into basic industrial installations and into power, transportation and communication systems. The conversion of high-grade resource assets into current living expenses by means of export can lead to tragedy."

If an underdeveloped country wishes to convert a portion of its ore into finished metal, it faces another level of capital cost and technological difficulty. Refining requires supplementary materials, which may or may not be readily available. For example, iron production requires limestone and metallurgical coal that can be converted to coke. Throughout most of Africa, Latin America and Asia such coal is scarce. In fact, it can be set down as a rule that no nation has yet built an advanced economy without a cheap and ready supply of metallurgical coal.

The problem of producing iron without high-grade coal is one to which the Western world, with all its vaunted technology, cannot supply a ready-made solution. The problem is being worked on, however, and a number of processes look promising. There are two general approaches. One is to convert low-rank coals into a coke with the properties needed in a blast furnace. The



TWO STEELMAKING METHODS are compared in these diagrams. In the conventional process (*bottom*) high-grade metallurgical coal is converted to coke and fed to a blast furnace along with limestone and iron ore. At least a portion of the ore must be agglomerated into clinkers before use. In the Strategic-Udy process (*top*) iron-ore "fines," low-rank coal and limestone are fed to a rotary kiln, which replaces the blast furnace. Final conversion to pig iron, and ultimately to steel, occurs in electric furnaces.

other is to reduce the iron ore directly with low-rank coal, oil or natural gas by a technique not requiring a blast furnace.

The FMC Corporation and the United States Steel Corporation have jointly developed a process that converts low-rank coals to blast-furnace coke. In this process the coal is crushed and partially oxidized in a "fluidized bed": a reaction chamber in which fine particles behave somewhat like a fluid. After moisture and volatile hydrocarbons have been driven off, the particles are pressed into briquets, which are further treated to yield a product with properties almost identical with those of blast-furnace coke.

A number of direct-reduction processes bypassing the blast furnace have been studied. One of them, called the Strategic-Udy process, is being tried on a pilot-plant scale at the Orinoco Steel Plant of Corporacion Venezolana de Guayana (CVG). The process, conceived by Marvin Udy, has been developed jointly by the Strategic Materials Corporation and the Koppers Company, Inc. In the process low-rank Venezuelan coal, iron ore and fluxing materials are fed into a giant rotary kiln, where partial reduction of the iron ore takes place [*see illustration above*]. The kiln product is transferred directly to an electric furnace, which completes the reduction and produces pig iron.

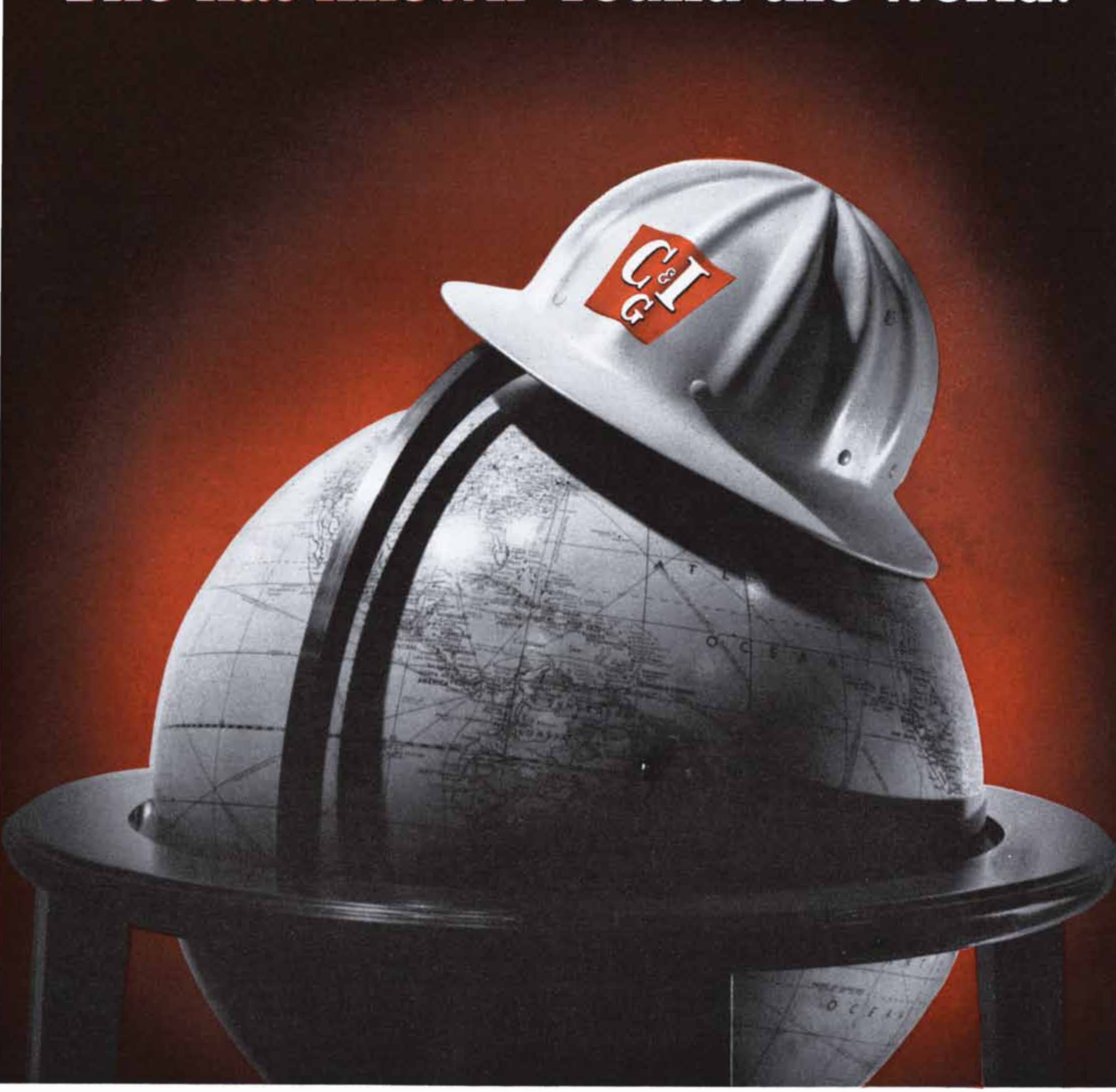
This article has mentioned only a few of the minerals essential to a vigorous economy. Of the 65 metallic elements in the periodic table the U.S. uses 30 in substantial commercial quantities. It uses 10 of them in amounts exceeding 50,000 tons a year and another 10 or 12 in amounts exceeding 1,000 tons a year. Only one of them, magnesium, which is extracted from sea water and other brines, is in virtually unlimited supply. In addition to metals the U.S. consumes more than 20 other mineral substances (e.g., salts of various kinds, sulfur, bromine, chlorine, iodine, phosphate rock, asbestos, gypsum, talc and mica) in quantities exceeding 1,000 tons a year. Of these perhaps half are quite abundant and create few problems either for the U.S. or for most underdeveloped countries.

In spite of the accelerating drain on the world's mineral resources it is now becoming recognized that they will never really be exhausted. Just as advances in technology have made it possible to exploit today ores so lean they would have been considered worthless only 50 years ago, new advances will make it possible to extract metals from still leaner ores in the future. In effect, technology keeps creating new resources. Meanwhile new geophysical and geochemical tools have uncovered a remarkable number of unexpectedly rich mineral deposits, which the world, if it is wise, can use as capital assets to advance the well-being of all.

AUTHOR'S NOTE

Valuable assistance in the preparation of this article was given by staff members of the U.S. Geological Survey and U.S. Bureau of Mines. Its publication has been authorized by the Director of the Geological Survey.

The hat known 'round the world!



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ace vehicles / AICBM defense equipment / Air d
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ir defense weapons / Air traffic control / Air/Air
radio communication equipment / Aircraft instru
ments / Air/Ground operating consoles / Air/Sp
aceborne surveillance control systems / Air-to-
air identification systems / Air-to-air missiles / A
ir-to-air search radar / Air-to-ground ranging rad
ar / Air-to-surface missiles / Analog devices / A
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jam equipment / Anti-satellite defense equipme
nt / Approach visibility equipment / Artillery tac
tical combat equipment ASW equipment / Audio
test facilities / Audio-visual systems / Backward-
wave oscillators / Ballistic missile decoys / Bal
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ters / Bandpass crystal filters / Benches, Test / Bioinstru
mentation packages / Boost intercept ballistic missile sys
tems / Boules / Bridge consoles (ship control) / Broadband
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C-band backward-wave oscillators / C-band forward-wave
amplifiers / Celestial guidance units / Celestial navigation
systems / Ceramic dielectric materials / Ceramic products
Ceramic rectifiers Do4-Do5 / Character display equipment
Checkout equipment / Choppers, Solid state / Circuit bo
ards / Circular connectors / Circulators, Microwave / Clos
ed-loop radar test sets / Coaxial cables / Coaxial circula
tors / Coders / Coherent mobile target indicator / Collision
warning and avoidance systems / Colored displ
ay equipment / Combat information center cons
oles / Combat surveillance equipment / Comma
nd and data handling equipment / Command an
d intelligence information processing equipment
Command systems, Satellite / Commercial com
munications satellites systems / Communicatio
ns systems and equipment / Comparators, Soli
d state / Computer-programmed test equipment
Computers and systems Contour mapping radar
Countermeasures equipment / Counters, Digital
Counters, Pulse video / Cryogenic devices / Cryo
stats / Cryptographers Defense systems / Delay
lines / Depth control equipment for submarines
Detection devices and systems / Dielectric amp
lifiers / Differential amplifiers / Digitizers, Voice
Direct readout display equipment / Direct-viewi
ng storage tubes / Domes / Doped germanium
detectors / Doppler navigation sets / Drone air

craft electronics / Droppable beacons / Dropp
able intelligence sensors / Drum memory devi
ces / Drum-programmed test equipment / Echo
ranging sonar / Echo sounding sonar / Edgeb
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romagnetic equipment Electromechanical devi
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er antennas / Filter circuits testers / Filters / Fir
e control equipment / Fire detection equipment
Flexible waveguides / Flight control, Automatic
Flight safety equipment Foam plastics / Formed
sheet metal printed circuit connectors / Fuzes
Gamma linear electron accelerators / Gates /G
CI landing systems / Gear boxes, Precision / Ge
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power supplies / Hit indicators, Radar / Homi
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play equipment / Hot and cold gas control sys
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ship control / Hyperbolic short range navigation
systems / Hypersonic space systems / ICBM s
urveillance, Infrared / IFF identification equipment / IFF
navigation systems / Image tube infrared sensitive elem
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dustrial systems, VIDEOSONIC* / Industrial training pro
grams, VIDEOSONIC* / Inertial guidance units / Inertial
navigation systems / Infantry tactical weapons / Infrared
devices and equipment / Infrared systems / Instrumenta
tion / Integrators / Intelligence systems / Interceptor fire
control systems / Intervalometer computers / Joule-
Thomson cryostats / Keyers / Ku-band amplifiers
and oscillators / Landing systems, Aircraft

Landing vehicles, Lunar / Large-scale gene
purpose computers / Lasers / Launch contro
listic missile / L-C filters / Lenses / Light beam
ys / Linear amplifiers / Liquid propulsion system
id transfer systems / Logistic information pro
equipment / Logistic lunar and planetary syste
ng-range navigation systems / Low-altitude air c
Low-frequency equipment / Machine tool contr
puters / Machine tool controls / Magnetic device
gnetic materials / Maintenance equipment / Ma
nce handbooks / Manipulators, Remote
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personic space systems / Map displays
ment / Mapping antennas / Mapping ra
arine equipment / Marker beacons / M
mplifiers / Masers / Materials, Non-meta
echanical assemblies, Optical product
dium frequency equipment / Medium-
ontrol and guidance sy
stems / Memo-Corder*
storage units / Memory
heads, Magnetic / ME
MO-SCOPE® / MEMOTRON® tubes / Meteo
systems / Meteorological equipment / Meteo
al satellites / Meters / Microminiature connec
icrominiature digital computers / Microminia
lay receptacle connectors / MICROSEAL*
MICROSEAL* transistors / Microwave device
course intercept ballistic missile systems /
communication satellite systems / Military d
dling equipment / Military information comp
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Mission control, Space vehicles / Mixer
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dicators / Moving target equipment / M
ers, Digital / Multimode star tracker disp
ipment / Multiple-base microwave lens
second switching silicon rectifiers / Nav
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Education for Development

Capital investments can be made not only in industry but also in people. This article compares problems of education in four underdeveloped countries: Nyasaland, Colombia, China and Egypt

by Frederick Harbison

The progress of a nation depends first and foremost on the progress of its people. Unless it develops their spirit and human potentialities it cannot develop much else—materially, economically, politically or culturally. The basic problem of most of the underdeveloped countries is not a poverty of natural resources but the underdevelopment of their human resources. Hence their first task must be to build up their human capital. To put it in more human terms, that means improving the education, skills and hopefulness, and thus the mental and physical health, of their men, women and children.

The way to start seems obvious and quite uncomplicated: build schools and launch a massive program of primary and secondary education and technical training. But the problem is not really that simple. These countries are not in a position to adopt any such crash program. Their limited funds for investment in education must be placed where they will do the most good. Moreover, the shotgun approach may create more difficulties than it solves; in some countries the training of more engineers, for example, may produce nothing but trouble. In any country, developed or underdeveloped, education can become socially malignant if its people do not have a chance and incentives to use it.

Each country therefore needs to think out a strategy for the education and development of its human resources. The strategy should be based on the character and traditions of its people, the stage of the country's development and the opportunities available for its advancement. This conclusion has been strongly impressed on me by a comprehensive study of 75 countries I have made in collaboration with Charles A. Myers of the Massachusetts Institute of Technology, which will shortly be published as a book under the title *Education, Manpower and Economic Growth.*

I will present in this article some of the main ideas that have come out of the study, illustrating them with brief descriptions of the situations in four countries that represent different stages of development, with problems typical of each stage. The four countries are Nyasaland, Colombia, China and Egypt.

Nyasaland is a small country in east central Africa that is fairly representative of a number of the newly emerging African states (Tanganyika, Kenya, Nigeria, Mali, Gabon, Northern Rhodesia). It ranks as one of the least developed countries. It has been exploited for three cash crops—tea, tobacco and cotton—grown on large plantations that until now were owned and managed mainly by white settlers. Most of the country's three million people are small farmers scratching out a meager living; the estimated per capita income is only about $60 a year. Modern industrialization is far beyond the present reach of the country and therefore its economic growth must depend largely on the development of its agriculture.

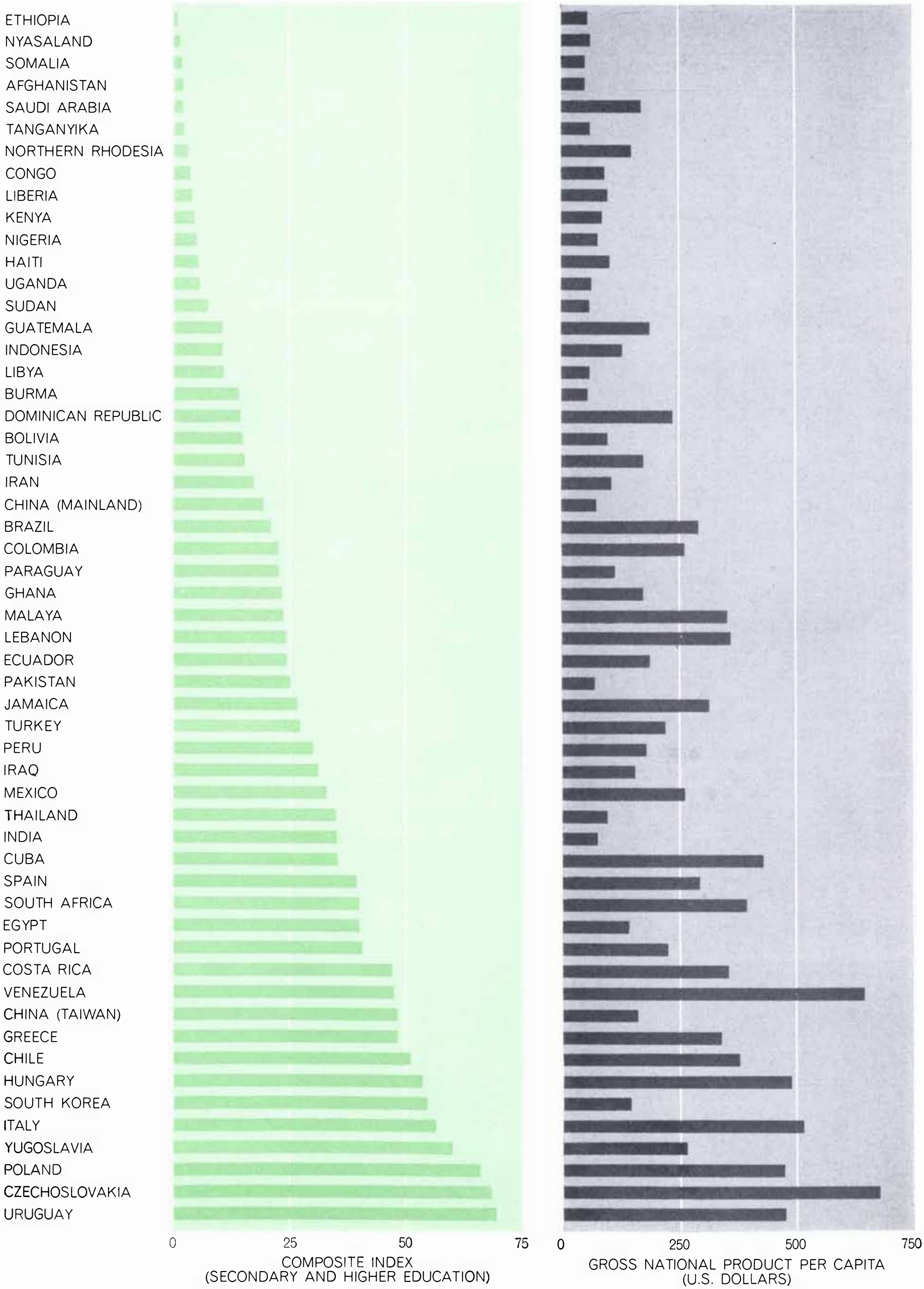
Nyasaland now has its own government and legislature, but it still must depend on foreigners to fill about 90 per cent of the high-level jobs in government and private occupations that require people with at least a secondary school education. In the entire country there are only a handful of native doctors, one lawyer, one engineer and not a single native stenographer. The country has no scientists of its own. No more than about 400 Nyasas have completed secondary school and only about 50 have had any university education—all, of course, outside the country.

Although about 40 per cent of the children of elementary school age attend school, the dropout rate is very high: of 33,000 who started school in 1951, only 620 went as far as 10 years of schooling. Most of the country's elementary school teachers are unqualified, having had no more than a primary education themselves, and in the secondary schools only about a third of the qualified teachers are African.

Naturally the Nyasaland government has an acute desire to make the country truly independent by training Africans for the high-level jobs in government, business and education that now have to be turned over to non-Africans. Since this will be at best a slow process, it appears to be the better part of discretion for the government to keep the foreigners as long as possible and enlist their co-operation in training their eventual replacements. And in the replacement program the government's best prospect is to upgrade and train Africans on the job—within the government, business establishments, plantations, schools and other institutions in which it needs skilled people.

The Nyasas who take over these jobs naturally want to be paid the same salaries as the foreigners they replace. This is difficult for the government, because it faces extraordinarily high expenses for the educational and other new

HUMAN-RESOURCE DEVELOPMENT in 55 nations is indicated in chart at left on opposite page. Arbitrary index, devised by author and Charles A. Myers of Massachusetts Institute of Technology, reflects enrollment ratio of relevant age groups in secondary and higher education. Gray bars at right side of chart show gross national product. Harbison and Myers found close correlation between education and national product, although other factors such as nation's resources and markets also influence G.N.P.


ETHIOPIA
NYASALAND
SOMALIA
AFGHANISTAN
SAUDI ARABIA
TANGANYIKA
NORTHERN RHODESIA
CONGO
LIBERIA
KENYA
NIGERIA
HAITI
UGANDA
SUDAN
GUATEMALA
INDONESIA
LIBYA
BURMA
DOMINICAN REPUBLIC
BOLIVIA
TUNISIA
IRAN
CHINA (MAINLAND)
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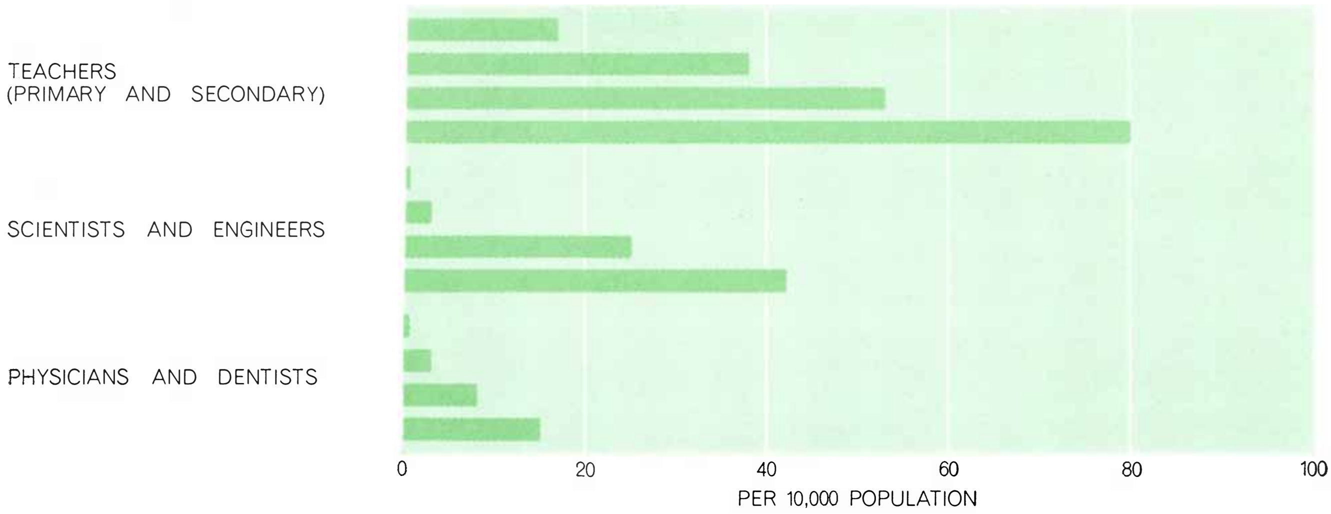
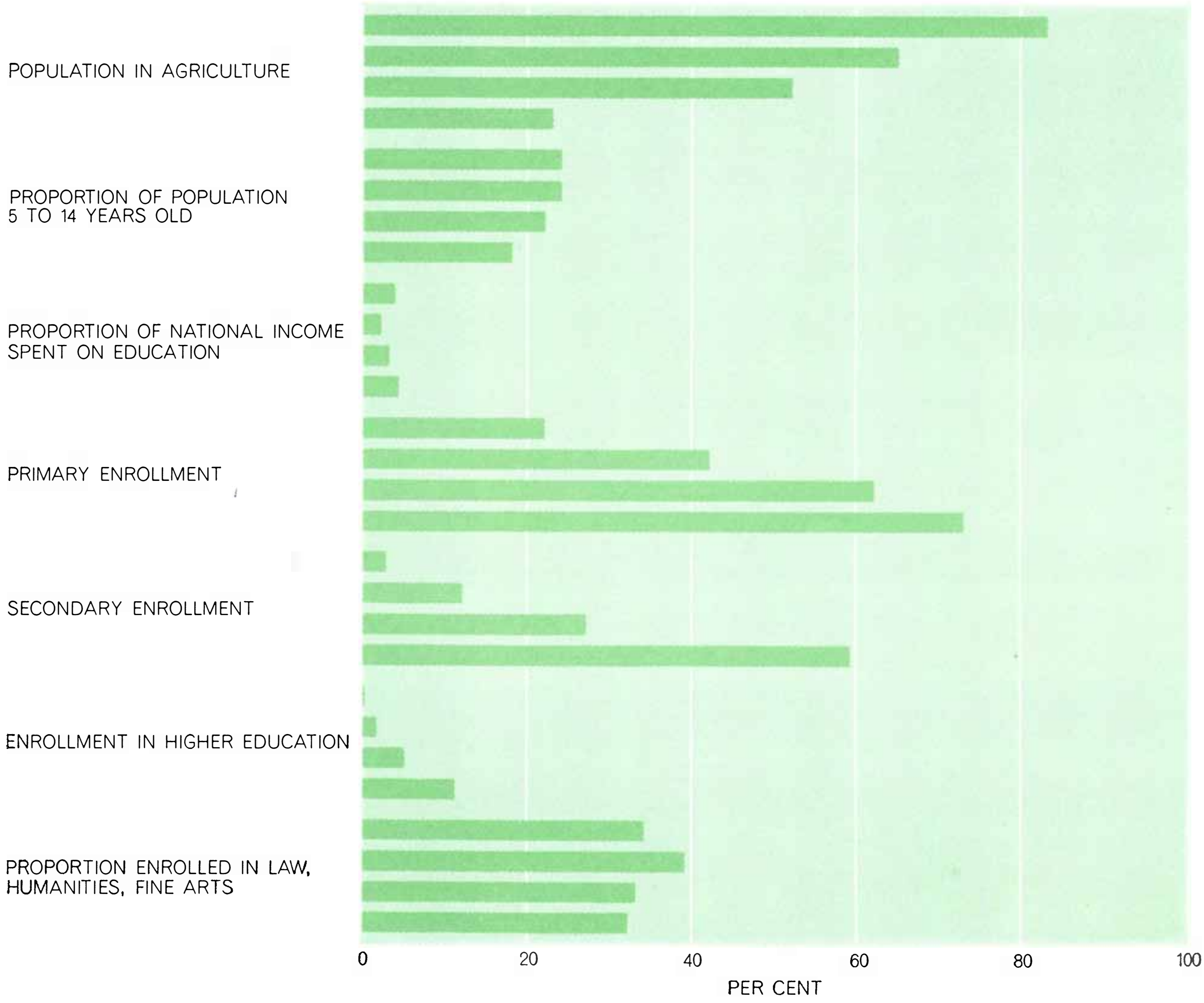
TURKEY
PERU
IRAQ
MEXICO
THAILAND
INDIA
CUBA
SPAIN
SOUTH AFRICA
EGYPT
PORTUGAL
COSTA RICA
VENEZUELA
CHINA (TAIWAN)
GREECE
CHILE
HUNGARY
SOUTH KOREA
ITALY
YUGOSLAVIA
POLAND
CZECHOSLOVAKIA
URUGUAY
0
25
50
75
COMPOSITE INDEX
(SECONDARY AND HIGHER EDUCATION)
0
250
500
750
GROSS NATIONAL PRODUCT PER CAPITA
(U.S. DOLLARS)



PROPORTION OF PROFESSIONALS in a population is an indication of level of human-resource development. Harbison and Myers grouped 75 countries into four levels of educational development: I, underdeveloped; II, partially developed; III, semiadvanced; IV, advanced. The chart shows the different proportion of professional people at each level. In each of the three job categories, top bar represents the Level I countries, other bars Levels II–IV. Filling gap often requires use of foreign professionals.



WIDE DISPARITY between the underdeveloped and the advanced nations appears in other indicators. Again in each group of bars Level I countries are at top and Level IV countries at bottom. Proportions in primary, secondary and higher education are per cents of the relevant age groups; proportion in "Law, humanities and fine arts" is per cent of the total enrollment in higher education.

services it must organize. Yet it must establish a rational system of incentives for its own people, making compensation commensurate with the importance of the job rather than with family status, political connections or other considerations that have dictated payment in the past. Without a proper system of incentives for ability and performance the investment in education will be wasted from the standpoint of contributing to the country's progress.

In building its educational system for the next two decades Nyasaland faces some hard choices. How much should it invest in elementary education and how much in secondary? If it is to make headway as a nation, it needs a literate people and a stronger wellspring of schooled youngsters coming up to build its future. On the other hand, it must have as soon as possible a core of educated Nyasas who can serve as the leaders of its economic and political development when the foreigners leave. Necessarily, then, for the next 10 years it should give the highest priority to secondary school education, which today enrolls only 1.5 per cent of Nyasaland's children of high school age.

Should it concentrate on general education in the secondary schools or on vocational and technical training? Again the decision is difficult but unavoidable: general education is clearly indicated. Vocational training is four to five times more expensive per student; there are no schoolteachers competent to give it; it is difficult to forecast exactly what vocational skills the new nation will need most, and such training can be given more efficiently on the job.

In the case of higher education the choice is also tricky but, for good and understandable reasons, it is less difficult. For some time to come it would be cheaper for Nyasaland to send students to universities abroad and pay their tuition than to build a university. As a matter of national prestige, however, and to retain its ablest youths instead of running the danger of losing them permanently, it is important to Nyasaland to have its own university. Consequently the present government has committed itself to building an institution of higher education. It will be able to focus on the kinds of higher learning the nation needs most and to stand as a symbol and leader of its culture.

Although elementary schooling must take a back seat in financing for the next decade, it need not languish. The main emphasis there should be on improving the quality of teaching and seeing that those pupils who do enter school go through to the end of the primary grades. A beginning can also be made in introducing modern tools of education, such as appropriate local textbooks and study materials, visual aids, radio, television and other devices. And once the immediate necessities of secondary and higher education are taken care of Nyasaland should move on to provide elementary schooling for all its children.

Last but not least, Nyasaland and all other countries in its situation have a great need and opportunity for adult education. Formal classes in basic education for the country's men and women could go a long way toward making up for the deficiencies of their early schooling and raising the national literacy. In addition to this the adult education program should offer extension courses in agriculture, health, child care, home building and other subjects that will be an immediate contribution to the improvement of the lives of the people.

Colombia, usually classed as an underdeveloped country, is fairly well advanced compared with Nyasaland. On our scale of measurement of human resources it stands about midway between primitive Nyasaland and the developed countries of western Europe. We classify it as a "partly developed" country, along with some other countries in Latin America and nations such as Turkey, Iran, Pakistan and Ghana.

Colombia has 13.6 per cent of its high-school-age youngsters enrolled in secondary schools, compared with 1.5 per cent in Nyasaland; it has 25 universities, with 1.8 per cent of its college-age population enrolled; its gross national product per capita is about $260, against Nyasaland's $60. Colombia is still primarily agricultural, with 54 per cent of its people engaged in farming, but it has rapidly growing industries and its economic growth in the near future will depend mainly on further industrialization.

For top-level jobs Colombia has all the educated manpower it needs, except in engineering and science. But it is very short of skilled people at the technical and subprofessional levels: technicians, foremen, assistants in agricultural research and guidance, teachers, nurses and so on.

Colombia's system of higher education is unbalanced, offering as it does many courses of study in the humanities and law but few in science and engineering. Moreover, the quality of its universities is low: they are poorly equipped with libraries and laboratories and rely almost entirely on ill-trained, part-time teachers. The emphasis on the humanities and law at the expense of the sciences is an expression of the sacrifice of quality for quantity; it costs only about a sixth to a fourth as much to give the students law courses as it does to teach them engineering or science. Thus Colombia finds (as countries starting their own universities also do) that it can accommodate the largest number of students per dollar by skimping on science and technology.

Even more inadequate is the training of technicians and subprofessional workers. Compared with 23,000 students in the universities, Colombia in 1962 had only 1,150 in technical institutes; it is turning out more engineers than technicians, although the proportion should be the other way around. In the developing countries even more markedly than in advanced ones, young people prefer college to a technical school by a wide margin because it means higher prestige and better pay when they graduate.

Oddly enough, although Colombia supports 25 universities and offers a university education at a very low tuition, it shows much less interest in secondary education. There are few public secondary schools; most Colombians who want to go to college must prepare at a private school. Enrollments in the private preparatory schools are limited, and less than 5 per cent of Colombian families can afford their fees. Thus secondary education in Colombia is a bottleneck allowing only the children of the rich to go on to universities, instead of being a door leading to opportunity for the development of the country's able youth.

Colombia's primary schooling also is underdeveloped. Considerable money has been spent in building schools, but the curriculum is poorly planned, the teaching substandard and the dropout rate high. By the third grade a majority of the pupils have quit, and only about an eighth of the children who enter the first grade go all the way through the five years of elementary school.

The strongest element in Colombia's educational establishment is a system of training factory workers that is financed by a tax on employers and controlled by their organizations. Outstanding is the work of the National Service of Apprenticeship (SENA). It has built and equipped modern vocational training centers, employs expert instructors and not only trains apprentices but also gives in-service instruction of many kinds to workers in the factories.

In Colombia as in Nyasaland the greatest immediate need, from the standpoint of developing the country's human resources, is to expand and reform the secondary school system. Along with providing free secondary education for all those who are qualified to take advantage of it, Colombia should develop the agricultural, scientific and engineering faculties of its universities. It should improve the quality of the student body and of the teaching in the universities rather than merely enroll as many students as possible. This shift in emphasis would be politically unpopular, but a proper system of incentives could make it palatable. The government will need to take the lead in improving the relative pay and status of scientists, engineers and workers in other professions where there are critical shortages. The same strategy should be applied to the recruitment of people into the technical and subprofessional occupations. These jobs probably could be made sufficiently inviting if the pay were comparable to that received by general college graduates and if the subprofessionals were given opportunities for promotion to professional posts by taking spare-time university courses.

China, our third illustration, also is a partly developed country. Its educational enrollment ratios are much like Colombia's: it enrolls about 40 per cent of the population in elementary schools, 14 per cent in secondary schools and 1 per cent in higher education. But there the resemblance ends. The mere statistics in this case give little indication of the size and intensity of China's educational effort and progress.

The Communist government of mainland China has organized an all-out program to train and mobilize manpower. In the nine years between 1950 and 1959 China increased its enrollment in elementary schools threefold, in secondary schools ninefold and in higher education sixfold. Today the country has 100 million students in school—more than the combined totals of the U.S. and the U.S.S.R. It is turning out three-fourths as many engineers as the U.S. and ranks third in the world in this respect, after the U.S.S.R. and the U.S. in that order. Perhaps the most remarkable statistic, giving the measure of China's effort, is that, of the country's present 250,000 scientists and engineers, 90 per cent have been trained since the Communist government came to power in 1949.

Once a land of philosophers, artists and peasants, China is being transformed into a nation of technocrats. Its Confucian sages have been replaced by scientists, engineers and industrial managers. Its educational program is geared mainly to industrialization. In its universities the humanities have been downgraded, and more than 55 per cent of the students are enrolled in science and technology, compared with 25 per cent in most other countries. China seeks to gain standing as a world power through rapid industrialization, and as its first objective it aims to reach Britain's level in industrial production by 1967.

China has a long way to go economically. Its gross national product per capita is probably no more than $75. The strategy of its officials and planners in education seems to be to try to do everything at once—to attack all the expedient approaches and above all to emphasize action. As recently described by a Chinese Communist newspaper, the educational program includes schools operated not only by the state but also by all kinds of agencies including factories, mines and "street organizations." The Chinese people are studying full time and part time, in school and at home, in tuition courses and free ones. The quality of most of their education, including much of that in the universities, is questionable, and so is the strategy of an onward rush by any and every possible means. It may result in crippling steps backward as well as leaps ahead.

Egypt, our fourth example, is an odd case: except in certain specialties, it has a larger number of highly skilled people than it can use. The reason I have chosen to discuss its situation is that Egypt represents certain countries (among them India) that seem to be spending more effort in producing high-level skills than is justified by their present stage of development.

By most criteria Egypt is an underdeveloped country—limited in resources, mainly a nation of farmers (65 per cent), low in gross national product per capita ($140) and only semiliterate in terms of the proportion of its children who go to elementary school. But taking secondary and higher education into account, Egypt is a semiadvanced country.

In proportion to its population Egypt has more students in universities than Britain and twice as many in secondary and higher education as West Germany. Egypt has an alarmingly high rate of unemployment among university graduates, and the government is hard pressed to find jobs for them as junior clerks and minor functionaries in the already overstaffed ministries. Thousands of Egyp-

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tian schoolteachers, engineers and agronomists have left home to teach and work in neighboring Arab countries.

The government of Gamal Abdel Nasser is attempting to relieve the pressure of high-level unemployment and correct Egypt's unbalanced educational system in several ways. It is encouraging its unemployed graduates to work in less developed countries and is inviting those countries to send students to its universities. It plans to expand and improve the education of skilled technicians and administrative personnel, of whom it has a shortage. It could and should proceed rapidly to provide elementary schooling for all its children, for which it can easily train all the teachers it needs. Common sense also suggests that Egypt should cut back its university enrollments and raise the standards of secondary and higher education. The clamor of parents and their children for more education, however, makes this politically impossible. Consequently it appears that Egypt's best hope is to go in for kinds of economic development that give maximum opportunities for the employment of highly educated people.

These four countries—Nyasaland, Colombia, China and Egypt—are merely samples of the 75 that Myers and I have studied, from the world's most underdeveloped nations to the most advanced. I should like to sum up a few of the generalizations that emerged from the study.

First, there is a strong correlation between a country's educational development and its economic productivity. Using an indicator of educational development that is based on the enrollment in secondary schools and universities, we found that in the 75 countries the coefficient of correlation between educational level and the gross national product per capita is .888. The best single indicator of a country's wealth in human resources is the proportion of its young people enrolled in secondary schools.

Second, education alone is not enough to assure a nation's prosperity. For example, in its level of education Japan certainly ranks among the world's top 10 countries, but its gross national product per capita is only about \$300—far below the advanced countries' \$1,100 average. Egypt, India and Thailand also rank high in education and relatively low in gross national product per capita, whereas in countries such as Saudi Arabia, Liberia and Venezuela the situation is reversed. Obviously many factors other than education enter into a country's economic progress, including its natural resources, foreign markets, outside assistance and so on. Therefore we cannot say that an investment of x dollars in education will produce a y result in economic growth. All we can predict is that a well-educated and motivated people will do extraordinarily well, as the little country of Israel, with its very limited natural resources, is demonstrating today.

Third, in its educational investment a country must adopt a balanced program, suited to its own needs and stage of development, or it may run into trouble. It will have a number of choices to make, and for its educational program it will have to find the best compromise among: (1) quality and quantity, (2) science and the humanities, (3) vocational training in school and on the job, (4) regulation of salary incentives by the state and by the market and (5) the needs of the individual and the needs of the state.

Fourth, a country's educational investment and goals must be shaped realistically to the level of its economic development. Whereas in a nation such as the U.S. a high school education barely qualifies a person for a semiskilled job, in an underdeveloped or partly developed country it may suffice for the highest positions until the country is able to advance to a higher level.

Fifth, education generates a strong demand and push for more education. This has been true in all the advancing countries. The development of elementary schools creates a demand for secondary education and this in turn for higher education of many kinds. Unlike the demand for material goods, which may become saturated, the demand for education is never really satisfied, not only because it offers the individual an endless frontier of advancement in career and status but also because it opens irresistible frontiers for the human mind and curiosity.

Detailed quantitative research on education as a factor in national development is itself in need of development. Many of the variables can be identified as precisely as variables in economics, and it should be possible to work out rational strategies in educational policy as in other economic affairs.

Unfortunately it seems most unlikely that science will ever find a formula for the abolition of inertia and political immorality. But education contains seeds that, as history has repeatedly shown, can inspire and energize a whole people.

The Structure of Development

Analysis of an economy by the "input-output" method reveals its internal structure, which is dictated largely by technology. Applied to underdeveloped economies, the technique maps out paths to growth

by Wassily Leontief

Estimates of gross national product, total consumption, income per capita, rate of investment and similar indices of economic activity are now compiled and published by practically all countries. Such figures give quantitative expression to the otherwise plainly apparent fact that some countries are rich and others poor. When they have been plotted over the recent past, they indicate that the gap between the rich and the poor has been widening. These statistics do not of themselves suggest any ready explanation of the difference in over-all performance among the national economies. Nor do they point to any practical ways to narrow the gap.

As the authors of the preceding articles in this issue of *Scientific American* have shown, the earth's resources are ample for the needs of the present world population and even for a much larger one. It is true that the distribution of resources is uneven. It is also true that the poor countries do not make full use of the resources they have. They raise less food per acre and per man-hour, and they realize little of the value of their mineral wealth above the price of the ore or the crude oil at the dockside. Described in these terms the disparities in the well-being of nations are nowadays summed up in the somewhat more useful observation that they reflect differences in degree of "development."

For the understanding that must precede any constructive action it is necessary to penetrate below the surface of global statistics and such round terms as "development." Each economic system—even that of an underdeveloped country—has a complicated internal structure. Its performance is determined by the mutual relations of its differentiated component parts, just as the motion of the hands of a clock is governed by the gears inside. Over the past 25 years the internal economic gearwork of a large number of countries has been described with increasing clarity and precision by a technique known as "interindustry analysis," or "input-output analysis." Because the results improve as more fine-grained statistics are fed into it, the technique has demonstrated its effectiveness largely in the study of more highly developed economic systems.

INPUT

OUTPUT	SECTOR 1: AGRICULTURE	SECTOR 2: MANUFACTURES	FINAL DEMAND	TOTAL OUTPUT
SECTOR 1: AGRICULTURE	25	20	55	100 UNITS
SECTOR 2: MANUFACTURES	14	6	30	50 UNITS
HOUSEHOLD SERVICES	80	180	40	300 UNITS

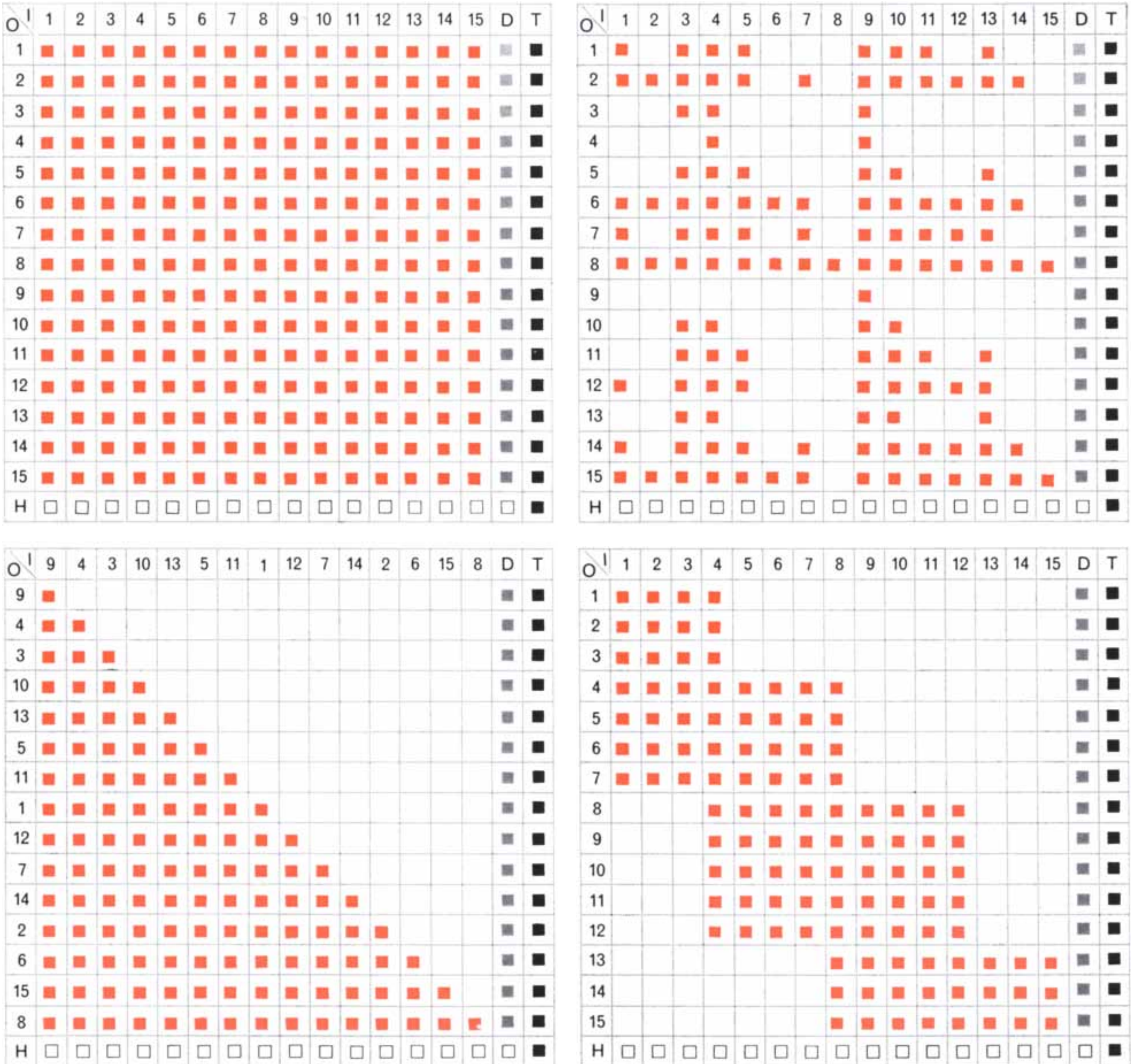
INPUT/OUTPUT COEFFICIENTS

	SECTOR 1: AGRICULTURE	SECTOR 2: MANUFACTURES	FINAL DEMAND
SECTOR 1: AGRICULTURE	0.25	0.40	0.183
SECTOR 2: MANUFACTURES	0.14	0.12	0.100
HOUSEHOLD SERVICES	0.80	3.60	0.133

INPUT-OUTPUT table (*top*) and input-coefficient matrix (*bottom*) show "internal" transactions between productive sectors of simple model economy in relation to "Final demand" and "Total output" of each sector. Table displays outputs from each sector in corresponding horizontal row, inputs to each sector in vertical column. In matrix the columns display ratio between each input to a sector and total output of the sector (*see text on opposite page*).

The data of input-output analysis are the flows of goods and services inside the economy that underlie the summary statistics by which economic activity is conventionally measured. Displayed in the input-output table, the pattern of transactions between industries and other major sectors of the system shows that the more developed the economy, the more its internal structure resembles that of other developed economies. Moreover, from one economy to the next the ratios between these internal transactions and the external total activity of the system—true gear ratios in the sense that they are determined largely by technology—turn out to be relatively constant.

Recent advances in input-output analysis and in the bookkeeping of underdeveloped countries have made it possible to apply the technique to a number of these economies. Their input-output tables show that in addition to being smaller and poorer they have internal structures that are different, because they are incomplete, compared with the

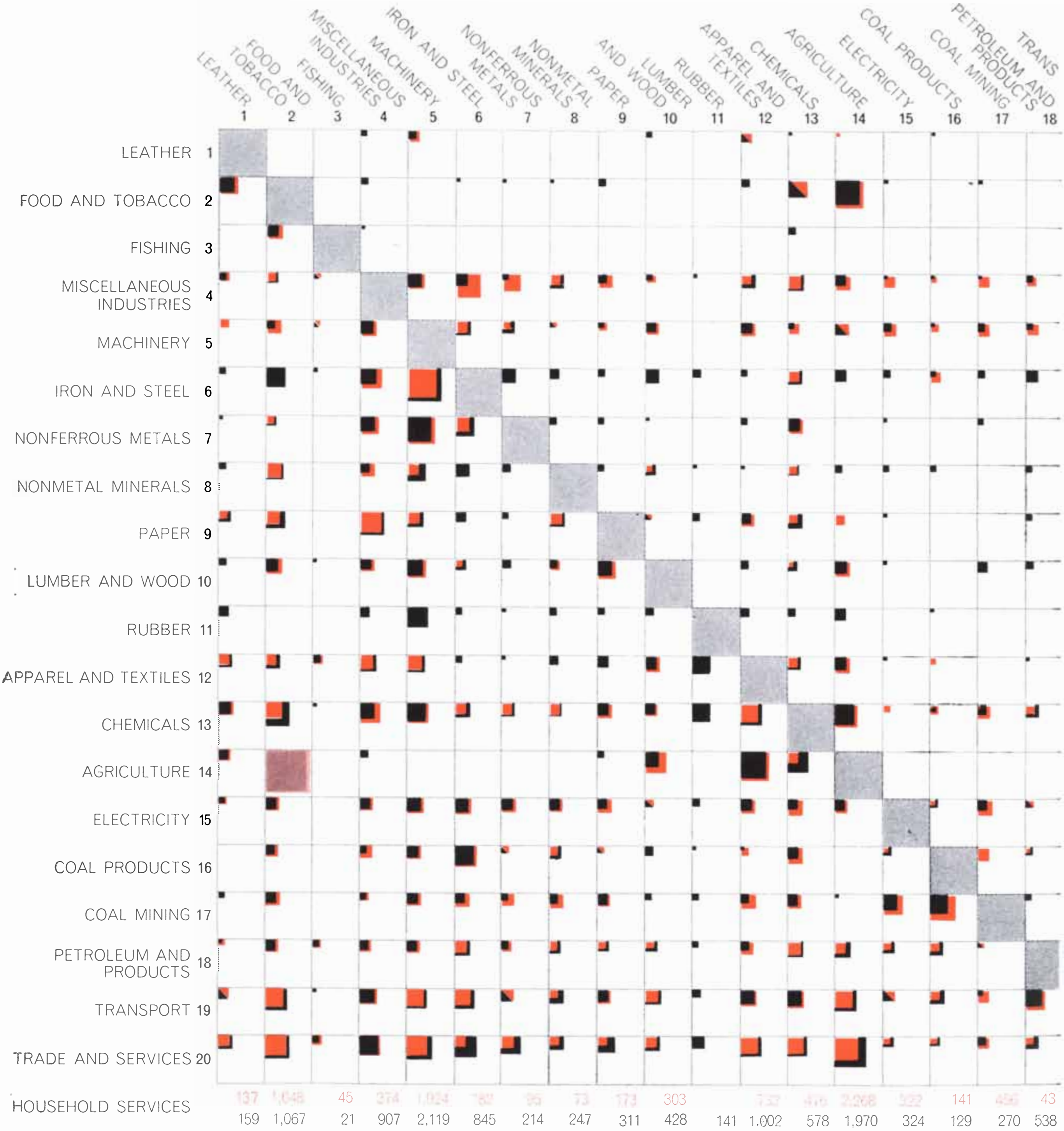


INTERNAL STRUCTURES of model economies are revealed by input-output tables. Colored squares signify inputs from sector in a given horizontal row to sectors in vertical columns intersected by the row; gray squares, the input from each sector to "Final demand" (*D*); black squares, the total output (*T*) of each sector; open squares, the inputs of prime factors from "Household services" (*H*). Table at upper left shows completely "interdependent" economy; table at upper right shows random pattern of interindustry transactions. Latter table appears at lower left with sectors rearranged (note sequence of sector "call numbers"); this "triangulation" of table reveals hierarchical pattern of interindustry transactions. "Block triangular" model at lower right shows interdependence of industries within blocks, as in first model, and hierarchical relation between blocks as in third (*see page 151 of text*).

developed economies. From such comparative studies a fundamental analytical approach to the structure of economic development is now emerging.

Construction of a national input-output table is a major statistical enterprise. By now tables for some 40 countries have been prepared. Some countries (among the underdeveloped countries: Israel, Egypt, Spain and Argentina) have published comprehensive, detailed and quite accurate tables. Others, having just entered the field, have not yet advanced beyond rather sketchy compilations of limited accuracy. The growing literature in this field, however, testifies to the fact that, with the practical know-how gained in the preparation of the first experimental table, the second- and third-generation tables become invested with the elaboration and professional finish required for an effective scientific instrument.

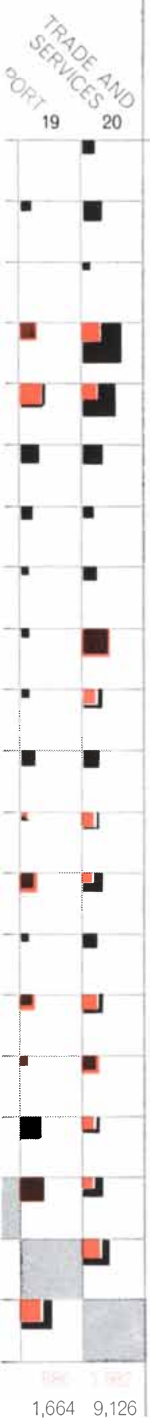
The input-output table is not merely a device for displaying or storing information; it is above all an analytical tool. Depending on the purpose at hand and the availability of reliable information, the economy can be broken down into any number of industries or sectors. The table for the U.S. economy as of 1947, prepared by the Bureau of Labor Statistics of the U.S. Department of Labor, has 450 sectors. For purposes of this demonstration an economy can be broken down into two industrial sectors: agriculture and manufactures [*see illustration on opposite page*]. In the table for such a simple model economy the numbers in the horizontal row labeled "Agriculture" show that this sector, in the course of delivering 55 units of output as end products to "Final demand" and 20 units as raw materials (for example cotton) to "Manufactures," delivers 25 units of its own output (for example feed grains) to itself. "Final demand" can here be taken as including the goods and services consigned to investment and export as well as to current consumption in the households of the economy. The total output of 100 units from the agricultural sector therefore satisfies both the "direct" final demand for its end products and the "indirect" demand for its intermediate products. On the input side the numbers in the column labeled "Agriculture" show that in order to produce 100 units of total output this sector absorbs not only 25 units of its own product but also 14 units of input (for example implements) from "Manufactures" and 80 units—of labor, capital and



DEVELOPED ECONOMIES of the U.S. (*black squares and numbers*) and of western Europe (*colored squares and numbers*) show great similarity in structure when their input-output tables are "triangulated" in same order and superposed. Areas of black and colored squares are proportioned to volume of interindustry transactions, scaling from largest black square at row 6, column 5. Gray and tinted squares at row 14, column 2, indicate transactions too large for this scale. "Intraindustry" transactions, along diagonal, other prime factors—from the sector called, by convention, "Household services."

The great virtue of input-output analysis is that it surfaces the indirect internal transactions of an economic system and brings them into the reckonings of

O.E.E.C. EUROPE: WEST GERMAN FEDERAL REPUBLIC (NOT INCLUDING WEST BERLIN) AUSTRIA BELGIUM DENMARK FRANCE GREECE IRELAND ICELAND ITALY LUXEMBOURG NORWAY NETHERLANDS PORTUGAL UNITED KINGDOM SWEDEN SWITZERLAND TURKEY



FINAL DEMAND (O.E.E.C. EUROPE)	FINAL DEMAND (U.S.)	TOTAL OUTPUT (O.E.E.C. EUROPE)	TOTAL OUTPUT (U.S.)
233	251	243	269
2,973	2,848	3,328	3,233
36	13	58	30
506	740	897	1,286
2,612	3,030	2,813	3,370
90	542	583	1,304
–39	58	211	342
107	264	152	385
43	98	312	461
380	433	496	581
	145		273
1,124	1,331	1,244	1,527
326	430	836	1,073
629	1,002	2,947	2,938
143	181	440	408
154	116	373	244
[illegible]	109	572	304
–60	358	146	648
673	1,397	1,206	2,070
3,631	8,713	4,305	10,237

U.S. (1947) O.E.E.C. EUROPE (1953)

(ALL UNITS = 10 MILLION DOLLARS)

are not shown. The two negative figures in western European final demand indicate that imports of the commodities in question exceed domestic deliveries to final demand.

economic theory. Within each sector there is a relatively invariable connection between the inputs it draws from other sectors and its contribution to the total output of the economy. This holds for an underdeveloped economy, where the input from "Household services" necessary to produce 100 units of agricultural output might represent a full 80 man-years of labor, as well as for a highly developed country where this input would reflect a larger component of capital and is likely to be offset by inputs of fertilizers, insecticides and the like from the industrial sectors. In fact, for use as an analytical tool, the input-output table must be recast into a matrix showing the input ratios, or coefficients, characteristic of each sector. The input-output table for the model economy, recast into such a matrix, shows that .25 unit of agricultural output, .14 unit of manufactures and .8 unit of prime factors from "Household services" are required to produce one unit of total output from the agricultural sector [*see illustration on page 148*].

Each sector or industry thus has its own "cooking recipe." The recipe is determined in the main by technology; in a real economy it changes slowly over the periods of time usually involved in economic forecasting and planning. The input-coefficient matrix can be derived, as it is in the present demonstration, from the interindustry transactions for a given year or from engineering data or from a combination of these and other sources of information. For any bill of final demand, the matrix makes it possible to compute the inputs each industry must absorb from all other industries in the course of fulfilling the final demand for its output and meeting the indirect demand for that output generated by the final demands of the industries to which it in turn supplies inputs. The computation involves the iterative solution of a set of simultaneous linear equations. Since the number of equations increases as the square of the number of sectors, the computing of a table sufficiently detailed to yield significant information is a task for machines.

It was the labor of computation that prompted the first systematic studies of the structural characteristics of an economy as they are displayed in an input-output table. During the late 1940's Marshall K. Wood, George D. Dantzig and their associates in Project Scoop of the U.S. Air Force undertook to rearrange the rows and columns in a table of the U.S. economy in such a way as to minimize the computation required to yield numerical solutions. Such rearrangement brought into sharper relief the interindustry and intersectoral transactions that tie industries and sectors together in the subunits of the total structure of the economy. As more and more countries have begun to compile tables, comparative studies of their structural characteristics have begun to appear.

Dependence and independence, hierarchy and circularity (or multiregional interdependence) are the four basic concepts of structural analysis. The definition and practical significance of each of these ideas can be demonstrated visually by schematic model tables in which colored squares rather than numbers signify the presence or absence of interindustry transactions [*see illustration on page 149*]. In the first of these tables a square appears in every one of the 225 boxes formed by the intersection of the 15 numbered rows and columns of the industrial sectors. Each industry in such a system is dependent on all the others; it supplies inputs to all other sectors and draws inputs from all of them. Translated into mathematical language, this means that each of the 15 variables representing the output of each of the sectors figures directly in each of the input-output equations. In the operation of this economy any increase in the output delivered by any one sector to final demand (represented by the gray square at the right-hand end of the row) would require an increase in the inputs to this sector (reading down the column) from all other sectors without exception. Hence a single increase in direct demand can set up a whole chain of indirect demands, ultimately increasing the total output of every sector in the system.

A more likely and natural system is represented by the model in which some boxes are empty. The industry in whose column one of these empty boxes appears draws no input (or perhaps an insignificant input) from the industry whose row it intersects at this point. If the corresponding box formed by the reverse combination of column and row is empty, then these two sectors can be described as being independent of each other. Where intersectoral dependence is indicated by a square in this table, however, one such square may trigger a whole chain of indirect demands, finally involving both members of an apparently independent pair of sectors.

Such relations become clearer in the model in which all the squares fall below the diagonal running from the upper left corner to the lower right corner of the matrix. Actually this "triangular" system was constructed by rearrangement of the rows and columns of the "natural" system described in the preceding paragraph, as is indicated by the sequence in which the call numbers of the sectors now appear. The highly structured hierarchical relation between the different sectors was obscured in the first random display—an accidental effect, perhaps, of the sequence in which the census bureau of this imaginary economy assigned call numbers to the sectors. In the rearranged table it can be plainly seen that sector 9, now in the far left column, absorbs inputs from all the other sectors but delivers its entire output directly to final demand. Sector 8, now in the far right column, requires for its operation, in addition to a portion of its own output, only labor, capital and

	1 HOUSING: PUBLIC AND PRIVATE	2 CONSTRUCTION: INDUSTRIAL AND AGRICULTURAL	3 CONSTRUCTION: SERVICES AND TRANSPORTATION	4 DIAMOND POLISHING	5 APPAREL	6 LEATHER AND PRODUCTS	7 CANNING, BEVERAGES, SWEETS, TOBACCO	8 VEGETABLES, FRUITS	9 POULTRY, EGGS	10 FLOUR MILLS, BAKERY PRODUCTS
HOUSING: PUBLIC AND PRIVATE 1										
CONSTRUCTION: INDUSTRIAL AND AGRICULTURAL 2										
CONSTRUCTION: SERVICES AND TRANSPORTATION 3										
DIAMOND POLISHING 4				532						
APPAREL 5					15,355	61	48	1,140		325
LEATHER AND PRODUCTS 6	1			36	208	18,321	3			11
CANNING, BEVERAGES, SWEETS, TOBACCO 7				1	2	19	21,056			4,392
VEGETABLES, FRUITS 8							13,536	1,582		96
POULTRY, EGGS 9							24	2,986	8,707	483
FLOUR MILLS, BAKERY PRODUCTS 10							1,877		19,065	35,803
FISH, MEAT, DAIRY PRODUCTS 11				8	2,019	5,911	3,749		965	1 399
CEMENT, GLASS, CERAMICS 12	44 689	17 987	14,275	67		25	1 358			18
SHIPS, AIRCRAFT 13										
MOTOR VEHICLES 14	248	889	830					1,231		
MISCELLANEOUS INDUSTRIES 15	173		13		914	67	6			
MACHINERY 16				7	192	62	287	478		404
ELECTRICAL APPLIANCES 17	4,921	2,336	1,306		2				14	
METAL PRODUCTS 18	11,168	12,556	5,000	18	54	588	3,448		621	143
BASIC METALS 19	13,811	5,797	7,749	100	14		555			30
PRINTING, PUBLISHING 20			1		40		928			27
PAPER AND PRODUCTS 21	152	1	36	2	542	246	3,002	324	467	618
CARPENTRY, JOINERY 22	23,133	2,570	6,974		201					
WOOD PRODUCTS 23	1,674	962	1,753		14	328	370	1,304	294	4
RUBBER AND PLASTIC PRODUCTS 24	63	5	1		339	183	218	17		19
SPINNING, WEAVING, DYEING 25					81,578	1,554	16	4		8
BASIC CHEMICALS 26	5,383	628	977	9	75	1,752	2,445	7,439	5,331	866
LIVESTOCK (EXCLUDING POULTRY) 27					24		413	7,532		32
GRAINS, FODDER 28							1,965	4,058	24,309	46,081
CITRUS FRUITS 29							2,405			6
FORESTRY AND RECLAMATION 30	1,780	1,227	213		261	24	3,781	3,659		71
INDUSTRIAL CROPS 31					763		11,880			334
ELECTRICITY 32				192	465	210	2,572		102	1,764
OIL, SOAP 33	803		86		29	148	612		11,679	3,252
PETROLEUM 34	784	440	899		128	67	1,365	558		1,259
MINING 35	6,999	1,166	4,822	45,814	6	37	367	169		231
WATER 36	38	6	13		14	15	322	8,752	32	128
BUS AND TAXI SERVICES 37										
RAILWAYS AND TRUCKS 38	19,118	6,466	9,085	13	984	173	927	3,248	2,691	4,139
SHIPPING AND AIR TRANSPORT 39										
COMMUNICATION SERVICES 40	405	264	102	1,063	280	252	573	268	1,257	2,758
TRADE 41	6,670	2,491	2,018	9	1,283	1,237	4,630	919	4,718	1,527
SERVICES AND OVERHEAD EXPENSES 42	18,979	5,889	10,699	1,167	7,481	4,763	11,905	600	400	10,375
HOUSEHOLD SERVICES	156,238	55,457	60,746	19,954	92,206	44,060	56,045	103,531	74,139	20,781

	11 FISH, MEAT, DAIRY PRODUCTS	12 CEMENT, GLASS, CERAMICS	13 SHIPS, AIRCRAFT	14 MOTOR VEHICLES	15 MISCELLANEOUS INDUSTRIES	16 MACHINERY	17 ELECTRICAL APPLIANCES	18 METAL PRODUCTS	19 BASIC METALS
HOUSING: PUBLIC AND PRIVATE 1									
CONSTRUCTION: INDUSTRIAL AND AGRICULTURAL 2									
CONSTRUCTION: SERVICES AND TRANSPORTATION 3									
DIAMOND POLISHING 4					31	152		77	
APPAREL 5	68	40	9	31	27	2	13	230	2
LEATHER AND PRODUCTS 6	1	2	2	20	174	51	1	7	1
CANNING, BEVERAGES, SWEETS, TOBACCO 7	2,624	6			13	80	4	22	
VEGETABLES, FRUITS 8	346								
POULTRY, EGGS 9	2,126								
FLOUR MILLS, BAKERY PRODUCTS 10	201								
FISH, MEAT, DAIRY PRODUCTS 11	8 189	20			7	12			
CEMENT, GLASS, CERAMICS 12	860	10 561	3	661	481	78	610	449	644
SHIPS, AIRCRAFT 13			1,056						
MOTOR VEHICLES 14		400	1	23 161	51	232	71	2 776	13
MISCELLANEOUS INDUSTRIES 15	4	40		25	1435	153	171	628	185
MACHINERY 16	240	1,182	715	2,089	27	7,359	705	2,182	452
ELECTRICAL APPLIANCES 17		123	119	305	254	1,381	8,046	576	482
METAL PRODUCTS 18	841	1,946	192	1,629	627	5,593	3,208	19,017	1 007
BASIC METALS 19	132	2,048	422	4,158	2,256	6,505	4,459	28,039	13,158
PRINTING, PUBLISHING 20	118	6			27	11	5	35	1
PAPER AND PRODUCTS 21	853	2,010	49	402	1,313	28	389	431	85
CARPENTRY, JOINERY 22		93		6			102	509	
WOOD PRODUCTS 23	129	66	33	142	582	329	604	544	2
RUBBER AND PLASTIC PRODUCTS 24	19	126	43	700	380	181	1,261	618	67
SPINNING, WEAVING, DYEING 25	5	49	28	614	355	45	128	39	8
BASIC CHEMICALS 26	298	1,592	138	913	883	981	1,490	3,090	610
LIVESTOCK (EXCLUDING POULTRY) 27	95,745				77				
GRAINS, FODDER 28	5				14			42	16
CITRUS FRUITS 29	123								
FORESTRY AND RECLAMATION 30	25	300	182	239	525	81	85	780	1
INDUSTRIAL CROPS 31	514							222	
ELECTRICITY 32	650	3,262	117	594	135	346	306	1,320	487
OIL, SOAP 33	11,559			36	11	2	27	41	105
PETROLEUM 34	415	4,530	108	201	97	117	137	688	658
MINING 35	52	5,833		194	62	8	75	197	2,083
WATER 36	110	173		6	7	1		60	
BUS AND TAXI SERVICES 37									
RAILWAYS AND TRUCKS 38	336	5,579	59	586	182	389	407	1,182	683
SHIPPING AND AIR TRANSPORT 39									
COMMUNICATION SERVICES 40	125	608	40	615	131	448	308	1,434	710
TRADE 41	756	1,811	165	2,107	995	1,237	1,500	4,105	1,211
SERVICES AND OVERHEAD EXPENSES 42	1,787	7,667	933	4,830	3,337	3,341	4,567	8,460	1,486
HOUSEHOLD SERVICES	14,859	56,330	7,424	33,173	16,914	26,191	24,375	64,943	[illegible]

UNDERDEVELOPED ECONOMY of Israel is displayed in input-output table with sectors "triangulated" as in U.S.–western Europe tables on preceding pages. The 42 industrial sectors reveal structure of economy in finer detail, and final demand is shown in three columns: domestic final demand, exports and imports. Import figures in red are subtracted from sum of inputs to industrial sec-

other prime factors from "Household services"; on the other hand, this sector delivers inputs to all other sectors as well as to final demand.

In the hierarchical order of an economy with a strictly triangular matrix, the sectors above and below the horizontal row of any given sector bear quite different relations to that sector. Those below are its suppliers; any increase in final demand for its product generates indirect demands that cascade down the diagonal slope of the matrix and leave the sectors above unaffected. The sectors above, however, are its customers; an increase in final demand for the output of any one of them generates indirect demand for the output of the sector in question. An economist charged with the task of computing the indirect effects of an increase in final demand for the

	…CTS 21	…TRY, JOINERY 22	WOOD PRODUCTS 23	…BBER AND PLASTIC PRODUCTS 24	SPINNING, WEAVING, DYEING 25	BASIC CHEMICALS 26	LIVESTOCK (EXCLUDING POULTRY) 27	GRAINS, FODDER 28	CITRUS FRUITS 29	FORESTRY AND RECLAMATION 30	INDUSTRIAL CROPS 31	ELECTRICITY 32	OIL, SOAP 33	PETROLEUM 34	MINING 35	WATER 36	BUS AND TAXI SERVICES 37	RAILWAYS AND TRUCKS 38	SHIPPING AND AIR TRANSPORT 39	COMMUNICATION SERVICES 40	TRADE 41	SERVICES AND OVERHEAD EXPENSES 42	DOMESTIC FINAL DEMAND	EXPORTS	IMPORTS	TOTAL OUTPUT
																						4,700	312,530			317,230
																							117,137			117,137
																							127,598		581	127,598
																							26	68,755	2,440	68,992
5	10	407	11	20	967	58		295			62		78	1	162		343	58	233	517	1,303	15	170,828	15,178	649	205,473
5	1		1	59	25	1		3	5				1		5		140			3	3		59,147	2,513	22,337	80,103
7	153	40	64		70	967	1,101						43		139				4	2		1,848	121,472	20,886	1,661	152,688
							600						392										130,240	4,668	23	149,799
									814														122,500	17,174	8 021	154,791
	1				1	891	4,684															183	78,186	4,513	43,143	137,384
		1	32	18	33	237	96								5							424	143,036	21,097	3,637	144,115
1	69	167	27	23	26	601						37	144	45	257	122	2		24	6	2,781	,783	6,616	5,533	35,178	106,403
																			2,466			47	42,516	931	47,261	11,838
		8	1				384	3,553	1,292	2,024	331	105		20	39	212	8,293	19,366				6,173	48,458	4,536	9,380	77,437
9	47	1		30	62	55						20	4	3	28	35	39	7	2	10	25	3,287	27,525	5,679	75,813	31,410
0	79	168	169	157	581	34	149	1,376	500	757	123		219	376	753	440	66	4		518		8,945	97,877	1,375	40,732	55,334
			1	9	24	1						206	1	6	276	222	359	829		210		8,728	61,895	1,150	22,372	53,054
5	115	3,689	523	683	52	1,373	407	1	416	2,513		596	103	271	331	518	10	199	220	89	2,561	3,536	74,391	4,857	63,563	142,743
7	28	2,162	148	82	210	114				5,161		53	5	778	750	111	47	63	13	51		733	2,247	753	2,365	39,336
4	177	1	1	33	20	72						7	42				221		10	1	622	23,810	28,789	2,431	18,397	76,125
0	12,098	1	34	219	418	806			2,607			5	388	3	53	19	11		4	18	8,003	3,217	3,568	1,969	31	34,944
		9,843	100										1			1							57,130	52	9,106	100,684
7	33	7,461	4,876	26	106	102	61		11,464	1,038		284	31		7			1	71	4	3,461	22	1,799	7,906	1,364	38,808
7	33	1,278	15	2,279	131	554	3	38	15	47	7	20	5	6	31	53	2,625	5,529		14	2,366	3,697	11,424	18,205	24,758	51,268
3	316	3,334	1	6,201	67,571	452	56				796	2	1		4	15	20	5	153	16	49	7	13,604	12,853	38,381	165,542
5	1,330	1,016	1,062	7,125	4,000	15,560	997	9,633	5,642	56	2,066	235	3,152	1,115	664	149		7	114	70	3	646	18,955	8,024	7,614	79,135
		2	12		1,758	14	4,498		2,632														72,030	558	72,974	177,713
						23	59,682	9,225			1,490												4,803	8,326		87,065
																							28,366	86,390	36,119	117,290
3	35	9,210	11,712	4,114	76	728		694	396	800		4	46		162	17			1	27		1	43,515	355	39,509	49,016
				7	15,622						705		29,877										3,736	6,505	1 511	30,656
7	679	307	493	1,062	2,264	2,344							447		1,197	21,106	47	45	21	632		3,994	17,138		9,243	63,114
4	72	7	13	38	310	2,549	8,852						3,223	6	53	1			2			2,414	23,580	1,766	20,517	62,087
1	411	46	430	348	676	3,209	112	1,358	508	1,495	112	15,815	189	928	1,285	771	5,348	9,598	2,513	599		6,782	19,659	1,786	18,987	65,963
3	127			311	28	6,611					85	1	82	47,799	434	107				5		4	3,312	13,290	2	31,327
1	90	2	3	8	141	210	7,106	8,622	8,591	2,124	3,926		96	128	235		4	8	41	59		1,254	7,611			49,935
																						30,878	77,122			108,000
2	494	591	418	307	591	2,237	6,041	5,652	2,522	585	830	1,623	863	126	881	1,638	865	4,463	361	5,401	385	63,884	42,827	7,321	22,604	207,435
																			14,573			13,917	22,755	92,149	2,671	120,790
9	568	561	572	502	766	916	365	107	359	25	20	24	1,247	5,406	49	21	367	176	444	2,728	150	29,171	18,907	10,160	[illegible]	82,670
9	1,115	2,136	1,043	681	816	3,558	1,492	973	590	888	177	1,190	3,233	37	485	344	3,199	5,648	867	179	21,078	6,398	385,961	9,521	[illegible]	492,367
0	3,370	7,163	3,131	4,426	10,099	7,590	2,200	1,100	400	1,900	100	7,968	3,896	1,901	5,171	5,082	6,066	14,029	55,885	5,381	59,796	200,029	464,062	75,840		870,800
4	13,493	51,082	13,911	22,500	58,098	27,268	78,827	44,433	78,537	29,603	19,826	34,919	14,278	7,008	17,871	18,951	79,928	147,400	42,768	66,130	389,781	441,273				

tors, final demand and exports to give total domestic outputs; imports exceed 50 per cent of domestic output in many sectors. Principal exports are from diamond-polishing and citrus sectors.

Upper sectors in table deliver most of their output to final demand; lower sectors deliver most of their output as inputs to the other industrial sectors, thus satisfying final demand indirectly.

output of this sector would need to know, therefore, only the input coefficients for sectors below it. If he wants to compute the indirect effects on this sector of demand originating elsewhere, he needs to work only with the input coefficients for this sector and the sectors above it. In the case of the fourth "block triangular" model he would find that relations between sectors within each block are similar to the mutual interdependence that ties together all the sectors in the first of these model systems, whereas the relations between the blocks ("multiregional interdependence") are analogous to those between the sectors in the triangular model.

The convenience of the economist and the computing machine does not, of course, constitute the sole or the most significant purpose served by such rearrangement of an input-output table. The "triangulation" of the table serves also to expose the internal structure of the interindustry transactions. These define groups and blocks of more closely related industries. The forecaster is likely to find that he must reckon with the fortunes of all the industries within a group in order to plot the future course of one of them. The planner may discover that the effort to promote the growth of an industry in one block requires the prior development of industries in another block and may trigger the development of industries in still another block.

The triangulation of a real input-output table—that is, the discovery of its peculiar structural properties—is a challenging task. It is complicated by the fact that one must take into account not only the distinction between zero and nonzero entries but also the often more important difference between their actual numerical magnitudes. The degree to which triangulation reveals significant structural details depends also on the fineness of the sectoral breakdown. A single entry in a highly aggregated table may conceal the solid block of a triangular matrix or a narrow strip of finer intersectoral relations. Lack of sufficiently detailed information about the internal structure of groups and blocks of industries may impose severe limitations on attempts to explain the behavior of the economic system as a whole.

The larger and the more advanced an economy is, the more complete and articulated is its structure. The U.S. and western Europe respectively produce about a third and a quarter of the world's total output of goods and services. It is not surprising, therefore, to discover that

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Turkey. Next year, Turkey will have a new steel plant—the largest in the Middle East. All electrical equipment by Westinghouse.

Pakistan. Westinghouse has been designated supplier of electrical equipment for Pakistan's first major steel mill.

Japan. Westinghouse is building a 325,000 kw generator for Japan. This brings to 1,300,000 kw the capacity of new Westinghouse generators in Japan in the past five years.

Brazil. Westinghouse motors and controls will run a new steel mill in Brazil—South America's most modern integrated, automated steel plant.

Kuwait. Four Westinghouse "water factories" in the desert of Kuwait are turning salt water from the Persian Gulf into nearly 18 million gallons of fresh water every week.

Spain. Westinghouse is installing steam-turbine generators, with 700,000 kw capacity, in 11 different power plants.

Taiwan. Westinghouse built the world's largest silicon rectifier, to provide and control electricity for refining aluminum. This raises Taiwan's aluminum production 150 per cent, to 20,000 metric tons per year.

Mexico. At the outset, oil will fuel a 225,000 kw electric plant in Baja California. The steam-turbine generators by Westinghouse are equipped to switch over to fluid coke, a waste residue of an anticipated oil refinery nearby.

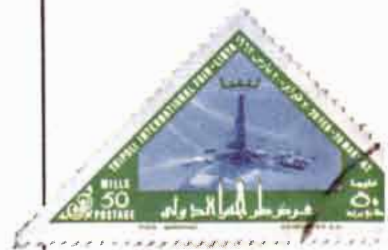
Korea. Westinghouse has been chosen to supply electrical equipment for Korea's first steel mill, the first major industrial plant to be established in that country.

Venezuela. Forty-five Westinghouse gas turbines at work in the oil producing area, the largest concentration of gas turbines in the world.

Italy. This year, northern Italy will have continental Europe's largest atomic electric plant, a 270,000 kw nuclear power plant by Westinghouse.

Argentina. This year, Argentina has its first mill for manufacture of coated book papers. Power drives by Westinghouse.

Indonesia. In the Republic of Indonesia, Westinghouse is now installing a 50,000 kw steam-powered electric plant.



Libya. On December 28, 1961, a Westinghouse 20,000 kw steam turbine went into operation as the first step toward Libyan industrialization.

India. In West Bengal Westinghouse is supplying the Bandel Thermo Power Plant, a 350,000 kw station scheduled for completion in 1965, and especially designed to use low grade coal mined in India.

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GT&E SUBSIDIARIES: General Telephone Operating Companies in 32 states • General Telephone & Electronics Laboratories • General Telephone & Electronics International • General Telephone Directory Co. • Automatic Electric • Lenkurt Electric • Sylvania Electric Products their input-output tables yield the same triangulation. Discounting the larger over-all size of the U.S. economy, the similarity between the two sets of intersectoral relations comes vividly to the fore when the triangulated input-output tables of the two systems are superposed on each other [*see illustration on pages 150 and 151*]. Between them they contain—with some well-known but minor exceptions—a complete array of economic activities of all possible kinds.

Each of the industries in this combined table has its own peculiar input requirements, characteristic of that industry not only in the U.S. and in Europe but also wherever it happens to be in operation. The recipes for satisfying the appetite of a blast furnace, a cement kiln or a thermoelectric power station will be the same in India or Peru as it is, say, in Italy or California. In a sense the input-coefficient matrix derived from the U.S.-European input-output table represents a complete cookbook of modern technology. It constitutes, without doubt, the structure of a fully developed economy in so far as development has proceeded anywhere today.

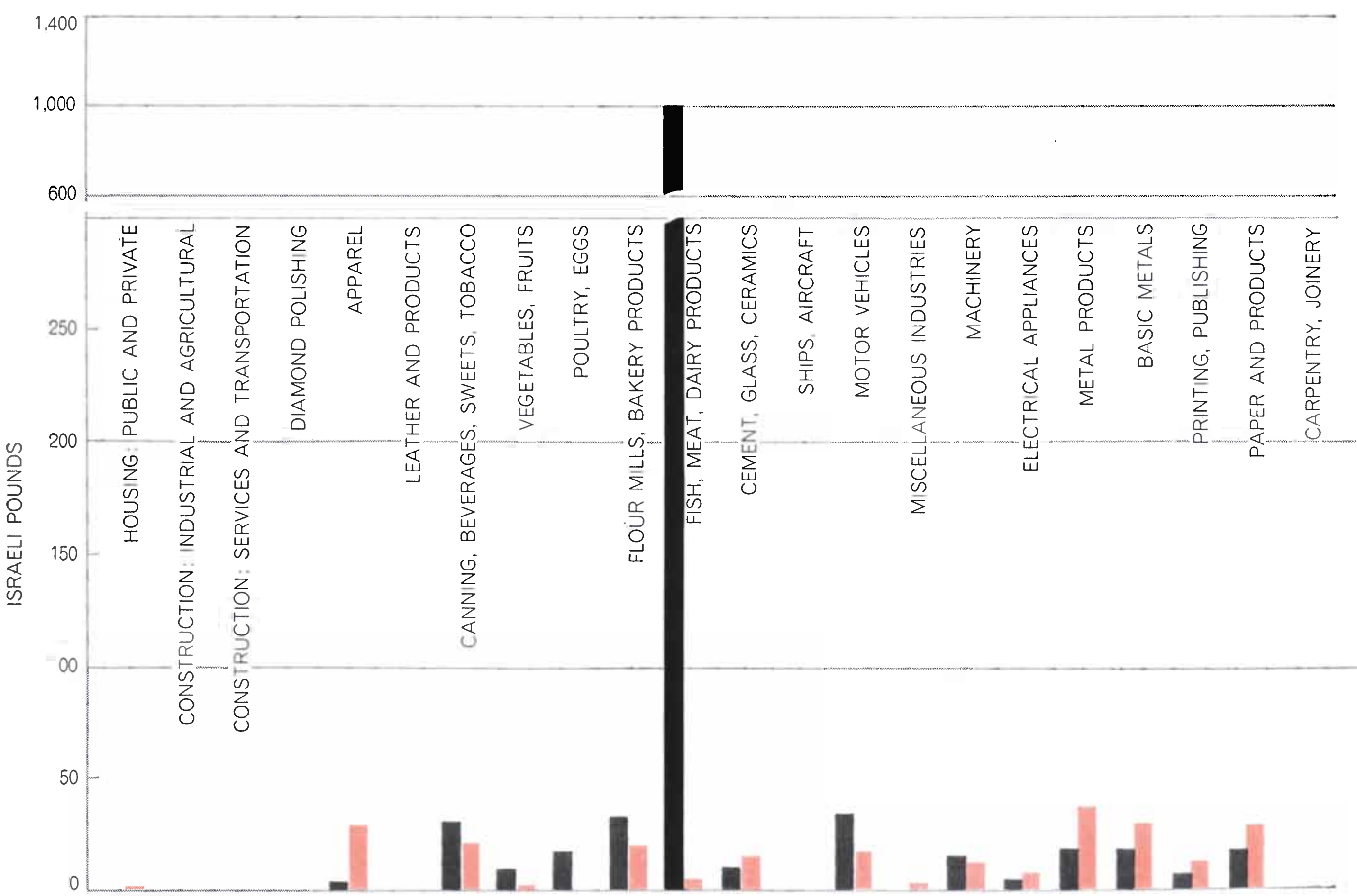
An underdeveloped economy can now be defined as underdeveloped to the extent that it lacks the working parts of this system. This lack can be explained in narrowly economic terms as due to the amount and distribution of productively invested capital; in social terms, as a reflection of the composition and efficiency of the labor force, or in geographical terms, as the result of the country's endowment with natural resources. This last element deserves special mention, because much has been said in recent years about the possibility of designing custom-made technologies to meet the special conditions prevailing in certain underdeveloped countries. Celso Furtado, in his article "The Development of Brazil" [*see page 208*], mentions the scarcity of coal in that country and speaks of the need for a new technology to reduce the iron in the abundant local ores. Leaving aside the intrinsic merit of such proposals, the fact is that the choice of alternative technologies hardly exists. The process of development consists essentially in the installation and building of an approximation of the system embodied in the advanced economies of the U.S. and western Europe and, more recently, of the U.S.S.R.—with due allowance for limitations imposed by the local mix of resources and the availability of technology to exploit them.

In the absence of such complete development a country can consume goods without producing them because it can import them. It must pay for its imports, however, by producing other goods for export instead of for domestic consumption. Two countries can thus display identical, or at least very similar, patterns of domestic final demand and yet have very different patterns of production. The smaller and the less developed a country is, the more it can be expected to exploit its productive capacity independently of its immediate needs and to bridge the gap between production and consumption by means of foreign trade. Consequently the full diagnosis of the ills of an underdeveloped country—as well as the formulation of a realistic development plan—requires a detailed quantitative analysis of the dependence of all the domestic industries not only on the configuration of final domestic demand but also on the composition of the country's foreign trade.

Of all the developing countries, Israel possesses the most detailed and complete statistics necessary for an analysis of this kind. An input-output table prepared from data compiled by Michael Bruno of the Bank of Israel and triangulated according to the U.S.-Europe plan appears on pages 152 and 153. In this table final demand is broken down into three components: domestic final demand (including investment as well as consumption), exports and imports. The import figures are printed in red because they are negative figures with respect to the country's foreign-trade account and because they must be subtracted from the sum total of domestic final demand, exports and the deliveries of the commodity in question to other industrial sectors (indirect demand) in order for one to arrive at the figures for total output at the end of each row.

Israel's heavy dependence on imports becomes apparent on inspection of the table. In five sectors ("Ships, aircraft," "Machinery," "Basic metals," "Industrial crops" and "Mining") it can be seen that the country's imports exceed domestic output by large margins. In five other sectors ("Grains, fodder," "Forestry," "Motor vehicles," "Electrical appliances" and "Paper and products") imports are equal to more than 50 per cent of domestic production. Imports exceed domestic final demand plus exports in six sectors ("Grains, fodder," "Basic metals," "Paper and products," "Basic chemicals," "Industrial crops" and "Mining"); this is because the indirect demand for imports of the commodities in question exceeds final demand. Most of these imports, in other words, are distributed as inputs to other industries along the row in which they are entered.

Perhaps the most useful way to see how Israel—or any other underdeveloped country—stands today is to construct a model of the economy as it would appear if it enjoyed self-sufficiency; that is, to determine the structure of production Israel would have to achieve in order to maintain its present actual consumption and investment entirely from domestic output and without recourse to foreign

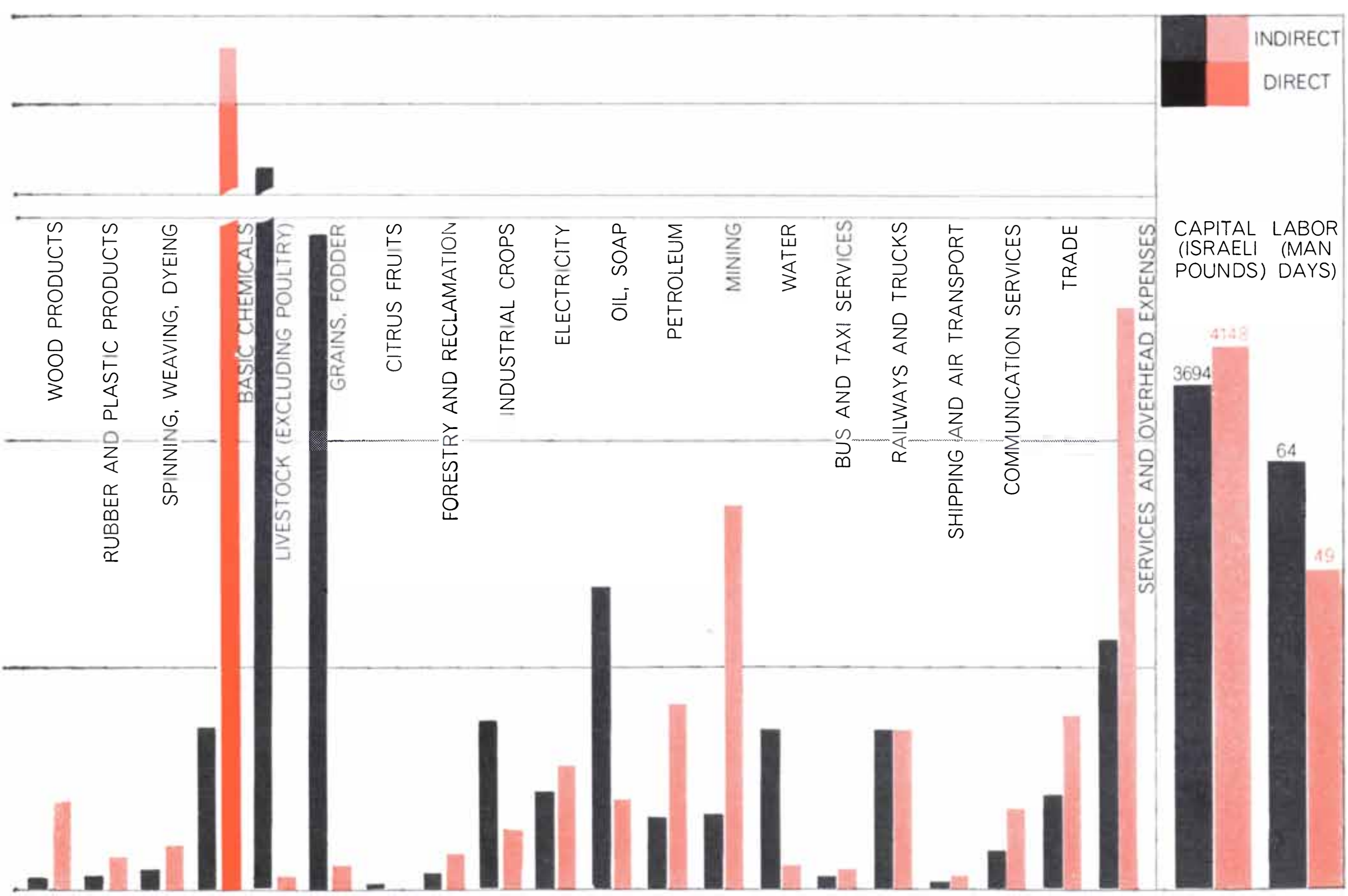


INDIRECT DEMAND generated in Israeli economy by "direct" or final demand for IL. 1,000 worth of products from "Basic chemicals" (*colored bar*) and "Fish, meat, dairy products" (*black bar*) sectors is shown here. Inputs from other industries to these sectors (*shown as tinted and gray bars respectively*) needed to satisfy indirect demand were computed from input-coefficients for these sectors. Reference to the Israeli input-output table on pages 152 and 153 shows that many of these inputs ("Grains, fodder" particularly) trade. Such a model will show, among other things, how far Israel falls short of possessing a fully articulated modern industrial economy, in which sectors it is weakest and in which sectors it can push its development most fruitfully.

The first step in the construction of such a model is to prefabricate the sector "modules" from which it is to be built. This means to compute from the input-coefficient matrix of the economy the inputs that are required—directly and indirectly—to enable each sector to deliver an additional unit of output to domestic final demand. Direct demand for IL. (Israeli pounds) 1,000 of "Basic chemicals," for example, generates indirect demand for inputs from 34 of the 42 sectors into which the Israeli economy is broken down in the matrix—including an input of products worth IL. 266 from "Basic chemicals" itself [*see illustration below*]. Similarly, direct demand for IL. 1,000 of output from the "Fish, meat, dairy products" sector calls for the input of IL. 725 of "Livestock" and IL. 292 of "Grains, fodder," along with numerous inputs of smaller value from other sectors. It should be noted that the direct demand for "Basic chemicals" generates an indirect demand of IL. 5 on the "Fish, meat, dairy products" sector and, reciprocally, that the direct demand for "Fish, meat, dairy products" sets up an indirect demand for IL. 70 of "Basic chemicals." In these computations it is not necessary to distinguish between imports and domestic production, because the coefficients remain constant, whether the inputs are imported or produced at home. With the computations run for all sectors it is possible to determine the total outputs required of the entire economy in order to allow each domestic industry to satisfy the domestic final demand for its products.

The final demand to be met from within the Israeli economy is displayed as a series of colored blocks running across the top of the chart on the next two pages. As in the input-output table on pages 152 and 153, the country's exports are added (as gray extensions) to the tops of the blocks; the imports, represented by blocks of hatched lines, are subtracted. This presentation shows vividly how much the Israeli economy depends on imports, with blocks of hatched lines cutting deep into the colored blocks and even descending below them in the six sectors where the imports required to satisfy indirect demands exceed final demand.

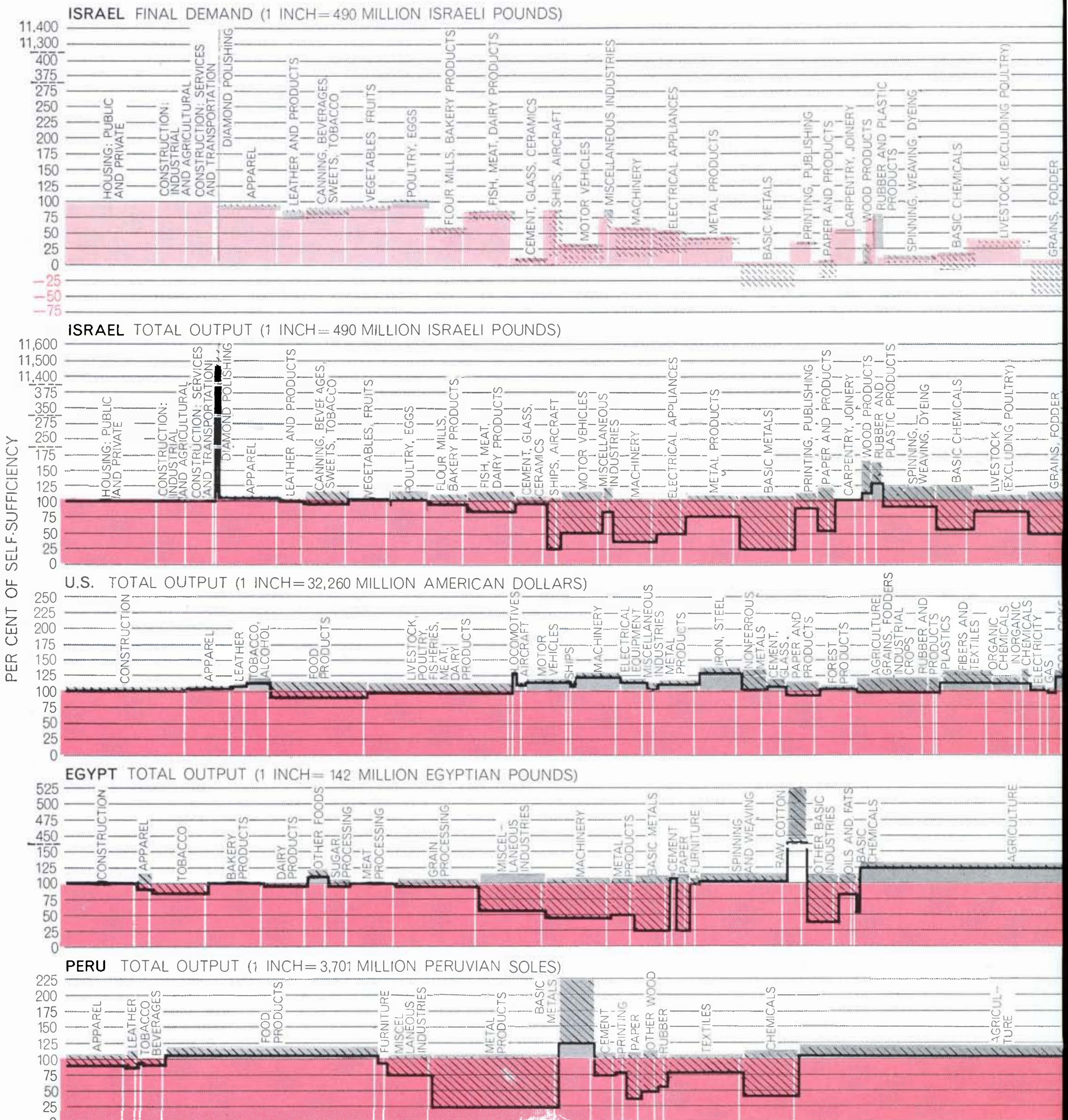
The Israeli economy in the hypothetical state of self-sufficiency is represented by the row of colored blocks of equal height that runs across the chart just below. Although they represent sectors of greatly different magnitude, all the blocks in this chart are of equal height because the vertical scale represents "Per cent of self-sufficiency" and the monetary dimensions of the sectors are shown on the horizontal scale. The area of each block thus represents the total output required of that sector in order



are drawn from imports. Note that direct demand on each sector generates indirect demand for its own products. Similar input-coefficient "modules" constructed for all sectors of the economy make it possible to compute the total output required to satisfy the direct and indirect demand generated by any given level of final demand or by any given volume of exports or by import-replacing outputs from domestic industries, as shown in "sky line" chart of the Israeli economy and other economies on next two pages.

to satisfy the direct and indirect demands of the Israeli economy at self-sufficiency. The per cent that is allocated directly to final demand in each case is indicated by the height of the corresponding final-demand block in the row of blocks above.

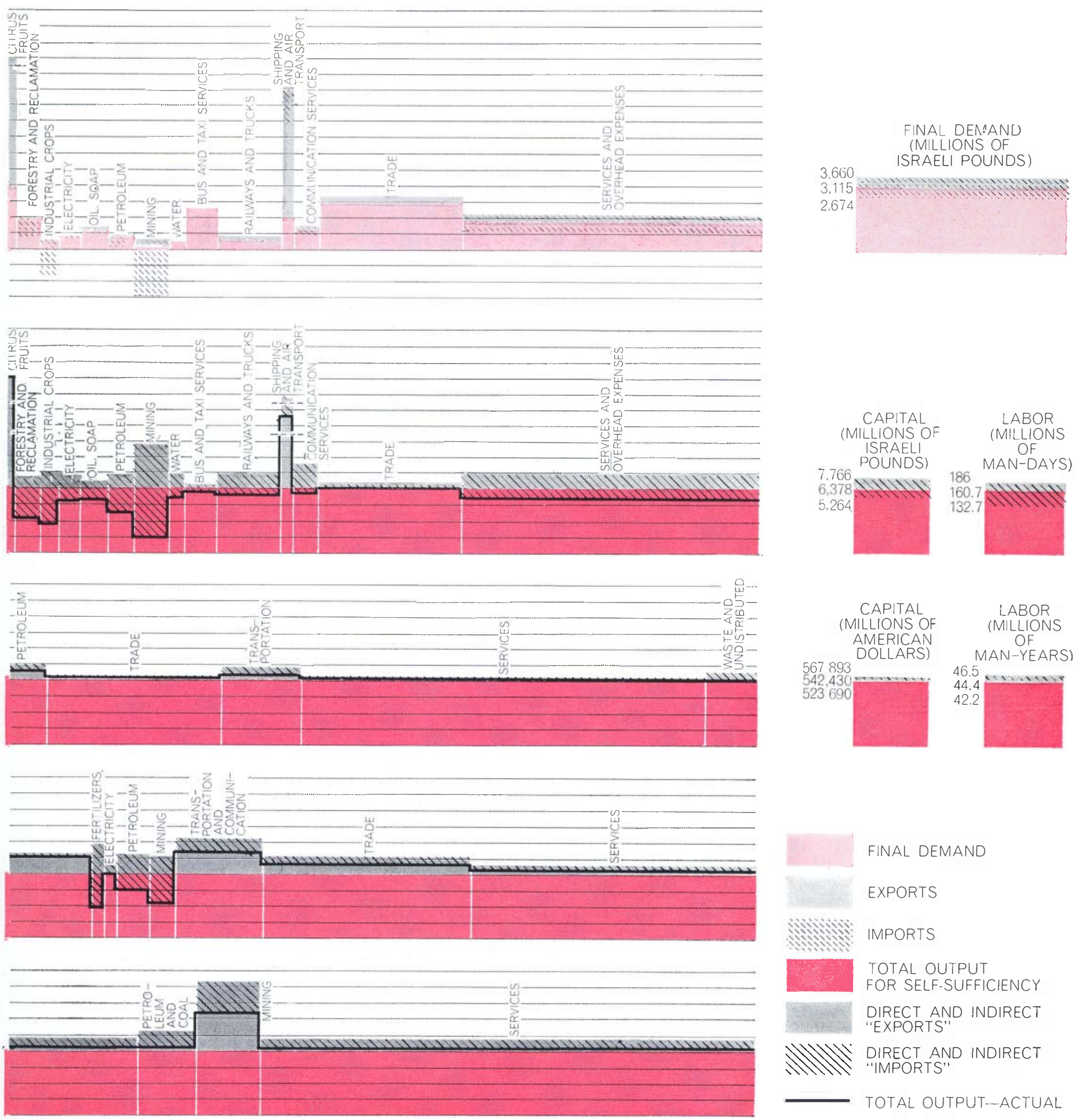
As a matter of fact, with the combination of labor, capital and natural resources available to it in 1958, the year on which these hypothetical computations are based, the Israeli economy could not possibly have produced sufficient amounts of all the different kinds of goods and services that directly or indirectly were required to maintain the actual consumption and investment levels of the economy in that year. Domestic final demand was nonetheless maintained at those levels through recourse to foreign trade. By raising some outputs above the requirements of domestic direct and indirect demand, the country produced exportable surpluses.



DEVELOPED AND UNDERDEVELOPED economies are contrasted in these sky-line charts of the U.S. and of Israel, Egypt and Peru. Total output required for self-sufficiency is indicated by height of tinted blocks (*see key at right*). Horizontal scales give monetary dimension of each sector; vertical scale, per cent of self-sufficiency. Heavy line shows actual total output of each

In other sectors imports filled the gap between domestic output and the total direct and indirect demand of the economy. In Israel and elsewhere imports serve to economize resources that happen to be comparatively scarce, whereas exports provide a way to put to good use other resources that would otherwise be less effectively employed or perhaps not employed at all.

The crucial relation between foreign trade and the structure of the Israeli economy can best be assessed in two steps. To the tops of the colored blocks of the hypothetical self-sufficient system are added gray blocks; these represent the direct and indirect demand that would have to be met by each sector in order to produce from domestic resources, and without drawing on imports, the exports shown by the gray blocks in the final demand row above. As might be expected, some sectors are called on to increase their outputs even



economy; underdeveloped economies fall short of self-sufficiency. Final-demand profile for Israel at top shows volume of domestic demand (consumption and investment), exports and imports, to be satisfied directly and indirectly by outputs shown in row below. Graphs at far right show Israeli foreign-trade deficit and capital and labor components of domestic output and foreign trade.

though none or scarcely any of this output goes directly into exports. The substantial increase in the output of "Grains, fodder," for example, would be accounted for in part at least by the indirect demand set up by exports of "Fish, meat, dairy products," in accordance with the input-coefficient shown in the chart on pages 160 and 161.

The next step takes account of the effect of imports. The effect is analogous to that of exports, but it works in the opposite direction. An import of IL. 1,000 worth of "Basic chemicals," for example, not only eliminates directly the demand for an equal amount of "Basic chemicals" from the domestic industry but also, as shown in the chart on pages 160 and 161, reduces the indirect demand for the products of 33 other industries and "Basic chemicals" as well. From the input-coefficients for all sectors hatched blocks are now constructed to represent the amount of each kind of goods that would be required, directly and indirectly, to produce in Israel the bill of imports shown in the final-demand row at the top of the chart. These theoretical import-replacing outputs are subtracted from the total height of the colored and gray blocks in the self-sufficiency row. The lowered and irregular "sky line" thereby established shows the actual output of the Israeli economy from sector to sector as a per cent of the level of output that would give the country self-sufficiency.

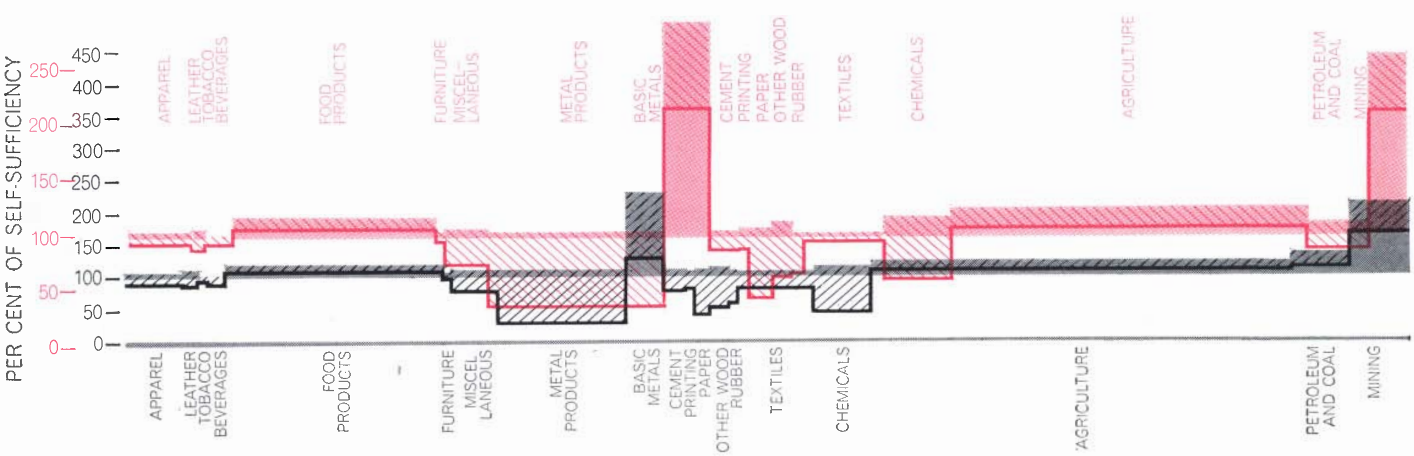
The fact that so few sectors of the Israeli economy rise above the self-sufficiency horizon and that so many fall below it is explained to a great extent by the relatively large amount of foreign aid received by the country. In addition to offsetting the export-import deficit, such aid also permits the country to substitute capital indirectly for labor. As the bar graph at the right-hand end of the chart of the hypothetical self-sufficient Israeli economy shows, the attainment of actual self-sufficiency would require a larger outlay of labor than of capital.

These considerations undoubtedly also apply to resources, although lack of sufficiently detailed information at present makes it impossible to establish the precise relation between domestic resources and the structure of the Israeli (or any other) economy. In connection with resources it should be remarked that no economy can be completely self-sufficient. As employed in the present analysis, self-sufficiency should be taken to mean the state of development at which nonreplaceable imports are covered by the exports needed to pay for them. The sky line in the chart indicates that the Israeli economy still falls well below self-sufficiency thus defined. Foreign aid makes it possible, however, for Israel to maintain not only a much higher level of domestic consumption than it could have achieved otherwise but also a much higher rate of investment and growth toward mature development.

The same chart presents analogous sky lines for the U.S. economy and for the underdeveloped economies of Egypt and Peru. Comparison of one of these countries to another must be qualified because of the differences in the way their statisticians have aggregated the various industries of each country into sectors. The sectors are arrayed, however, in each profile in the same sequence in which they should and—let us hope—will eventually appear on a triangulated input-output table of the economic system of the entire world.

In common with Israel, it can be seen, Egypt and Peru present jagged total-output profiles, with many sectors falling short of the self-sufficiency line. The U.S. profile, in contrast, is flat and averages out somewhat above self-sufficiency. This is a reflection of the country's mature development: its favorable balance of trade and the additional outflow of foreign aid-in-kind. The chart also demonstrates, incidentally, that the celebrated unfavorable balance of payments and the worrisome weakness of the dollar are the result of paper transactions.

Each of the underdeveloped countries specializes in the massive export of a few agricultural and mineral commodities and depends on imports for the supply of a broad spectrum of manufactured goods. (The diamond-polishing industry of Israel is worthy of special mention: established in that country by refugees from Nazism, it serves a comparatively minuscule domestic final demand and earns significant foreign credits to cover imports.) The U.S. economy, on the other hand, exports a great diversity of manufactured goods and imports a few agricultural and mineral commodities. An underdeveloped economy is consequently the mirror-image of an advanced economy.

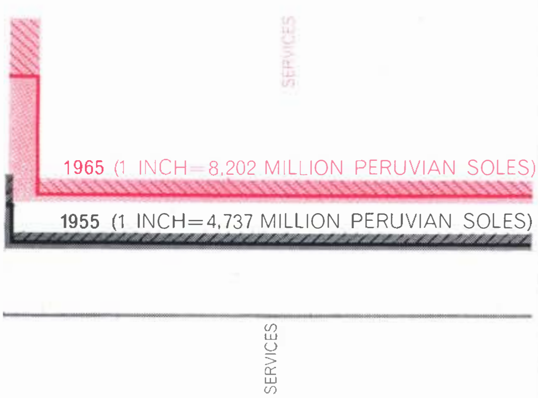


DEVELOPMENT OF PERU projected as of 1965 by UN Economic Commission for Latin America is compared with actual state of economy as of 1955 as shown on preceding pages. Monetary value of outputs of sectors is indicated by horizontal scale. Over-all increase of 73 per cent in total gross output satisfying domestic demand lifts self-sufficiency line to higher level indicated by scale in color at left. Output required by direct and indirect demand of exports is added above the line and represented by tinted blocks; output similarly required to replace imports is represented by hatched blocks in color and is subtracted from new totals for each sector. Heavy colored line at base of these export blocks shows domestic output projected for 1965. Corresponding picture for 1955 is shown in black and gray profile below. The sectors in the sky line for 1965 show a general shift from left to right reflecting

Comparison of the four national economic structures reveals a striking hierarchy based on the ratio of agriculture to total economic activity. The agricultural and food sectors of the U.S., although they far outproduce those of the other countries, constitute only about 15 per cent of the country's total output. Israel comes next, with about 24 per cent of its total activity in agriculture, then Egypt with 36 per cent and Peru with 40 per cent. This may serve as a fair index of their different degrees of development.

The sky lines of the three underdeveloped countries, instead of displaying random ups and downs, are characterized by gradual transitions from clearly defined high plateaus to well-formed valleys. This is no accident: the sectors that approach one another in height represent groups of industries closely related by their interindustry transactions. In the Israeli profile, for example, there are obvious connections in the three-step order of the "Metal products," "Electrical appliances" and "Machinery" sectors, which are stated more explicitly at the intersections of their rows and columns in the input-output table.

Economic systems tend naturally to combine the international division of labor with the minimization of transportation costs. The latter costs can be kept down if an industry is located or developed in close proximity to the largest direct customers for its outputs or the suppliers of its inputs. Quite independently of transportation costs, however, a growing economy derives a considerable, although less measurable, advantage from developing whole families of struc-



larger expansion of output from industrial sectors. The agricultural and extractive sectors continue to generate the principal exports, and the country's dependence on imports is reduced. Industrial expansion requires substantial increase in fuel consumption and imports of fuels exported in 1955.

turally related industries rather than isolated industries that depend on foreign trade for supplies and markets. The incessant process of technological change derives strong stimulus from intimate contact between sellers and buyers, between the maker and the potential user of a new process or product. As an economy passes from one phase of its development to another, "block reaction" will cause low blocks to grow tall, whereas blocks that now protrude above the sky line will gradually lose their domineering stature.

Developmental evolution along these lines is illustrated by the comparison of the actual profile of the Peruvian economy for 1955 with the hypothetical profile of that economy for 1965; this projection is based on the projections of the United Nations Economic Commission for Latin America [*see illustration on preceding two pages*]. The upward shift of the self-sufficiency horizon reflects a large increase in the over-all level of final domestic demand. This upward shift is accompanied by a horizontal displacement of the sectors from left to right that reflects the faster growth of the industrial sectors in relation to that of the agricultural sectors. Dependence on imports is diminished, although the same commodities continue to account for the bulk of the country's imports. Agriculture, basic metals and the extractive industries continue to provide, directly and indirectly, the exportable surpluses. As the result of rapid industrial growth, however, the profile shows that Peru will cease to be an exporter of petroleum and coal and will become, for a while at least, an importer of these fuels.

Input-output analysis thus makes it possible to project changes in the structure of a developing economy in terms of the underlying composition of domestic consumption and investment, exports and imports. The predetermined coefficients of inputs required directly and indirectly to deliver each type of goods and service to final demand provide modules that can be combined in many different ways to draft internally consistent blueprints for the future. The mere existence of an elaborate projection will not, of course, bring about economic growth. Much political acumen and drive, much sweat and tears goes into the actual realization even of the best-conceived developmental plan. Progress, however, will be faster along a road well mapped in advance and the cost of progress in terms of labor, capital and human sacrifice considerably less.

The Development of Nigeria

The first in a series of four articles on specific problems of development. Nigeria, the most populous nation of Africa, has just launched its advance toward self-sustaining growth

by Wolfgang F. Stolper

On March 29, 1962, the Federal Finance Minister of Nigeria, Chief the Honorable Festus Sam Okotie-Eboh, rose in the Nigerian Parliament to make his annual budget speech. "I can see a vision," he said, "of a new and prosperous Nigeria—a Nigeria whose blood is virile and whose aspirations are fired by noble objectives. The sleeping giant of Africa is awake and determined to take her rightful place marching with the rest of humanity."

Okotie-Eboh has a habit of naming his annual budgets, and he chose "Mobilisation" for this one—which covered the fiscal year to March 31, 1963—because Nigeria was about to embark on her first National Development Plan, to take effect April 1, 1962, and to continue for six years. "For the very first time in our history," Okotie-Eboh said, "an effort [is] being made to look at the resources and the priorities from an . . . all-Nigeria perspective."

The plan embodies a bold and fateful undertaking. Nigeria is an underdeveloped country in an early stage of the development process: newly independent of a political colonialism but continuing in what amounts to an economic colonialism because of its dependence on a few material exports and many manufactured imports; long on agriculture and manpower but short on manufacturing and skills; rich in potential but still far from its proclaimed goal of "a modern, diversified and virtually self-sustaining [economic] system."

VILLAGE ON THE NIGER (*opposite page*) **perches between forest and river that gives Nigeria its name. Village typifies smallness and isolation of most towns in primarily rural nation. The Niger and tributary Benue constitute Africa's largest river system.**

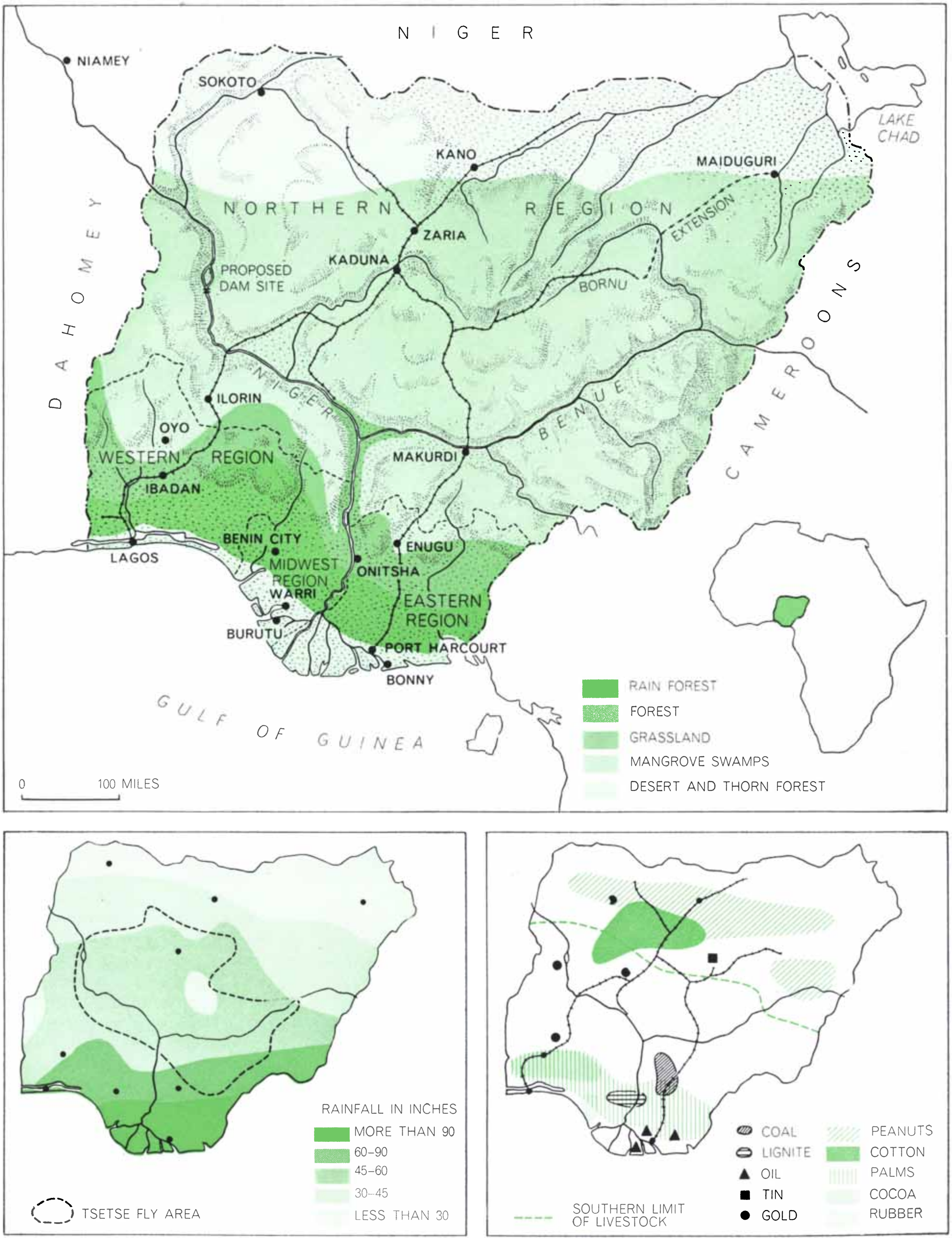
Much depends on the success of this and subsequent plans. Nigeria is a democracy patterned on British lines. It is also the largest Negro nation. If it can build roads and industries, bring electricity to its villages and educate its youth while safeguarding its internal liberties and external borders, it will set an example that other African nations may well follow. Moreover, success would kill once and for all the pervasive thesis that the Negro is innately incapable of organizing a modern society. If Nigeria fails, the equally pernicious belief that only authoritarianism can provide an effective road to development may gain a universal hold in Africa, and the champions of apartheid will be emboldened.

Nigeria is a big country. Its population of between 35 and 40 million is the largest in Africa. It also ranks among the larger African nations in territory: 356,500 square miles, which is slightly more than the area of Texas and Oklahoma combined. Beyond the bare statistics, Nigeria is a country of great variety—in its geography, people, politics and economics.

Geographically Nigeria has four distinct regions [*see illustration on next page*]. Along the coast, which is close to the Equator, is a region of torrid, swampy lowlands. Here the delta draining Africa's largest river system, the main streams of which are the Niger and the Benue, is cut by scores of channels into hundreds of islands. Farther inland is a belt of dense rain forest, largely composed of cottonwoods, mahogany, satinwoods and cedars. To the north of the forests lies the vast grassy plain that forms most of Nigeria. The forest and the southern part of the savanna country are suitable for growing cocoa, rubber, rice, yams, cassava and oil palms but are inhospitable to cattle because of the tsetse fly. In the northern savanna there is herding of cattle, sheep and goats and successful cultivation of cotton, soybeans, millet, Guinea corn and peanuts (which the Nigerians, like the British, call groundnuts). The fourth geographical region, in the far north, is thorn forest and near-desert.

Throughout much of the country appear significant mineral deposits. Petroleum, recently discovered in the delta, has rapidly become one of the country's major exports. On the central plateau are tin and columbite, a black mineral that yields the increasingly useful metal columbium. Coal, with indicated reserves of 240 million tons, is found in several places, but it is of low grade; there are also considerable deposits of limestone and iron ore.

The people of Nigeria belong to a homogeneous racial group. There are, however, some 250 different tribes, ranging from millions of individuals to a few thousand, and almost every tribe has its own language. Since "tribe" is anthropologically a rather vague term, the British administration in Nigeria sought to clarify the situation there by defining a Nigerian tribe as "one or more clans descended from one legendary ancestor, though the legend may have been lost; originally observing one common shrine, though the memory may have been lost; speaking one language, though perhaps not the same dialect, and enlarged by assimilated peoples." In the absence of a common Nigerian tongue English serves as the official language and as somewhat of a lingua franca, known at least by the educated. Another result of the tribal profusion is a diversity of religions. Christianity predominates in the south, the result of more than a century of missionary activity, and Islam in the



CHIEF CHARACTERISTICS OF NIGERIA are outlined in these maps. Top map depicts major political and physical features. Only three of the regions, which have a role comparable to that of U.S. states, now exist; the Midwest Region is in process of formation following a plebiscite in July. Rainfall map (*bottom left*) also shows tsetse fly area. The fly's economic impact is reflected by colored line on map at bottom right; cattle cannot flourish in fly-infested areas, so that there is little livestock-herding south of line.

north, the result of incursions from North Africa centuries ago. Throughout the country pagan religions survive in large number and variety.

Politically Nigeria is divided into three autonomous regions: Northern, Eastern and Western. A fourth region, the Midwest, is in process of establishment; it will consist of the provinces of Benin and Delta, which are now part of the Western Region. There is also a small federal territory centering on Lagos, the national capital. Each of the three existing regions has a predominant tribal group, several other distinguishing characteristics and a strong regional pride.

The Northern Region, the capital of which is Kaduna, is the largest, both in area (281,782 square miles) and in population (some 20 million). Its predominant tribal grouping is the Hausa-Fulani, an alliance, strengthened by intermarriage, in which the Hausas are the more numerous but the Fulani are the ruling element. The North is a world apart from the other regions; it is the Moslem area, with conservative politics and a feudal social system in which power lies with the Moslem emirs chosen from noble families. But it is also an area with great political realism, a sense of the urgency of change and a determination to bring it about. The dominant political party is the Northern People's Congress, headed by Alhaji Sir Ahmadu Bello, considered by many the most powerful man in the nation.

In the Eastern Region, of which the capital is Enugu, the Ibo is the dominant tribe and the National Convention of Nigerian Citizens the dominant party. A leading figure in the party is Nnamdi Azikiwe, the Governor-General of Nigeria and the grand old man of Nigerian nationalism. With eight to 10 million people in its territory of 29,484 square miles, the Eastern Region is the most densely populated area in the country. Its population has a reputation for energy and resourcefulness.

The Western Region is populated mainly by the Yoruba, who are traditionally town dwellers; this is reflected in the fact that the urban population of the region (people living in cities of more than 20,000) is about 30 per cent, in contrast to 7 per cent in the East and 4 per cent in the North. Ibadan, the capital of the Western Region, is the largest Negro city in Africa, with probably a million inhabitants; it is also the seat of University College Ibadan, the Federal University of Nigeria. The Western Region has an area of 45,376 square miles and a population estimated in 1961 at 7.1 million. In politics, unlike the other regions, there has always been a strong opposition in the regional parliament. The Action Group, headed by Chief Obafemi Awolowo, was once dominant but split a year ago, and during a brief interregnum a federal administrator ran the region; the regional government now consists of a coalition between an Action Group bloc (the United Peoples Party) and the National Convention of Nigerian Citizens.

The major exclusive responsibilities of the regional governments are agriculture and education below the college level. These governments obtain most of the revenue they raise themselves (as distinct from what the federal government gives them) from agricultural products—either as export duties, produce sales taxes or profits of the Marketing Boards, which buy the major export crops from producers at prices substantially below those obtaining in the world market.

At the federal level the Northern People's Congress has an absolute majority in Parliament and is the senior member of the coalition government headed by Alhaji Sir Abubakar Tafawa Balewa (a member of the party) as prime minister. The other partner in the coalition is the National Convention of Nigerian Citizens. Formerly the Action Group constituted the loyal opposition; since the split in that party and the arrest of Awolowo, its leader in Parliament, on charges of treason, the opposition has had no clear spokesman.

Underlying the political relations at the federal level is considerable tension, originating principally in regional and tribal jealousies. Efforts by the major parties to expand outside their own regions have met rebuffs, and the parties have therefore tended to become increasingly regional in outlook.

These political differences, reinforced by regional pride and autonomy, exert a centrifugal influence on the federation. Nevertheless, there is a strong Nigerian national consciousness, and there are powerful unifying forces. One is the heritage of British law, parliamentary government and civil service, together with the unifying effect of the English language. Moreover, the federal government has exclusive responsibility for national defense, foreign affairs and the money system; it operates the railroads, the major ports and many other enterprises through statutory corporations that have actual or virtual monopolies and function throughout the Federation; it is responsible for the main highways and the communication system, and it provides approximately two-thirds of the revenue received by the regional governments.

Economically Nigeria, like all parliamentary democracies, is a mixture of public and private enterprise. The latter is extensive but tends to gravitate toward small-scale activities; large ventures are more often undertaken by the government or by expatriate business.

Nigeria's economy received a substantial impetus in the 100 years of British rule, although more as a result of normal colonial enterprise and trade than through any deliberate policy to achieve "economic development." By 1911 the country had a railway from Lagos to Kano. The road system by 1960, the year of independence, had grown to 46,761 miles, of which 5,267 were paved. The state-owned Electricity Corporation generated 448.3 million kilowatt-hours of power in 1960, a better than thirtyfold increase over 1937.

It was also significant for Nigeria's development that the British for many years pursued a policy of making colonies pay for themselves. In contrast to the attitude adopted by the French toward their African colonies, the British made no systematic attempt to provide a sheltered market for Nigerian exports—a policy that, whatever its shortcomings, had the advantage of keeping Nigerian exports competitive. Under this policy Nigeria emerged from World War II with substantial sterling assets (mostly accumulated by the Marketing Boards), and it also was in a position to finance its own ordinary budget and make substantial capital investments out of budget surpluses.

Toward the end of the British period there were some attempts at systematic, planned development at the government level to supplement the build-up of Nigeria under private enterprise. In 1929 and 1940 the British Parliament passed Colonial Development and Welfare acts, but they did not really get off the ground because of the depression and the war. In 1945 a third act made £120 million available to all the colonies in the period from 1946 to 1957; each colony was asked to produce a 10-year development plan. In terms of the need these efforts did not go very far, but they constituted at least a beginning.

How much this move toward systematic development quickened the growth of Nigeria is difficult to say because of the lack of adequate statistics on the economy before 1950. It is a matter of record, however, that there was substantial growth during the 1950's. In terms of 1957 prices the gross domestic product of 1950 was about £699.3 million (the Nigerian pound, like the British, is equivalent to $2.80) and in 1960 about £1,023 million—an average increase of approximately 4 per cent per year, which is good by the standards of underdeveloped countries. Gross fixed investment (in roads, schools, housing, plant and other fixed capital assets) rose from about 7 per cent of gross domestic product in 1950 to more than 15 per cent in 1960—also a considerable achievement. Consumer expenditures rose during the decade from £609.4 million to £870 million; that rise exceeded any possible population increase and therefore represented an improvement in the average standard of living.

The increase in the real goods provided during this period showed the more concrete aspects of the abstraction represented by the term "gross domestic product." The output of cement, textiles and many other consumer products increased many times. The number of telephones in service increased from 7,760 to 38,690. Port cargo doubled (to 7.31 million tons) and railroad freight rose 50 per cent (to 1.25 billion ton-miles). Spending on education was £3.1 million in 1950 and £26.3 million in 1960.

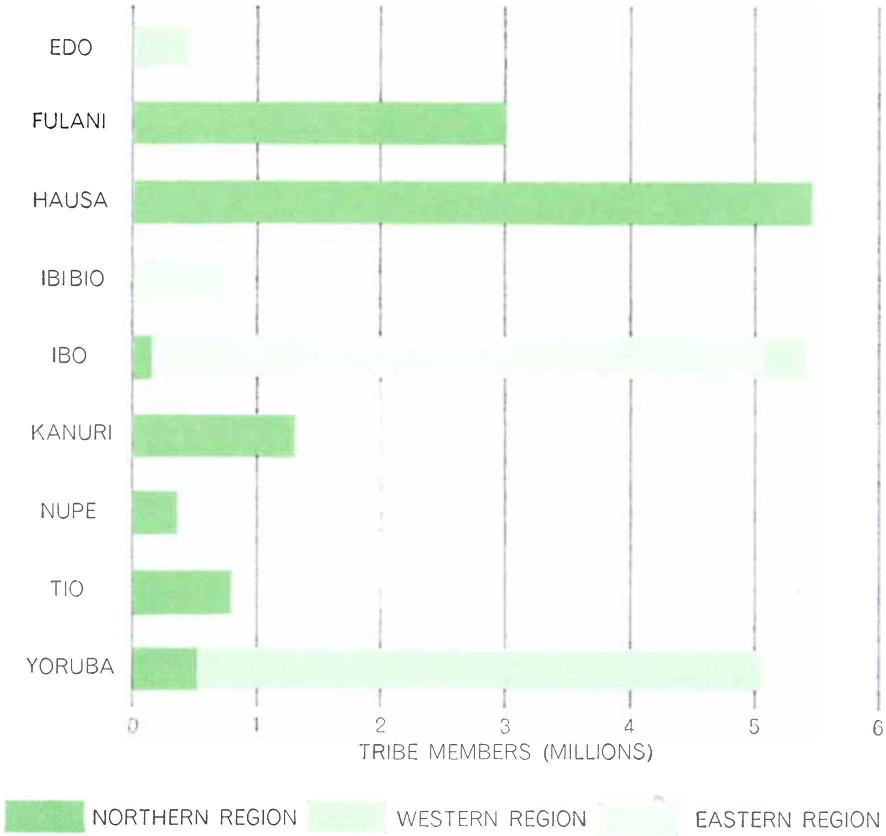
In 1959, a year before independence, the Nigerian government issued what amounted to a formal portrait of the economy: *Economic Survey of Nigeria*. It indicated that a majority of the population lived in rural areas and that 75 per cent of the adult labor force worked in agriculture, forestry and animal husbandry; that the cultivation of field and tree crops accounted for 50 per cent of the national income and 85 per cent of the country's exports, in addition to enabling Nigeria to feed itself. The survey observed that "the prospects for raising the wealth of the country and the level of the National Income rest largely on the possibilities of increasing exports and developing industry." With respect to exports the survey foresaw "good grounds for hoping that oil exports will become important," as they have, but cautioned that "it is to agricultural production that Nigeria must look for some time to come for any major increase in export earnings." On the subject of industry, which was described as "not yet a major contributor to Nigeria's national income," the survey said: "It is a major objective of Government policy to promote the growth of industry in Nigeria, both to increase the wealth of the country and to provide new sources of employment. Industrialisation will also help to make Nigeria less dependent on the relation between the world prices for the primary products which she exports and manufactured goods, nearly all of which she at present imports" [*see illustration on page 178*].

Some of the other statistics showed how far Nigeria had to travel on the development road. Her per capita income of less than £30 a year put her in the lowest 20 per cent of the 100 areas in the world classified as underdeveloped, and even that income was unevenly distributed among the regions. Illiteracy was high; the 1952–1953 census had reported only 12 per cent of the population as being literate, and although that figure rose somewhat thereafter, the educational attainments of the population still fell considerably short of the requirements for industrial development. By now, in the two southern regions, about 80 per cent of the school-age children are in elementary schools. But Nigeria was and is particularly short in high-level manpower: entrepreneurs, administrators and all manner of professional and technical people. In fact, skills are the country's greatest need.

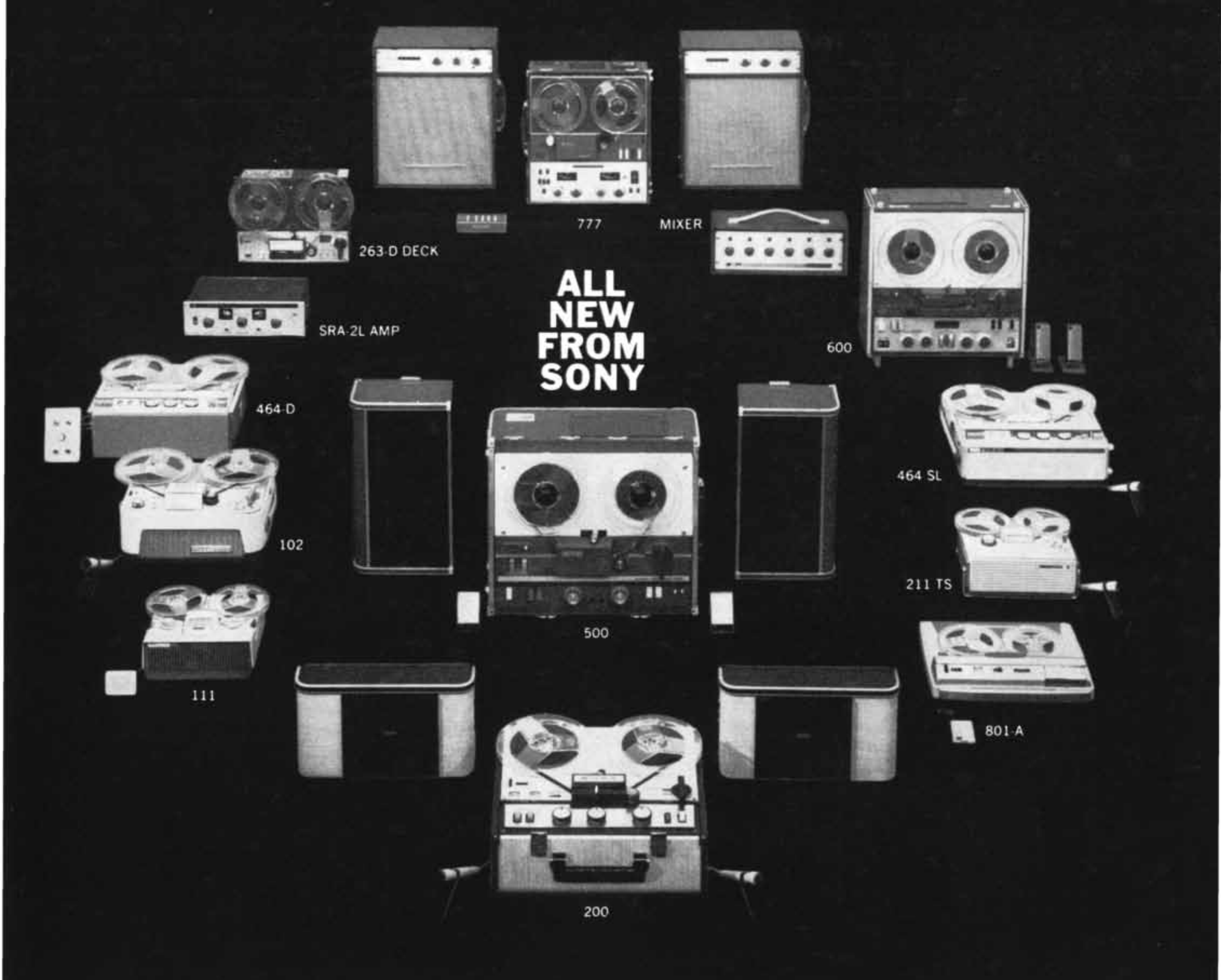
Also reflecting the country's underdeveloped status was the composition of the labor force and imports. Not only was the greater part of the labor force engaged in agriculture but also nearly 60 per cent of those so engaged were producing primarily for subsistence rather than the market. Imports, according to a study by Ojetunde Aboyade of University College Ibadan, consisted in 1959 of 48 per cent soft consumers' goods, 10 per cent durable consumers' goods, 30 per cent capital goods, 11 per cent processing and raw materials and 1 per cent miscellaneous imports.

At a more abstract level past developments showed some other disquieting facts. As the rate of investment in development had increased, a substantial export surplus had changed in 1954 to an import surplus. Sterling assets had thereafter dropped from £263.1 million in March, 1955, to £147.5 million in December, 1961. The balance of payments would therefore have to be watched.

The rate of domestic savings had meanwhile remained at about 10 per cent of gross domestic product. That was a high rate for an underdeveloped country. But with sterling reserves falling, capital investment could be maintained at a high level only through



TRIBAL DIVISIONS constitute important factor in Nigerian life. Nation has about 250 tribes, varying in membership from millions to a few thousand. Chart shows how each existing region has a dominant tribe and also tribal minorities; same will be true of new Midwest Region, where Edo will be principal tribe. Languages are almost as numerous as tribes.



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IN NEW YORK, VISIT THE SONY SALON, 585 FIFTH AVENUE.

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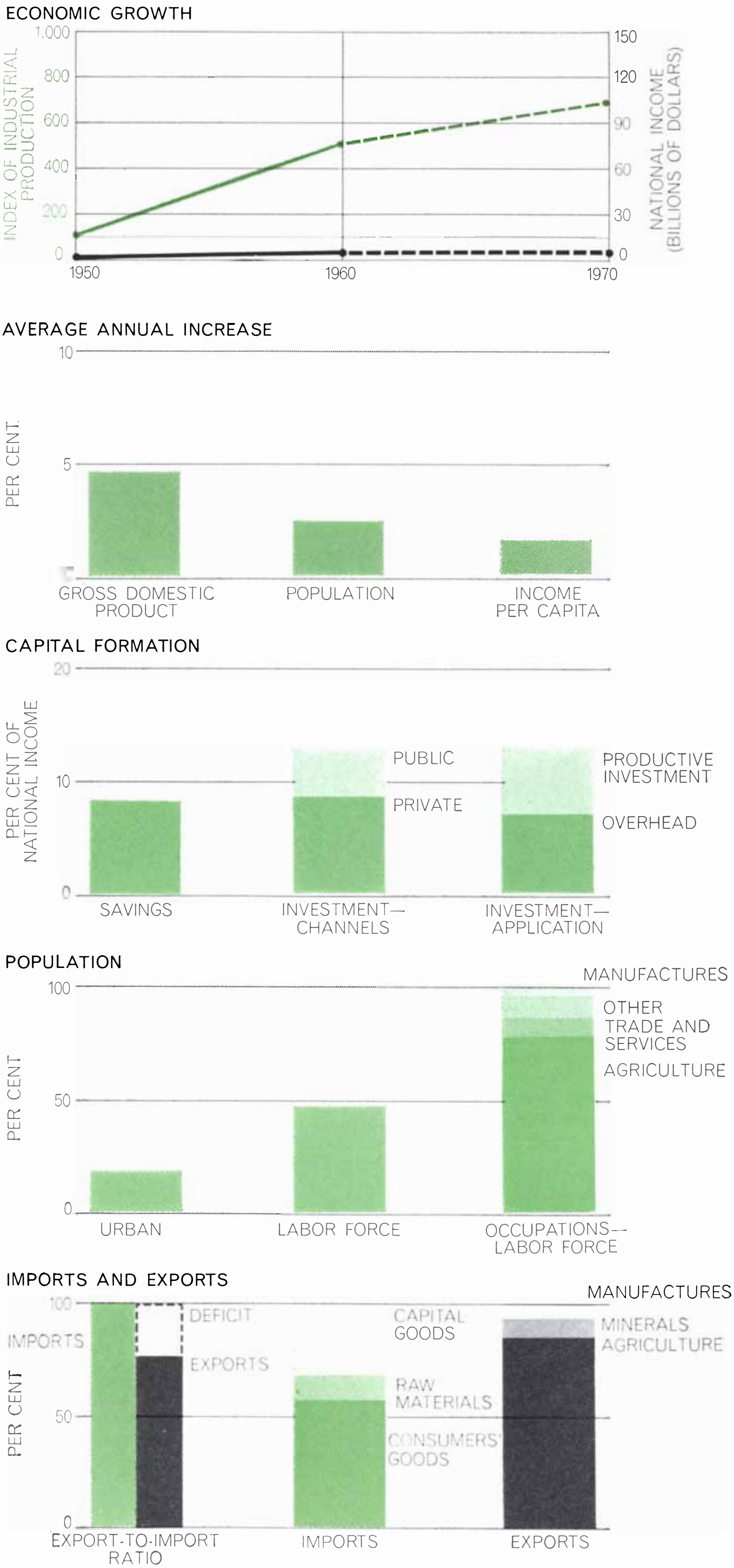


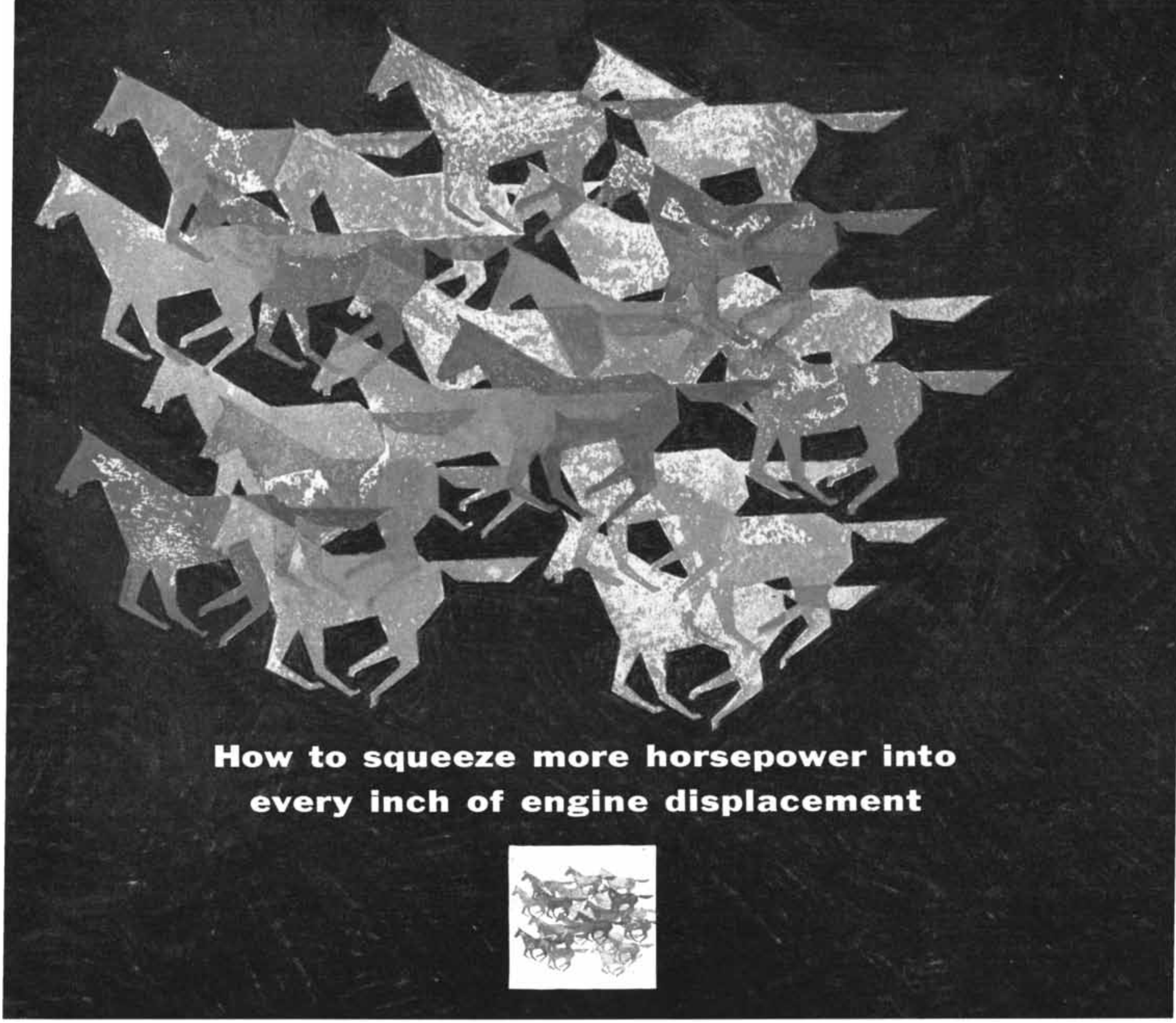
increased domestic savings or increased capital imports. The former, however, would require a considerable effort and could, through an increased tax burden, produce heavy political repercussions, whereas the latter would affect the balance of payments adversely by increasing the amount of money needed to service the external debt.

Finally, the increase in the gross domestic product had begun to slow down. Some of this was the result of falling prices for the country's raw-material exports and some the effect of adverse weather on agricultural output. But part of the responsibility clearly lay in the fact that some of the past capital expenditures had been for projects that were slow to produce results.

These facts set the context for thinking about the National Development Plan in the interregional Joint Planning Committee and its secretariat, the Federal Ministry of Economic Development, where I headed the Economic Planning Unit for 18 months under a grant from the Ford Foundation. The declining growth rate, the prospect of still lower export prices, the drop in sterling balances and the need to increase the mobilization of domestic resources for development all pointed to one conclusion: It was essential to put more emphasis than past development efforts had on directly productive investments and less on "social overhead," which includes education, health and housing.

From this determination it also followed that we would have to emphasize the central role of the ordinary annual budget, which the Nigerians call the recurrent budget. This meant viewing the development problem as involving the mobilization and allocation of resources. It also meant resisting any attempt to see development as essentially a problem of governmental and private capital formation, or to separate development expenditures from nondevelopment expenses prematurely. Every capital project builds up additional recurrent expenditures; even if a hospital is a gift, the recurrent budget must provide the money for the staff. In addition, some of the most powerful development expenditures—such as for agricultural and industrial instruction services, which will raise productivity and product faster

ECONOMIC INDICES suggest how far Nigeria has to travel on road to desired development level. Comparable indices can be found for three other areas in different development stages: India (*page 192*), Brazil (*page 212*) and U.S. South (*page 228*).



...another example of Caterpillar capabilities at work

When Caterpillar Research Engineers talk about this project, they call it VHO.

Officially, it's a research project to design a family of four Very High Output engines for the U. S. Army Tank Automotive Command. The family goal: delivery of more working horsepower per inch of displacement than any compression-ignition engine now available. Horsepower-to-weight ratios will be in the gas turbine range.

Current design indicates a realistic initial target of 80 HP from each cylinder at 2800 RPM. This is without revolutionizing engine structure or creating highly sophisticated aspiration methods.

Even in the design stage, family likeness is certain. Of the 194 major parts needed for the entire family, only 30 parts have single usage and 164 are used in at least two models.

Because of this high interchangeability, vehicle designers won't be hampered by a single engine configuration. They will be able to arrange external accessories on these 4.5 x 5.5 bore and stroke engines to suit the vehicle ... without adding parts to the logistics system.

The VHO research program demonstrates another of Caterpillar's capabilities in the area of military vehicles and engines to power them.

If anyone knows how to squeeze a thundering herd of horsepower into a military compression-ignition engine—or create a highly specialized piece of ground support equipment—Caterpillar does. To find out just how far Caterpillar's abilities range, contact Defense Products Department, Peoria, Illinois.

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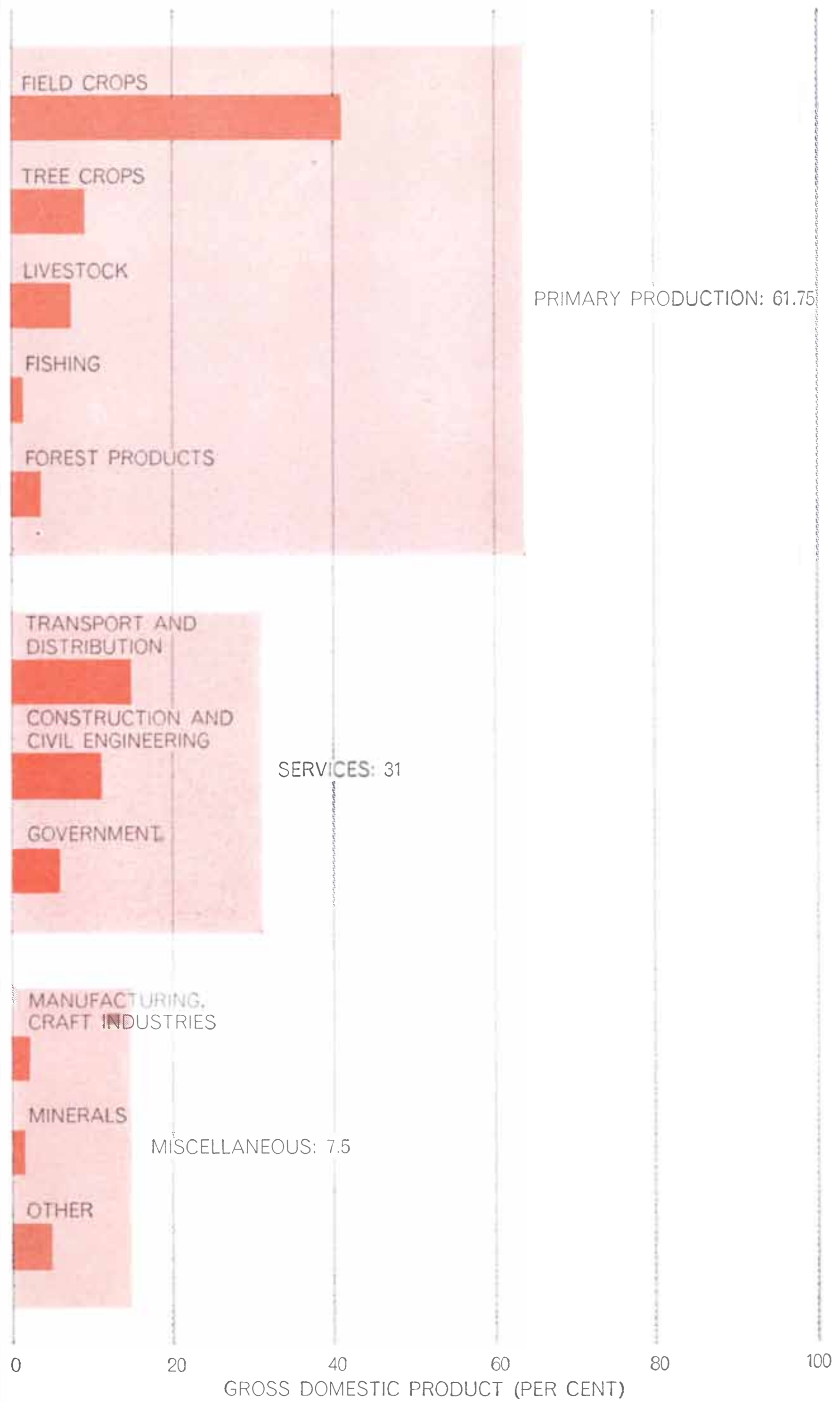
than any other categories of government outlay—are always included in the recurrent budget.

There was, therefore, a close relation between the recurrent budget and the size of the government's capital program. The recurrent budget also provided a major link with the private sector, since policies on such matters as subsidies and taxes have a direct impact on the budget.

Another of our basic principles was to view our role as one of co-ordinating and helping rather than imposing a central will. To a certain extent this was inescapable because of Nigeria's federalized structure and the strong sense of autonomy in the regions. But we also



GOODS AND SERVICES making up Nigeria's gross domestic product are shown in three major categories indicated by colored areas. Agriculture and related activities (*top*) constitute by far the biggest part. Among aims of development plan are increased earnings from agriculture and a considerable reduction in country's dependence on manufactured imports.

FRIDAY, NOVEMBER 13, 2026.
REMEMBER THIS DATE...IT'S DOOMSDAY

This Doomsday is nothing to scoff at. It is not the work of crackpots. It is a carefully considered estimate published in *Science* magazine by three serious scientists.

These men have been studying the rate at which people have been giving birth to people since 5000 B.C. Then they calculated ahead and concluded that on November 13, 2026 the planet earth will contain 50 billion people (current total: less than three billion). And that, unless our world's production of food is stepped up immeasurably, these people will almost certainly starve.

If our heaping dinner tables make Doomsday seem absurd; if our highly publicized crop surpluses make the Starvation Age seem remote, ponder this:

If those 50 billion future citizens were invited to share our plenty, they could eat their way through America's gigantic stored surpluses *in less than one day.*

That's the population explosion you've heard about.

Cyanamid has heard about it, too. That's one reason why several hundred Cyanamid scientists and technicians are at work in a new Agricultural Research Center—a rolling, 640-acre laboratory-farm near Princeton, New Jersey.

There, they work, read, talk and sometimes stare out at the countryside. They consider, as the autos roll by, that New Jersey now has 800 persons per square mile (and so, incidentally, has Japan). And that in 2026 it will have *10,000* per square mile (and so, incidentally, will Japan). All of which makes them search a little harder for ways to match that population explosion with a food explosion.

These scientists know that agricultural science must hurry. It must replace two ears of corn with four, four chickens with eight, eight hogs with sixteen. Then they must do it again. And again.

The people of Princeton are confident that they can do it. Already they are discovering which nutrients produce the biggest, healthiest livestock. They are growing plants in man-made, man-controlled temperatures ranging from arctic to jungle; in humidities ranging from desert to New York in August.

They're discovering better ways to cope with insects, too. Right now, insects and disease eat or destroy *30%* of all the food we plant. With fifty billion mouths to feed, we really won't be able to afford that kind of free-loading much longer.

Much progress has already been made. Cyanamid's AUREOMYCIN® chlortetracycline has helped farmers cut more than a third off the time it takes to bring plump, tender broilers to market.

And much progress is being made today. A new insecticide called CYGON® dimethoate is stopping barnyard flies dead in their tracks. Fly-free cattle, science knows, will grow fatter and give more milk.

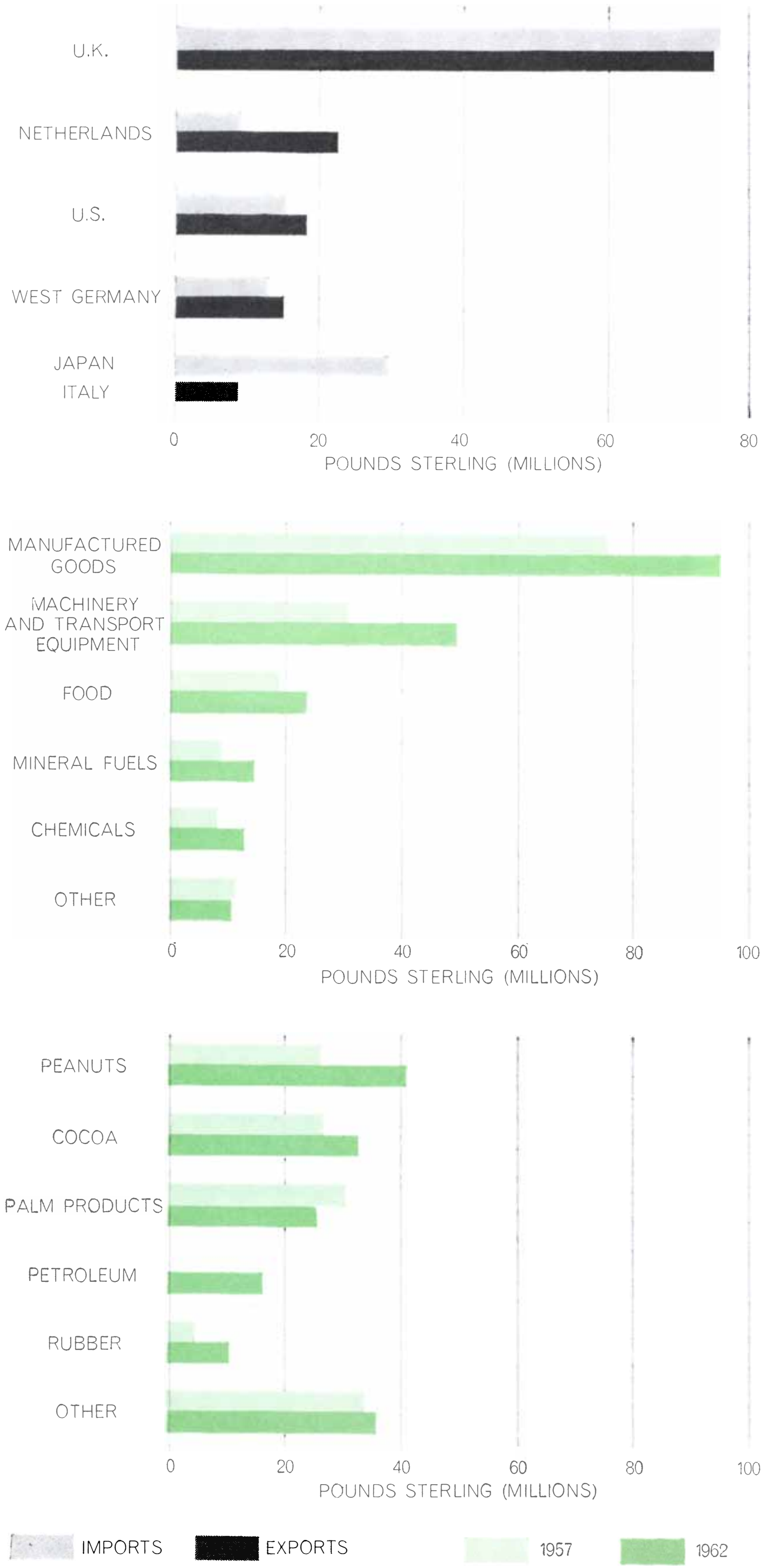
Cyanamid subscribes to the often-ignored axiom: Look after the future in the present. That's one reason for the new multi-million dollar Princeton Agricultural Center.

Another reason is that agricultural research is sound, profitable business. Good ideas that have reached their time usually are.

This is the story of one research effort by one Cyanamid division. Eleven other divisions operate in the United States and eighty-seven foreign countries. Working together they create an atmosphere charged with diversity, alertness, and progress.

CYANAMID

AMERICAN CYANAMID COMPANY
WAYNE, NEW JERSEY



IMPORTS EXCEED EXPORTS in usual annual trading by Nigeria. Charts show direction and composition of trade: at top, the countries that provided most of the imports and received most of the exports in 1962; at center and bottom respectively, principal imports and exports, indicating extent to which nation depends on agriculture for export earnings.

wanted to evoke the interest and draw on the experience of the people at the grass roots in order to bring as many as possible into the development process. We thought it absurd in any case for a man sitting in Lagos or any of the regional capitals to pretend to know in sufficient detail such matters as the agricultural problems in the Lake Chad area. We therefore emphasized development of the planning framework from below and the decentralization of decision-making in the execution of the plan.

The National Development Plan as finally evolved includes co-ordinated undertakings by the federal government and each of the three regions. Total government capital expenditures envisioned over the six years of the first plan are £676.8 million, of which 71.4 per cent is to be apportioned to "economic development," meaning the directly productive sectors of the economy such as agriculture, trade, industry, electricity and communications; 20.8 per cent to social overhead and 7.8 per cent to administration, a category that includes defense.

In the economic-development sector of the plan the greatest outlay—£143.8 million, or 21.3 per cent of the total plan expenditure—will go to the transport system. The greater part of that outlay will be federal, directed chiefly toward highway improvement, port development and expansion of the national railroad system.

Electricity will receive £101.7 million, or 15.1 per cent of the plan total. Virtually all the outlay will be federal, and two-thirds of that will go toward what is in effect the cornerstone of the plan—the Niger dams project. The broad aim of that project is the establishment of a nationwide electricity grid and the comprehensive development of the river that gives the country its name; the first stage, which the current plan includes, is the construction of a dam at Kainji. The second stage calls for a dam at Jebba by 1982 and the third stage for a dam at Shiroro Gorge. The total installed capacity, once the three stages have been completed, will be 1.73 million kilowatts.

The Kainji Dam is the largest single project in the first plan. In many ways it epitomizes Nigeria's efforts toward integrated development of her natural resources. It will provide electricity for all parts of the country. It will improve navigation on the main rivers, thereby lowering transport costs and providing easier access to the interior from the sea. It will regulate floods and help agricul-

Classic Jobs of Measurement
Performed by Electro Instruments

A Foreword by
Dr. Walter East
President, Electro Instruments, Inc.

"You name it, we'll find a way to measure it," our brash engineers keep assuring me. I like their spirit, even if it has been costly to me in the way of expensive dinner bets!

It was with a measuring breakthrough that Electro Instruments was born. Our original Stepping Switch Digital Voltmeter was the first to substitute electronically driven switches for mechanical needle movement devices. It quickly proved itself an ideal instrument for speedier, more accurate, more reliable measurement—with useful applications in many industrial operations.

Since that time we have pioneered 19 other electronic "firsts."

These have led to ways of refining many older measuring systems. But, more important, they have extended the areas in which our instruments, and our systems, can serve industry.

The end result for which industry employs measurement is economy . . . be it in personnel . . . time . . . materials . . . investment. Looking through our "case histories," I ran across a number of outstanding examples of economies effected by use of Electro Instruments.

I thought we might usefully present these to industrial engineers, executives, superintendents, as ideas they might consider for their own operations.

Many readers, I appreciate, will have industrial measuring problems quite different from those cited in the examples. On this point, I think our engineers are worth re-quoting: "You name it, we'll find a way to measure it!"

Electro Instruments' *solid state* Digital Multimeters bring greater speed, higher reliability to many jobs of measurement, and at a lower investment.

Electro Instruments offers the world's most carefully designed X-Y Recorders.

Spectra performance recorded without need for photography

In many biochemical operations, recorded profiles are necessary for accurate identification of compounds, and for purposes of quantitative assay. Used in connection with newly developed instruments capable of exciting molecules to a state of phosphorescence, Electro Instruments X-Y Recorders have proved a means of producing visual display of spectra without need for photographic equipment or processes.

500 man hour job cut to 33 ½!

Telescoping a job that once required 500 man hours into a 33½-hour operation is no mean feat! Yet a system employing an Electro Instrument Digital Multimeter accomplished just that — for one of America's major spacecraft* companies.

What was involved was the testing of printed circuit cards. Each of 1000 cards produced daily by the company had to be given 32 separate tests for quality. It took an experienced electronics technician and inspector 15 to 45 minutes per card to perform the job.

In the interest of speeding up this tedious job, experiments with an automatic electronic testing machine were begun. The eventual solution proved to be a punched tape system — designed, incidentally, by one of the company's engineers — with an Electro Instruments Digital Multimeter employed as a key parameter.

Each of the 1000 cards are now given the 32 quality tests in *less than 2 minutes*—with results being displayed at the push of a button! (*Name on request)

Electro Instruments, Inc.
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ELECTRO INTERNATIONAL, INC., ANNAPOLIS, MARYLAND • TRANSFORMER ENGINEERS, SAN GABRIEL, CALIFORNIA ture, but it will pay on electricity alone.

The category of "primary production," which includes agriculture, livestock, forestry and fishing, will receive £91.7 million, or 13.6 per cent of the plan total. A third of that will be spent by the Eastern Region, the remainder in approximately equal shares by the other two regions and the federal government. The money will go for such undertakings as research, training, irrigation, crop improvement, farm settlements and plantations and a fishing harbor at Lagos. On this subject the plan observes: "The expansion and modernisation of agriculture and related production is of crucial importance to the development of the Nigerian economy. The proceeds from export products will determine to a large extent the volume of imports which can be made available for economic development in other sectors; the efficient expansion of domestic food production will determine not only whether the Nigerian people will eat better but also whether they can effectively reduce dependence on imported foodstuffs; the increased productivity of agriculture will determine whether the income of the great majority of the people can be effectively raised and this will in turn determine the size of the domestic market for the new industries which are expected to spring up."

The final major category of economic-development expenditures is "trade and industry," which will receive £90.2 million, or 13.4 per cent of the total. About half of that spending will be federal; regional outlays will range from £23.4 million in the Western Region to £9.9 million in the Northern Region. Chief among the projects is the construction of an iron and steel mill at a site as yet to be determined; it is expected to cost £30 million and to be in operation by 1966 at the earliest. The mill is envisioned as being the center of a complex that will provide an extensive stimulus to the economy by using Nigerian ores, limestone, electricity, oil and coal in addition to producing upward of 125,000 tons of steel products annually for the growing economy and thereby reducing the country's dependence on imported steel.

Another major project in the trade-and-industry category is an oil refinery under construction at Port Harcourt by a combine of the Shell oil group and the British Petroleum Company Limited, which are sharing the £8 million cost with the four governments. Ultimate ownership of the refinery will be 40 per cent in the hands of the Nigerian government, 40 per cent Shell and British Petroleum and 20 per cent Nigerian stockholders. The refinery will be profitable and also result in substantial import savings, with outlays for petroleum imports expected to drop from £11.7 million this year to £3.4 million by 1965, when the refinery will be fully in operation.

This portion of the plan also provides for the establishment of a National Development Bank "to join foreign skills and experience and foreign private capital with Nigerian skills and capital in the development of new industries and the expansion of existing ones." This bank is coming into existence during 1963. In addition there is provision for an array of technical and advisory services for Nigerian private industry. Outlays of £30 million for communications, mainly the telephone system, and £24.3 million for drinking and industrial water projects complete the economic-development section of the plan.

In the social-overhead sector of the plan the largest outlay will be for education, which will receive £69.8 million, or 10.3 per cent of the plan total. The program calls for substantial expansion of teacher training and school capacity at all levels. Town and country planning will receive £41.7 million and health measures £17 million.

The financing of the plan depends heavily on foreign aid, which is expected to supply fully half the need. The Nigerian federal and regional governments hope to have £263 million available from their own resources toward the £653.8 million in planned capital expenditures (that figure being the £676.8 million in capital projects outlined by the plan less £23 million in "underspending," i.e., a predictable shortfall). There is therefore a gap of £389.8 million, of which £327.1 million is to be covered by "assumed foreign aid" and the remainder is so far "uncovered." The Nigerians hope that they can eliminate the uncovered gap by budgetary economies.

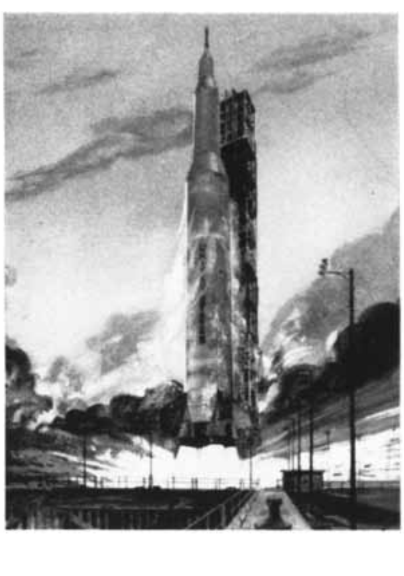
Nigeria's development also will continue to depend heavily on private investment, which hitherto has been slightly greater than public investment. The plan contemplates that two-thirds of the total gross investment will come from government funds and one-third from private sources. This does not reflect any political bias, however, and it is in fact expected that private investment will provide more and public investment less than outlined in the plan. The private investment anticipated by the plan over the six years is at least £400 million, about half of it from abroad. Achieve-

JET AIR FREIGHTER. New Boeing cargo jet, now in service, makes the Atlantic a six-hour ocean. Distribution systems built around jet air freight generate so many savings — in inventory, warehousing, crating and ground-handling expenses — that over-all costs are reduced. Deliveries in hours instead of weeks improve competitive sales positions and speed capital turnover. Boeing cargo jets carry larger payloads at lower ton-mile costs than any other commercial transport. Now flying with Pan American, Northwest Orient and World airways, Boeing cargo jets enter service soon with American, TWA and Irish airlines.

Capability has many faces at Boeing

MICROMINIATURE thin-film circuitry research is one of many advanced areas of Boeing electronics activities, which include electronics systems for Minuteman missiles and space vehicles.

SATURN V, drawing, right, will stand tall as 30-story building and hurl 100 tons into earth orbit. Boeing is developing, building and testing for NASA the S-IC first-stage booster with thrust of approximately 160,000,000 horsepower.



U.S. AIR FORCE volunteers, using Boeing oxygen recovery system, completed 30-day simulated space flight with only four-day oxygen supply. Boeing space research includes propulsion, controls, orbital docking and life support systems.

BOEING

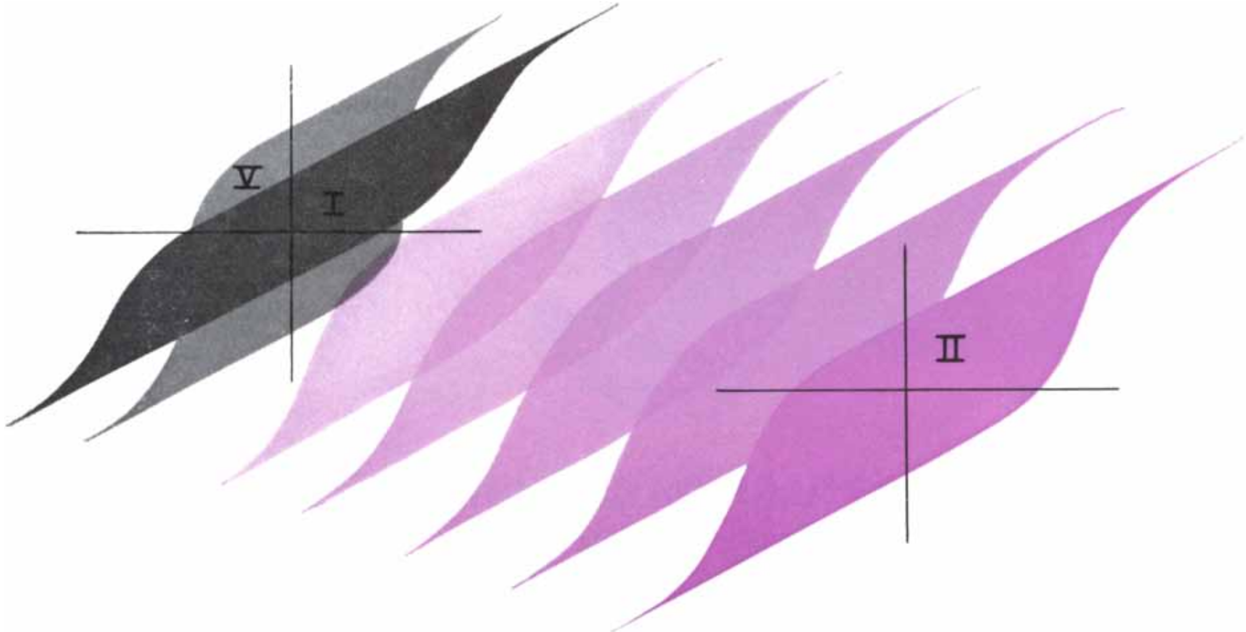
Space Technology • Missiles • Military Aircraft Systems • 707, 720 and 727 Jetliners • Systems Management • Helicopters • Marine Vehicles • Gas Turbine Engines • Also, Boeing Scientific Research Laboratories ment of that objective will require an increase of at least 10 per cent over present levels of foreign private investment in Nigeria and constitutes one of the major challenges of the plan.

This first plan is an ambitious one–I think overly ambitious. Something of this appears in the results of the first year, although they also reflect the inevitable delays and difficulties involved in setting so big a venture in motion.

By the end of that year commitments of foreign aid came to only £105.5 million–£80 million committed by the U.S. before the plan went into effect, £15 million from Great Britain, £8.5 million from West Germany and £2 million from Switzerland. A substantial loan from the International Bank for Reconstruction and Development toward the Kainji Dam is expected. Nevertheless, substantially more will be needed. In the development of capital projects during the first year governmental and private investment were approximately equal. Investment in the economic-development sector was £46 million, or about £9 million below the plan target; within that sector investment in the highly productive area of agriculture fell short but investment in transport (notably roads and bridges) was considerably in excess of plan targets. Total expenditure in the social-overhead sector at £18 million was some £2.5 million above the plan target, even though relatively little was spent in the high-priority field of education and relatively much on health projects. Administrative expenses were almost double the projected amount because of the unforeseen amount of expenditure on national defense, which has joined agriculture, industry and technical education as a major plan priority.

Moreover, recurrent expenditures rose sharply, moving Okotie-Eboh to remark in his 1963 budget speech that he was "deeply concerned." Exports fell by about £3 million because timber and palm-product shipments dropped in both volume and price, the cocoa price fell drastically and the cotton crop was halved by adverse weather. The effort to tap domestic savings had results that Okotie-Eboh called "disappointing."

There were, however, some bright spots. Imports in 1962 dropped by £20 million, or about 10 per cent, and the greater part of the decline was in such consumers' goods as textiles, clothing, household utensils and beer. In contrast, imports of capital goods and machinery rose significantly [*see illustration on page 178*]. As a result the balance-of-

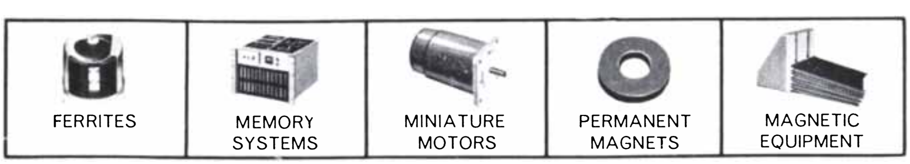


we probed material mutations . . .

discovered a low-cost motor magnet

The fantastically expanded use of small electric motors, in both battery-operated and plug-in devices, gave our research people a challenge — and an opportunity. The project — come up with a lower cost, yet efficient ceramic magnet material for a DC motor field. ■ Using our unique materials research experience, we varied the techniques involved in the development of our original INDOX® ceramic magnet materials; experimented with different firing temperatures, environments, and cooling rates; applied special manufacturing techniques to obtain production quantities comparable to laboratory samples. ■ The result — INDOX II, a mutation of our INDOX I and INDOX V materials having the low-cost advantage of the first and the superior magnetic characteristics of the second. INDOX II has a residual induction (B_r) of 2700 gauss; coercive force (H_b) of 2250 oersteds; intrinsic coercive (H_{ci}) of 2800 oersteds and peak energy product (B_dH_d) of 1.65 x 10^6 max. When used to replace wound fields in DC motors, INDOX II reduces cost, improves efficiency, lowers heat losses, cuts noise, reduces motor size and weight. ■ Indiana General engineers are happy to place their magnetic experience at your disposal — from designing new permanent magnet materials to building complete memory systems for logic storage. **Call or write for free booklet, "This is Indiana General"** to Indiana General Corporation, Valparaiso, Indiana.

INDIANA GENERAL



payments position improved and imports shifted toward those contributing directly to development. In addition to this encouraging trend private investment had done well and many public projects got off to a good start.

Nigerian development is indeed gathering way, but there are some shoal waters in its course. A major deficiency in the output of university graduates and persons of intermediate education to reduce the dearth of skilled manpower appears inevitable. Frederick Harbison [see "Education for Development," page 140] has estimated that Nigeria needs 2,000 university graduates a year, whereas only 1,000 Nigerians are receiving university degrees at home or abroad, and that the annual requirement for persons with a secondary school education is 4,000 more than the 1,500 the school system is producing. At the same time, ironically, the country has a growing problem of "school-leavers"—primary school graduates who are not equipped for any government or business jobs but who flock to the towns looking for them fruitlessly.

There is also the possibility of dangerous distortions in development priorities. Although directly productive projects are often difficult, showpiece projects that have no direct effect on economic growth are often easy. The results of the first year indicate a tendency to drift toward them.

Political stresses also may affect the development process. Nigeria is scheduled to become a republic in October, probably along Indian lines, and it is possible that the transition will produce strains. It also remains a possibility that the regional balance, already somewhat disturbed by Northern domination and the creation of the Midwest state, may change further toward complete Northern rule of the country.

In contrast, however, was the outcome of a recent discussion about adopting a preventive-detention act—the device so many authoritarian governments have used to suppress political opposition. Nigeria's rejection of that idea is strong evidence of the deep root that liberty has taken and of the moderation and strong sense of direction of the national leadership.

Nigeria has great potential and a strong determination to develop it. Her goal of becoming self-sustaining is attainable, and she should eventually reach it. How long that will take is difficult to say. My estimate, which many Nigerians consider unduly pessimistic, is that it will require at least a generation.

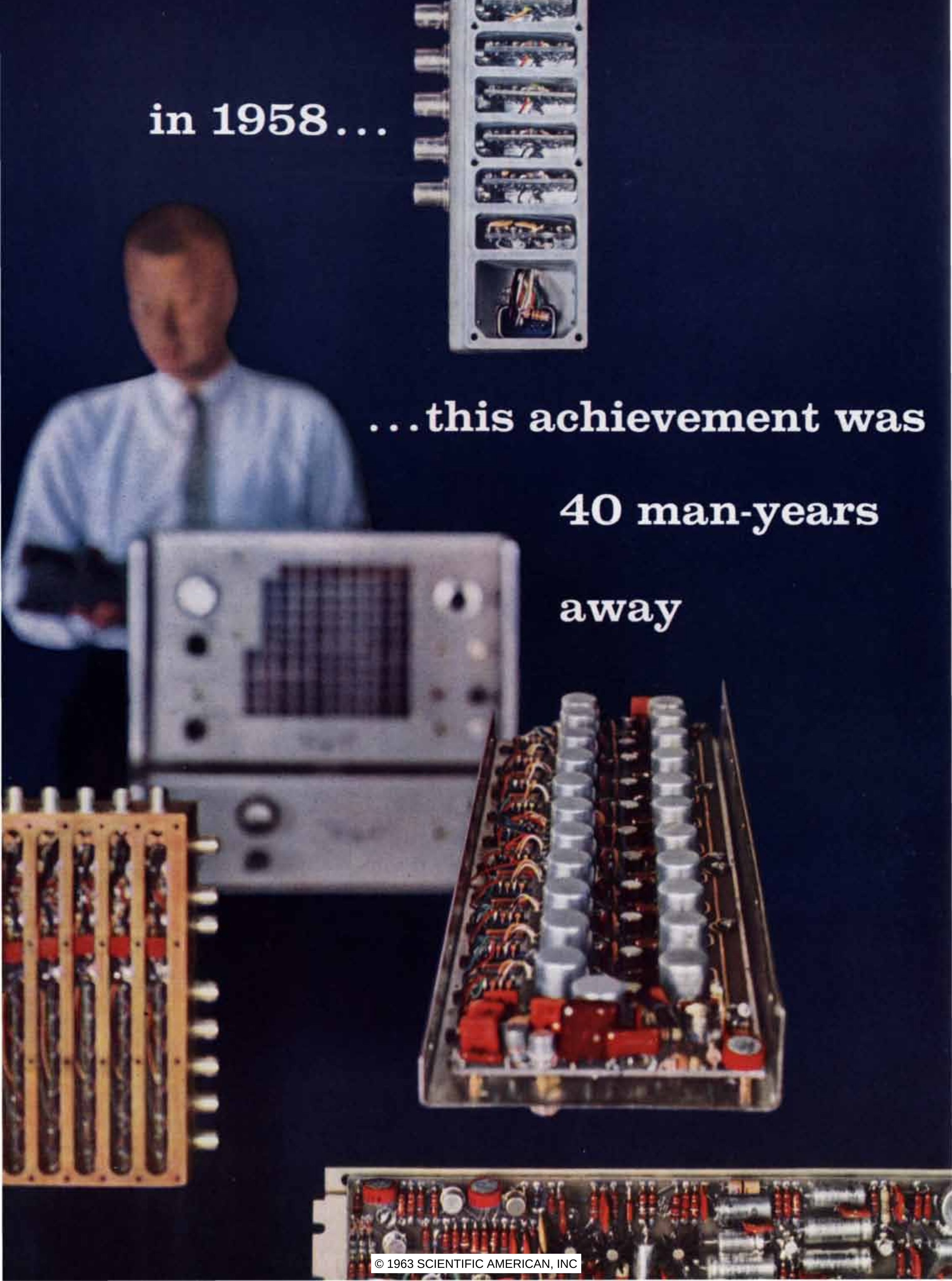
Holding the line . . . for a richer harvest

Boll weevil, codling moth, leaf rollers, thrips and beetles . . . these are only a few of the thousands of insects that chew up millions of dollars worth of farm crops each year. Fortunately, however, they are no match for a new Union Carbide product called SEVIN insecticide. In the United States and many other countries, the use of SEVIN has already saved such staple crops as cotton, corn, fruits and vegetables from destruction by ravaging insects. ▶SEVIN comes from years of research in Union Carbide laboratories and at an experimental farm in North Carolina where scientists prove out their latest agricultural chemicals. ▶This is only one area in which chemicals from Union Carbide help improve everyday living. The people of Union Carbide are constantly at work searching for better products that will meet the needs of the future.

A HAND IN THINGS TO COME

UNION CARBIDE

LOOK for these famous Union Carbide products—SEVIN Insecticide, "6-12" Insect Repellent, LINDE Synthetic Emeralds and Stars, PRESTONE Car Care Products. Union Carbide Corporation, 270 Park Avenue, New York 17, N.Y. In Canada, Union Carbide Canada Limited, Toronto.


in 1958...
...this achievement was
40 man-years
away

Components of the new Hewlett-Packard Frequency Synthesizer

PROGRESS

in electronic measurement results from continuing research and development work. Scientists and engineers need faster, more accurate instruments to bring into areas of the known that which formerly could not be measured.

One of the most significant instrument developments of the past year, representing 40 man-years of effort, is the remarkable new Hewlett-Packard Frequency Synthesizer, a source of five billion discrete frequencies.

In such critical fields as single-sideband communications, radio navigation, missile and satellite tracking, variable frequency signal sources are needed with accuracy and stability usually available only in laboratory-type fixed frequency standards. However, conventional oscillators do not provide this accuracy and stability, and the frequency of a lab standard is not variable.

In 1958 Hewlett-Packard engineers turned their attention to new techniques for answering this combination of requirements. Rather than trying to improve conventional electronic circuits, they began development of an instrument which could synthesize a signal of any desired frequency from a single, precisely controlled standard. Stringent objectives were established.

The synthesizer was to deliver signals ranging from 0.01 cycle per second to 50 million cycles per second—in increments of 0.01 cps! Stability, accuracy and purity of each of the 5 billion discrete, selectable frequencies were to be equivalent to the characteristics of the frequency standard. The instrument was to be solid state; spurious signals were to be at least 90 decibles below the level of the selected signal; and any output signal was to be selected by front panel pushbutton, or by remote control in no more than 1 millisecond.

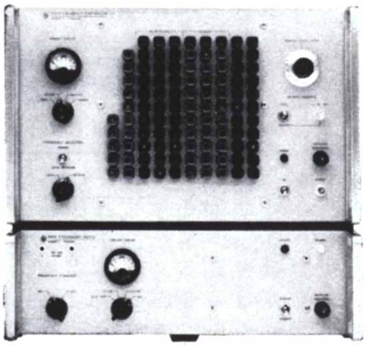
These requirements, and many more, were needed by potential users. The new hp 5100A-5110A Frequency Synthesizer meets them.

The discrete frequencies, derived from a single precise source, are created by complex electronic processes of multiplication, division, addition and subtraction. New techniques for harmonic generation were developed to accomplish the multiplication; methods of heterodyning and mixing were refined to accomplish the addition and subtraction.

Major refinements in both circuit technology and mechanical arrangements were made to meet the stringent requirements. Switching, for example, has to be electronic to achieve the 1 millisecond goal, but electronic switching can produce unwanted spurious signals. New filtering techniques were developed to maintain the specified output purity.

Numerous interacting problems were encountered and solved to achieve realistic instrument design and construction within the demands of the specifications. Engineers on the project even had to design and build special instruments to measure certain parameters, since no suitable commercial instrumentation existed.

Yet, despite the initial unknowns and the problems, the Hewlett-Packard frequency synthesizer is now a reality. It meets or exceeds all the requirements put upon development engineers by both the users and themselves. It is practical testimony to the validity of a continuing R & D program which places Hewlett-Packard at the forefront of precision electronic measurement.



The 5100A Synthesizer (top) is driven by the hp 5110A fixed frequency unit (bottom), which provides a stability of 3 parts in 10^9 per day. The 5100A delivers signals from 0.01 cps to 50 mc in increments as small as 0.01 cps. Any discrete frequency may be selected conveniently by front-panel pushbutton, or remotely in less than 1 millisecond. Non-harmonic spurious signals are 90 db down. hp 5100A, $10,500; hp 5110A $5000.

HEWLETT-PACKARD COMPANY

1501 Page Mill Road, Palo Alto, California 94304

Divisions and Affiliates: Hewlett-Packard S.A., Geneva; Hewlett-Packard (Canada) Ltd., Montreal, Que.; Boonton Radio Company, Dymec Division, Harrison Laboratories Division, HP Associates, F. L. Moseley Co., Sanborn Company. Plants: California, Colorado, Massachusetts, New Jersey, England, Germany.

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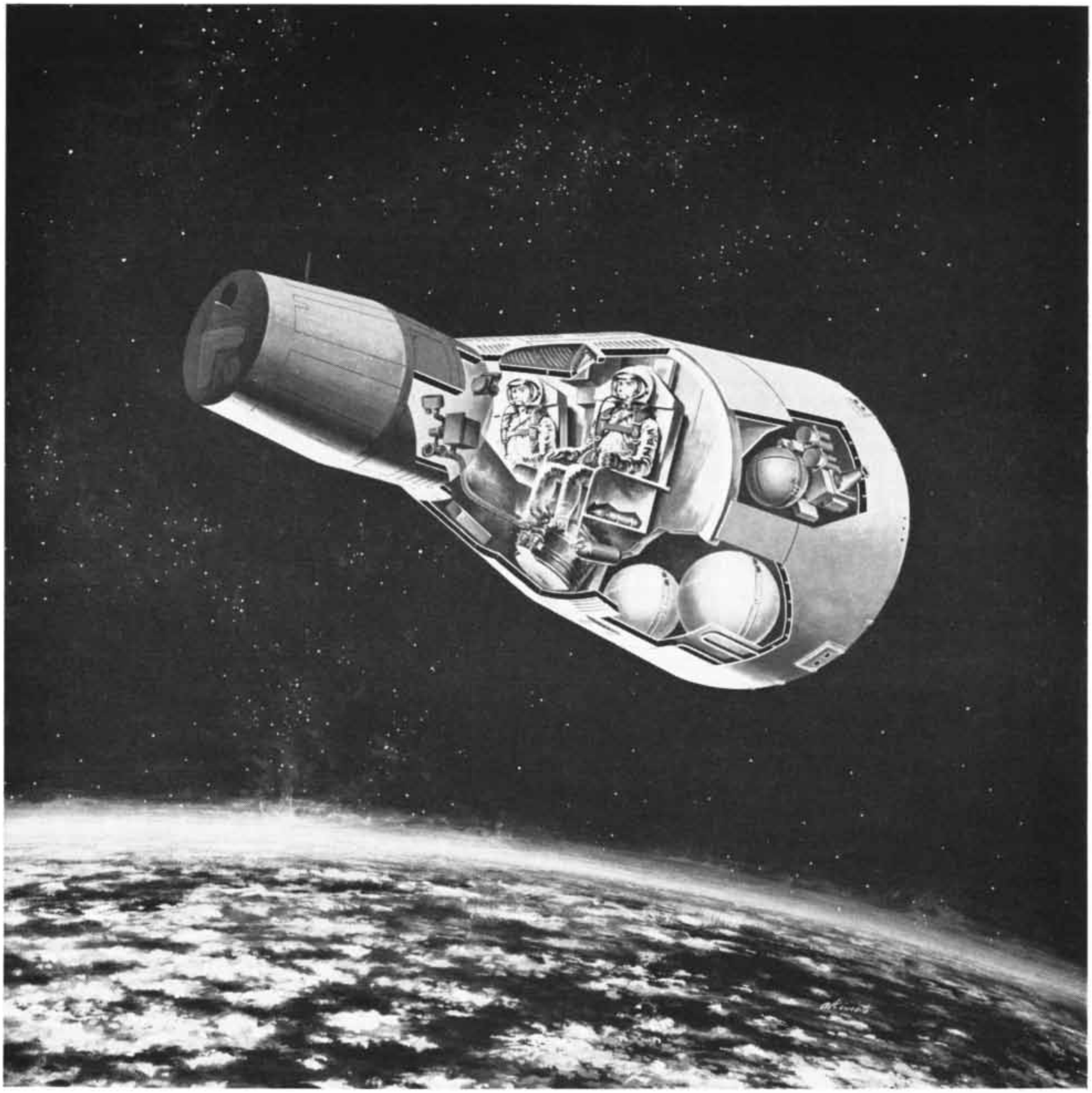


The Development of India

With a diversified population of 450 million, it has perhaps the most complex problem of development. It seeks to advance by methods that follow its traditional avoidance of coercion

by Pitambar Pant

India joined the community of 20th-century nation-states in 1947, the second largest in population and the seventh in land area. The people had won their independence in a struggle unique for its stress on peaceful means. From the beginning of the struggle the national leadership, under Mahatma Gandhi, recognized that the pledges of the independence movement would not be redeemed until the mass of the people were assured work, a tolerable standard of life and opportunity for continued advancement. Today the country is committed to a crucial experiment in economic development. India believes that industrialization and the attendant radical reconstruction of society can be achieved fairly rapidly and without reliance on class hatred or the invocation of violence and coercion.

This belief is a matter of faith; history offers no clear precedent to support it. In the past, revolutionary violence offered the only path to radical social change, and in those days the pace of the underlying change in the living conditions of people was generally slow. In our time, however, the advance of science and technology, the better knowledge of social and economic processes and an improved climate of international co-operation have brought material prosperity within the reach of all people. And political democracy has brought with it the possibility of peaceful change.

India is now in the second year of the third in a succession of five-year plans that are guiding its development. Its 450 million citizens—nearly a sixth of the population of the world, speaking a multiplicity of languages, cherishing a diversity of cultural traditions and still segregated in a multitude of castes—live in 15 states and eight territories that constitute the Indian Union. Yet change is already and everywhere apparent. The jet airplane flying overhead is as much a part of the landscape as the bullock cart carrying produce from village to town. The thatched mud huts of villages in the Punjab surround the modern capital at Chandigarh designed by the French architect Le Corbusier. While the atom is being harnessed to supply energy from a reactor of advanced design at Tarapur, cow dung will continue to be burned as the primary source of fuel in millions of Indian homes. India has many scientific laboratories and outstanding scientists, but the astrologer remains a respected member of society.

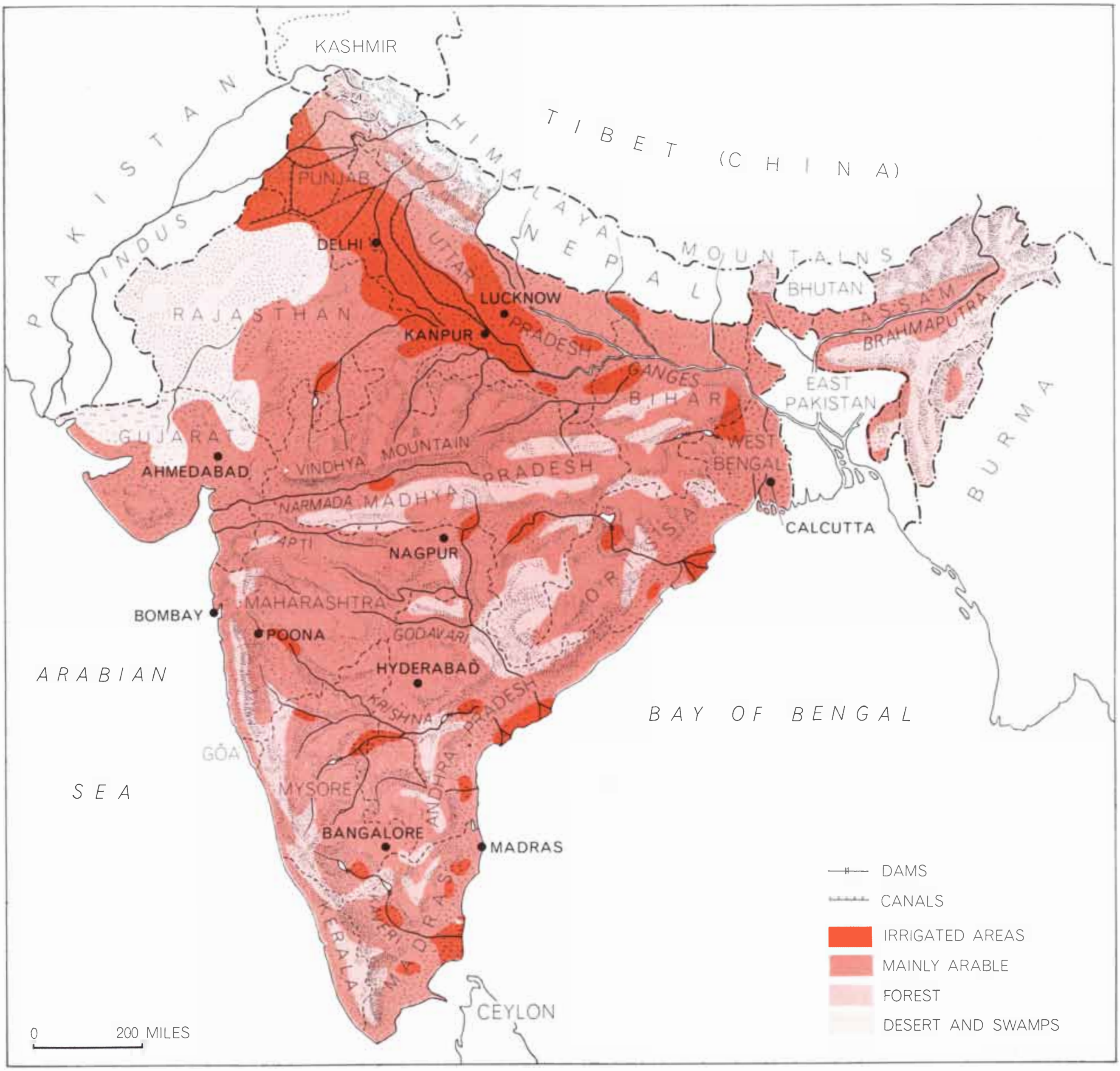
Of India's total area of 721 million acres, one-fifth is under forest and two-fifths are under cultivation. About 20 per cent of the cultivated area is irrigated. Of the cropped area 80 per cent is used for producing cereal grains and pulses (the seeds of leguminous plants such as peas and beans). These constitute the staple food, and because the farming is largely for sheer subsistence they are grown everywhere. The kind grown—whether rice, wheat, barley and maize or the indigenous *jowar, ragi* or *bajra*—depends on the local climate, soil and availability of water. Cash crops include tea, coffee, sugar cane, oilseeds, tobacco, jute and cotton, spices and tropical fruits. Jute and cotton manufactures, tea, tobacco and spices account for nearly half the export earnings of India.

Lack of water at the right time is the principal handicap and hazard to Indian agriculture. The rains are seasonal monsoons coming once or twice a year; they are undependable from year to year. Most of the rain comes in the summer and floods to the sea in rivers further swollen by the melting of the Himalayan snows. A scanty monsoon can seriously damage the chief harvest of the year.

In recent years Indian planning has laid great stress on irrigation. With irrigation not only is the main harvest assured but also two or three crops a year are possible. At present an estimated 70 million acres are under irrigation; some of the land has been irrigated for ages past. About 40 million acres get water from wells, tanks and minor works, and 30 million acres are supplied by large and medium-sized projects. Another 100 million acres are believed to be irrigable by the development of ground-water supplies and the abundant but unharnessed river waters.

India has most of the mineral resources necessary for its industrial development. It has one of the largest reserves of high-quality iron ore in the world, estimated at 21 billion tons. The supply of coking coal, estimated at two billion tons, is not large but is sufficient for the development of substantial steel production by established technology. Bauxite, the chief ore of aluminum, is fairly widely distributed in high-grade deposits. India is one of the largest producers of manganese and has a virtual monopoly of mica mining. There are also fair reserves of limestone, gypsum, refractory materials, ilmenite (titanium ore) and some gold and copper and minor minerals.

For energy resources the Indian economy can count on 50 billion tons of coal down to the fully workable depth of 2,000 feet. Intensive oil exploration, initiated six years ago with the help chiefly of the U.S.S.R., has resulted in the discovery of new fields in Gujarat and Assam; domestic production of crude oil is expected to reach seven million tons within a few years. The abundant monazite sands in Kerala provide


KASHMIR
PAKISTAN
INDUS
TIBET (CHINA)
HIMALAYA MOUNTAINS
NEPAL
BHUTAN
ASSAM
BRAHMAPUTRA
PUNJAB
DELHI
RAJASTHAN
UTTAR PRADESH
LUCKNOW
KANPUR
GANGES
BIHAR
EAST PAKISTAN
BURMA
WEST BENGAL
GUJARAT
AHMEDABAD
VINDHYA MOUNTAIN
NARMADA
MADHYA PRADESH
CALCUTTA
TAPTI
NAGPUR
ORISSA
MAHARASHTRA
BOMBAY
POONA
GODAVARI
HYDERABAD
ARABIAN SEA
KRISHNA
ANDHRA PRADESH
BAY OF BENGAL
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MYSORE
BANGALORE
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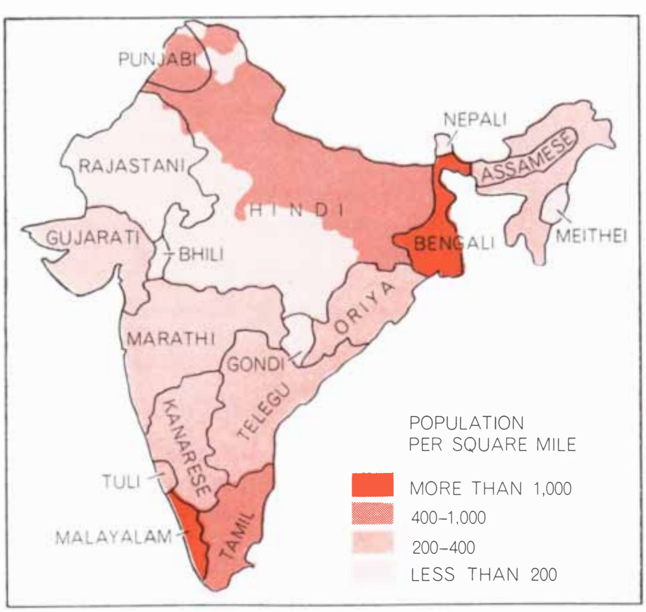
PUNJABI
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TELEGU
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MORE THAN 1,000
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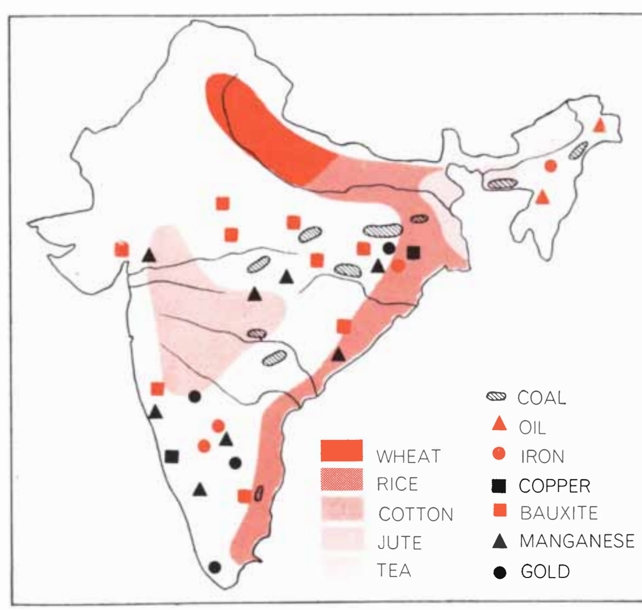
200–400
LESS THAN 200


WHEAT
RICE
COTTON
JUTE
TEA
COAL
OIL
IRON
COPPER
BAUXITE
MANGANESE
GOLD

a rich source of thorium for the development of atomic energy. Of the electric potential of the river waters, estimated at more than 40 million kilowatts, not even 10 per cent has yet been exploited.

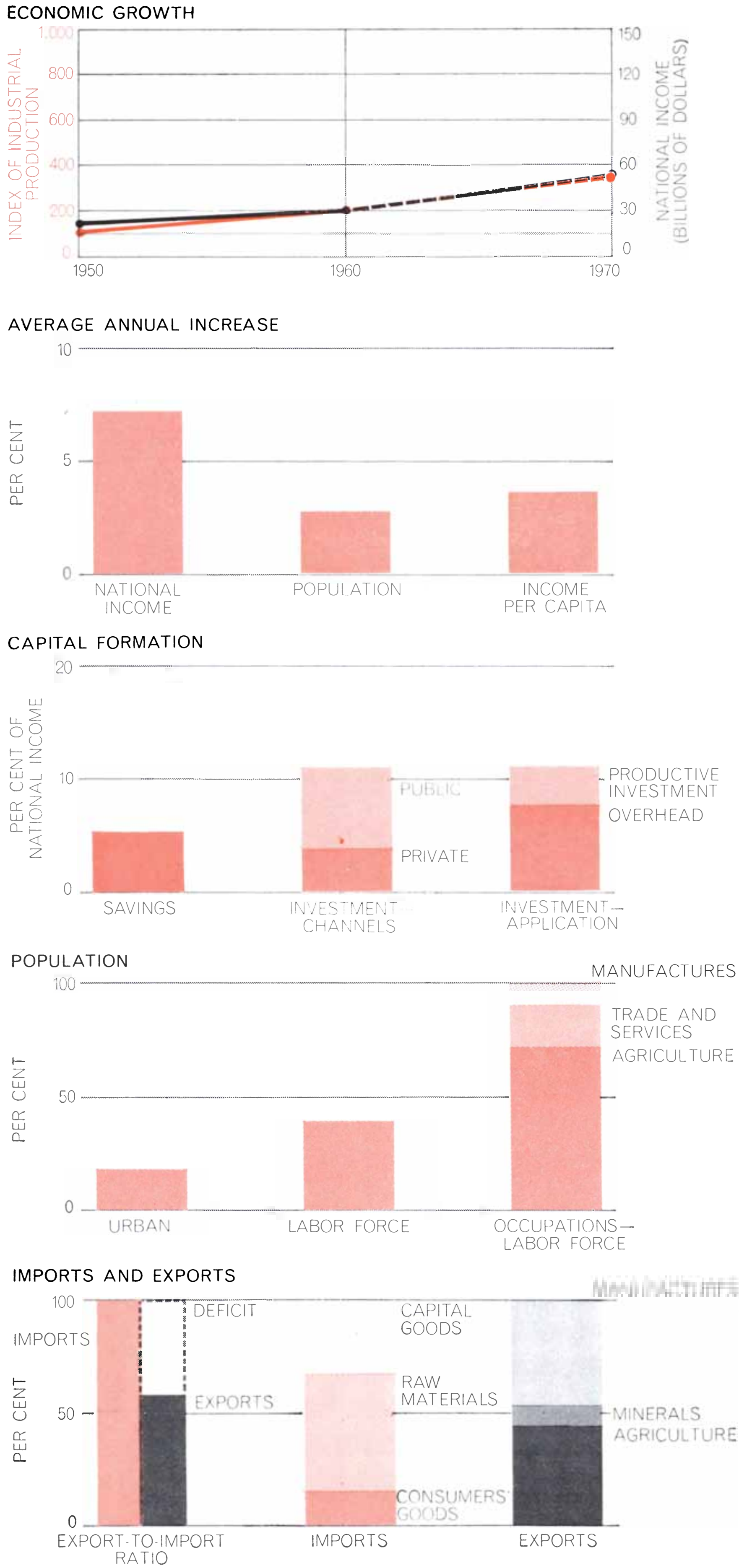
Some 360 million Indians live in 570,000 small villages dotted all over the country. Although there are 2,690 towns and cities, only 107 have a population of more than 100,000; seven cities are large, having a population of more than a million each. The population of the towns is growing perhaps twice as fast as that of the country as a whole, with migration from villages playing an important part. Nearly 25,000 of the towns and villages had been electrified by 1961, compared with only 4,000 a decade earlier.

Agriculture engages 70 per cent of all male and female workers: 130 million out of a total of 188 million. It contributes nearly half the national income, but the average income per worker engaged in agriculture is only 40 per cent of the average income per worker in other sectors. Manufacturing in organized factories contributes only 10 per cent to national income and employs fewer than four million workers.

As a consequence of India's population growth—nearly 2.5 per cent per year—half the population is less than 20 years old; persons over 60 years are less than 5 per cent of the total. By 1975 the working population is likely to number 250 million, four times the present labor force of the U.S.

Today India is a poor nation. Poverty is not confined to groups of unfortunates or to backward regions; it engulfs almost the entire population. The average per capita product is barely $80 a year. The consumption of the poorest 10 per cent is as low as five cents a day and, notwithstanding the conspicuous consumption and the riches of a tiny minority at the top, the consumption of the richest 5 per cent aggregates no more than 50 cents a day. Mass poverty is associated with low output and low income per worker and with widespread under-

INDIA has an area of 1,126,500 square miles. Much of land indicated as being arable in the large map on the opposite page is not intensely cultivated. Map at lower left shows the country's major language regions; color indicates its population density by states. Major farm commodities and mineral resources appear on map at lower right.



employment of human and material resources.

In agriculture the yields per acre are low: in rice, one-third that of Japan; in cotton, one-fifth that of Egypt. The reason for the low yields is basically the use of poor agricultural technology. In the agricultural population there are wide disparities in income arising primarily out of the uneven distribution of land. Although the typical ceiling on ownership of land is about 30 acres, the number of persons who have tiny holdings of two acres or less runs into millions. With the best of effort and assuming substantial gains in future productivity per acre, income from farming is not likely to approach the minimum acceptable for the farm family—or the family of the landless agricultural worker—within a reasonable period.

The majority of the nonagricultural population is not much better off. Occupations in the services and trades are overcrowded and do not provide adequate incomes. Large numbers are engaged in traditional village industries, handicrafts or small manufacturing, using only simple tools and little or no power.

The large size of India's population makes the task of securing a rise in living standards much more difficult. To increase consumption of food grains by two ounces per head per day, for example, will require an increase of nine million tons in annual supplies. This means an increase of more than 10 per cent in domestic production or alternatively an increase in import expenditures of $750 million, which is more than half of India's total export earnings. Similarly, to provide the four or five million new workers who join the labor force every year with capital equipment at the rate of $200 each adds up to $1 billion per year—about equal to the foreign aid India expects to receive during its third five-year plan. Because of the high rate of population growth a good part of the investment is required merely to keep the average per capita income constant; only a part is available to increase per capita income.

The solution of these problems lies in transforming the technology of pro-

ECONOMIC INDICES give broad view of India's present state of development. They can be compared with charts setting out similar data for Nigeria (*page 174*), Brazil (*page 212*) and the U.S. South (*page 228*).

Honeywell data acquisition system records stresses on ships at sea

The extremely low recording speed capability of a Honeywell Magnetic Tape System and the versatility of a Honeywell Visicorder Oscillograph have teamed up to report a new story of the punishment ships take at sea. Lessells and Associates, Inc., Boston, used the Honeywell system to measure the vertical longitudinal stresses induced in the hull each time a ship is pounded by a wave.

A Honeywell LAR 7460 Magnetic Tape Recording system was installed aboard the S.S. Hoosier State, and later aboard a sister ship, the S.S. Wolverine State. Both are 520-foot, 15,000 ton freighters operated by States Marine Lines of New York.

Strain gages were attached to the port and starboard gunwales amidships to sense stresses produced by waves encountered over the turbulent trade routes of the North Atlantic.

The outputs of the gages were combined in a manner which would cancel the horizontal and transverse stresses and permit only vertical bending stresses to be measured.

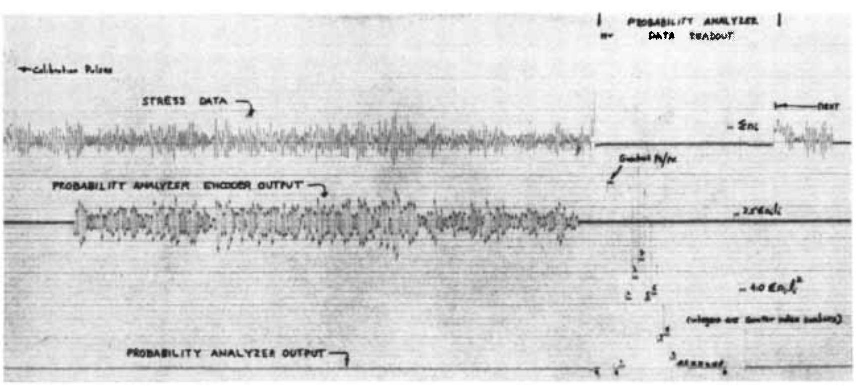
Data from the strain gages were then recorded at .3 inches per second on the 14-track LAR 7460 tape system. The extremely low speed capability of the recorder permitted 40 hours of data to be recorded on a single pass of a 10½-inch reel of tape. During the voyage, the ship's officers rewound the tape every 40 hours, permitting 160 hours of data to be recorded on a single reel of tape.

After the voyage, the tape was taken to Lessells' laboratory and played back from a Honeywell reproducing and amplifying system at 60 inches per second, or a speed ratio of 200 to 1. From the playback system, the data were recorded on a Honeywell Model 906 Visicorder oscillograph, operating at a paper speed of one inch per second.

The data were also fed through a probability distribution analyzer and this processed output was fed into the Visicorder to permit simultaneous observation of original and processed data. By being able to control both the recording speed and the playback speed, as well as the paper speed of the Visicorder, Lessells could obtain a permanent record of the data with any desired trace resolution.

Whatever your data acquisition requirements may be, Honeywell systems can meet your needs. Visicorder oscillographs are available with channel capacities from 1 to 36 and paper speeds from 1 inch per hour to 160 inches per second. Honeywell Magnetic Tape Systems range from the economical Honeywell 8100 portable recorder/reproducer to complete laboratory systems, with capabilities including FM, direct, digital, and incremental recording.

For complete information, call your local Honeywell representative. Or write or call Honeywell, Denver Division, Industrial Products Group, Denver 10, Colo. (303-794-4311)



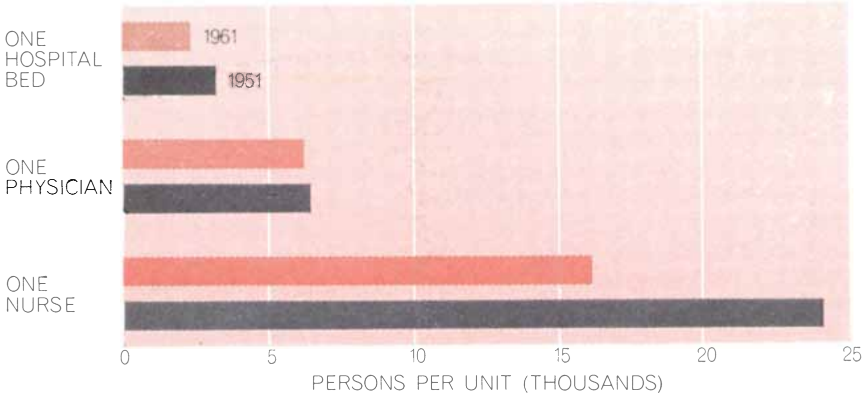
Top trace: Stress data as recorded on ship. Middle trace: Probability distribution analyzer encoder output. Bottom trace: Probability distribution analyzer output. Work performed under NOBS Contracts: #88349, Ships Structures Committee; #88451, Office Chief of Transportation, Dept. of Army.

The Honeywell reproducing and amplifying tape system and the Model 906 Visicorder Oscillograph in Lessells' Boston laboratory.

DATA HANDLING SYSTEMS

Honeywell

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.



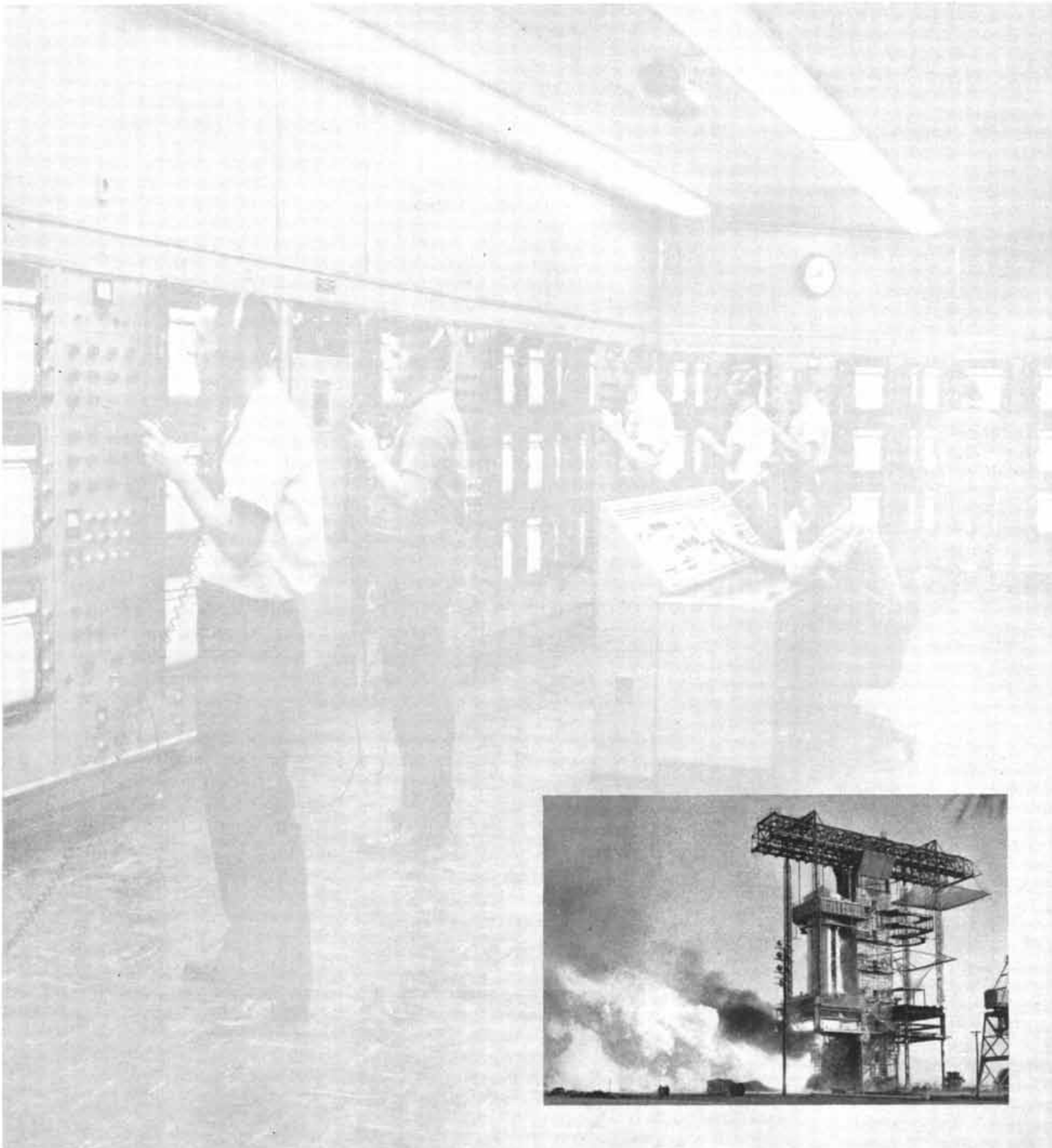
MEDICAL SERVICES are improving in India. Number of hospital beds, physicians and nurses is rising in relation to the population. For example, there was one hospital bed for 2,340 people in 1961 (*upper bar*) compared with one bed for 3,178 in 1951 (*lower bar*).

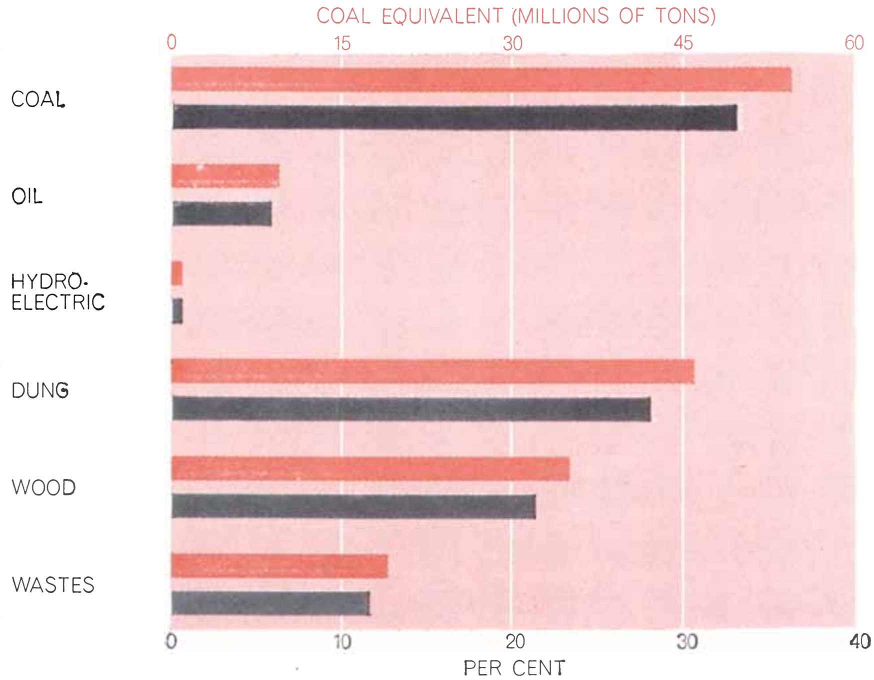
DECLINING DEATH RATE and stable birth rate are found in India as in many other underdeveloped countries. Top bar of each group represents 1956–1961, middle bar 1951–1956 and bottom bar 1941–1951. Infant mortality has dropped and life expectancy has risen.

duction in various fields and modernizing the economic institutions. The technical side of the task is to get technology from abroad firmly rooted in the Indian soil through the rapid extension of scientific education and research and the rapid build-up of productive facilities. The economic side of the problem is to mobilize the physical resources by fiscal and financial means. In order to support increased investment increased savings are required. In other words, a larger proportion of current production has to be set aside for building a productive capacity designed to yield a larger flow of goods and services in the future.

It is a difficult and delicate problem in a democracy of poor people to raise the rate of savings fast enough. Income per head is low, and for the very large number the margin for reduction of current consumption is small. The savings of the few rich are not enough. In the parliamentary democracy of India, based on adult franchise, the government has undertaken to increase the rate of capital formation by persuasion and without accentuation of inequalities of income. Accepting these social and political limitations, India's planners envision an increase in the rate of domestic savings from 5 per cent of national income to 20 per cent over the 25 years from 1950 to 1975. Certain regimes, with a different political structure and social philosophy, have found it possible to raise rates of savings to 20 per cent or more in much shorter periods.

Within three years after the attainment of independence the government appointed a Planning Commission—a purely advisory body, even though Prime Minister Nehru has been its chairman from the outset—to develop a long-term strategy for economic growth. Development is a continuous process. The five-year plans have therefore been framed in the context of a long-term, continually evolving "perspective plan." The function of perspective planning is to relate economic development to social objectives and to provide a quantitative framework that expresses this relationship. It has to bring out the complex interdependence of the various sectors and to reveal possible obstacles to growth so that timely and co-ordinated action can be taken. Such an analysis is helpful in framing decisions regarding investments with long gestation periods, in the structuring of education in relation to the needs of society, in the reform of fiscal and financial institutions and finally in the regional distribution of activity



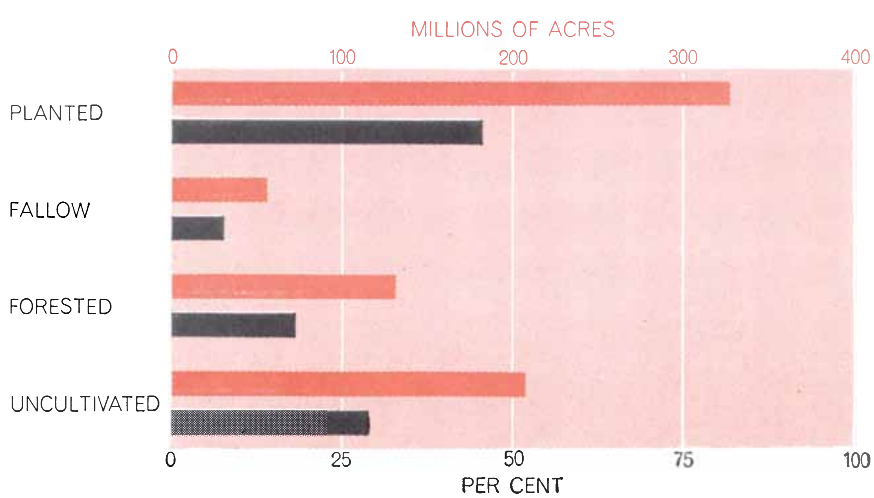


SOURCES OF ENERGY in India include one unusual in the West: cattle dung. It is the most important in the noncommercial category (*lower three pairs of bars*) and accounts for 28 per cent of energy consumption. Colored bars are coal equivalents, gray bars per cent.

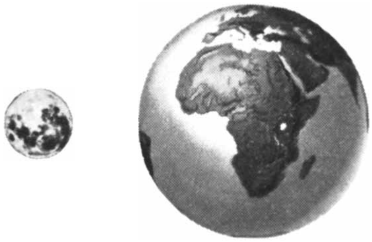
within the setting of national development.

Another function of the perspective plan is to educate public opinion on issues of development and to promote the kind of open discussion that is likely to secure a common consensus of political parties. This is perhaps easier in a poor society in which all can agree without controversy on at least one objective: the abolition of poverty. When the purpose is nothing less than to transform society, planning ceases to be an esoteric subject or a mathematical exercise. It must be imbued with deep social purpose and revolutionary zeal. The problems must be boldly faced and alternatives must be discussed in concrete and quantitative terms, for the understanding, appreciation and acceptance of the people.

In the course of time national political parties, instead of being labeled by ideology, may begin to be identified with the rates of growth they represent. The conservatives in India may then be those



LESS THAN HALF OF LAND in India was planted in 1961. The rest was allowed to lie fallow, was forested or uncultivated. Colored bars represent acres, gray bars per cent.



NEW HOPE FOR UNDER-DEVELOPED NATIONS RESULTING FROM BASIC SPACE RESEARCH

Lunar and space missions such as Project Apollo seldom seem, in their far-out glamour role, to be closely related to that great fundamental... mankind. Yet one single aspect of the Apollo program —fuel cells—holds a vast amount of hope. Especially for under-developed nations.

Often referred to as "continuous batteries," fuel cells convert chemical energy directly to electrical. They are the newest power sources to emerge from scientific research into the realm of practical engines. The specific cell system aboard Apollo will be a Hydrox® unit, reacting hydrogen and oxygen, and is the result of research at Leesona Moos Laboratories, one of the first in America to undertake studies on fuel cells. Hydrox will supply electrical power for vehicle control, communications, and numerous other power needs aboard this lunar mission. Marking the first such use of these new power sources, the Hydrox installation will inaugurate a new age in the generation of electrical power. Final engineering and manufacture of the units for Project Apollo will be carried out by Pratt & Whitney Division of United Aircraft, under license from Leesona Corporation.

But space missions are only the first part of the story. At the same point in time that Leesona Moos began studies of Hydrox fuel cells, a concomitant project was undertaken to develop an even more advanced system... a cell using air as oxidant and inexpensive hydrocarbons or their derivatives as fuels. These hydrocarbon-air (Carbox®) and mixed-gas/air (Aminox™) developments of Leesona Moos do not require reactants of high purity, and are very flexible from a logistics point of view. Low cost and readily available fuels are used, and the universal oxidizer—air—supplies the other portion of the reaction mix. Because the fuel cell is an extremely efficient engine—efficiencies of up to 70% are attainable, vs. 30% for a conventional diesel—the result is an exciting new means of generating electrical power at low operating expenditure. Pratt & Whitney Aircraft in the United States, and Energy Conversion Ltd.,* of England, are carrying out further developmental engineering on these systems under license from the Leesona Corporation.

These new Leesona power sources, of high efficiency and low fuel costs, can readily be seen to provide the world with an entirely new type of electric generator. Fuels of the hydrocarbon variety are fairly abundant throughout the world. The fuel cell, though scientifically sophisticated, is neither unwieldy nor complex in its operation, and requires little maintenance. Units with power levels from those required for a one-family dwelling up to communal or industrial ground-power stations have been projected in Leesona Moos studies, and found feasible.

The impact Carbox and Aminox can have on the emerging countries is readily understandable. The development of a nation can almost be measured by its ability to produce and consume electrical power. In this mechanized world, virtually all industry waits on the availability of electricity. If an emergent economy must hold off its development until completion of large-scale hydroelectric projects, a distinct problem of time and expenditures arises. If, on the other hand, the nation had access to Carbox and Aminox type fuel cell systems, which could be tailored to the need and would operate on locally available fuels, the basic first step toward an industrialized economy and higher living standards would be achieved.

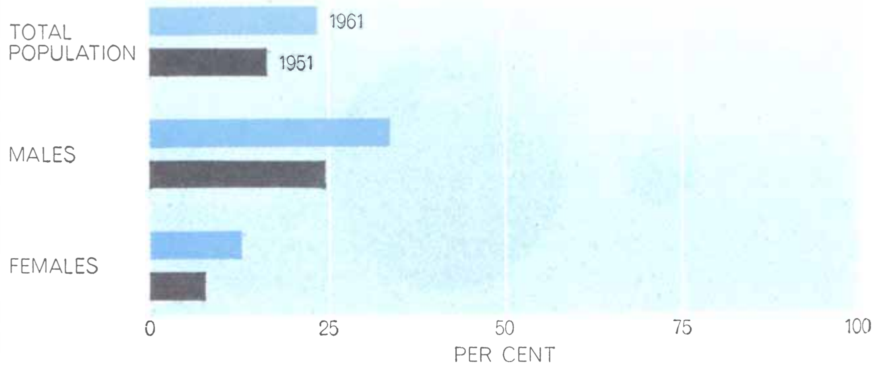
Leesona believes its efforts, plus the great additive capabilities of our United States and international partners, will soon result in working installations of the Carbox and Aminox systems to advance the standards of all mankind. Meanwhile, the sibling Hydrox system supplies power for a moon voyage. And research continues.

**Energy Conversion, Ltd., is a new corporation founded by four British companies: National Research and Development Corporation; British Petroleum Company, Ltd.; British Ropes, Ltd., leading manufacturer of rope and steel cable; and Guest, Keen, and Nettlefolds Group, major steel manufacturers.*

LEESONA MOOS

LEESONA MOOS LABORATORIES

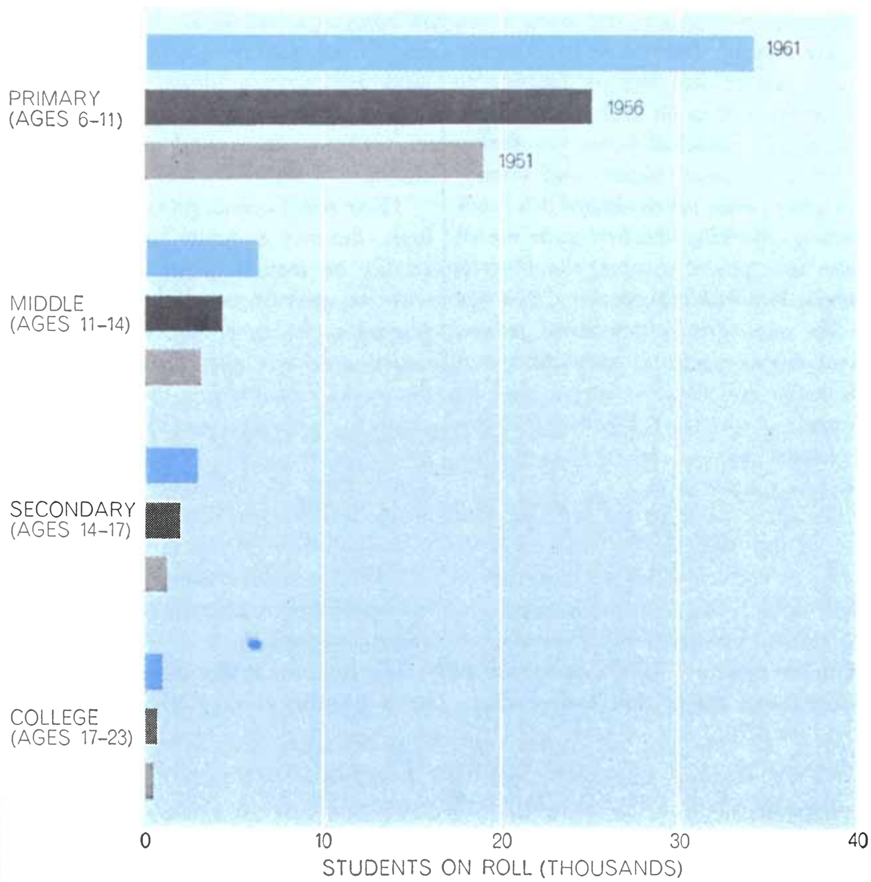
A Division of Leesona Corporation • Lake Success Park, Community Drive • Great Neck, L. I., New York



LITERACY in India has been increasing but it is still not high. More than 75 per cent of the population is illiterate. The upper bar of each pair is for 1961, the lower bar for 1951.

who urge a 5 per cent rate; the radicals, those who advocate a 7 per cent rate, and the men of reason and moderation, those who work for 6 per cent!

The basic strategy thus laid down for the five-year plans can be briefly outlined. Agriculture plays a dominant role in the Indian economy and is the sector that contributes principally to the supply of food and clothing that accounts for two-thirds of the total consumption expenditure of the average Indian household. Much greater production of a variety of crops will be required. This will be possible only by enlisting advanced agricultural techniques: optimum utilization of water by irrigation and drainage, the use of organic and inorganic fertilizers, pesticides, better implements, more careful crop planning in relation to soil and climate, improved genetic strains and reduction of crop



INCREASE IN STUDENTS is plotted. In 1950–1951, 25.4 per cent of the children six to 17 years of age were enrolled in schools; in 1955–1956, 32.1 per cent; in 1960–1961, 39.9 per cent.

SILICOLOGY

Silicone Surfactants' Peak Performance Cuts Costs Of Rigid Foam Insulation

Ask the man who knows insulation. He'll tell you about polyurethane rigid foams and the big job they've been doing since the introduction of silicone surfactants.

Rigid foams have become the choice for insulating refrigerators, reefers, storage tanks, and hot or cold pipes. They can be foamed on the spot. They're light, low in thermal conductivity.

Silicone surfactants have made a big difference. For example, finer and more uniform cell structure eliminates voids and areas of high density so that you get better insulation. Full rise lets the foam fill all nooks and crannies, even travel around corners. You get more foam, lower density, lower K factor. There's also a higher percentage of closed cells resulting in less air penetration and heat transfer by convection.

As the originator of surfactants for polyurethane foams and the leading innovator in silicone technology, Union Carbide is constantly developing new products to do a better job. You select from the most complete product line, get the specific surfactant for your particular system.

For example, L-530 is recommended for difficult foaming conditions. Added to either resin or "quasi" component, L-530 is designed for sorbitol and aromatic started polyols.

Another silicone surfactant, L-531, is suited for sorbitol started polyols. Used by adding to either resin or "quasi" component, L-531 is a superior emulsifying agent for resin and fluorocarbon premix.

Silicone L-5310 is preferred for sucrose as well as sorbitol started polyols. This surfactant is recommended for the most stringent foaming conditions.

Highly versatile, L-5310 is the outstanding general purpose surfactant, well suited to a variety of systems.

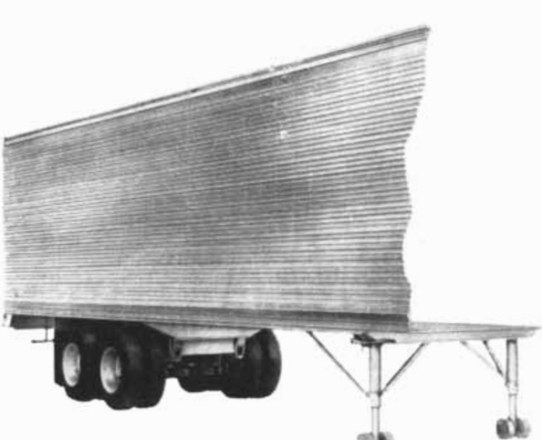
If you formulate polyurethane foams, consider the advantages of Union Carbide silicone surfactants. For full information, complete and mail the coupon below. In the meantime, make it a point to see your Silicones Man—he'll be glad to give you complete information on silicones for foams and general uses.

Silicone surfactants make a big difference, as rigid foam on the right shows. L-5310 surfactant gives higher rise, lower density, better insulation values using the same quantity of raw materials.

UNION CARBIDE

SILICONES

UNION CARBIDE is a registered trade mark of Union Carbide Corporation.



Foamed-in-place polyurethane rigid foam provides the insulation for this huge reefer, which will carry meat and other refrigerated products.

Photo Courtesy of Trailmobile

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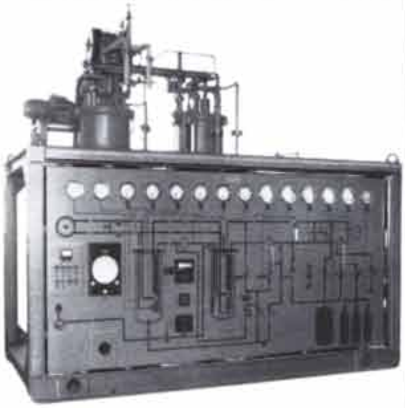


losses by greater attention to storage and processing industries. The farmer has to have access to more knowledge and the requisite supplies, and he should have adequate incentive. Ultimately it is on the will and initiative and effort of the millions of farmers that the outcome depends. As a palliative to widespread underemployment and low income in rural areas, particularly among landless agricultural workers, large programs of labor-intensive rural works—forestation, road building and land improvement through irrigation, drainage and terracing—are being organized and carried out.

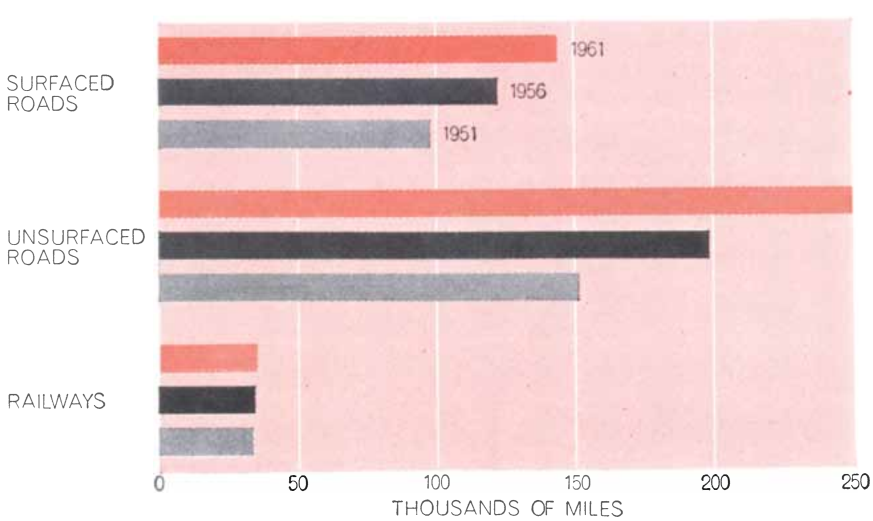
The role of industrialization in the scheme of things is not only to create new opportunities for employment but also to provide the technology and the fruits of technology that will improve the productivity and material condition of the people in the villages as well as in the towns. The economy of India is large and the potential size of the market is enormous. Even in the near future there is a great variety of products for which demand will be sufficient to allow production on an efficient scale in a few plants.

At this stage of its development India cannot produce all the things its growing economy requires. Although the industrial countries—and even some underdeveloped countries—have large exportable surpluses to pay for their imports, India—in common with most underdeveloped countries—labors under an export-import deficit [see "The Structure of Development," by Wassily Leontief, page 148]. This is partly because of difficulties in generating larger surpluses for export and partly because of tariff barriers erected by the industrialized countries. Since the creation of new industries and the increased requirements for intermediate materials generated by expanding industries give rise to large imports, the strategy of rapid development calls for heavy current foreign-exchange deficits in order to forestall endless, unmanageable deficits later on.

India has been receiving foreign assistance of the order of $1 billion per year from a number of countries, including the U.S.S.R.; nearly 40 per cent has been contributed by the U.S. If the momentum of development is to be maintained, foreign aid must continue to fill a gap of at least this order of magnitude in India's foreign-payments account for another decade.

The country must exert its utmost to expand its exports and at the same time India's friends must be prepared to accept and encourage such effort. Because of the continuing foreign-exchange shortage, India is compelled to continue restricting the entry of nonessential imports and regulating the availability of foreign exchange. This also means that the domestic development program must aim at meeting most of the requirements of intermediate and finished manufactured goods. Concurrently India has to find ways to expand and improve education, health, sanitation and housing and create social conditions for vigorous cultural advance. Co-ordinated development in all these fields is scarcely less important than expanding the supply of consumers' goods.

The urgency and complexity of the task, together with the possibility of achieving in this century substantial



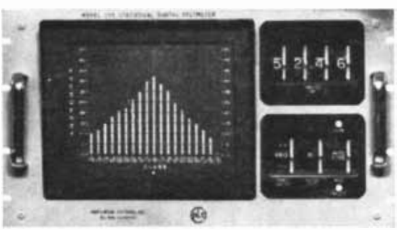
GROWTH OF SURFACE TRANSPORTATION, an important factor in development, is shown here. Top bar of each group is for 1961, middle bar for 1956 and bottom bar for 1951.

New ways to solve measuring problems . . . digitally

Frankly, if you haven't looked closely at digital measuring instruments and systems lately, you're in for a pleasant surprise. Recent and exciting developments in digital voltmeters and associated equipment have provided entirely new ways to solve voltage measuring problems.

Here are a few of them:

Data Classification is Automated



An entirely new type of instrument—the Statistical Digital Voltmeter—automatically provides an accurate statistical description of a test, experiment or production run. All three NLS models automatically classify input voltages and display results as a bar graph. With suitable transducers, they'll classify lengths, pressures, resistors, etc.

Typical results: quality is increased and costs cut in electronic component testing by reducing scrap . . . the exact time for machine adjustment is indicated in fabrication industry . . . man-hours are substantially reduced in reliability and environmental testing.

Elusive Varying Voltages and Pesky Peaks

Until now, no instrument—digital or otherwise—has been able to measure and record varying voltages and peaks with sufficient accuracy for many applications. The problem has been solved by the new CH3 Clamp-And-Hold Digital Voltmeter. It also measures non-varying voltages as a standard DVM.

Or if you must measure varying voltages at a high repetition rate, use the new NLS IDS2 Sample-And-Hold Module in conjunction with an NLS 15 A-to-D Converter.

Here two CH3s are used in experimental psychology. One measures a human's response to physical disturbances and the second measures rate and extent of the disturbance.

Ground Problems?

. . . not with the new RV2 series of low-cost, reed-relay digital voltmeters that feature complete ground isolation and exceptionally high common mode rejection. One is battery-operated for portability and the other lower-cost model operates from conventional AC outlets only.

Automating Mass Spectrometers and Analysis of Noise-Ridden Peaks

"Payout in six months due to savings of $50,000 a year." That's the report of a major chemical company on its use of an NLS MSD2 Mass Spectrometer Digitizer to automate the tedious and time-consuming task of peak measurement and evaluation. Upon recognizing a true ion voltage peak by a unique digital approach that rejects noise peaks, the system provides a printed record of the peak with its corresponding acceleration voltage—plus a punched tape record and visual display. In addition to its proven success in mass spectrometer use, the MSD2 holds great promise for other applications requiring highly accurate measurement of voltage peaks.

0.001% Resolution in AC Voltage Measurement

With introduction of a new type of AC-to-DC converter by NLS, the accuracy of digital AC voltage measurement now approaches that of DC—also measuring speed is increased. Used with an NLS 5-digit voltmeter, the Model 225 provides full 5-digit (0.001% of full scale) resolution and 0.01% linearity and stability.

High Speed . . . at Lower Cost

For applications requiring high speed, high accuracy and fully automatic operation at a price that has our competitors worried, NLS has unveiled the V91 series of all-electronic digital voltmeters that promises to be the most popular of all NLS instrument types. Speed is from 10 to 130 milliseconds/measurement. Price: $2,985 to $3,685 depending upon printer output.

Amplification Without Compromise

The new NLS 144 meets every requirement that our customers could dream up for a precision differential AC/DC amplifier.

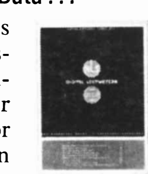
5-Digit DC Measurement

Has your limited budget prevented you from buying a full 5-digit DVM? Consider the new NLS 485 with automatically selected ranges of ±9.9999/99.999/999.99. Price: $1,000 (or more) below any other NLS 5-digit DVM.

Did We Miss Your Problem?

Chances are, you'll find the solution in the NLS line of digital measuring instruments and standard systems—world's largest by purpose . . . by price. Or your nearby NLS engineering/service center (29 in U.S.—soon 40) will help design a custom system to meet your needs.

36 Pages of Technical Data . . .



on 21 new instruments that increase your measuring capability is available without cost or obligation. Simply ask for "Catalog Supplement" on your letterhead.

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rapid gains by the harnessing of well-demonstrated technology, explain India's reliance on planning. In this still developing art the planner learns to project the pattern of the growth of "final" demand arising from current consumption and investment and from the expenditures of government. The goods and services required by the "indirect" demand of the productive sectors are also taken into account. Coupled with the consideration of saving on imports and promoting exports, this is enough to give a good idea of the things to be produced. It turns out that fast development of industry is required, particularly in the metallurgical, fuel, machinery and chemical fields. After careful consultation with state governments, the ministries of the central government and representative organizations and groups of the private sector, the targets of production are set. The state is directly responsible for providing the transport, power, major and medium irrigation and the training and research facilities needed to sustain the agricultural and industrial expansion. Certain key branches of industry that are of a strategic nature, or that involve large but slow-yielding investments, are also developed under the auspices of the public sector. This leaves a large and expanding field for the private sector to explore profitably.

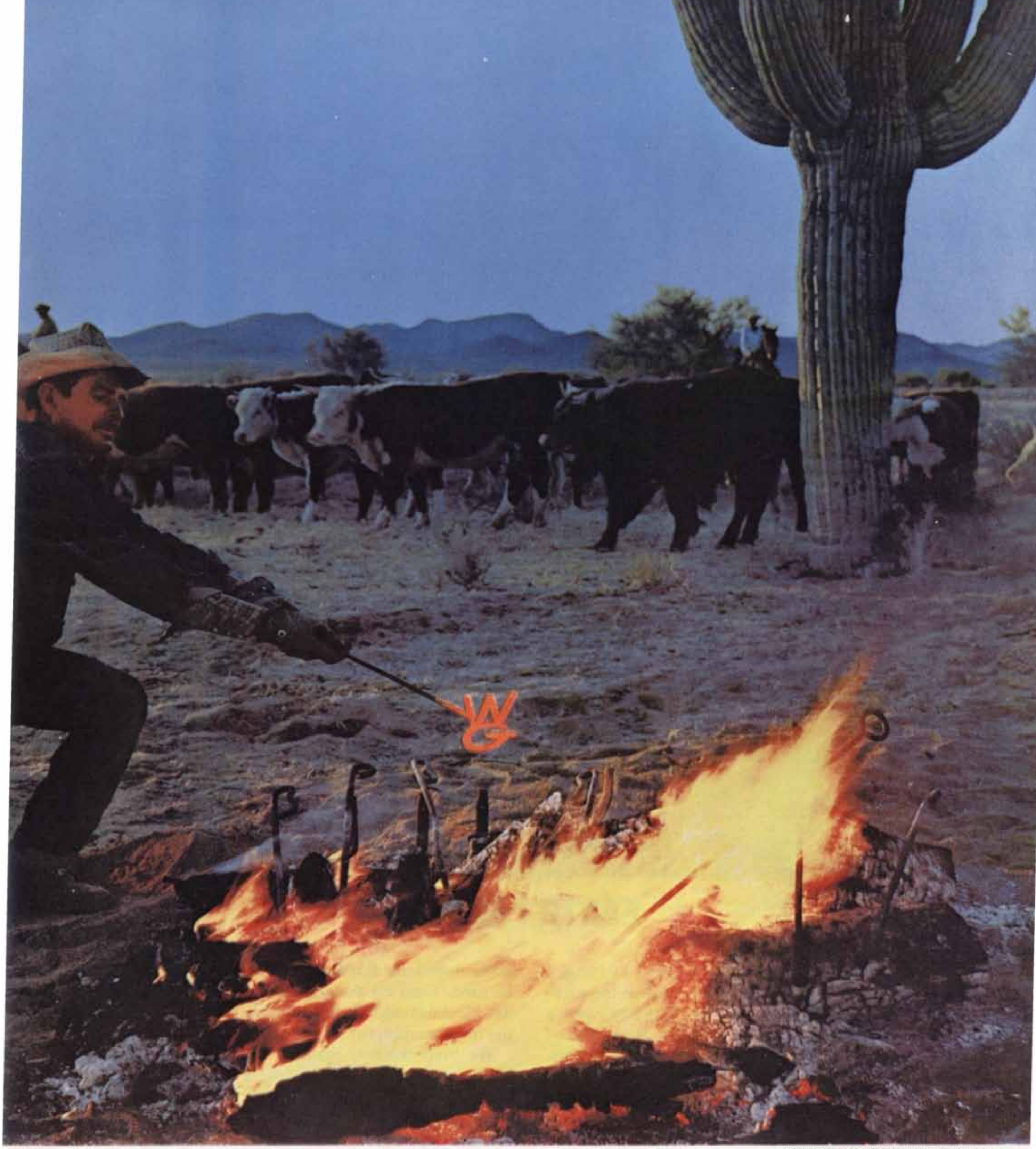
The development of agriculture and that of industry act and react on each other; they are complementary and not competitive. Their requirements are different and the scarce inputs they need are largely dissimilar. In agriculture and rural development the problem is primarily organizational. The organizational task of persuading 70 million households to function efficiently may well be the more difficult one, but it will not be rendered easier by curtailing the development of heavy industry.

Taken as a whole, the accomplishments during the first and second five-year plans have been considerable. The national income has risen from 99 billion rupees ($21 billion) in 1950–1951 to 142 billion rupees ($30 billion) in 1960–1961, in constant prices of 1960–1961. In spite of an unexpectedly large population increase (totaling 80 million) during the decade, income per person has risen by 19 per cent. Agricultural output increased by 37 per cent and that of industry by about 100 per cent. Industrial growth brought significant diversification and consolidation, particularly in the basic metals, chemicals, fuel and machinery industries.

In the sphere of education, health and other social services the achievement has been heartening. In 1961 nearly 34 million children in the age group of six to 11, some 60 per cent of the total in this group, were attending schools, compared with 19 million, or 43 per cent, in 1951. The number of students in higher secondary schools and universities has increased nearly two and a half times. The expansion in technical education is even more striking. By 1960 there were 100 engineering and technical colleges in India compared with 49 a decade earlier. The enrollment in engineering colleges and in institutions teaching agriculture and veterinary sciences has increased fourfold since 1950, and the number of engineers per million population has increased from 150 to 250.

Significant progress in the control of mass communicable diseases such as malaria, smallpox and cholera has brought a sharp reduction in death rate. The life expectancy of the average Indian at birth is estimated to have increased by 10 years—from 32 in 1950 to 42 in 1960. A beginning has been made in establishing a nationwide system of health services; the number of hospitals and dispensaries has increased by nearly 50 per cent and the number of hospital beds by one-third. A central feature of the country's public health program is the promotion of family planning, a topic on which the Indian people have evinced an altogether rational and receptive attitude.

A new dynamism that can be sensed throughout the society strengthens India's capacity for continued development. Valuable experience has been gained in the construction and operation of large and complex undertakings. The rate of investment, on which the future so largely depends, has been stepped up from 5 per cent to 11 per cent; the absolute volume of investment has nearly tripled during the past decade. Industrial investment in the five years of the first plan was less than four billion rupees; it increased to 16 billion rupees during the second plan, the share of the private sector rising from 3.4 billion rupees to 8.5 billion rupees. With the rapid expansion of domestic production of basic metals, chemicals and machinery the country has strengthened its capacity for accelerated development based increasingly on its own resource. In the sphere of agriculture the enlargement of irrigation potential, the establishment of the National Extension Services and the Community Development Program (which now reaches more than half of the village



population), the reconstitution of the village panchayats as organs of local self-government and the extension of co-operative credit constitute the major forward steps.

In the third five-year plan (1961–1966) now under way the principal objective is to secure a rise in national income by 30 per cent, the pattern of investment being designed to sustain this rate of growth in subsequent periods. Agricultural production is to be increased by 27 per cent and developed in order to achieve self-sufficiency in food grains and substantial increases of other commodities to meet the requirements of industry and of exports to earn foreign exchange. In the industrial sectors the third plan and the perspective looking beyond it aim to secure sufficient increases in domestic production of steel, fuel, power, fertilizers and chemicals, machinery and equipment. An increase of industrial production by 70 per cent is envisioned, and the total investment of 104 billion rupees will be somewhat in excess of the aggregate investment during the preceding 10 years.

A fifth of this investment must be financed out of foreign aid. This fifth is critically important as a counterbalance to the deficit in foreign exchange and as a source of technical assistance, not merely as a supplement to domestic savings. Many countries of the world, regardless of ideology, have committed themselves to assisting India to make its plan a success.

Last year, just as the mobilization for development had begun to strain the resources of the nation, a military danger of unprecedented character arose on the northern frontier. In response to the invasion from China, defense had to be given an overriding priority; a massive rise in taxation, aggregating 20 per cent, had to be put through to meet its costs. The diversion of effort has upset frugally calculated plans; manufacturing capacities cannot be fully utilized; important work in scientific research is impeded for want of small amounts of foreign exchange and the price level has shown a disturbing tendency to rise.

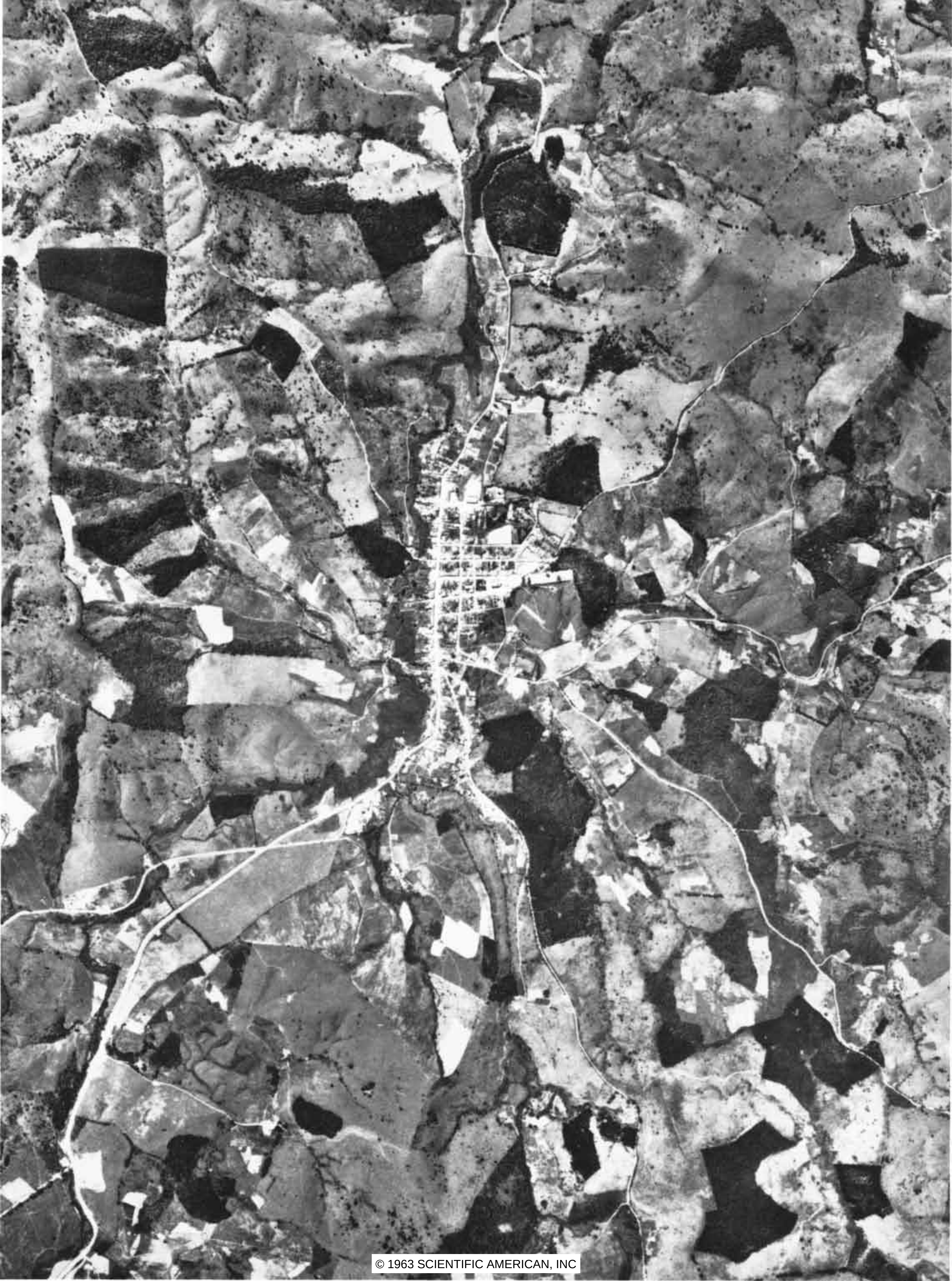
Nevertheless, the goals of the third five-year plan are being vigorously pursued. The achievement of these goals is vital to the success of the fourth five-year plan, projected for completion in 1970–1971. By that time the country is expected to be in possession of capacity for annual production of 19 million tons of ingot steel, 250,000 tons of aluminum, 25 million tons of cement, about

$4 billion worth of machinery (including transport equipment), 170 million tons of coal, 24 million kilowatts of electric power, two million tons of nitrogenous fertilizers (in terms of nitrogen), 125 million tons of food grains and 400 million tons of long-distance freight carried by railroads. Put alongside the figures for corresponding items in 1950—steel ingots 1.4 million tons, aluminum 3,700 tons, cement 2.7 million tons, coal 33 million tons, electricity 2.3 million kilowatts of installed capacity, fertilizers 9,000 tons of nitrogen, food grains 50 million tons and long-distance freight carried by railroads 92 million tons—it is easy to show the very large growth over 20 years. Elevated to these levels of output, the economy will have substantially increased its capacity for capital formation and self-sustained growth.

The long-term targets projected in the third plan are modest in relation to the needs of the people. Even with the plan fully realized, per capita income in 1975 will still be no more than $110, which is a third of the Japanese per capita income now. This underscores the urgency of accelerating the pace of development. There are uncertain elements in the picture. Agriculture is one of them; it is not too easy to see how to make it respond fully to treatment. Foreign exchange availability is another.

Will foreign aid be available at the right time—particularly in the present decade—and in the required magnitude? Can India hope to get the cooperation of friendly countries that will enable it to expand its exports? Will it be possible to think in terms of long-term commitments for aid and trade so that the long-range strategy India has in mind can be carried through successfully? These are questions to which India alone cannot give an answer. They are obviously important. Without foreign aid India will still continue to build its economy. It will, however, be an uphill task, and progress will be slow. With assurance of aid India will not relax its efforts and indeed may find it possible to increase them.

The next decade is the crucial period. The strength and stability of this the most populous democracy in the world and the feasibility of economic and social transformation within the democratic framework are on test. Those of us who share a conviction in the humane values of an open society may hope that India's efforts will evoke the necessary understanding and material support from the international community.



The Development of Brazil

Although Brazil must still be classified as an underdeveloped nation, it is the most advanced of the nations in the Tropical Zone and it is well on its way toward self-sustaining growth

by Celso Furtado

Brazil is undoubtedly the least known of the world's big countries. To most non-Brazilians it comes as news that Brazil stands fifth in geographic extent, eighth in population and 11th in gross domestic product. Still more significant is the news that Brazil has begun its industrial revolution. During the past 25 years the country's essentially rural economy, specializing in the production of a few tropical agricultural commodities for export, has been transformed into a recognizable industrial economy, with nearly half the population concentrated in urban areas. In this brief period, it appears, Brazilian industry has attained enough size and a sufficient degree of internal diversification to set the nation on the course of self-sustained economic growth.

On the basis of annual income per capita Brazil must still be classified as an underdeveloped country. In 1962 this figure was equivalent to about $380, as measured in cruzeiros with an internal purchasing power comparable to that of the U.S. dollar at home. The figure is somewhat lower when one converts cruzeiros into dollars at the prevailing rate of exchange; it is about $186. But even the larger figure is only a seventh that of the U.S. and not much more than twice the average prevailing in other underdeveloped countries. Multiplied by a population of 77 million, however, $380 per annum generates an internal demand that is already supporting the country's industrial development. During the past 15 years the distinguishing trend of the economy has been the progressive substitution of consumers' goods manufactured within the country for products previously imported from the industrially developed economies abroad. By 1960 consumers' goods had fallen to 6.4 per cent of the total value of Brazilian imports; consumer expenditure for imported durable goods amounted to only .1 per cent of consumer income and the expenditure for imported nondurable goods to .5 per cent.

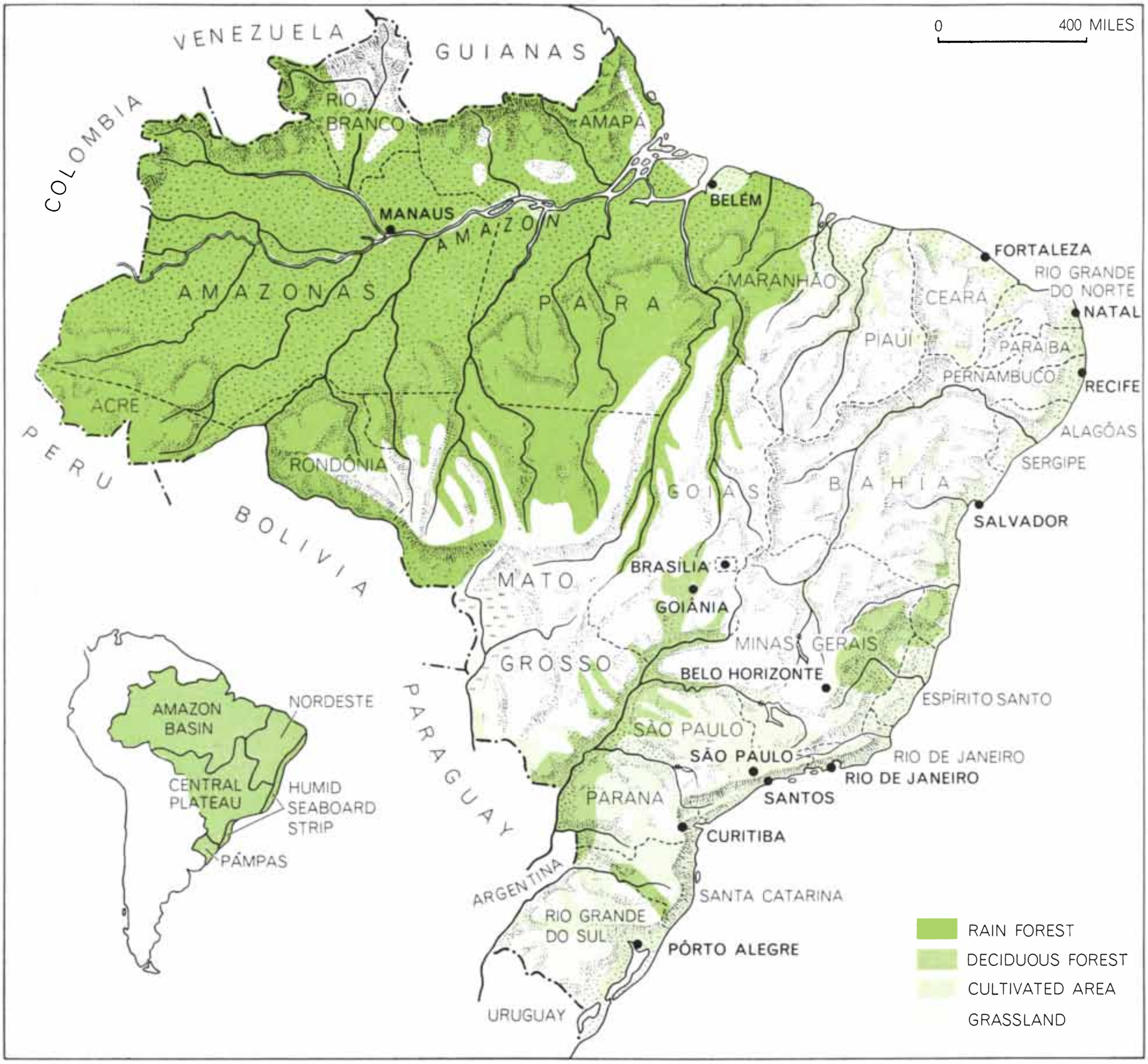
A similar trend has become evident during this period in the importation of producers' goods and equipment. Although Brazil in 1961 depended on external sources for significant portions of its demand for basic materials—steel, aluminum and heavy industrial chemicals and, to a greater degree, newsprint, fertilizer and fuels—the expenditure for imported materials absorbed less than 2 per cent of aggregate current investment in that year. Brazil's own industrial system meets about 70 per cent of the country's demand for industrial equipment, particularly for heavy electrical machinery, machine tools and oil-country gear. The principal role of imports in the economy has become the transmission of the more advanced technology available in North America and Europe.

That Brazil now verges on self-sustained development is evidenced by the fact that internal economic activity no longer depends on the volume of the country's exports and the prices they bring in the world market. Even in the recent period of decline in exports and commodity prices the demand of the internal market has attracted investments at a rate adequate to maintain the growth of the economy.

To rank Brazil in the list of nations according to per capita income is to conceal at once the substantial development already achieved and the poverty and backwardness that remain to be cured. In the verdant and strongly industrialized savanna and plateau country of the south, Brazil is on the annual-income-per-capita basis very nearly a "$1,000 nation," to use the vivid terminology of P. M. S. Blackett, the British physicist and student of economic development. On the range and in the dry-farming country of its drought-afflicted northeastern interior, however, Brazil is still not far from being a "$100 nation." The Amazon basin, which embraces fully half of the geographic domain but only 4 per cent of the population, presents still another stage of development, or lack of it: a great wilderness frontier awaiting a full assay of its resources, occupied here and there by some of the few remaining truly aboriginal peoples of the Western Hemisphere. It is not only the great size of Brazil that explains these disparities but also the vagaries of the history of the country since it came under European conquest and occupation more than 400 years ago.

The land of Brazil was the first in the New World to yield an agricultural commodity for export to the Old. At a time when only the mining of precious metals brought adventurers and settlers across the Atlantic, the Portuguese established sugar plantations on the hot and humid seaboard of the continent south of the Amazon delta. The sugar production of the islands of the Atlantic—the Cape Verdes and the Madeiras—had already established a market in Europe and had given the Portuguese a head start in the arts of tropical agriculture. A century before the settlement of New England by the English the Brazilian plantations were on the way to achieving a monopoly over sugar as a commodity in inter-

STATE OF SÃO PAULO, richest in Brazil, is shown in the aerial photograph on the opposite page. The small city of Salesopolis, an agricultural market place 50 miles east of the city of São Paulo, appears in the center. Coffee, sugar, cotton, rice and tobacco are the leading agricultural products of this fertile region of the country.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BOLIVIA
MATO GROSSO
BRASÍLIA
GOIÂNIA
MINAS GERAIS
BELO HORIZONTE
ESPÍRITO SANTO
SÃO PAULO
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RIO DE JANEIRO
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SANTOS
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ARGENTINA
SANTA CATARINA
RIO GRANDE DO SUL
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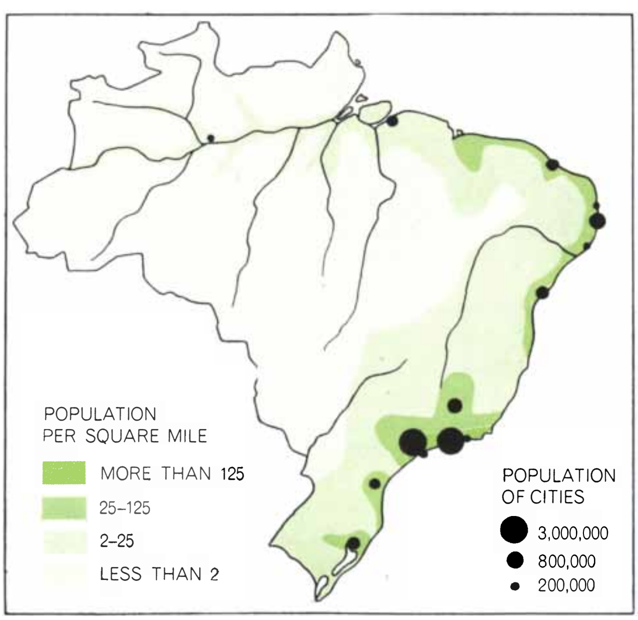
POPULATION PER SQUARE MILE
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LESS THAN 2
POPULATION OF CITIES
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800,000
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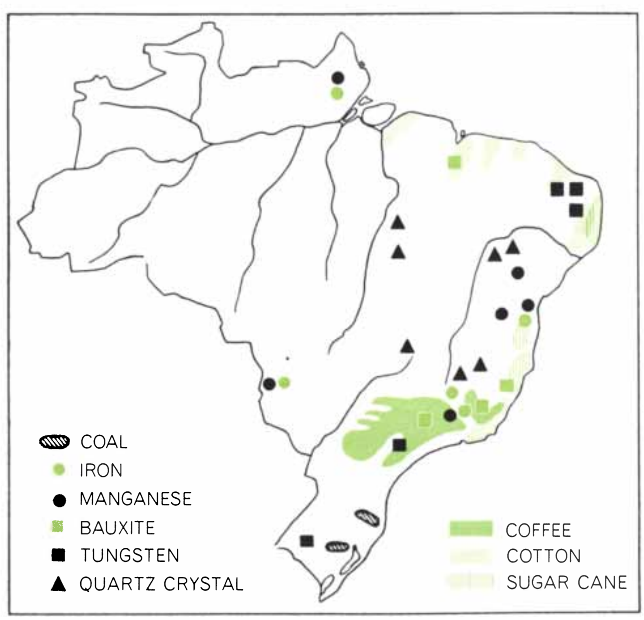

COAL
IRON
MANGANESE
BAUXITE
TUNGSTEN
QUARTZ CRYSTAL
COFFEE
COTTON
SUGAR CANE

national trade and the principal agricultural commodity carried on the high seas. For two centuries the sugar industry—occupying the narrow strip of suitable land that reaches no more than 60 miles inshore and runs from the present state of Rio Grande do Norte southward 1,500 miles to the state of Paraná—provided the economic base for the occupation of Brazil. This economy rested from the outset on the labor of slaves imported mainly from Africa.

A few score of miles inland from the ocean a sharp climatic change reduces the annual rainfall to less than 20 inches and the rocky soil quickly loses the rain that falls. This is the Brazilian Nordeste (Northeast), currently the country's most depressed region. The settlement of the Nordeste during the 16th and 17th centuries was occasioned mainly by the raising of cattle to supply draft beasts for the sugar plantations and mills. As time passed the region also entered world trade with the production and export of leather. The slave labor for this industry was recruited largely from the native Indian population.

To the New World, Portugal exported its feudal institutions. The land was deeded by the crown under *donatarios* to noblemen or others ennobled for the occasion; this gentry brought foremen, herdsmen, artisans and laborers from the home country, but without women. The consequent intermingling of Portuguese with Indian and Negro blood has left its ethnic impression on modern Brazil: nearly half of the population is mestizo or mulatto and the people know no color line today.

In the 17th century, as a result of the annexation of Portugal to Spain (from 1580 to 1640) and the war between Spain and the Netherlands, the Brazilian sugar region came under the domination of the Dutch, who controlled the refining and marketing of sugar in Europe. After a quarter-century, in 1654, the Dutch were at last expelled from Brazil. Having meanwhile mastered the technology of sugar production, they pro-

BRAZIL is the fifth largest country in the world; its size in relation to South America is shown in the inset map at left center on the opposite page. Although it is politically divided into 20 states, economic planners generally partition Brazil into five climatic and topographic regions, also shown on the inset and on the large map at top. Population density is depicted in the map at bottom left, mineral resources and agricultural products are in the map at bottom right.

ceeded to establish a competing plantation system in the West Indies, thereby liquidating the Brazilian sugar monopoly. Brazil now entered a long period of economic decline that ended in the first decade of the 18th century with the discovery of gold in the plateau region.

Throughout the 18th century Brazilian economic history was dominated by the expansion of gold mining and also of diamond mining. Brazil became, in fact, the main source of gold for the European economy during the period of fast development that culminated in the industrial revolution in England and later on the continent of Europe. The territory of the present states of Minas Gerais, Rio de Janeiro and São Paulo were settled at this time by Europeans whose numbers began to offset the preponderance of African stock along the coast to the north.

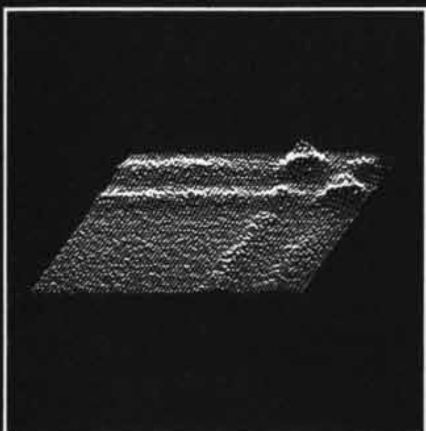
The production of gold and diamonds declined in the last decades of the 18th century with the onset of the ultimate contest between England and France, signaled in North America by the French and Indian War and the American Revolution and followed in Europe by the French Revolution and the Napoleonic Wars. The economic life of Brazil entered on a new course. The European settlements of the states of the south-central region, particularly in São Paulo, proceeded to develop a classical colonial export agriculture. Their position was consolidated in the middle of the 19th century, when coffee became a major commodity in international trade. During the last quarter of the century the coffee economy attracted a new flow of emigration from Europe to Brazil and made São Paulo the most densely populated region of the country.

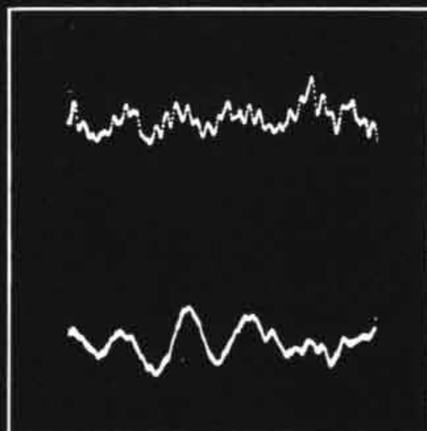
The arrival of the automobile in the first decades of the present century brought the rain forests of the Amazon region into temporary prominence in the world economy. Brazilian plantations of the rubber tree *Hevea brasiliensis* were ruined by blight, however, and soon lost their markets to blight-free cultivation of the tree in the East Indies. The coffee economy of the country meanwhile also began to show symptoms of crisis. Successive periods of surplus production brought government intervention

ECONOMIC INDICES for Brazil can be compared with those for Nigeria (*page 174*), India (*page 192*) and the U.S. South (*page 228*). National income shown in chart at top is based on conversion from cruzeiros with an internal purchasing power comparable to that of the U.S. dollar at home.

Measuring the Power of

The Infinitesimal . . . The Invisible . . . The Infinite





A Multi-Parameter Analyzer (MPA) is used in nuclear research for studies of the basic structure of nuclei. The photo above is a typical display from TMC's version of this new device. It shows a 4096-point isometric display of a portion of the gamma-ray spectrum from radioactive cobalt-60. In this two-parameter arrangement of an MPA system, the horizontal axes represent gamma-ray energy — E_x and E_y — and the vertical axis represents the number of events. The two largest peaks show the statistical count distribution of coincident 1.17 and 1.33 Mev gamma-rays from cobalt-60.

The Computer of Average Transients (CAT) makes available low-cost, on-line instrumentation for automatic averaging of evoked potentials. The above figures illustrate this technique with EEG signals obtained from electrodes attached to the occipital region of the scalp. The top trace shows the evoked response from one light flash stimulus. The lower trace shows the averaged responses from 300 stimuli. The length of each trace represents about 0.5 second in time. ■ The CAT, then, is a portable computer, wholly integrated, that can be used in a wide variety of signal averaging applications, with results available for immediate interpretation.

One of the biggest problems in receiving and decoding telemetered data from deep space is that of faithfully reconstructing the signal to determine its information content. The photo above shows a typical PCM signal plus noise (top trace) as received from a space transmitter. The lower trace shows the regenerated PCM signal in digital NRZ form at the output of a sychronizer and signal conditioner circuit. The latter is a sub-unit of a large decommutation system that converts a commutated PCM signal into many channels of proportional analog voltages. These voltages drive oscillographs, strip chart recorders, meters, etc. for subsequent analysis of acquired test data.

Measuring the latent energy in a nucleus . . . the information inherent in a brainwave . . . or the phenomena occurring in outer space, are problems whose solutions are as fascinating as they are difficult. But the photographs above show that they are being solved, with new electronic instruments conceived and built by the Divisions of TMC. Our experience and talents are devoted to fine tools for precise, technical measurement . . . of the infinitesimal and the infinite. If interested in further technical details write: Technical Measurement Corporation, Dept. S, 441 Washington Avenue, North Haven, Connecticut.

DOMESTIC: Gardena, Calif.; San Mateo, Calif.; La Grange, Ill.; Silver Spring, Md.; Stoneham, Mass.; White Plains, N. Y.; Oak Ridge, Tenn.; Dallas, Texas.
IN CANADA: Allan Crawford Associates, Ltd., 4 Finch Avenue, W., Willowdale, Ontario, Canada.
IN EUROPE: Technical Measurement Corporation, GmbH. Mainzer Landstrasse 51, Frankfurt/Main, Germany.
IN JAPAN: Nichimen Company, Ltd., Muromachi, Nihonbashi, Chuo-Ku, Central P.O. Box 1136, Tokyo, Japan.

TMC

TECHNICAL MEASUREMENT CORPORATION

aimed at stabilizing the price by large-scale stockpiling. These oscillations reached their climax in the 1930's, when the Brazilian government, under the strong-handed administration of Getúlio Vargas, adopted the policy of deliberate destruction of coffee surpluses.

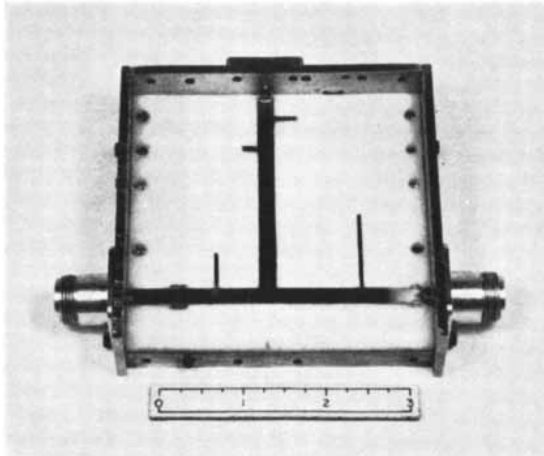
Thus throughout the four centuries from 1530 to 1930 the Brazilian economy depended on external demand to provide the stimulus for its growth. Three long-period cycles left their mark on the country's development: first, the impulse from sugar exports from 1530 to 1650; second, the dynamic impetus of gold from 1700 to 1780; third, the expansion of the world market for coffee from 1840 to 1930. The intervening periods of relative economic stagnation were marked by important political events. During the first of these periods, from 1650 to 1700, there began the great move for territorial expansion that carried the Brazilian borders far beyond the limits of the Treaty of Tordesillas, arranged by the Pope in 1493, which divided the world beyond the seas between Portugal and Spain. The second period, between 1780 and 1840, ushered in the independence of Brazil as a sovereign nation. Brazil became the seat of the Portuguese empire in 1807, when Dom João VI fled the Napoleonic conquest to set up his capital first in Bahia and then in Rio de Janeiro. His son Dom Pedro, whom he appointed regent upon his return to Lisbon in 1821, became entrained in the movement toward independence and was proclaimed emperor of Brazil on December 1, 1822. During the long reign of Dom Pedro II, who was installed as regent at the age of five in 1831, was crowned emperor in 1840 and was forced into abdication and exile in 1889, the absolutist heritage of the Portuguese monarchy gave way to parliamentary institutions. Brazil became a constitutional republic in 1891, with a constitution modeled closely on that of the U.S. and a federal government strong enough to keep its vast territory united in a single state.

The discontinuities of this chronicle of development hold the explanation of the present extreme disparities of material existence in the country's various regions. Until very recent times development has gone forward in one region and then another without relation to conditions in the other regions or to the life of the nation as a whole. In regions and periods gripped by stagnation or decline the people managed to survive by developing one or another kind of local subsistence economy without any self-sustaining impulse for growth. Where growth occurred it was based on the exploitation of resources in response to external demand.

This period in the economic history of Brazil came to an end in the worldwide economic crisis of 1929. The collapse of export-commodity prices cut the nation's import-purchasing power abruptly in half. Throughout the long depression of the 1930's the power of the federal government expanded as the coffee planters became increasingly dependent on the protections it could provide. The coffee plant is a perennial and its yield cannot be turned on and off from season to season in response to the market. In order to avoid disaster in this sector the Brazilian government maintained the price to the coffeegrower by buying the unmarketable coffee—and burning it. Over the 10-year period 80 million bags of coffee were burned.

At current prices the coffee thus destroyed would amount to $3.2 billion, or about a third of the net investment made in the country during the coffee-burning period. The government's action therefore had the effect of a daring compensatory (or "deficit-financing") policy; it maintained domestic purchasing power and facilitated the transition of the Brazilian economy toward freedom from its historic dependence on external demand. Although the policy also generated serious inflationary pressures, the maintenance of internal demand brought the Brazilian economy into the world market on favorable terms as an importer in view of the depression of prices, particularly the prices of used machinery and secondhand equipment. There began, therefore, a new phase in the development of Brazil, a phase based on internal demand. It was in this period that the trend toward the replacement of imports of consumers' goods by goods of local manufacture first asserted itself.

Investment funds formerly channeled to the production of coffee and other export products now flowed to the manufacturing of goods that had traditionally been imported. These investments not only amplified consumer purchasing power and hence the demand for such goods but also curtailed the supply of these goods from abroad by diverting available import funds to the purchase of intermediate materials and capital equipment used in manufacturing. The substitution of domestically manufactured goods for imported goods thus tended to be self-regenerating. There was no slackening of imports, because the new industries exerted such a strong



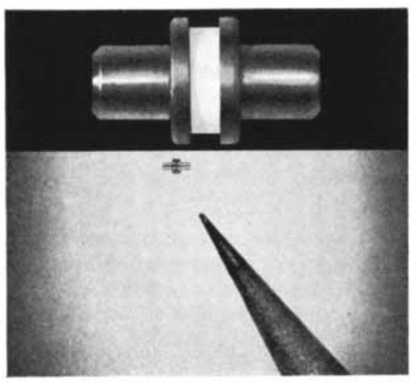
Narrowband stripline doubler has produced 3 watts of output power at 4 Gc.

Microwave Harmonic Multiplication: Watts of Power Output, Potential Bandwidths of 40 Percent

Improvements in variable capacitance diodes have made possible the frequency conversion of microwave power in an efficient, reliable manner by harmonic multiplication. At Bendix, advanced microwave technology has been combined with semiconductor research to achieve 6 watts of CW output power at 2 Gc and 3 watts output at 4 Gc.

A recent analytical approach makes possible the design of efficient microwave multipliers having bandwidths in excess of 20%. An exact modern synthesis procedure for distributed circuits has been developed to solve microwave network problems heretofore unapproachable. These include filter designs requiring specified transfer and input frequency characteristics, exactly matched frequency distribution multiplex filters, and bandpass filters having extremely high spurious rejection bandwidth ratios of 15:1. The method as applied to wideband harmonic multiplication eliminates reactive loading on the diode due to input and output filters.

Currently, diode research is being conducted on advanced mesa geometries and other methods of increased power handling, and on doping and novel epitaxial techniques to enhance frequency cutoff (f_{co}). Epitaxial-diffused diodes have been developed for high power applications with 10 mil junction diameters, breakdown of over 100 volts and f_{co} in excess of 150 Gc. This means efficient power conversion. Heat generated within the diode is conveyed from the junction by a unique pressure contact*. The diode pill package is mounted on a large microwave ground plane to provide good heat sinking. Further improvements enable doubler efficiencies in excess of 50% from 5-10 Gc to produce output power greater than 2 watts.



Ultraminiature variable capacitance diode with increased power handling ability and performance independent of orientation.

The new theoretical approach, incorporating functionally designed diodes, enables wideband efficient doubling, never before accomplished; and with watts of power. Potential applications stimulate the imagination: large channel capacity communication sources using high deviation FM, frequency hopping anti-jam and local oscillator systems, frequency multiplex applications, ECM systems, laboratory UHF and microwave power sources, and countless more where reliability is important and the system design is awaiting the technology.

Bendix Research embraces a wide range of technology including acoustics, nuclear, solid state physics, quantum electronics, mass spectrometry, photoelectronics, electron beam and tube technology, measurement science, applied mechanics, energy conversion systems, dynamic controls, systems analysis and computation, navigation and guidance, microwaves, digital techniques, data processing and control systems. Motivation: to develop new techniques and hardware for The Bendix Corporation to produce new and better products and complete, integrated, advanced systems for aerospace, defense, industrial, aviation, and automotive applications. Inquiries are invited. We also invite engineers and scientists to discuss career position opportunities with us. An equal opportunity employer. Write Director, Bendix Research Laboratories Division, Southfield, Michigan.

*Patent Pending

Research Laboratories Division

THE Bendix CORPORATION

WHERE IDEAS UNLOCK THE FUTURE

demand for intermediate materials and capital equipment.

Demand in these sectors of the import trade has continued to grow ever since. This has weighted the balance of trade and of payments against the Brazilian economy, which is only too well known for its tendency toward external indebtedness. From necessarily slow beginnings in the coffee-burning period, however, the tempo of development has been stepped up until the present. The rate of increase in the gross national product averaged 5.8 per cent over the period from 1947 to 1961. Even after discount for the high rate of population growth this has yielded a net improvement of 3 per cent per annum in income per capita. During the most recent five-year period the rate of increase in the gross domestic product has averaged 7 per cent—a figure compounded of a 4.8 per cent increase in agricultural production and a most impressive 12.7 per cent increase in industrial output.

Since the production of consumers' goods has been increasing at a rate identical with that of the gross domestic product, the driving impulse for growth must necessarily have been supplied by the rapid expansion of the capital-goods industries. The 1955–1961 figures for these industries support the inference: a 100 per cent increase in steel production (to 2.5 million ingot tons); a 125 per cent increase in the output of the machine-building industries; a 380 per cent increase in electrical and communication equipment, and a 600 per cent increase in transport equipment.

The 4.6 per cent increase in agricultural production maintained over the past 15 years is a creditable figure, and it has mounted to 4.8 per cent in the past five years. Nonetheless the gain has been largely offset by the growth of the population and still more by urbanization and the attendant increase in demand for a marketable surplus. Relatively speaking, the supply of agricultural goods has become smaller. Agricultural prices have consequently risen about 50 per cent faster than industrial prices in the course of the persistent inflation that has attended economic growth.

Bearing in mind that the process of substituting consumers' goods produced at home for imported goods had been largely completed by 1957, the continued growth of the industrial sectors of the country is evidence of fundamental change in the structure of the economy as a whole. A typical agricultural economy is plainly undergoing transformation into an urbanized industrial economy. The decline in the ratio of foreign trade to gross national product is one of the key indices. It is a measure of Brazil's increasing independence of its former semicolonial economic ties. The outlays for intermediate materials and fuels now make up the bulk of the import bill. They have been increasing each year, however, at a rate almost equal to that of the gross domestic product. These outlays constitute a measure of the advance still required to make the country's growth self-sustaining.

There is no doubt that Brazil's vast territory holds resources ample for its future development, even though these resources still remain largely uncatalogued. The scanty knowledge of these resources is in itself, of course, a symptom of underdevelopment. From what is known, however, it is clear that available technology—largely developed in regions of temperate climate and for the combination of resources found in the Northern Hemisphere—is by no means readily adaptable to the Brazilian tropics and to the country's peculiar assortment of resources. The immense forests of the Amazon basin, for example, await development by a technology that is still only incipient; Brazil meanwhile imports more than 20 per cent of its wood pulp and 70 per cent of its newsprint requirements. Similarly, extensive acreages of soil with good physical characteristics and adequate water lie idle for lack of an agricultural technique appropriate to them. Particularly cruel is the situation in the poverty-ridden Nordeste, where some six million acres of such soils go uncultivated.

Preliminary surveys show that more than 100 million acres of potentially arable land—twice the acreage now farmed—lie open to future exploitation. Of these lands only a fraction will require irrigation. To this abundance of land must be ascribed the fact that agricultural development in Brazil is still predominantly extensive, that is, by outward movement of the agricultural frontier. Of the 57 per cent increase in output achieved in the past decade, more than four-fifths must be attributed to an increase in the area under cultivation and less than one-fifth to the improvement in yield per acre, which, as Nevin S. Scrimshaw demonstrates in his article "Food" [*page 72*], is the true frontier of agriculture.

Surveys of Brazilian mineral resources, still far from complete, indicate the country's immense industrial potential. Iron ores already prospected amount to more than 10 billion tons and those inferred come to nearly 10 billion more,

altogether constituting two-thirds of Latin-American reserves and 20 per cent of the world's known deposits. Reserves indicated by geology but still unsurveyed may be larger still. Known deposits of manganese total 60 million tons of high-grade ore, and nearly 200 million tons of bauxite have been prospected. Nickel and tin are relatively abundant, but copper, lead and zinc appear to be less so.

The principal obstacle to the exploitation of Brazil's huge iron resources is the lack of coking coal. This is an accident of geological history common to the underdeveloped nations of the Southern Hemisphere and serves as the prime example of the need for the development of an indigenous technology. In this case it is the need for a technique to accomplish the primary reduction of the ores by means other than the blast furnace, so well adapted to the concurrent abundance of coal and iron in the Northern Hemisphere.

Also in common with other Southern Hemisphere countries, Brazil has comparatively thin energy resources. Coal reserves are estimated at about two billion tons, a not very impressive figure by North American standards, and the coal is low in quality. The first substantial oil deposits have only recently been drilled; although proved reserves are expanding rapidly, they amount to a mere six-year supply at the present rate of consumption. Water power promises to yield no more than 30 million kilowatts, of which less than five million has been developed. Until technology brings in economically sound alternatives Brazil must remain an importer of fuels.

Although the market economy has furnished the chief impetus to industrialization so far, it is becoming clear that maintenance of the present rate of growth will require increasing initiative in the public sector. Through the work of a central agency under the office of the President co-ordinating a system of decentralized planning, Brazil now has a three-year plan and the federal government is setting priorities in investment policy. The removal of the seat of the government to the nation's new capital in the frontier town of Brasília has played more than a symbolic role in directing the energies of the nation inward to the wealth of its interior.

Inevitably development has heightened the tensions between the emerging nation and the social institutions and power system that persists from feudal times. As recently as three decades ago the big landowners were the ruling class

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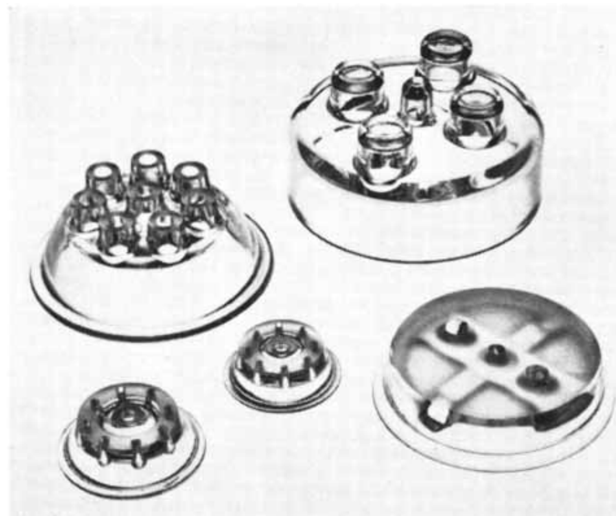
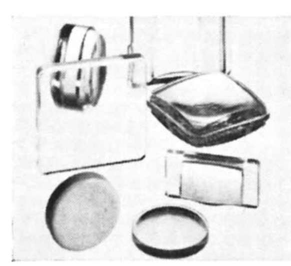


These are upside down. We call them flares and they become the bases for electronic tubes. They're a volume item because radio and television sets take a lot of tubes, glass because of its remarkable electrical characteristics.

Customer experts grind and polish these optical-glass segments and turn them into bifocal eyeglass lenses.

We pump these out by the thousand because customers blow them up deep down inside sluggish oil wells. Precision is important because they're designed to hold shaped charges. Glass is important because it turns to powder when the charge lets go, doesn't clog up pumps as metal casings might.

Potpourri of precision in volume—clockwise from bottom left: remelted, this button becomes the white glass behind the mercury in your fever thermometer; square face plate for a gas or electric meter; gauge glass; light lens for sewing machine; top finder for camera; lens for recessed airport-runway light, and a 28mm face plate.



CORNING

CORNING GLASS WORKS

of Brazil. The abolition of slavery in 1888 gave way to a labor system characterized by deep social differences between employers and employed. Although the government was representative in form, it was almost exclusively operated from the top down; the executive power was able to select its own candidates in the legislative branch and enforce election results.

In 1930 there began a rapid dismantling of the old feudal agrarian system. With the decline of export agriculture, industrial entrepreneurs and the labor unions took a stronger hand in politics. Their growing power is inhibited, however, by the overrepresentation of rural areas in the electoral system and by an electoral law that disenfranchises the nonliterate majority of urban workers.

At present Brazil is a nation in transition. Its system of representative democracy has shown great flexibility in recent years but this flexibility is now stretched to its limits. The most serious threat to peaceful transition arises from the fact that the most urgently needed reform—the political reform that will make the government more truly representative of the new urban and industrial society—has proved to be the most difficult to achieve. Until this higher degree of effective democracy is won, other institutional changes compelled by economic developments must generate dangerous tensions. The extension of social security to rural laborers, for example, has been pushed through only recently after 10 years of hard struggle in the federal legislature. The agrarian reform now being debated in the Brazilian congress will undoubtedly constitute a decisive test of the limits of pressure bearable by the present political system.

Brazil's approach to industrial maturity has great significance for the world as a whole, in view of the nation's extraordinary potentialities for future growth. By the end of the decade the population of Brazil will have come close to 100 million, with more than 60 million living in urban regions. Steel production will have exceeded 10 million tons and the foundations for self-sustained growth will have been secured. Because Brazil will be the first nation in the Tropical Zone to achieve industrialization, its culture and technology will surely have possibilities for world-wide projection. The democratic bias of the country's ethnic make-up will facilitate the projection of Brazilian values and ideals far beyond its own frontiers. Brazil is therefore bound to play an important role in relation to the new nations that are being formed in the tropical world.

Basic Research at Honeywell
Research Center
Hopkins, Minnesota

Measuring Heats of Fusion of Salts with a Dynamic Adiabatic Calorimeter

Modification of and additions to known techniques have led to a fast and accurate method of measuring heats of fusion and specific heats of materials.

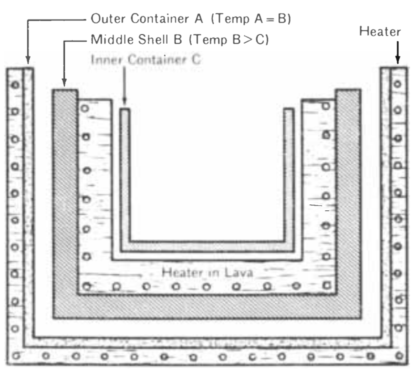
Fused salts are stable at high temperatures, have low vapor pressure, low viscosity and good electrical conductivity. They are also able to dissolve many different materials. Extremely useful in metallurgical processes, they have been used as heat transfer materials, power sources, control devices, and coolants and fuels in atomic reactors.

One area of interest to Honeywell scientists concerns heats of fusion of specific salts. Much older heat of fusion and specific heat data to be found in the calorimetric literature are inaccurate, particularly those on inorganic compounds with high melting points. At the same time present methods of obtaining accurate data are cumbersome, complex and time consuming.

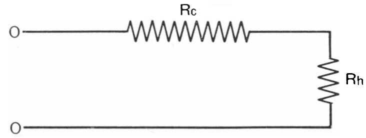
Modifying and adding to known techniques, Honeywell scientists have developed a calorimeter that gives direct reading, highly accurate data in as little as two hours.

A conventional calorimetry equation is $q_h = q_s + q_c + q_l$ or the heat supplied to the system equals the heat absorbed by the sample (q_s) plus the heat absorbed by the calorimeter (q_c) plus any heat loss (q_l).

Honeywell's approach (see illustration) is to eliminate q_l by maintaining adiabatic conditions between the outer shell (A) and the next or middle shell (B) and to maintain a constant temperature gradient between a higher temperature in the middle shell (B) and a lower temperature in the inner shell (C) containing the sample. The equality of temperatures at (A) and (B) forbids heat from passing from the middle (B) to the outer shell (A) so that after the middle shell temperature reaches its control point all heat must pass to the sample. The outer-middle shell adiabatic condition and the middle-inner constant temperature gradient condition are maintained with two feed-back control systems. If these conditions are met q_l can be ignored and $q_h = q_s + q_c$. If the sample is removed $q_h = q_c$ and q_c becomes known so that q_s can be determined by a simple subtraction. The problem then becomes how to accurately measure q_h.



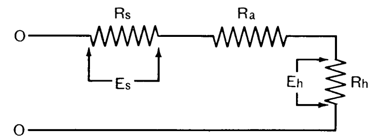
The problem $q_h = \int$ watts x time or $\int$ amps x volts x time is simple to pose, but the integration is difficult without a constant current, voltage or wattage. To obtain a constant power (amps x volts), Honeywell borrowed an approach of Rosengren whose circuit is such that the



difference in power dissipated by R_h will be negligible between any two temperatures if $R_c = \sqrt{R_{h1} \times R_{h2}}$ where R_{h1} is resistance at temperature 1 and R_{h2} is resistance at temperature 2, whereas without R_c the power dissipation decreases inversely as R_h increases.

Desiring, however, to use an adjustable system to cover different temperature ranges, Honeywell separated R_c into R_a, an adjustable resistor, and R_s, a known standard resistance.

Then, adding a potentiometer to measure E_s across R_s and E_h across R_h,



$E_s = R_s i_s$, where i_s is the same as i_h and R_s is known. Thus watts across R_h can be determined: $E_h E_s/R_s$ = watts of constant power.

With a strip chart recorder measuring the temperature of the sample only when power is demanded, a direct readout of the heat of fusion (q_h) is possible. The chart reads time directly between any two points. Therefore, when temperature ceases to climb, fusion is taking place and when temperature rises again fusion is completed.

Since q_h = watts x time, and watts ($E_h E_s/R_s$) is maintained constant, q_h becomes a known factor x time, so that by an easy conversion, time for fusion is in effect, q_h, the heat of fusion. By comparing plots with and without the sample, specific heat data are also easily obtained.

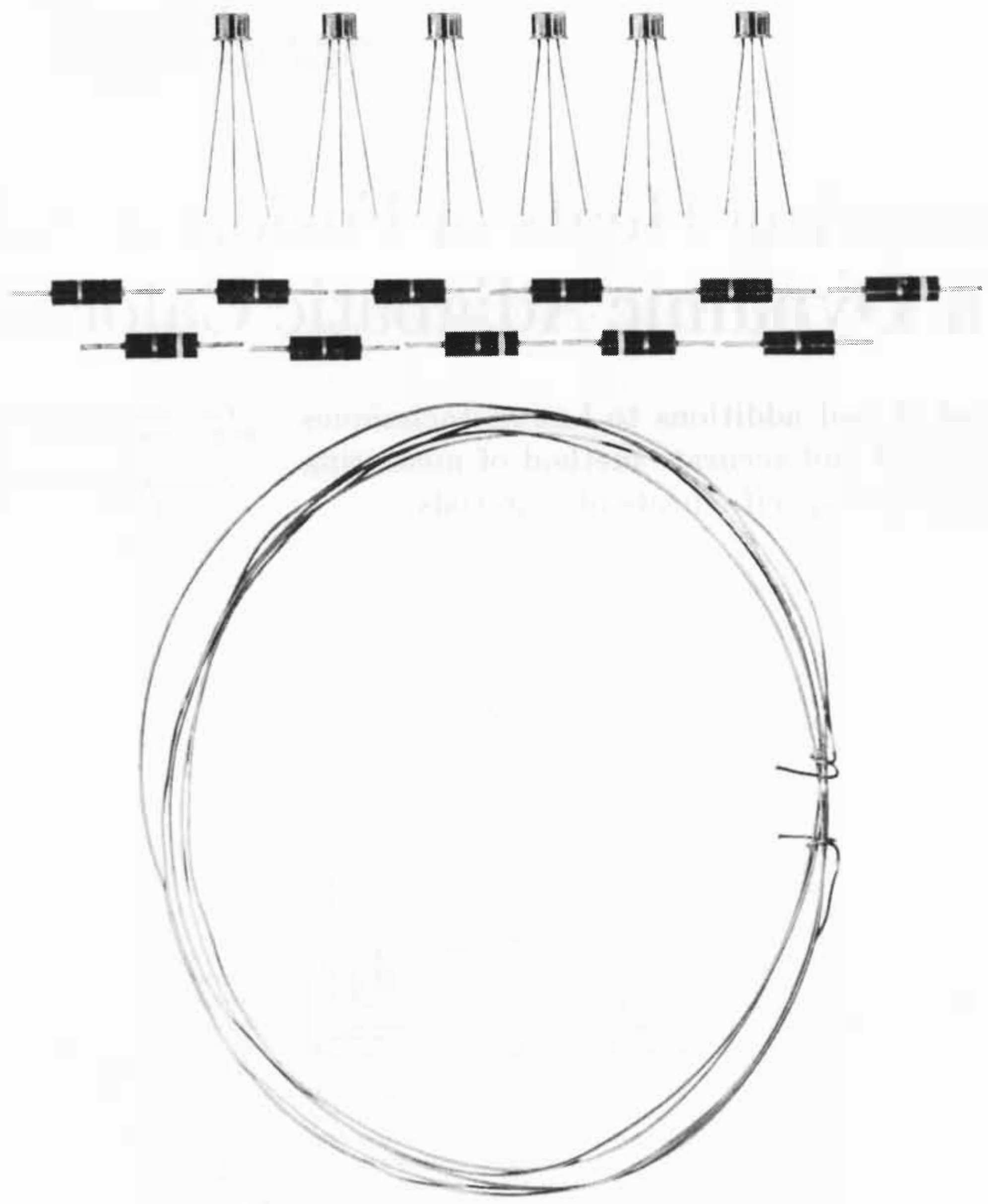
This chart, plotted automatically in two to three hours, replaces computations that took several weeks. Results have been impressive. In measuring the heat of fusion of benzoic acid in five runs, one was +1.7% above the Bureau of Standards figure, one +2% and three exactly on standard.

Work is continuing at Honeywell's Research Center. As heats of fusion of various salts are more readily measured and predicted, further uses are expected. If you are engaged in high temperature calorimetry and wish to know more about Honeywell's work in this area you are invited to write Dr. Cyril Solomons, Honeywell Research Center, Hopkins, Minn.

If you are interested in a career at Honeywell's Research Center and hold an advanced degree in any branch of science you are invited to write Dr. John Dempsey, Director of Research, at this same address.

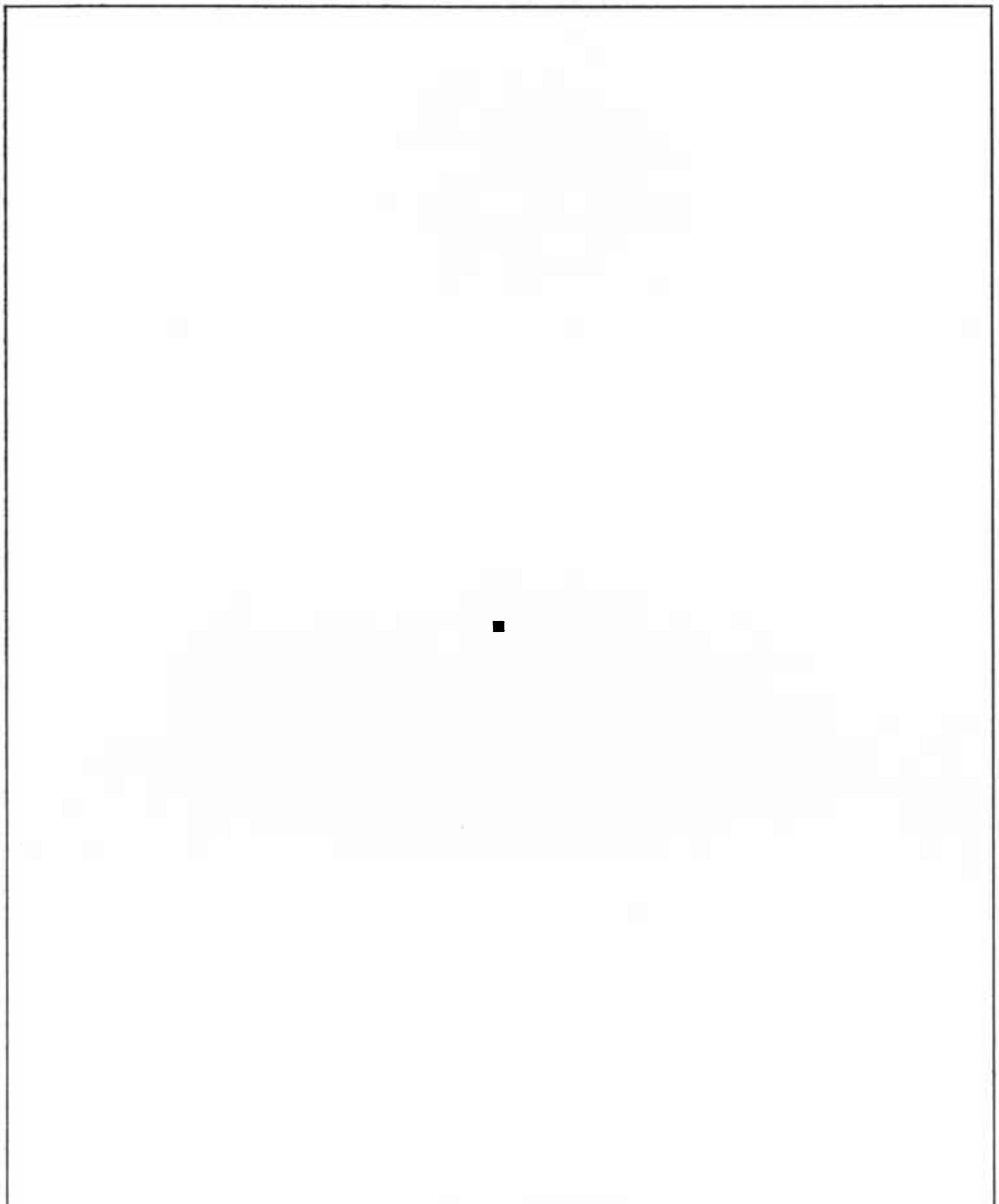
Honeywell

Before:



SIX TRANSISTORS, 11 RESISTORS AND TWO FEET OF WIRING.

After:



SIX TRANSISTORS AND 11 RESISTORS (INTEGRATED). NO WIRING NEEDED.

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The Development of the U.S. South

Not so long ago the 13 Southern states were an underdeveloped "country" within the U.S. An account of the process by which a quasi-colonial region was integrated into the national economy

by Arthur Goldschmidt

Just 25 years ago President Roosevelt released with his own endorsement a report by the National Emergency Council that described a region of the world whose "potentialities have been neglected and... opportunities unrealized." The report told a story of inadequate housing, education and health facilities, of an agriculture characterized by absentee ownership, single-crop farming, underemployment and per capita incomes under $200 a year. Too poor to accumulate savings, the people had not developed their own industries and lived in a quasi-colonial economy, exporting staple crops and raw materials and importing most of the manufactured products they consumed.

The report dealt not with a region of Asia or Africa or Latin America but with the 13 Southern states of the U.S. In 1938 the U.S. South was an underdeveloped area within the most developed country in the world, "the nation's economic problem No. 1." Now, 25 years later, the South is emerging from that state of underdevelopment. It has attained the diversification of agriculture and industry and the potential for self-sustaining growth that characterize a viable modern economy. Although it still lags behind the rest of the U.S., it has essentially achieved the economic goals toward which such countries as Nigeria, India and Brazil are striving. These past 25 years of its 100-year struggle with poverty illustrate the crucial importance of outside assistance to a people attempting to break through the interrelated barriers that bar the way to development.

These barriers, as the economist H. W. Singer has said, are a series of "vicious circles within vicious circles and of interlocking vicious circles":

Poor people have poor health and low energy; low energy results in low productivity, which keeps people poor.

Absentee and large-scale ownership patterns demand single-crop farming, which is dependent on unstable markets, which dictate credit systems that perpetuate undesirable land-tenure patterns.

Economic development requires capital; capital must come from savings; saving requires cutting down consumption —but a poor economy must consume most of what it produces.

Low economic activity cannot create the tax base for producing the revenue required for such "infrastructure" investments as transport, power and education—which are essential to increased economic activity.

Development activity in poor areas is initially more effective in reducing death rates than in producing goods, so that populations increase and living levels are lowered.

Development requires change; but in the traditional societies of underdeveloped regions power is often in the hands of those most bound by tradition and resistant to change.

The Swedish economist Gunnar Myrdal has described these vicious circles as a downward-spiraling "cumulative process of circular causation." It can be summed up by the saying "Poverty is its own cause." These deterrents to development affect pockets of poverty within the developing and even the most developed nations as well as the underdeveloped countries of the world. It is true that technology and industry offer the means of distributing wealth and well-being throughout a country, and that today the more highly developed a society becomes, the more it tends to achieve economic equality for its people—a modern version of the egalitarianism of primitive hunting-and-gathering societies. The process, however, does not spread automatically from one sector or section to others. Rather, unevenness of development is implicit in the process of development. Disparities of income, differences in the state of technology and consequent productivity, and wide variations in levels of living are the conditions of any society that has left the moorings of its primitive economy and launched on the turbulent process of development.

The principal disparity within the developing countries is a sharp discontinuity between the economies of the agricultural mass of the country and the capital city or a few main industrial centers. But sometimes whole areas have stood still or retrogressed in an otherwise developing economy, either because they are "new" areas, remote from the original focal points of development (the old U.S. West, Siberia, western China and western Australia), or because they are physically inhospitable regions (eastern Bolivia and eastern Peru). Others are bypassed for more complex economic and political reasons and fail to share in the economic development of the rest of the country. While these regions lag they are a serious brake on the progress of the whole economy. The depressed Nordeste of Brazil is one such bypassed area in a developing country. In a more advanced country, Italy, the southern provinces have yet to share fully in the benefits of a modern economy.

The U.S. South was similarly bypassed in the course of the nation's in-

FARM SCENE on opposite page illustrates some of the changes brought about in Southern agriculture in the past 25 years by improved technology and diversification of crops. The aerial photograph of a farm near Dublin, Ga., shows (*top to bottom*) fields of cotton, corn, peanuts and again corn.

dustrial development. It was not just that the South's cotton-tobacco-slave economy cut it off from the commercial and industrial advance of the rest of the nation or that it suffered directly from the Civil War and Reconstruction. According to classical economics the operation of the market and the play of trade should tend to equalize development between the advanced and the retarded parts of a country. Myrdal has pointed out that the process is not that simple. If there are "spread effects" that move outward to elevate the poorer regions, there are also "backsetting effects": patterns of trade, migration and the movement of capital within a country favor the rich and developing sections at the expense of poor and underdeveloped sections. Myrdal suggested that national policy can intervene to strengthen the spread effects, and that this is what has happened in most of the advanced nations. But in the case of the U.S., Federal intervention tended historically to aid the development of the North and to retard the South.

U.S. Government intervention in development reached back to the Articles of Confederation; indeed, concern with national development was the proximate cause of the meeting of state delegates at Annapolis in 1786 that called the Constitutional Convention. Homesteading policies, beginning with the Northwest Territories Ordinance of 1787, coupled with the disposition of large grants of public lands for infrastructure investment in transportation and education, were intentionally designed to promote development and to spread it westward across the continent. These Federal policies had little applicability in the South, where there were no extensive public lands left for disposal. Tariff policies designed to help the industrialized sections of the country did so at the expense of the raw-material-producing Southern states. The University of Texas historian Walter Prescott Webb, in his 1937 book *Divided We Stand,* struck out at what he called the "economic imperial control of the North," attacking not only Government policies of discrimination but also policies of corporations that affected Southern development: restrictive licensing arrangements, discriminatory pricing systems and investment of insurance funds in Northern industry. He showed that even the Civil War pensions (predominantly paid to Northerners) were related to the tariff policies of the Federal Government because these payments, which provided purchasing power for Northern business, were a convenient method of siphoning off the embarrassment of riches that the U.S. Treasury reaped from tariff revenues. Webb's complaints were reminiscent of those of the "New South" movement in the 1880's and of the Populists in the 1890's. But the nation as a whole had largely ignored these pleas. The South remained in a stagnant backwater outside the mainstream of U.S. development.

In June, 1938, President Roosevelt called attention to the need for national involvement in the South's efforts at development. At his request the *Report on Economic Conditions of the South* mentioned at the beginning of this article was drafted by a group of Southerners in the Federal service and reviewed by an advisory committee of Southern citizens. The report did not have any formal status, nor was it in any sense a "plan" for the South. Written in simple language and high dudgeon, it was an effort to gain support for reversing policies of drift and discrimination and putting the influence of the Federal Government behind the development of the South. Its impact was felt throughout the country.

In examining "the factors that have produced the present economic unbalance" between the South and the rest of the country, the report covered to a remarkable extent the same range of problems discussed by experts currently reviewing similar underdeveloped segments of the world for the United Nations, the World Bank or U.S. foreign-aid agencies. "The paradox of the South is that while blessed by immense wealth, its people as a whole are the poorest in the country. Lacking industries of its own, the South has been forced to trade the richness of its soil, its minerals and forests, and the labor of its people for goods manufactured elsewhere." This might describe the majority of the countries of Asia, Africa and Latin America.

"The farming South depends on cotton and tobacco for two-thirds of its cash income," the report continued. "More than half of its farmers depend on cotton alone." With the characteristic insularity of its day the report stated that "no other similar area in the world gambles its welfare and the destinies of so many people on a single crop market year after year," ignoring the rice farmers of Thailand, the tea gardeners of Ceylon, the coffeegrowers of Colombia.

More than half of the South's farmers were tenants, and tenancy dictated one-crop farming because "landlord and tenant usually have not been able to find a workable method of financing, producing and sharing the return from such crops as garden truck, pigs and dairy products." One-crop farming in turn made soil conservation practices almost impossible—as it still does in many parts of the world. Inefficient use and control of water resources retarded economic development. Malaria afflicted more than two million Southerners, and the low-income belt of the South was "a belt of sickness, misery and unnecessary death." In the slums of "overcrowded, economically undeveloped Southern communities" lived families that shuttled "from farm to mill or mine and back again to farm," always with "too little income to enable their members to accumulate the property that tends to keep people stable." For years many had been "living only half-employed or quarter-employed or scarcely employed at all."

The South had 28 per cent of the

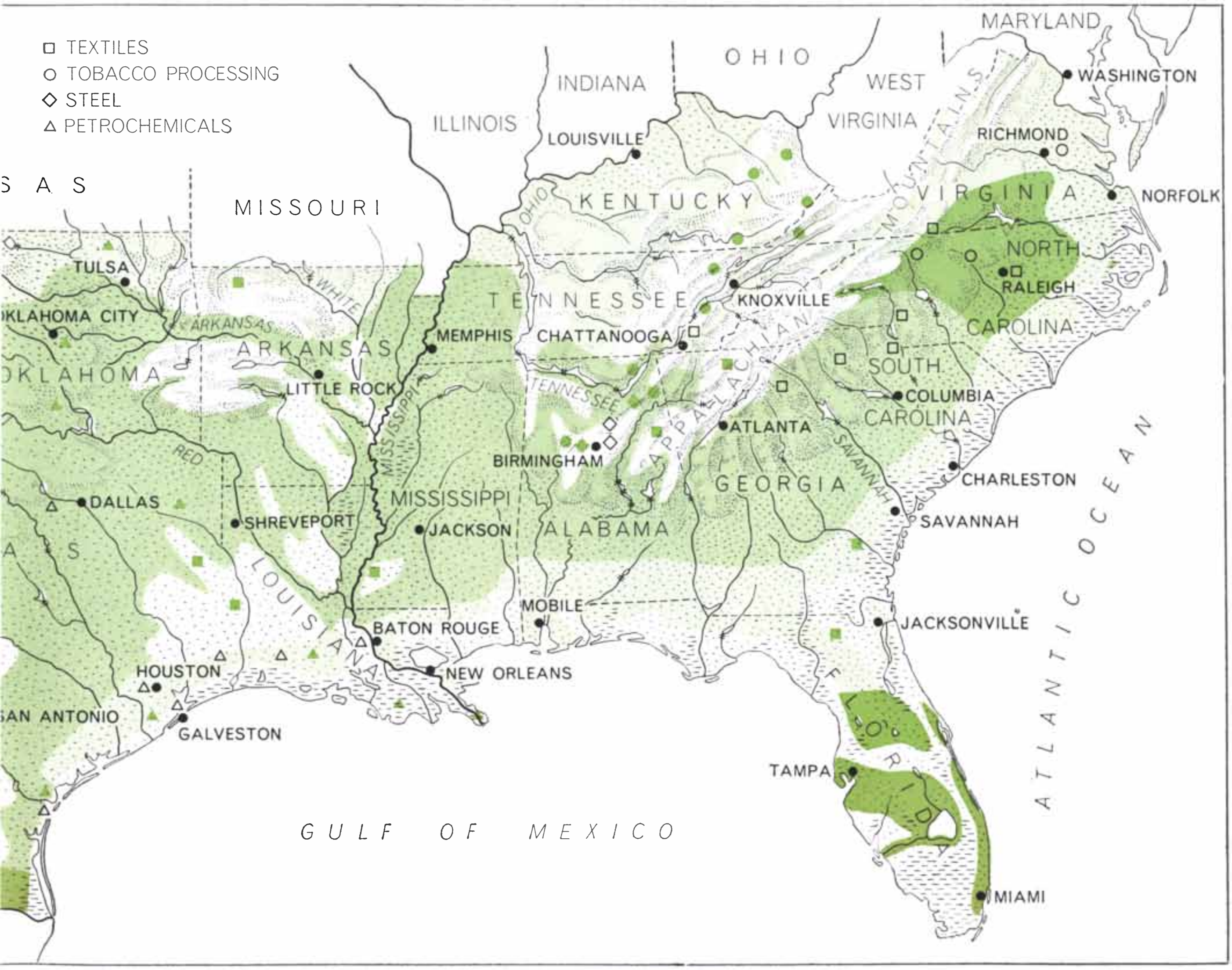
U.S. SOUTH, as discussed in this article, comprises the 11 Confederate states plus Kentucky and Oklahoma. Its area, 863,000

U.S. population but the South's banks held less than 11 per cent of the nation's bank deposits and less than 6 per cent of the savings deposits. Because money was scarce interest rates were high, making borrowing difficult for industry, for local governments and in particular for farmers, who had to pay interest as high as 20 per cent (as do borrowers in the less developed countries today). The South had to "look beyond its boundaries for the financing of virtually all of its large industries and many of its small ones." Outside financing turned policy-making power over to "outside management," a circumstance that disturbs many of the emerging countries now seeking capital from abroad.

The report insisted that the South got shortchanged in its terms of trade with the rest of the country, and it hammered away at the Government policies it considered responsible. Unwarranted differentials in railroad freight rates made it more expensive to ship manufactured goods to centers of consumption in the North and the Middle West from the South than from equidistant factories in the Northeast. High tariffs helped Northern industry but made it difficult for foreign countries to acquire dollars with which to buy Southern raw materials. The South was "caught in a vise that has kept it from moving along with the mainstream of American economic life. On the one hand, the freight rates have hampered its industry; on the other hand, our high tariff has subsidized industry in other sections of the country at the expense of the South."

Low incomes and revenues kept the infrastructure of governmental services meager. "Since the South's people live so close to the poverty line, its many political subdivisions have had great difficulty in providing the schools and other public services necessary in any civilized community." In 1936 the state and local governments of the South collected in taxes only $28.88 per person compared with $51.54 in the nation as a whole. "The South must educate one-third of the nation's children with one-sixth of the nation's school revenues." Not only were there inadequate schools and colleges but also there were "meager facilities ... for research that might lead to the development of new industries especially adapted to the South's resources." The lack of opportunity in the South was causing large-scale migration; "many of its ablest people" were leaving, just as is the case today in so many of the less developed countries.

Adding up all these factors in terms of individual incomes, the report found



square miles, is almost twice that of the six-nation European Common Market; its population, 48,802,000 in 1960, is 27 per cent of the U.S. population. Most of the South, stretching all the way from tidewater Virginia to the cattle ranges of Texas, has a long growing season and adequate rainfall. Colored areas on map denote agricultural land and show the leading crop in each region.

that in 1937 the average annual income of Southerners was $314 compared with $604 for other Americans. In none of the Southern states did the per capita income reach the national figure; in more than half of the states incomes were below 60 per cent of the U.S. average; in three they were less than half. Industrial wages were about two-thirds of those paid elsewhere in the U.S. For the farmers it was worse: even in 1929 Southern farm families had a per capita gross income of $186. For the tenant farmers it was still worse: the average cotton tenant family's income was $73 per person and sharecroppers' earnings ranged down to $38 per person. These figures are within the range of incomes in most poor countries of the world today.

The South was in 1938 a kind of colony of the U.S. but it was a built-in colony. The traditional antidote to colonialism—independence—was not appropriate. Only economic integration with the nation as a whole could cure the South and close the North-South gap. And this integration could only be accomplished by Federal action. There is a direct parallel today in the economic development of the former colonial regions of the world. Independence, although it is a political and moral imperative, does not in itself bring economic development. The emerging nations need to be integrated into the structure of the developed world's economy. No amount of bootstrap-pulling can do the job; outside assistance is essential.

The report made few specific recommendations for the amelioration of the conditions it found but it did call implicitly for action by the Federal Government: greater Federal expenditures for public works, resource development and relief; more favorable credit facilities, particularly for agriculture; correction of discriminatory freight-rate and tariff policies. The tone was occasionally xenophobic, but there was no demand for economic "independence"; the message was national, emphasizing the interdependence of Southern development and U.S. economic health. "The South is the nation's greatest untapped market.... Northern producers and distributors are losing profits and Northern workers are losing work because the South cannot afford to buy their goods." In spite of the complaints against freight-rate discrimination and tariffs, the report called not for a return to *laissez faire* but for the "national integration policies" and the "state interferences" that Myrdal says are required to keep a region or sector from lagging far behind in the development of a national economy.

Twenty-five years after the publication of the report the nation's major preoccupation with the South is no longer economic. To be sure, the income patterns of the Southern states still put all of them below the line of the national average, but the trend throughout the intervening years has been toward closing the gaps: the lower-income states have moved upward toward the national level while that level itself has moved upward [*see illustration on opposite page*]. There are still geographic disparities in employment and income in the U.S., but the contrast is now largely

ECONOMIC INDICES reflect the South's progress toward development when compared with the indices for Nigeria (*page 174*), India (*page 192*) and Brazil (*page 212*). The "regional income" was computed from personal income figures. Trade statistics are not available.

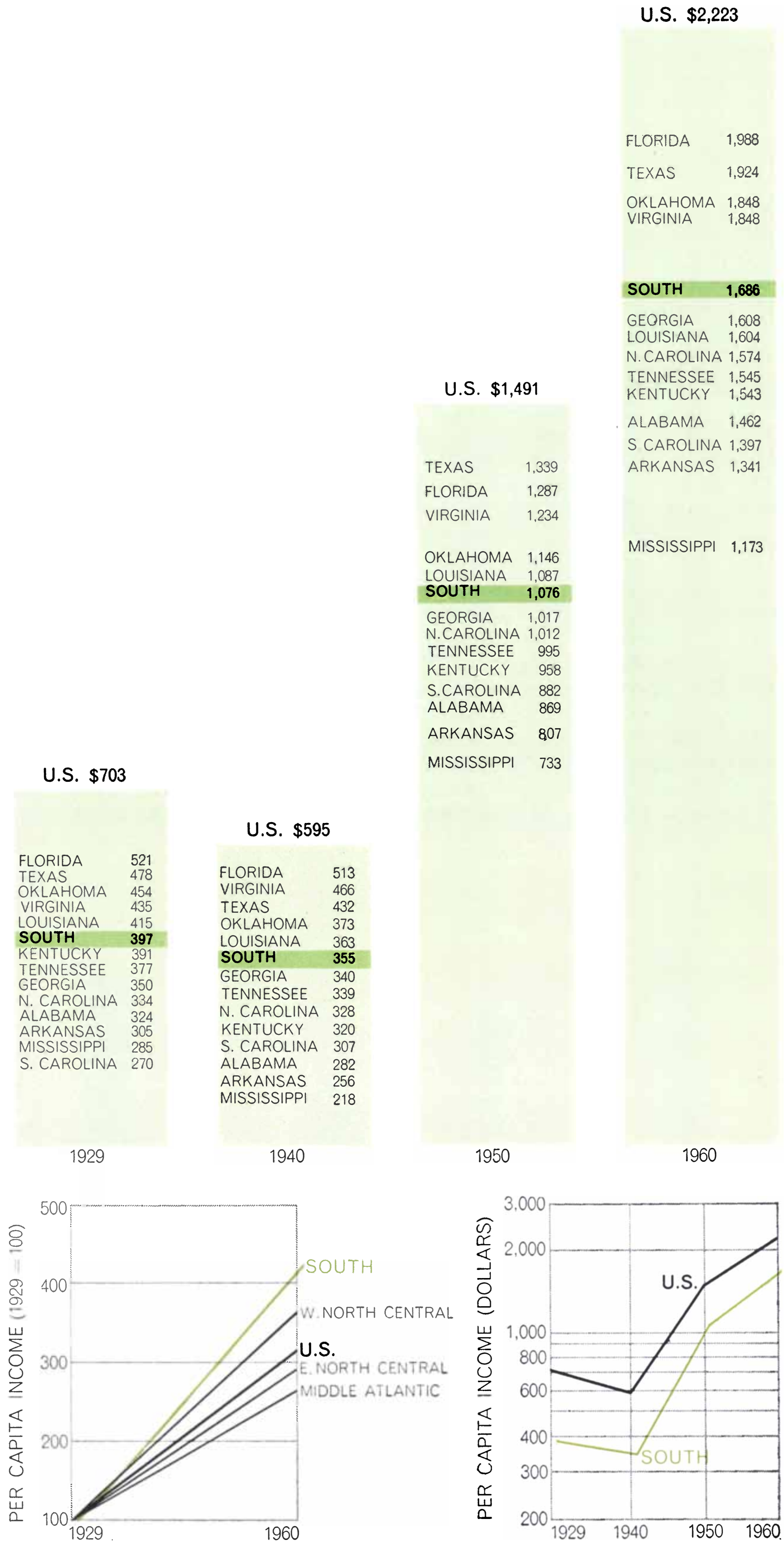
between scattered depressed enclaves (many of them still in the South) and the rest of the country. Economists generally agree that this integration of the U.S. economy was brought about not by the unseen hand of economic forces but by the long arm of national policy.

It is doubtful that the principal direct proposals of the report—the removal of the freight-rate differentials, the relaxing of restrictions on the sale of margarine or even the lowering of tariffs—had any substantial role in effecting the rise of the economy of the South. Nor were the relief payments called for enough to provide more than a temporary palliative. The conditions reported in 1938 were not caused by the depression but merely highlighted by it, and they required changes more drastic than countercyclical measures of employment and relief. Even Federal grants-in-aid to the Southern states, which had lagged on a per capita basis and were stepped up in 1939, did not rise appreciably above the national average until 10 years later.

The measures that achieved the most spectacular changes were those that attacked the root problems of Southern agriculture: "land reform" (in the broad sense used by the UN), including not only changes in land tenure but also improvements in farm credit, marketing, research and other services. These changes were effected in the South through Federal measures designed to correct the tenure and technology of agriculture and to increase its productivity. Programs of supervised rural credit and other aids to the lowest-income farmers, as well as broader programs of research, soil conservation and price supports, have radically changed the patterns of Southern agriculture.

The small, uneconomic farms are disappearing. There are more than a million fewer farms under 50 acres in the South than there were in 1935. The total number of farms has dropped from 3,263,000 to 1,572,000 and the average acreage per farm has doubled. Most impressive of all is the fact that there are some 1,400,000 fewer tenant farms today than there were in 1935. Tenants operate less than a fourth of the farms, compared with more than half in 1935. There were more tenant families in 1935 than there are farms today in the South.

Farm practices too have undergone basic changes. Soil and moisture programs have changed the very landscape of the South. Where once there were gullied hillsides and worn-out soil there is now a rich farmland improved by contour plowing, runoff-retardation works



GROWTH OF INCOME in the South is compared with that of the rest of the U.S. in these charts. The 13 states have moved upward in per capita income, as shown in the top chart, although none has yet reached the national standard. The two bottom charts illustrate in different ways the fact that the South has been growing faster than other regions of the U.S.

on small streams, supplementary irrigation and reforestation. In 1959 a third of the number of cotton farms with 60 per cent of the acreage produced a bigger cotton crop than in 1939. Although the South still produces most of the cotton of the U.S., the appalling dependence on that commodity has been ended. In part this has been the result of a technological change, the mechanization of cotton farming, that resulted in increased cotton production in Texas and Oklahoma and on irrigated farms in the arid Southwest, forcing the Southeast to diversify its crops. Roads and rural electrification have added appreciably to the productivity of Southern agriculture. The South received more than 41 per cent of the total loans of the Rural Electrification Administration from its inception in 1935 to 1961.

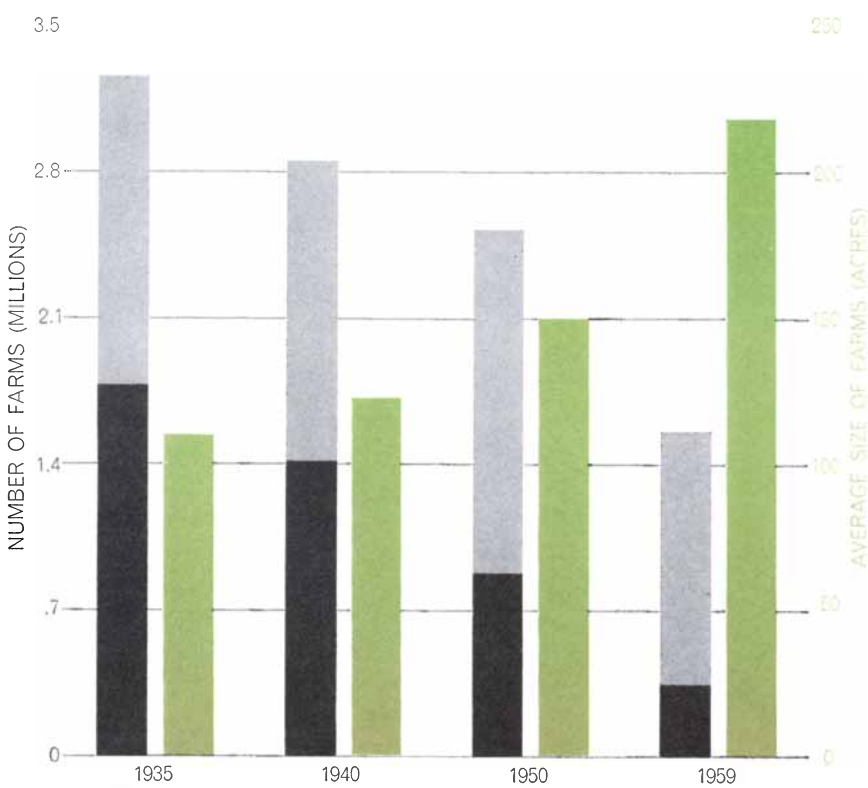
The agrarian reform of the South is not yet complete. The problem of tenancy has been replaced to some extent by the problem of the farm wageworker. Sixty-five per cent of the full-time farm laborers receive less than $5 a day in wages, and their average total annual income in 1960 was less than $800. But the net income per Southern farm had risen by 1960 to 87 per cent of the national average. More important than this relative rise was the absolute rise: at $6,238 in 1959 the gross money income per farm was nearly eight times the 1939 figure.

The agricultural sector was not the only front on which the Government moved to alleviate the conditions cited in the report. Water conservation and development projects, led by the pacemaking Tennessee Valley Authority program, brought navigation channels, flood control benefits and power to the region. The TVA power policies, in the American tradition of eschewing monopoly and spreading widely the benefits of public resources, affected rates and service far beyond its own network of transmission lines. Federal projects on the Red, the White, the Arkansas, the Savannah and the other major rivers of the region developed hydroelectric power that was firmed and augmented by the South's vast natural gas, oil and coal resources, so that the region now has nearly 30 per cent of the nation's generating capacity. The South's consumption of electric power increased from 21 per cent of the nation's production 25 years ago to more than 30 per cent in 1960.

Industrial development was directed to the South by the Defense Plant Corporation and other World War II agencies. But the new manufacturing plants of the South have been attracted also by more basic considerations, notably the ready availability of natural resources. The South produces more than 63 per cent of the country's crude oil and 78 per cent of the natural gas, and the expanding demand for petrochemicals has made a manufacturing industry out of what was once an extractive industry only. The South's new wealth in hydroelectric power has brought in chemical and metallurgical industries—notably aluminum—that require large amounts of electricity. These and the increased number of pulp and paper mills are among the growing resource-based industries that have joined textiles and tobacco. Meanwhile enlarged markets have attracted decentralized rubber and automobile assembly plants. By 1955 manufacturing had replaced agriculture as the leading source of personal income in the South. Whereas in 1929 agriculture had supplied about 26 per cent of the South's "earned" personal income, in 1961 it provided less than 9 per cent; in the same period manufacturing's share rose from 16 per cent to 22 per cent.

Gross weekly earnings of production workers in the South were still below the U.S. average of $92.34 in 1961. Earnings in Texas topped this average by a few cents but at the other end of the scale workers in Mississippi averaged $61.93. These figures, however, are affected by the types of industry in the region; in any given industry the wages paid in the South and in other parts of the country tend to be closer. Hourly earnings of textile production workers averaged $1.57 in New England in 1958, compared with $1.45 in the Southeast; the spread was even narrower in fine cotton goods, with New England's average $1.56 and the Southeast's $1.52. Federal minimum-wage legislation and the spread of union organization helped to integrate the South in the national economy. As a result the South was receiving 20 per cent of the nation's total personal income in 1955, compared with only 16 per cent in 1929. The per capita personal income in the South was 76 per cent of the national figure in 1961; in 1929 it had been only 57 per cent.

Southern housing is still below the national level. The 1960 census of housing reveals that the percentage of housing units classed as "dilapidated" is twice as large in the South as in the rest of the country. But the actual number of such units is only 1.5 million, whereas the 1938 report concluded that four million families in the South needed



LAND REFORM in the South is traced by this chart. The total number of farms has decreased steadily since 1935 (*gray bars*) and the number that are tenant-operated has gone down even more sharply (*dark gray*). Average acreage per farm increased (*color*).

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 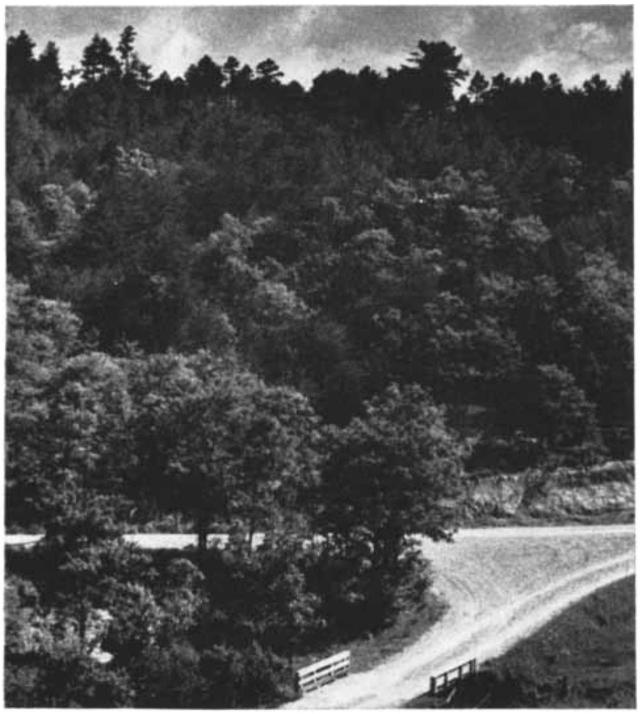

CONSERVATION TECHNIQUES have altered the Southern landscape. A hillside in North Carolina's Buncombe County, gullied and barren in the 1930's (*left*), was planted with seedlings in a TVA forestation program. The result 20 years later is shown at right.

to be rehoused. In the 25 years Federal programs to stimulate home-building and help people to buy homes had brought housing in the South closer to the national standard.

Rising incomes have made it possible for the Southern states to invest more in education; their spending per pupil rose from half of the U.S. figure in 1936 to more than 70 per cent in 1959–1960. The Southern states, however, are still far down on the scale: Mississippi spends only 55 per cent of the national figure, South Carolina 56 per cent, Arkansas 60 per cent. Even to attain these low school-spending levels the Southern states must devote a higher proportion of their citizens' income to education than the rest of the nation does. This is not only because of generally low income but also because of an unfavorable age distribution (more children), a larger proportion of children in public schools (fewer Catholics) and the added expense of maintaining lingering segregated school systems. As a result the South ranks high on a "sacrifice" scale relating spending on education to personal income. With the U.S. at 100, such a scale shows Mississippi at 125, South Carolina at 115 and Arkansas at 110.

Population control is often advocated to mitigate the problem of low incomes. In the South this has to some extent been accomplished by migration, both within and out of the Southern states, which has appreciably redistributed their population. (High birth rates have kept the total population at about the same proportion of the national total even though people have been leaving most of the states.) From 1940 to 1960 the South (excluding Florida) had a net loss of 5.6 million people through out-migration. Together with movements within the region this has resulted in a sharp relative increase in the number of people living in Florida and Texas and a relative decline in most of the other states, with absolute decreases in population in Mississippi, Oklahoma and Arkansas.

Economic progress in the South has been spotty and the development process is not yet complete, but this underdeveloped section of the U.S. has come a long way. Many of the vicious circles of self-enforcing poverty have been broken—and with them many of the traditional relations and patterns of living that may well have held the South back but have also been basic to its sense of its own identity, to a regionalism that could never be completely explained by geography, economics or even history. Development inevitably brings social upheaval and political tensions. As in the case of so many developing countries, some of the concomitants of economic change are deeply disturbing to many Southerners. In this situation fear of the future and nostalgia for the past occasionally outweigh courage and eagerness for progress. But the forces of Southern development and the nation's need for that development will not be denied.

The distinguished Southern historian C. Vann Woodward has suggested in his *Burden of Southern History* that the South's perspective on history is closer to the world's view than is that of the rest of the country because the South has shared with nearly all the peoples of Europe and Asia the experiences of military defeat, occupation and reconstruction. The South has shared another tremendous experience with the developing countries of the world: it has within recent years faced their problem of breaking the vicious circles that thwart development. It is an irony of history that this section of the U.S., which presents to the world such a disturbing picture of human relations because of the turbulent current effects of its development, should offer to the emerging countries so important a message bearing on their own concerns. Economic development is too important to leave to the blind play of economic forces; it can be hastened or hindered by the intervention of policies designed to increase productivity and promote welfare. And the process is strengthened by outside assistance. The rich nations of the world will have to do for the poor nations what the Federal Government of the U.S. did for the South.

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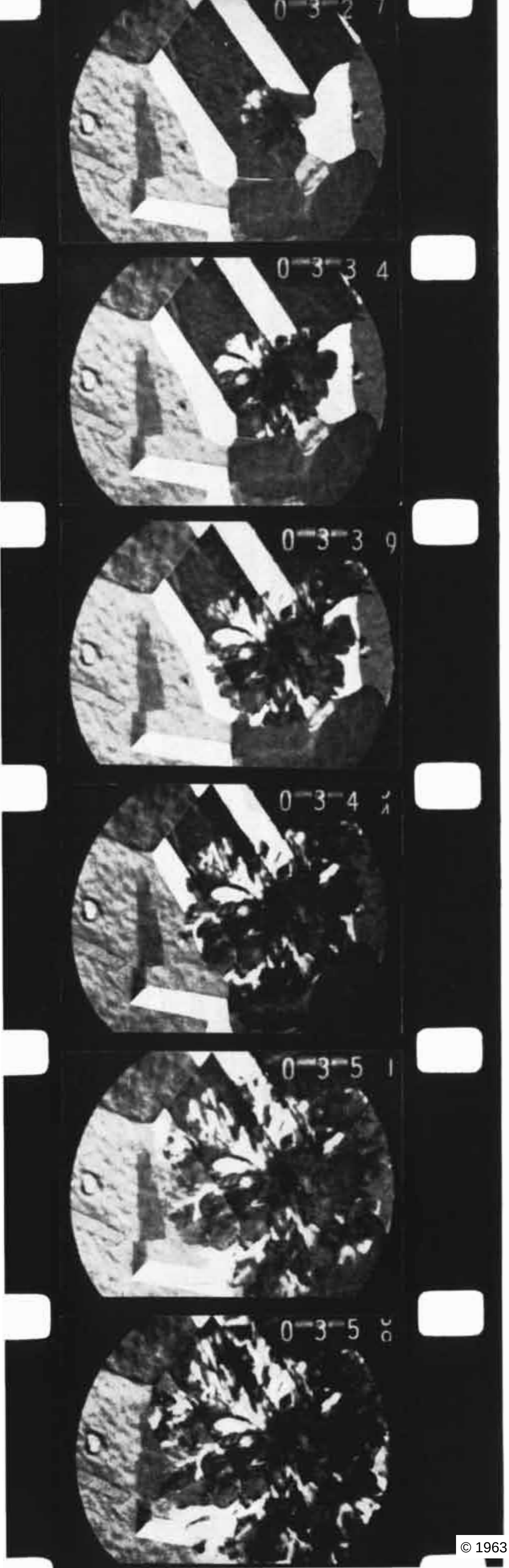

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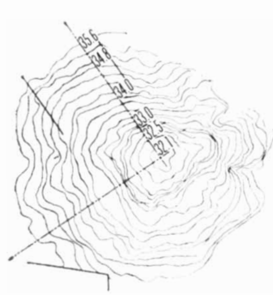


Time-contour map used for growth rate measurements.

Austenite transforming to pearlite in steel over a 3-second interval.

THE PLANNING OF DEVELOPMENT

Future development will not strictly parallel classical industrial revolutions. Technology, economics and ideology all make it likely that governments will play a central role in directing the process

by Edward S. Mason

The side-by-side existence in the modern world of developed countries and underdeveloped countries has suggested to generous and hopeful citizens of both kinds of country that the poverty of the latter can be cured by the rapid, systematic and large-scale transfer of the technology that has produced such great wealth for the former. Development is not, however, a matter of technology alone. The underdeveloped world cannot, in the words of one observer, "simply import the industrial revolution from abroad, uncrate it like a piece of machinery and set it in motion." The availability of modern industrial technology is a fact of great importance; it should assure that developing countries will not need to experience all the difficulties encountered by the Western countries in their achievement of self-sustaining growth. But putting this technology to effective use requires something more than borrowing it.

The borrowing, in the first place, involves the recipient country in economic and political as well as cultural relations with the lending country. At their present stage of development most developing countries are heavily dependent on the flow of foreign capital. Their creditors cannot realistically expect, however, that they will follow the precedents of development in the past to some predetermined and agreed-on destination. As the more extensive reviews of the status and progress of Nigeria, India and Brazil in the preceding pages of this issue of *Scientific American* have shown, the developing nations have entered on their present course from diverse historical backgrounds and a variety of economic situations. They include some of the world's oldest nations and some of the newest; some of the largest nations in domain and population and some of the smallest. Some are faced with heavy overpopulation, some with underpopulation and all with high rates of population growth; the differences among them in the ratio of population to resources are great. One group of underdeveloped countries, particularly the oil-rich countries, has readily exploitable and exportable resources to finance development; many others have difficulty scraping together an agricultural surplus for export. The prospects for development among the underdeveloped countries are as disparate as the conditions from which they have started.

In general it can be said of these countries that they are predominantly free-enterprise economies. Yet in all of them, without exception, governments are attempting to play a role in the development process substantially larger than the one Western governments played at corresponding stages in the development of their countries. There appear to be few underdeveloped countries without a four-year, five-year or six-year development plan. Yet in most of these countries there is little discernible relation between the announced purposes of the plan and what in fact gets done. Plainly the various objective and ideological considerations that condition the approach to development among the underdeveloped countries deserve the careful and sympathetic understanding of the citizens of nations that preceded them in the technological revolution.

Economic development requires a set of institutions, habits, incentives and motivations such that the inputs necessary to a continuous increase in output are self-generating. The essential inputs are capital, trained manpower and technology, and they are likely to be self-generating only in an environment in which the population seeks to improve its physical well-being and in which the rewards of effort are at least roughly proportional to the productivity of effort.

There are some countries—Burma may be an example—in which material improvement does not rank high in the scale of values accepted by most of the population. It is difficult to see under such circumstances how the inputs necessary to increased outputs are to be generated. There are other countries in which the reward for effort is siphoned off into other hands by landholding and land-use arrangements or by corrupt and rapacious governments. In Iran, at least prior to the current land reform, the share of the crop accruing to the cultivator was too low to induce increased effort. It would be well to recognize that in various parts of the underdeveloped world the prospects for economic growth will not become particularly bright until there are some rather profound changes in human motivations and values and in the sociopolitical structure. It is a mistake to think that economic development enjoys a high priority throughout the underdeveloped world. Some populations and in particular some ruling groups definitely prefer the status quo.

Nevertheless, in most of the countries under consideration here national income has been growing somewhat faster than population, in spite of an acceleration in the rate of population growth, and in some countries it has been growing a good deal faster. Brazil, Greece, Israel and Taiwan seem to have attained what can be called a self-sustaining and satisfactory rate of economic development. India, Pakistan, the United Arab Republic, Turkey, the Philippines, Colombia and perhaps a few other countries appear to have fair prospects for reaching this goal within the next decade or two. In these countries savings as a proportion of national income are increasing, education and training programs are producing results, and the spread and adaptation of Western technology, assisted in some cases by extensive foreign aid, is stimulating productivity. Nigeria and the other new nations of Africa south of the Sahara have much longer roads to travel.

The appropriateness of the dominant role in development asserted by their government is rarely questioned by public opinion in underdeveloped countries. Indeed, the pressure of opinion is usually in the direction of accelerating and expanding public action deemed necessary to the achievement of a rapid rate of growth. Whether or not the policies followed by these governments are those most conducive to development is a different question. At present, however, what they do or fail to do has relatively little effect on the day-to-day material condition of the people.

In countries with per capita incomes of less than $100 a year the share of government in national income customarily runs from 6 or 7 per cent to about 15 per cent. Where per capita incomes range upward to $700, as in some Latin-American countries, the government's share runs somewhat above 15 per cent. In western Europe and the U.S. the figure varies between 20 and 30 per cent. There is thus a rough correlation between per capita incomes and the share of government in national product.

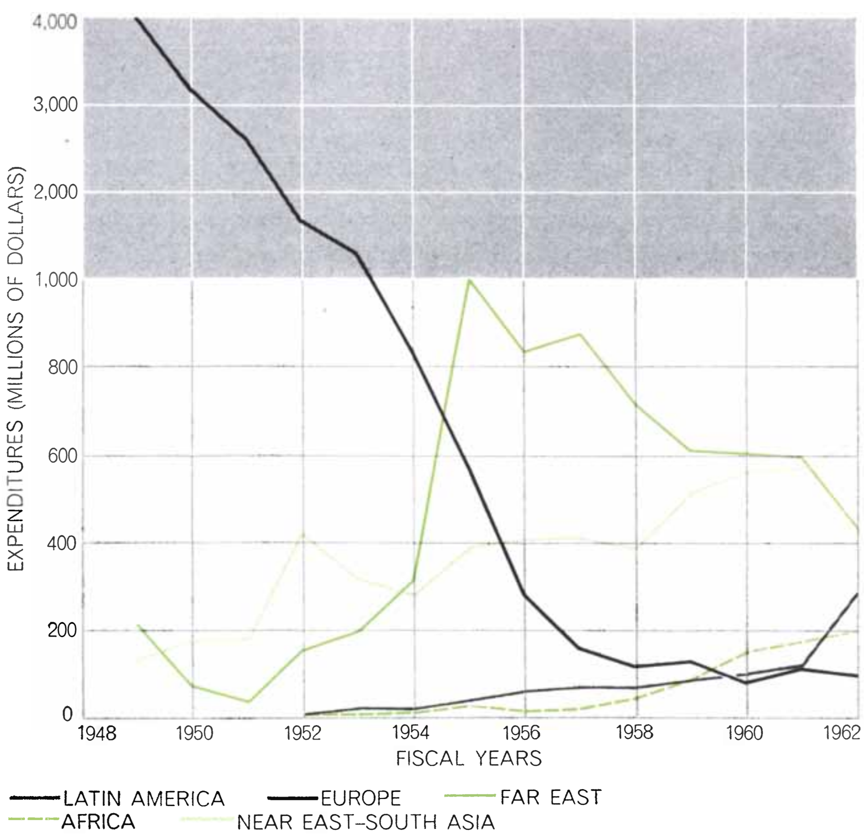
In non-Communist countries around the world, it would seem, the poorer the country, the larger the role of private enterprise in its economic life. This generalization requires closer examination. The reason for the preponderance of the private sector in developing economies is not far to seek. They are overwhelmingly agricultural economies, and this is true also of developing countries, such as China, that have Communist governments. Indeed, it can be reasonably assumed that in any country in which income per capita is under $100 per year, 50 to 70 per cent of its labor force will be employed in agriculture.

Such industry as exists will be predominantly handicrafts. Trade is almost exclusively in the hands of small merchants. Agriculture, handicrafts, trade and services are traditionally private activities and in underdeveloped countries must be expected to account for 80 per cent or more of total employment and around three-quarters of total income. From this one might conclude that what is done to stimulate activity in the private sector will generate more economic development than anything done in the public sector.

The dominance of the private sector at this juncture in the life of low-income countries obscures the role that their governments seek or are called on to play in their development. If one looks at the figures for new investment, that role becomes clearer. In Latin-American countries from 40 to 50 per cent of new investment is typically public. In India well over 50 per cent of planned investment is in the public sector. In Pakistan the figure is closer to two-thirds. Nor is the role of government in the channeling of economic activity limited to the area of public investment as conventionally defined. Functions that typically belong to the sphere of private enterprise in developed countries are frequently confined to the public sector in developing countries. The exploitation of mineral resources and the development of basic industries such as steel, fertilizer and cement are common examples.

Furthermore, in those activities that are confined to the private sector the flow of economic resources is by no means left to the direction of market forces. The geographical dispersion of new private investment is controlled by the provision of overhead-capital facilities in certain regions and their denial in others. Problems created by the shortage of foreign exchange are typically met by rationing the quantities available among various claimants; such allocation of foreign exchange is a powerful device in directing the flow of private resources. Frequently it is supplemented by licensing, price controls, the regulation of new security issues and other measures. Even in Puerto Rico, which probably relies on private—largely foreign—investment more heavily than almost any other underdeveloped area, development is stimulated and guided by government. Indeed, the government of Puerto Rico often builds and finances plants and, through the activities of an enterprising planning agency, ferrets out economic opportunities for private business.

Government, then, in most underdeveloped countries attempts to do much more in promoting economic development than it is customary for governments in advanced countries to do, and much more than it is usually supposed governments did in Western countries at similar stages of their development. It



U.S. FOREIGN AID has only recently been directed specifically to the task of development. The chart shows the destinations of U.S. economic aid since the beginning of the postwar program (*note the change of scale indicated by the gray panel*). The bulk of the aid went first to the Marshall Plan countries of Europe and then to U.S. allies in the Far East.

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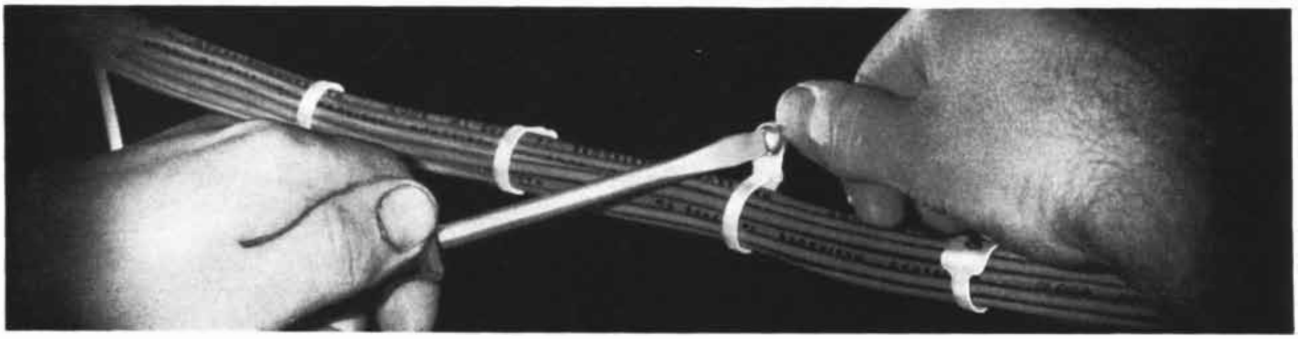

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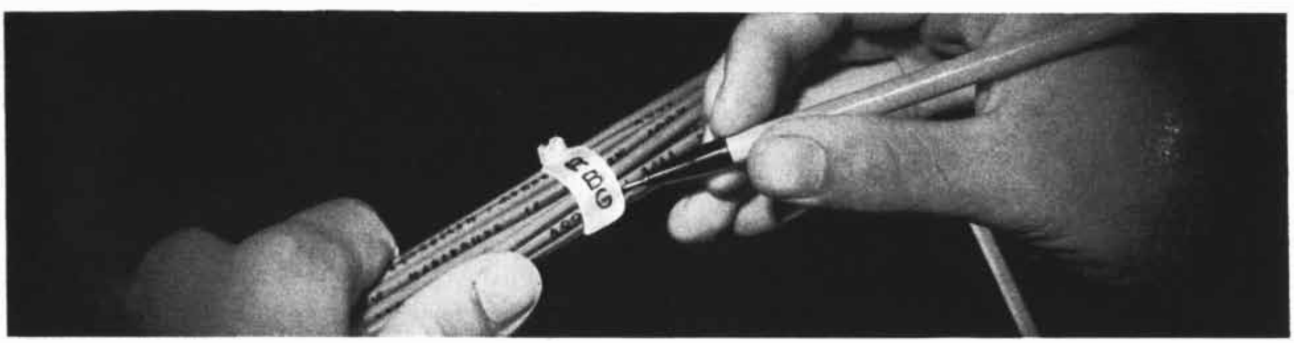

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TERMS OF TRADE have been unfavorable for the underdeveloped nations. The prices of their exports have gone down (*black line*), while those of the developed countries' exports, which they must buy, have been stable (*gray line*). Fluctuating commodity prices are a particular problem. The colored line traces the price index of a commodity group consisting of cocoa, tea and coffee, which are key exports respectively of Nigeria, India and Brazil.

is appropriate to ask why this is so and if government in many low-income countries is not, in fact, attempting to do too much. No flat judgment can be rendered here. In the first place, the impression that governments left development to private enterprise during the "classical" phase of the industrial revolution is at least partly an illusion. In England, it is true, the government on the whole limited itself to providing the proper atmosphere and left the rest—including even road building, port development and education—to private enterprise. This was not true elsewhere, however; certainly not in the U.S., where government furnished the infrastructure and, as in the case of the railroads, provided substantial subsidies from the public domain for private enterprise.

Perhaps the foremost example of government-stimulated and government-guided development in any private-enterprise economy is provided by Japan. Here the state directed investment by establishing publicly owned enterprises, undertaking joint ventures with private capital, subsidizing private investment and guaranteeing returns, and buying extensively for its own military and civilian accounts. In the decade after 1870 the state built and operated such diverse enterprises as mines for coal, copper and gold; iron foundries; shipyards; machine shops; model factories for cement, paper, glass, sulfuric acid, cotton spinning and many others. Undoubtedly the government's most fruitful contribution to the expansion of social capital was in the realm of education. The Japanese government seems, in fact, to have adapted its educational expenditures specifically to development purposes.

The emphasis given in much of the underdeveloped world to government-promoted development is not, therefore, without precedent. Nevertheless, it remains true that these governments are taking a stronger hand in development than the governments of the now developed private-enterprise countries did at corresponding stages in their history. In part this is the result of objective circumstances that condition the current development process; in part it is no doubt the product of an ideology that differs substantially from the one dominant in the early 19th century.

Foremost among the "objective" considerations is the large priority that must be given to roads, railways, harbors, power generation and distribution, communications, irrigation, industrial estates and the like. In most developing countries the capital requirements for such facilities will account for something like 50 per cent of the total investment. Although private capital used to be available for some of these purposes—foreign private capital, for example, financed railroad construction, telephone and telegraph systems and electric utilities at an early stage in Latin-American development—this is no longer the case. Indeed, existing privately owned facilities have been and are being acquired by Latin-American governments at a rapid rate. In sum, the investment role thrust on government in developing economies is likely to be a big one.

Government participation in the transfer of technology is also likely to be large. The early development of industrial technology in the West was undertaken by skilled artisans and tinkerers working in the 18th-century equivalent of the 20th-century garage, and the exploitation of new techniques went forward in the hands of individual and family firms operating in an environment relatively free from government control. Now that these techniques have been developed, however, they can be borrowed. In the borrowing process government enterprise is not as inappropriate as it probably would be in early stages of technical development. The modern application of these techniques requires large-scale units, the financing of which lies outside the capability of family-sized firms or the pools of private capital domestically available in underdeveloped countries. The transfer of technology through government agencies may well be inevitable. Here again the Japanese example suggests that in the early stages of industrialization large-scale intervention by government can facilitate and accelerate the process.

During the 19th century foreign private investment and enterprise were the overwhelmingly important agencies of technical transfer in most underdeveloped areas. It is still important, and dollar for dollar it is probably the most efficient form of transfer. But foreign private investment finds few opportunities in certain areas, and for various reasons it is unwelcome in others. It is now extensively supplemented by the technical-assistance programs of governments and the technical agencies of the United Nations. Currently these programs involve expenditures of at least $500 million a year. This type of technical transfer inevitably involves the extensive participation of government in the aid-receiving country.

Much the same sort of thing has been happening in the area of capital transfer. During the 19th century private

investment accounted for all but a small fraction of the flow of capital into underdeveloped regions. Although some of these funds went to finance publicly owned utilities, the amounts, as a proportion of total foreign investment, were small. In 1961, on the other hand, of the total flow of $8.75 billion in long-term funds from developed to underdeveloped countries outside the Soviet bloc, nearly $6 billion represented public loans and grants. (Aid from the Soviet bloc to developing countries outside comes to substantially less than $1 billion, mostly in the form of long-term loans at low interest rates and payable in commodities.) Most of these funds were used to finance activities in the public sector. This tendency is reinforced by the fact that the international and national lending and granting agencies prefer large projects; large projects in countries without highly developed private enterprise fall in the public sector. Whereas a loan or grant to cover the foreign-exchange requirements of a development program can and does find its way into the private sector, project lending for large installations stacks the cards against private enterprise of the sort that flourishes in most underdeveloped countries.

Certain aspects of this massive flow of funds deserve closer examination. In the first place, the $8.75 billion does not include military assistance. Since the settlement of the Algerian question almost all the funds under this heading have come from the U.S. and have been running at an annual rate of $1.5 to $2 billion. As is well known, these outlays tend to be concentrated in the seven or eight countries on the perimeter of Asia. Military expenditures, of course, compete with economic-development expenditures as claimants for available resources both in the developing countries and in the U.S. aid program. What is not so obvious is that expenditures for these presumably divergent purposes are to a certain extent complementary. Military roads and bridges are usually available for civilian use. The army in a number of developing countries is an effective agency for promoting literacy and the teaching of useful skills. Although military expenditures are likely to handicap economic development, a certain degree of complimentarity should be recognized.

Of the $6 billion in long-term public funds provided by the West to the developing countries in 1961, approximately 90 per cent took the form of bilateral aid. Most of the remainder came through UN agencies, principally the International Bank for Reconstruction and Development and the International Development Association. To an increasing extent, however, bilateral aid is coming under some form of multilateral co-ordination. Consortiums composed of various countries and agencies are now formed to finance the development programs in India, Pakistan, Turkey and certain other countries. Consultative groups of various countries belonging to the Development Advisory Committee with headquarters in Paris are beginning to co-ordinate bilateral aid to a number of developing countries. The countries of the European Common Market now co-ordinate aid to associated overseas areas.

The U.S. in 1961 provided roughly 60 per cent of the public funds made available to underdeveloped countries by the West. This includes the shipment of agricultural surpluses under Public Law 480, passed by Congress in 1954. Valued at world-market prices, surplus-food shipments have been running to about $1.5 billion a year. For certain countries this type of aid is as good as gold. In the United Arab Republic, for example, where land adapted to wheat cultivation is strictly limited, scarce foreign exchange otherwise available for development would, in the absence of these food shipments, have to be used for food imports. In other countries, however, the availability of U.S. food surpluses on a grant basis may lead to a rate of importation seriously damaging to domestic agricultural development. Agricultural surpluses are of substantial assistance in economic development and their volume is likely to increase rather than decrease, but these shipments cannot be equated dollar for dollar with other types of economic assistance.

The total flow of long-term funds, public and private, is of critical importance to the developing world at the present stage. Whether or not this flow is likely to increase it is difficult to say. Foreign private investment could undoubtedly be stimulated in a number of developing countries by a more receptive attitude. A diminution in the pace of the armament race would in all probability increase the flow of public funds. Under present circumstances, however, foreign aid can hardly be described as a politically popular undertaking in any advanced country.

Meanwhile, it must be admitted, the past decade's decline in the prices of the export commodities that earn foreign exchange for the underdeveloped countries has substantially discounted the aid they have received. In cocoa, tea and coffee—

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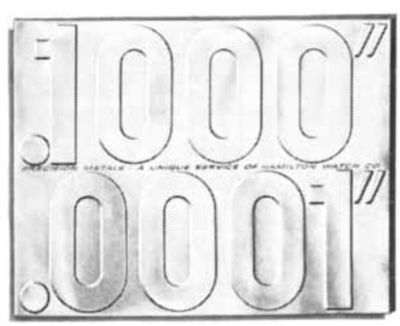

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The objective considerations that tend to bring governments into such a prominent role in development are reinforced by less tangible considerations of ideology. In the first place, many of the elite now occupying important government positions in underdeveloped countries were trained in the West during the period when 19th-century capitalism, with its emphasis on the "rights of property," was giving way to a "welfare state" capitalism, egalitarian in character and more concerned with "human rights." In their view it is necessary as well as appropriate to use the power of the state to lessen inequalities in the distribution of income and to give protection to less privileged elements in the population.

Among the "demonstration effects" of the West that impress an observer in many underdeveloped countries is the prevalence of the demand for social services of all sorts. According to one authority, "most underdeveloped countries want the blessings of the welfare state today, complete with old-age pensions, unemployment insurance, family allowances, health insurance, 40-hour week and all the trimmings." In Western countries a sustained growth in national output antedated the spread of social services of this type. Throughout most of the currently underdeveloped world, demand for these services here and now is all but politically irresistible. This shift in political values obviously assigns to government functions that are new and frequently difficult to administer.

Although the weakness of the private sector in many developing countries helps to explain the ascendance of government in their economic life, the pressure in this direction is frequently accentuated by a latent hostility to private enterprise, particularly foreign private enterprise. Such hostility is seen in the exclusion of private enterprise from certain areas of economic activity, in the preferred position given to public enterprise when it comes to the allocation of scarce foreign exchange, and in the detailed and pervasive controls set up to assure that no private action conceivably harmful to the public interest, as understood by government officials, can take place. Perhaps it is not so much a question of hostility to private enterprise as of misplaced confidence in the ability of public administrators to direct in minute detail the proper course of economic activity.

Ideological predilections in many underdeveloped countries take the form of not very well defined types of local socialism. In India one hears of a "socialist pattern of society." In the United Arab Republic the merits of Arab socialism are extolled. In various newly emergent African countries people speak of "African socialism." Without attempting to specify the meaning of these varieties of socialism, it can be said that they tend to encourage and rationalize the initiative of government in the promotion of economic development.

In attempting to acquit the heavy responsibilities thus assumed or thrust on them, the governments of underdeveloped countries espouse planning as the preferred, if not essential, development technique. The record shows, however, that the espousal of planning, from country to country, is more eloquent than its execution. The plan as it emerges from the planning agency may fail to win acceptance as a program of action by political authority; or, if the plan is ratified by duly constituted authority, political pressures and interministerial rivalries may cause development expenditures to depart from its prescriptions; or the resources and requirements as envisioned by the plan may turn out to be so remote from actual capabilities that the plan loses significance as a set of policy directives.

Examples can be cited in support of all these observations. Indonesia has never, since its independence, been without a plan. But no plan has enjoyed sufficient political support to have had significant effect on the course of the economic development—or nondevelopment—of that country. Various Latin-American countries have framed development plans but, in the absence of effective budgetary control over spending ministries, large differences have opened up between the word and the act. The United Arab Republic, which has done better than most, operates under a development plan that calls for a doubling of national income in 10 years. Since this target is considerably in excess of what Egyptian resources will permit, the actual growth rate falls short of the projected rate. The setting of overambitious targets, furthermore, has had a demonstrably adverse effect on the allocation of the country's domestic and foreign-exchange resources.

These examples do not constitute an argument against planning but against confusing the mere existence of a plan with effective planning. The assumption by government of anything like a directive role in the economy inevitably requires some sort of planning. The plan may be limited to the establishment of priorities in public investment and of some consistency in the policies affecting the private sector. Indeed, in this limited sense of planning, the U.S., like Molière's prose-speaking Frenchman, has been planning throughout its national life. The underdeveloped countries go further than this. It seems clear that wherever government deliberately seeks to accelerate the rate of development, effective economic planning is an essential part of the process.

The planners' principal concerns are three: How to increase the amount and quality of resources available for economic development, how to allocate public investment among the various development projects in the public sector and how to stimulate private production within the bounds established by the objectives of the development program as a whole. With respect to the first of these concerns, the expansion of resources available for investment involves not only the limitation of consumption in favor of savings but also, over a period of time, the direction of investment into the most productive channels. Under private enterprise this is the traditional function of market incentives. In underdeveloped economies, where public investment is so large a part of the total, the establishment of investment priorities becomes perhaps the central task of planning.

Planning agencies are of course advisory to political decision makers, and it goes without saying that planning will inevitably reflect the political characteristics of the government being advised. A totalitarian government may be able single-mindedly to pursue an objective at variance with the desires of a majority of the population. A democratic government could not follow such a course of action for long. Moreover, the structure of the governmental institutions, the class composition of the population and the competition of special interests will inevitably affect the character of the plan. All of this does not mean that democratic planning must be an economically irrational compromise of divergent political pressures. But it does mean that economic calculations operate within a fairly severe set of limitations.

A single-minded concern with economic growth might dictate an exploitation of economic opportunities in the order of their prospective social rates of return, but political influences may urge a geographically "equitable" dispersion of public investment. The economic calculus may indicate a thoroughgoing program of land reform as one of the most promising steps toward economic development. But political realism intrudes to suggest a policy of the second best. Confronted with severely limited resources, the development planners may be compelled, as in Nigeria [see "The Development of Nigeria," page 168], to pare down the allocation to social services and to primary education in favor of "productive" investment and technical training.

The fact that political forces "choose" objectives other than that of maximizing the rate of economic growth does not make these choices irrational. Even from the point of view of economic growth a geographical distribution of public funds dictated by political expedience may be desirable if such a distribution contributes to political stability. There are, moreover, national planning objectives apart from economic growth. The political process not only sets limits to economic calculation but also impinges on planning in more positive ways. A government strongly committed to economic development and enjoying the support of the governed can release and organize human effort that has not previously been put to effective use. Something like this was accomplished by the Japanese in the late 19th century, and something like it may be in the process of accomplishment in present-day India.

In those democratic underdeveloped countries that have been making substantial economic progress the major difficulties lie not in the interference of political interests with economic calculation nor in the quality of the economic analysis itself but rather in the fact that the administrative machinery has lagged behind development plans. A due regard for this limitation would hold down the size of the public investment program to dimensions capable of effective management; it would counsel against the imposition of controls whose execution is outside the competence of existing public services; it would emphasize the importance of necessary changes in government procedure.

To recite the mistakes, difficulties and limitations of the planning process in various developing countries is not to argue against planning as an essential technique of development. There are important objective reasons as well as ideological reasons why the role of government in planning and promoting economic development must be large.

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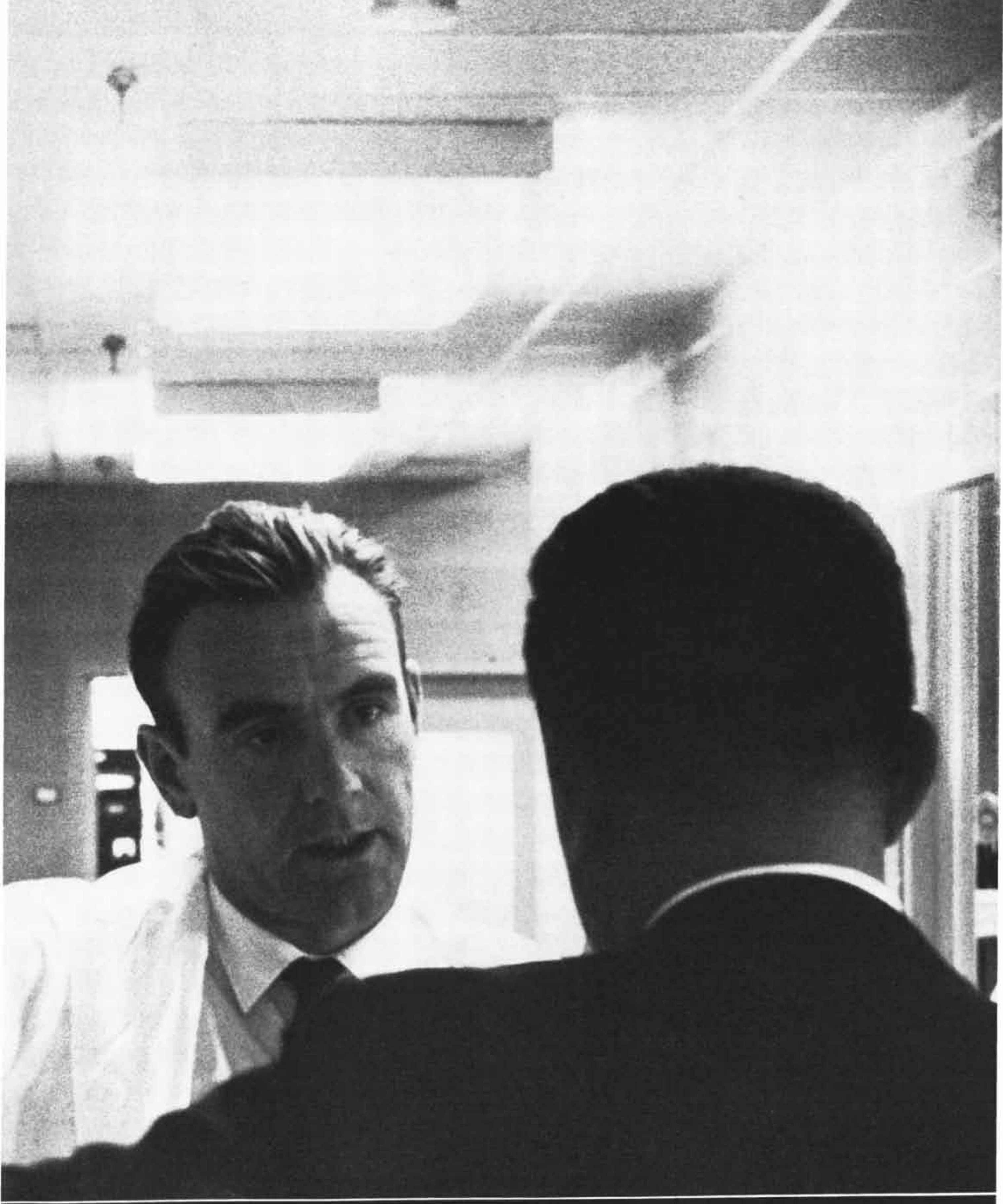


MATHEMATICAL GAMES

How to solve puzzles by graphing the rebounds of a bouncing ball

by Martin Gardner

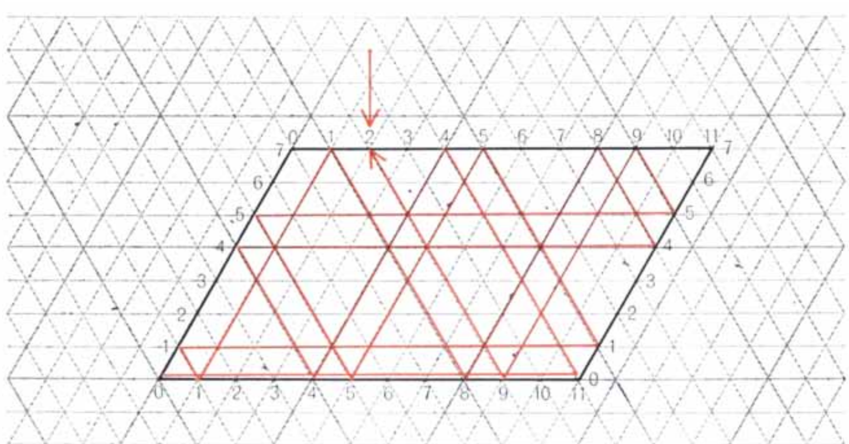
Throughout recorded history the bouncing ball has been indispensable equipment for a dazzling variety of indoor and outdoor sports. Games exploiting it range from the child's simple bouncing of a rubber ball ("One, two, three O'Lary . . .") to sports such as tennis, handball and billiards in which the ability to judge angles of incidence and reflection is essential to a player's skill.

The balls
shine round and clear, quick blobs
of color on faultless fields,
where rapid vengeance rolls
and clicks, returns
or poorly judged, deflects
to pass and spend itself in motion
rebounding gingerly from cushions . . .
"B.A. (Billiard Academy),"
by Herman Spector

Mathematicians and physicists are notoriously fond of pool and billiards. It is easy to understand why. The gingerly rebounds within faultless fields can be precisely calculated. Lewis Carroll, who taught mathematics at the University of Oxford, enjoyed playing billiards, particularly on a *circular* table he had made for himself. A much prized collector's item is the first edition of a two-page leaflet, published by Carroll in 1890 and never reprinted, that explains his rules for this game.

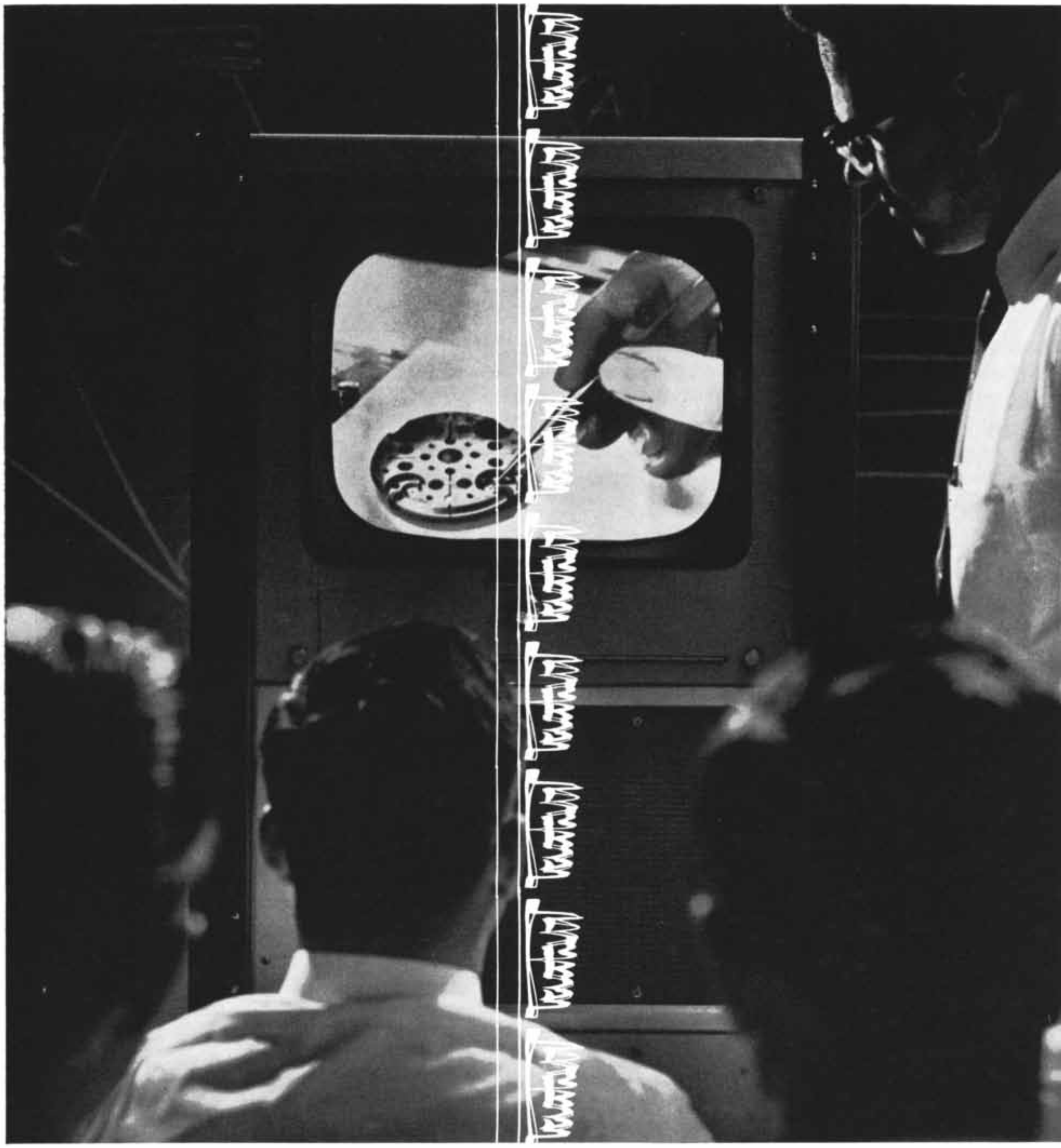
Hundreds of recreational problems concern the rebounds of elastic balls within perimeters of various shapes. Consider, for example, the following old puzzle: You have two vessels with respective capacities of seven and 11 pints. Beside you is a large tub of water. Using only the two vessels (and excluding all dodges such as marking the containers or tilting them to obtain fractional amounts), how can you measure exactly two pints?

The question can be answered by trial and error or by applying various alge-



11-PINT VESSEL	11	4	4	0	11	8	8	1	1	0	11	5	5	0	11	9	9	2
7-PINT VESSEL	0	7	0	4	4	7	0	7	0	1	1	7	0	5	5	7	0	7

Graph and 18-step solution of a liquid-pouring problem



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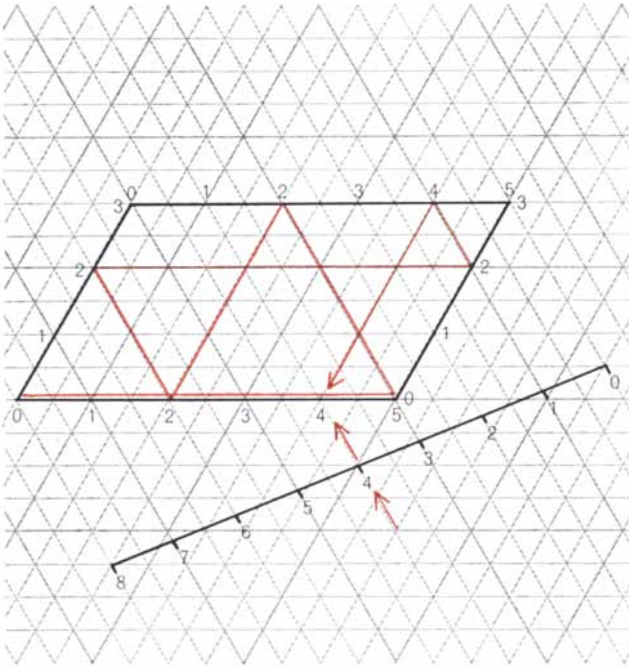
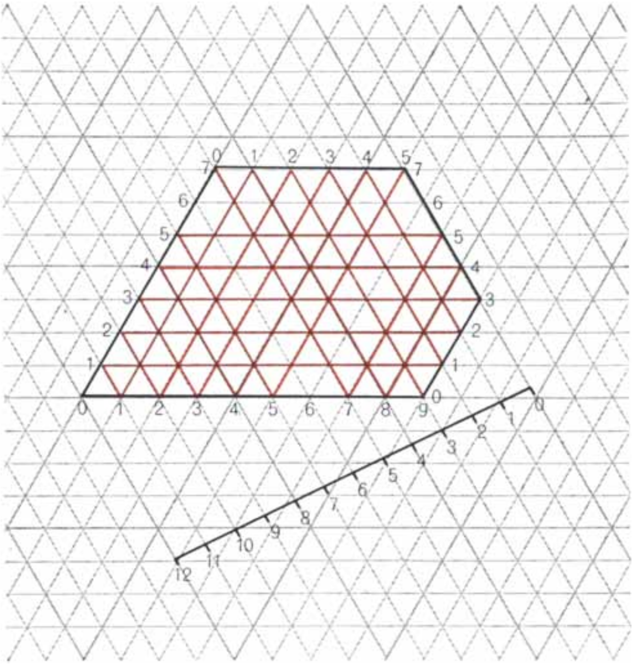


Graph of Tartaglia's puzzle



Graph for vessels of volumes 7, 9 and 12

braic procedures. What has all this to do with bouncing balls? Surprisingly, liquid-measuring puzzles of this type can be solved easily by graphing the paths of balls bouncing inside *rhomboidal* tables! (The method, using what topologists call a "directed graph," was first explained by M. C. K. Tweedie in *The Mathematical Gazette* of July, 1939.) The cushions of such tables are best drawn on isometric graph paper: paper with a lattice of equilateral triangles. In this case the sides of the table are seven and 11 units [*see illustration on page 248*]. Readings on the horizontal axis represent the amount of water in the 11-pint vessel at any time and readings on the vertical axis tell how much water is in the seven-pint vessel.

To use the graph, imagine a ball at point *0* in the lower left corner. It travels to the right along the base of the rhomboid until it strikes the right-hand cushion at a point labeled *11* on the base line: the 11-pint vessel has been filled and the seven-pint container remains empty. After bouncing off the right-hand cushion the ball travels up and to the left until it hits the top cushion at point *4* on the horizontal co-ordinate and on the seventh line on the side co-ordinate. This plot indicates that seven pints have been transferred from the 11-vessel to the 7-vessel, leaving four pints in the larger vessel.

If you continue to follow the bouncing ball until it strikes a point marked 2, keeping a record of each step, you will obtain the 18-step answer shown below the graph. Slanting arrows indicate that water is poured from one vessel into another. The vertical arrows show either that the 7-vessel is being emptied into the tub or that the 11-vessel is being filled.

Is this the shortest answer? No; an alternative procedure is to begin by filling the 7-vessel. This is graphed by starting the ball at the *0* point and rolling it *up* along the table's left side. If the reader traces the ball's path until it strikes a *2* point, keeping a record of the steps, he will find that his ball computer bounces out a solution in 14 steps—the minimum.

With a little ingenuity one can devise ball-bounce computers for any liquid-pouring puzzle in which no more than three vessels are involved. Consider the oldest of all three-vessel problems, which goes back to Nicola Fontana, the 16th-century Italian mathematician who called himself Tartaglia ("The Stammerer"). An eight-pint vessel is filled with water. By means of two empty vessels that hold five and three pints respectively, divide the eight pints evenly between the two larger vessels. The graph for this problem is shown at the left above. Here the eight-pint vessel is represented by a line paralleling a main diagonal of the rhomboid. The ball begins as before in the *0* corner. It is easy to trace a path that computes the minimum solution, which requires seven operations.

When the two smaller vessels have no common divisor and the third vessel is equal to or greater than the sum of the smaller vessels, it is possible to measure out any whole number from 1 to the capacity of the middle-sized vessel. For example, with vessels of 15-, 16- and 31-pint capacities one can measure any quantity from 1 to 16. This is not possible if the two smaller vessels have a common divisor. A graph for vessels of 4, 6, 10 will not bounce the ball to any odd number, and vessels of 3, 9, 12 will measure only the quantities 3, 6, 9. (In both cases only multiples of the common divisor can be measured.) If the largest vessel is *smaller* than the sum of the other two, there are further limitations. For example, vessels of 7, 9, 12 require that a corner of the rhomboidal graph be sliced off [*see illustration at right above*]. The bouncing ball will measure any quantity from 1 to 9 except 6. Although 7 and 9 have no common divisor, the smallness of the third vessel makes it impossible to obtain 6.

When the largest vessel is *larger* than the sum of the other two, the graph continues to be applicable. The reader may enjoy applying it to the following variation of Tartaglia's problem, as posed by Sam Loyd on page 304 of his famous *Cyclopedia of Puzzles*. (This is one of the puzzles for which the *Cyclopedia* fails to furnish an answer, a fact that may

Improved communications techniques by Motorola are reducing the delay between advanced semiconductor developments and full-scale utilization by industry, thereby . . .

Telescoping Education

In a little more than a decade, transistor technology has reached a level of development achieved by the vacuum tube only after the better part of half a century. And today, even before equipment manufacturers have had time to complete the switch from tubes to transistors, we stand on the threshold of a new technology — Integrated Circuits — which promises to have an even more drastic effect on the electronics industry.

The time cycle for this newest technical evolution, however, will depend largely upon the speed with which the equipment manufacturer attains the necessary know-how to utilize integrated circuits.

Although much has been written about advancements in integrated circuits, the added equipment reliability, performance, size and weight reduction, and cost savings to be expected from them, the fact remains that the ability of the design engineer to envision their use and to properly plan for future developments in his field depends upon his attaining a clear and thorough knowledge of integrated circuit technology. To evaluate progress being made, he must have an understanding of the techniques used by the integrated circuits manufacturer, the problems that can arise, and, of course, the practicalities of the present state of the art.

A BOLD SOLUTION . . .

On Friday, July 12, 1963, more than 160 top level engineers representing major industrial and military electronic equipment manufacturers in the United States and Europe left their respective laboratories and offices to converge on Phoenix, Arizona. The object: to take part in an integrated circuits program designed to telescope the educational lag in this new technology.

The course, sponsored by Motorola, marked the first known instance of a company in the highly competitive semiconductor industry extending a blanket invitation to learn how integrated circuits are produced and how to design for this technology.

Invitations to attend the course, made initially by personal letter from Dr. C. L. Hogan, Manager of Motorola Semiconductor Products Division, to the company's customers, and later by general advertisements, were greeted with widespread enthusiasm intermixed with skepticism. Would any company truly reveal not only the detailed results of its research, but also its actual production methods?

At Motorola's Semiconductor plant this question was answered decisively by a directive from Dr. Hogan:

To All Department Heads and Managers of the Integrated Circuits Effort: Effective immediately, all projects that do not influence contractual obligations will be interrupted or postponed pending the completion of an integrated circuits course comprehensively detailing the state-of-the-art. Each manager is responsible for a lecture session plus supplementary written material on a level similar to that of an indoctrination course for a key new employee in his own department.

The result of this directive was a comprehensive integrated circuits program whose scope and effectiveness exceeded the most optimistic expectations of the participants as well as those of the initial planners.

Comments by those who attended speak favorably of this program . . . comments such as "a unique textbook that will be talked about for months to come . . .", ". . . this part of the course could probably not have been done by any other company working in the field", " . . . by far the best compilation of information concerning the technology".

Of special interest is the philosophy behind such a bold undertaking . . . a philosophy dictated by the phenomenal acceleration of space age scientific developments and recognition of the fact that industrial progress is hampered more by ineffective communications than by the time required to prove new theories or develop new processes.

Contends Dr. Hogan, "The era of integrated circuits has already passed from the research phase to the production stage and heralds a revolution in the electronics industry unmatched even by the invention of the transistor."

"But what good are the potential benefits, what good is the capability of making integrated circuits, if the know-how required for their effective utilization is bottled up within the confines of a few semiconductor manufacturers? Only by disseminating information on new developments as quickly as possible to the equipment manufacturer can we achieve the rapid and widespread implementation of this new art and thus be of greatest benefit to the industry and, in the process, to ourselves."

This Motorola credo did not begin with the integrated circuits course. Handbooks on Power Transistors and Zener Diodes and Rectifiers published while these devices were still in their infancy, have become standards in the industry. A newly published High-Speed Switching Transistor Handbook provides a new insight into the problems of high-speed transistor switching circuit design. Various applications seminars, conducted by teams of Motorola's semiconductor experts, are heavily attended.

Motorola believes these educational efforts are a vital part of its responsibility to industry.

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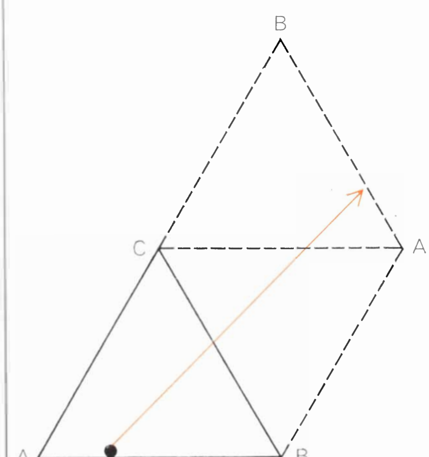
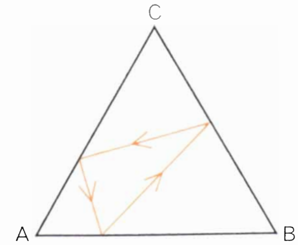
explain why the puzzle has never been reprinted.)

Some U.S. soldiers managed to "capture" a 10-gallon keg of beer. "They naturally sampled a part of it," writes Loyd, making use of three-gallon and five-gallon containers. The rest of the beer was carried back to camp in three equal portions—one in the keg and the other two in the two containers. How much did they drink and how did they measure the remainder into three equal parts? The best solution is the one with the fewest steps for the entire procedure. Each step, including the drinking operation, involves an integral number of gallons, and it is assumed that no beer is wasted by being tossed out. Next month we will give the answer and show how to obtain it with the bouncing ball.

The reader will find it entertaining to experiment with vessels of various sizes, using the ball computer to explore all that can be done with them. For more information about the technique, including its extension to four vessels by means of tetrahedral graphs, the interested reader is referred to two fine articles by T. H. O'Beirne in the *New Scientist* of June 22 and 29, 1961.

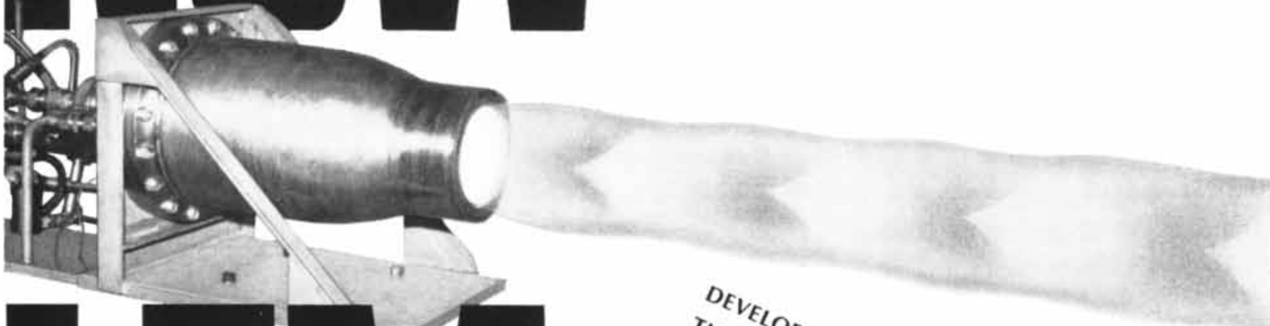
A different type of ball-bouncing problem is that of finding cyclic paths along





Reflection path in equilateral triangle

NOW



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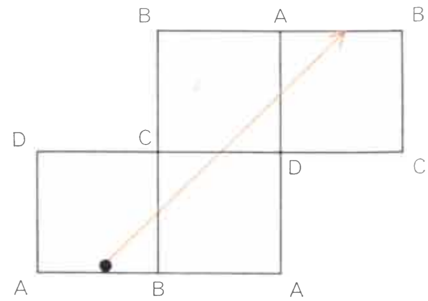
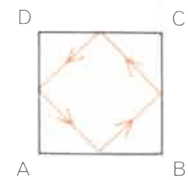
LOS ANGELES · VANDENBERG AFB · NORTON AFB, SAN BERNARDINO · CAPE CANAVERAL · WASHINGTON, D. C. · BOSTON · HUNTSVILLE · DAYTON · HOUSTON which a ball can bounce forever inside a polygon, always tracing the same path and hitting each side only once in each cycle. Such problems can be solved by using the powerful technique of mirror reflection. A table in the shape of an equilateral triangle provides a simple example. Suppose we place the ball at the spot shown in the upper part of the illustration on page 252. We wish to drive it against side *B-C* so that it rebounds, hits side *A-C*, then returns to its original position on side *A-B*. The path is easily found by mirror-reflecting the triangle twice, both times along a different side, as indicated by the broken lines. The straight line from the ball to its last mirror reflection traces the desired path. We have only to reflect the two broken triangles back onto the original one. This can be done physically by drawing the triangles on tracing paper and ruling a heavy line from ball to ball. Cut out the figure, then fold the triangles into a single triangle. Each fold is a mirror reflection. Hold the folded triangle up to a light and you will see the cyclic path as in the lower part of the illustration. If we add the further restriction that each segment of such a path must be the same length, it is easy to see that there can only be one solution: the path that



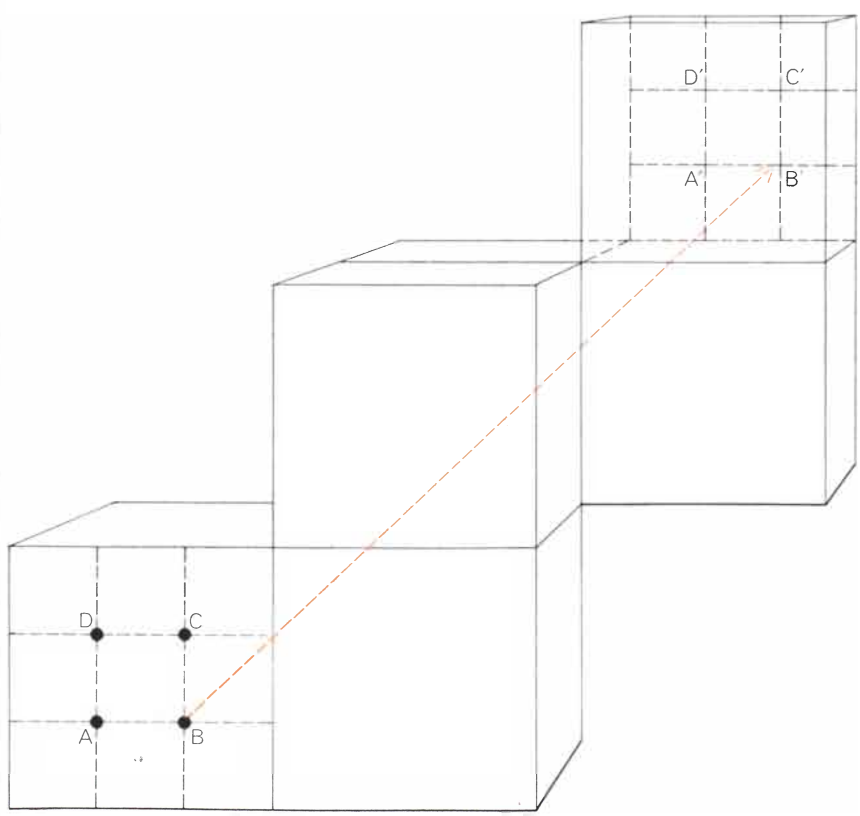


Equal-segment path in a square

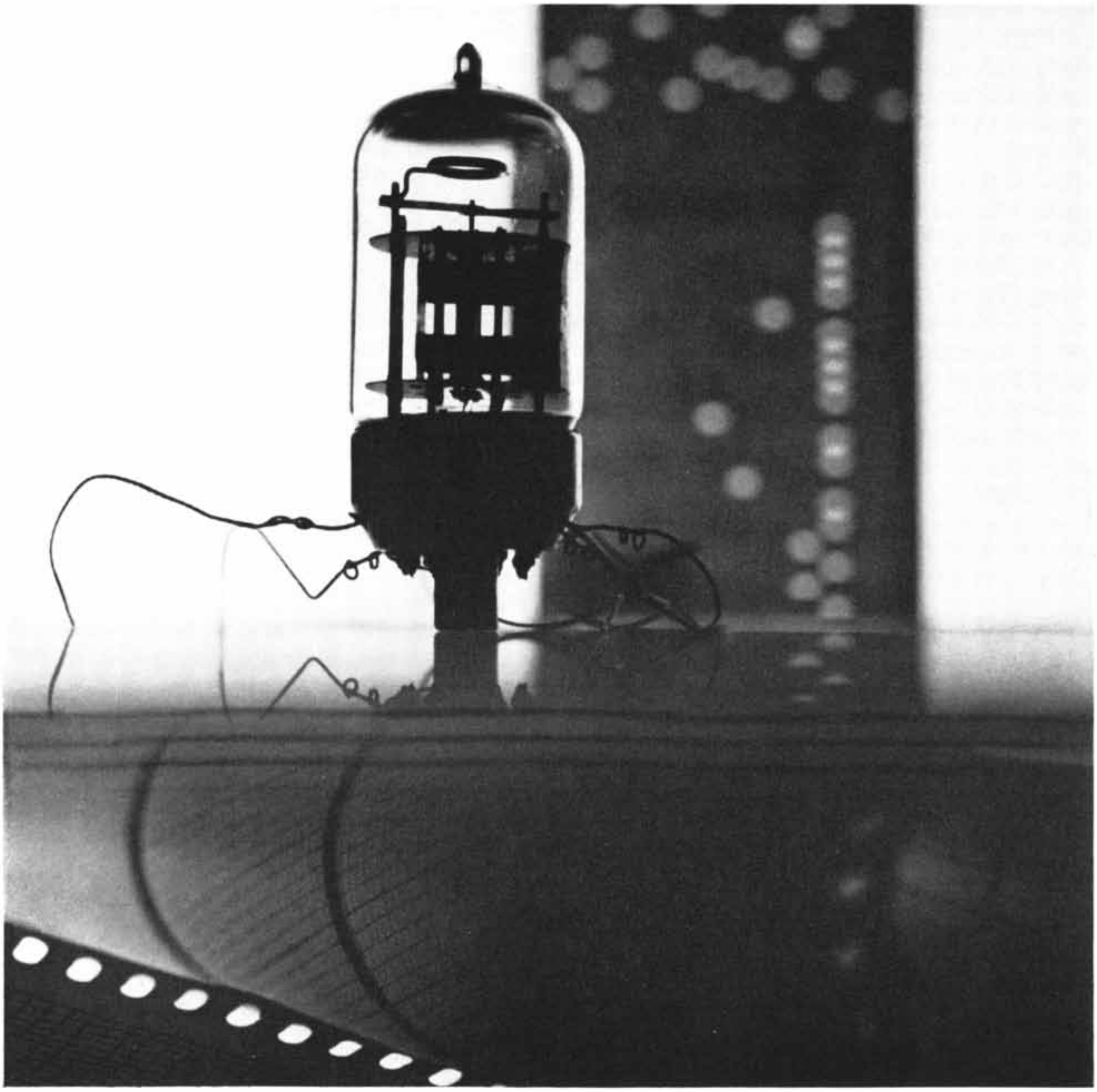
joins the mid-points of the three sides.

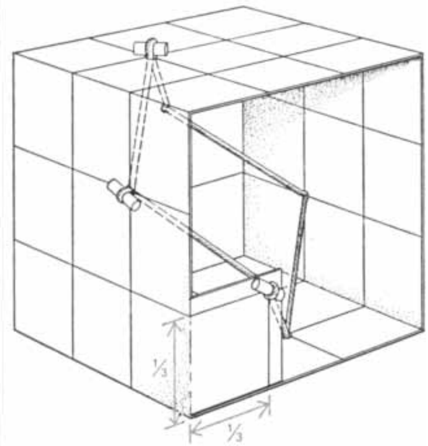
The same procedure will find cyclic paths inside other polygons. The illustration above shows a square reflected along three different sides, and the colored line is its only cyclic path with segments of equal length.

At this point two interesting questions



Solution to Lewis Carroll's cube-and-ball problem





Model showing path inside a cube

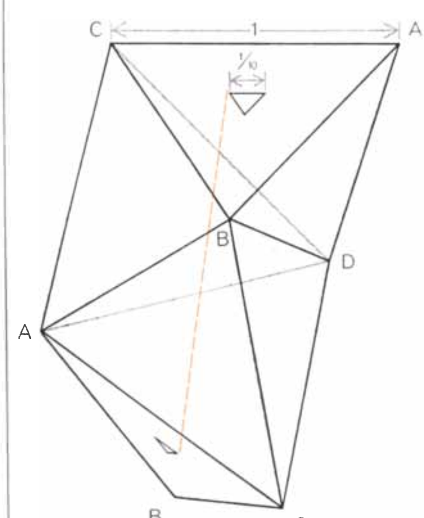
arise. Are there cyclic paths with equal segments inside the solid analogues of the square and equilateral triangle: the cube and tetrahedron? The ball is assumed to be an idealized elastic particle (or a light ray inside a solid with interior mirror surfaces), taking straight paths in zero gravity and bouncing off the sides in the usual manner: with equal angles of incidence and reflection on a plane perpendicular to the side against which it bounces. The ball must strike each face only once during the cycle and travel the same distance between each consecutive pair of bounces. (Striking an edge or corner is not regarded as striking the faces meeting at that edge or corner; otherwise the cube problem would be solved by a ball moving back and forth between two diagonally opposite corners.)

Warren Weaver, in one of his many articles on Lewis Carroll, has disclosed that the cube problem is found among Carroll's unpublished mathematical notes. It is the sort of problem that would appeal to the inventor of circular billiards. Actually the notion of playing billiards inside a cubical "table" is not as farfetched as it might seem. With gigantic space stations perhaps only a few decades away it takes no great prophetic ability to foresee a variety of three-dimensional sports that will take advantage of zero gravity. Pool adapts neatly to a rectangular room with cushion walls, floor and ceiling, corner pockets and balls numbered from 1 to 35 that are initially arranged in tetrahedral formation. Of course, there would be difficulties. Air resistance offers much less friction than the felt surface of a pool table does. If the tetrahedron were broken by a fast cue ball, entropy would increase at a rapid rate. It would be hard to keep

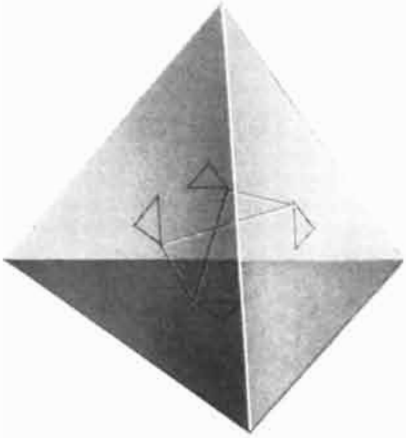
out of the way of balls flying about in random directions like the molecules of a gas in thermal equilibrium!

But back to Carroll's problem. The reflection technique used with squares can be applied to cubes. Five reflections are required and the colored line in the bottom illustration on page 254 traces the desired path. It is one of four different paths, identical in shape, that solve the problem. (If all six faces of the cube are ruled into nine smaller squares, each path touches every face at one corner of the central square.) The illustration on page 256 shows a cardboard model that demonstrates the path after the six cubes have been "folded" into one another. The cord is held in place by passing loops through small holes and securing them on the outside with pegs made of wood. If you think of the cube as being formed of 27 smaller cubes, you will see that every segment of the path is a diagonal of a small cube. Each segment therefore has a length of $1/\sqrt{3}$ on a unit cube. The path's total length is $2\sqrt{3}$.

As far as I know, Roger Hayward, who illustrates "The Amateur Scientist" in this magazine, was the first to find this solution. (He published it in *Recreational Mathematics Magazine* of June, 1962.) The shape of the path, he writes, is known to organic chemists as a "chair-shaped hexagon." It occurs often in carbon compounds, such as cyclohexane, in which six carbon atoms are single-bonded in a ring with other atoms attached outside the ring. "It is interesting to note," writes B. M. Oliver of the Hewlett-Packard Company in Palo Alto, Calif., "that the path appears as a 1×2



Solution to problem of ball in tetrahedron



Acetate model of path in tetrahedron

rectangle in all projections of the cube taken perpendicular to a face, as a rhombus in three of the isometric projections taken parallel to a diagonal of the cube, and as a regular hexagon in the fourth isometric view. A queer figure, but that's the way the ball bounces!"

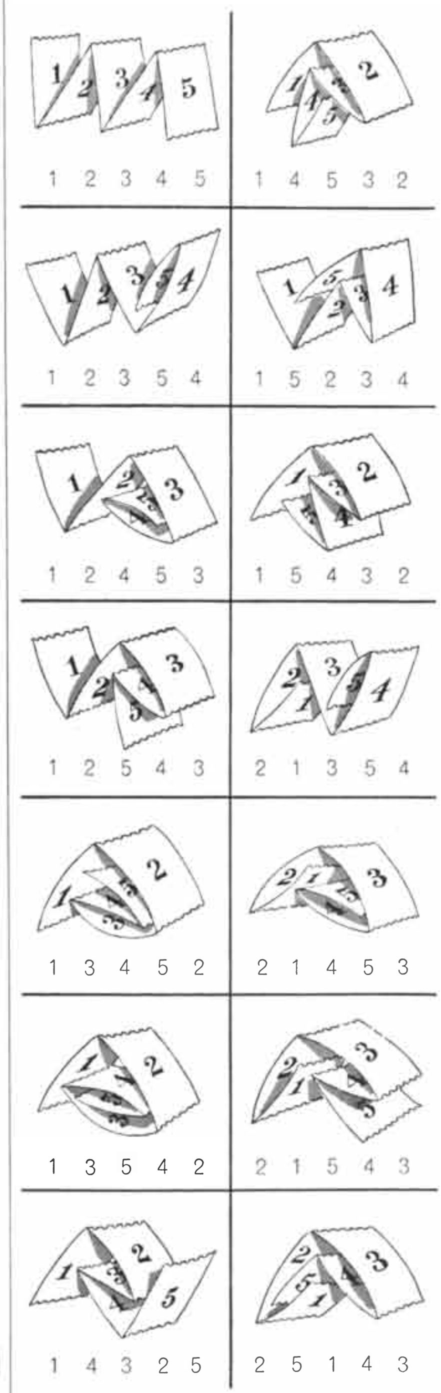
A similar cyclic path inside a tetrahedron was discovered in 1962, also by Hayward. It is easy to reflect a tetrahedron three times [*see illustration on page 258*] and find a cyclic path that touches each side once. The difficult trick is to find a cyclic path with equal segments. One is shown by the colored line. There are three such paths, all alike, touching each face of the solid at one corner of a small equilateral triangle in the center of the face. The side of this small triangle is a tenth of the edge of a tetrahedron with an edge of 1. Each segment of the ball's path has a length of $\sqrt{10}/10$, or .31622777+, giving the path a total length of 1.2649+.

Hayward made a handsome acetate model in which nylon thread traces the path of the bouncing ball (or light ray) after the four tetrahedrons have been "folded" together [*see illustration above*]. He cut the sides from sheets of acetate and cemented them along their edges after drilling four small holes at the proper points. Before cementing the last side he looped the thread through the holes of three faces and held it with pieces of tape on the outside. The two free ends were drawn through the hole in the fourth face, which was then cemented to the other three. After tightening the thread by pulling on the loops he sealed each hole with a drop of acetone mixed with Duco household cement and trimmed the outside loops and ends. A similar acetate model can be made of the cube. In both models threads of different colors can be used to show all possible paths.

The three introductory combinatorial questions raised in last month's column are answered as follows:

Four socks guarantee a matching pair.

A dollar can be changed in 292 dis-



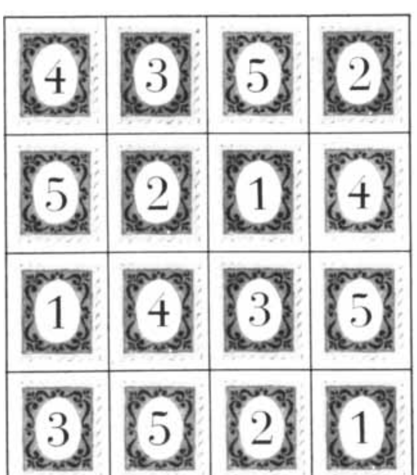
Answer to the stamp-folding problem

tinct ways. For a full solution, using recursive computation, see the last two pages of George Polya's *How to Solve It*, a Doubleday Anchor book.

A strip of five stamps, blank on both sides, can be folded in 14 distinct ways [*see illustration on page 262*]. (If the stamps are printed on one side, you might think the number of ways would double, but it increases only to 25. Why?) Mark B. Wells of the Los Alamos Scientific Laboratory became interested in this problem a few years ago. With the aid of the MANIAC computer he found the number of distinct foldings for six, seven, eight and nine stamps to be 38, 120, 353 and 1,148 respectively. The problem of finding a formula for n stamps remains unsolved.

Readers were also asked to change the Adams magic hexagon to a hexagon with 22 as the sum of each three-cell row, 42 as the sum of each four-cell row and 62 as the sum of each five-cell row. This can be done by replacing the number in each cell with the difference between that number and 20.

The problem of placing 16 stamps with values of one, two, three, four and five cents in a four-by-four square, with no two stamps of the same value in any row, column or diagonal (including the smaller diagonals), can be answered with a maximum value of 50 cents [*see illustration below*]. This is probably two cents more than most readers were able to achieve. The trick is to use only three four-cent stamps. "The reader will probably find, when he sees the solution," remarked Henry Dudeney when he first published the puzzle, "that, like the stamps themselves, he is licked."



Solution to stamp-placing problem

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National Aeronautics and Space Administration
at the Aeronautics and Space Committee Hearings,
U.S. House of Representatives, 1963.

General Electric's Apollo Support Department has been selected to assist NASA in the integration support, checkout and reliability assessment of the Apollo system. Without doubt, it takes an unusually mature and competent man to perform under the realization that his individual work can be of significant importance to such a program.

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THE AMATEUR SCIENTIST

How to repeat Cavendish's experiment for determining the constant of gravity

Conducted by C. L. Stong

How dense is the earth? Without the answer to this key question Newton's law of gravitation would hold little practical interest for the astronomer bent on predicting the course of a planet or an engineer dispatching a space probe to the moon. Newton's law states that any two bodies attract each other with a force proportional to the product of their masses and inversely proportional to the square of the distance between them, but it does not specify the proportions numerically. The constant of proportionality that relates the units on each side of the equation is merely symbolized by the capital letter *G*. Newton could conceive no experiment that would yield a numerical value for *G*. He resorted to the stratagem of evaluating *G* by estimating the density of the earth. Evaluating the surface properties of the earth, he concluded that the density of the planet must be five to six times greater than the density of water. A simple calculation then gave the equivalent value for *G*. The estimate was shown to be surprisingly good a century later when Henry Cavendish finally succeeded in putting the question directly to nature by means of an experiment that has become somewhat misleadingly known as "weighing the earth." Amateurs who set out to duplicate the experiment will find no clearer description of the apparatus and its origin than the one Cavendish presented in the opening paragraphs of a paper he read before the Royal Society of London on June 21, 1798.

"Many years ago," he wrote, "the late Rev. John Michell of this Society, contrived a method of determining the density of the earth, by rendering sensible the attraction of small quantities of matter; but, as he was engaged in other pursuits, he did not complete the apparatus till a short time before his death, and did not live to make any experiments with it. After his death the apparatus came to the Rev. Francis John Hyde Wollaston, Jacksonian Professor at Cambridge who, not having conveniences for making experiments with it in the manner he could wish, was so good as to give it to me.

"The apparatus is very simple; it consists of a wooden arm, six feet long, made so as to unite great strength with little weight. This arm is suspended in an horizontal position, by a slender wire 40 inches long, and to each extremity is hung a leaden ball about two inches in diameter; and the whole is inclosed in a narrow wooden case to defend it from the wind.

"As no more force is required to make this arm turn round on its centre than what is necessary to twist the suspending wire, it is plain that if the wire is sufficiently slender, the most minute force, such as the attraction of a leaden weight a few inches in diameter, will be sufficient to draw the arm sensibly aside. The weights which Mr. Michell intended to use were eight inches in diameter. One of these was to be placed on one side of the case, opposite to one of the balls, and as near it as could be conveniently done, and the other on the other side, opposite to the other ball, so that the attraction of both these weights would conspire in drawing the arm aside; and when its position as affected by these weights was ascertained, the weights were to be removed to the other side of the case, so as to draw the arm the contrary way and the position of the arm was to be again determined; and, consequently, half the difference of these positions would shew how much the arm was drawn aside by the attraction of the weights.

"In order to determine from hence the density of the earth, it is necessary to ascertain what force is required to draw the arm aside through a given space. This Mr. Michell intended to do by putting the arm in motion, and observing the time of its vibrations, from which it may easily be computed."

Cavendish then explained how he modified the apparatus so that it could be operated from a remote position, since the mass of an observer's body at close range would attract the small lead balls enough to introduce significant error. He also recognized the necessity for adding a mechanism "to accurately remove the weights to the other side of the case so as to draw the arm the contrary way." He equipped the arm with a small mirror that reflected the image of an ivory scale to a telescope equipped with a cross hair at the observing position, a scheme that served both to keep the observer away from the apparatus and to amplify the apparent displacements of the balance arm.

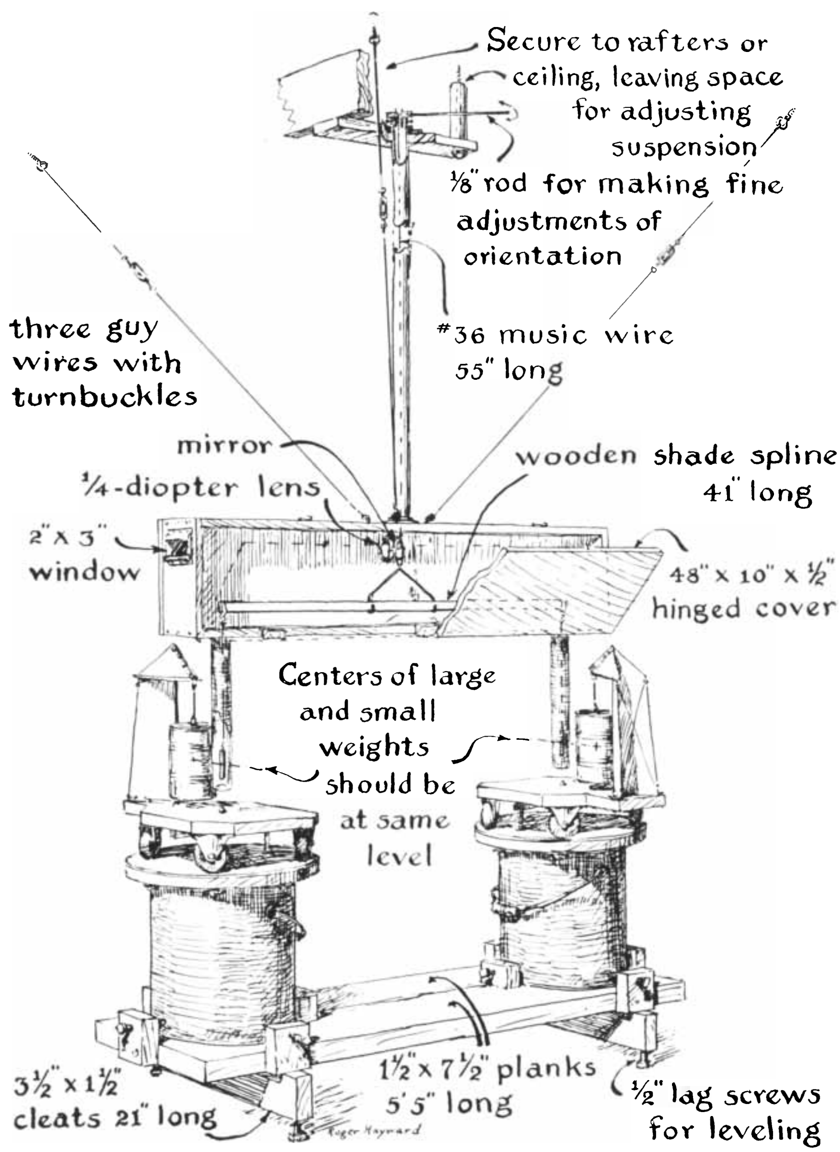
In spite of these major modifications of Michell's apparatus, Cavendish reported a puzzling effect. Now and again, for no apparent reason, the small balls of lead spontaneously "wiggled around," a phenomenon that Cavendish finally attributed to air currents in the case. This may well have been the source of the disturbance. On the other hand, his weights may have been influenced by stray electrostatic charges because he did not shield them from the flame of an open candle with which he illuminated the scale. Nevertheless, Cavendish was able to calculate the density of the earth as being 5.448 times that of water, almost precisely in the middle of Newton's estimated range, and he assigned a value to G of 6.754×10^{-8} (as expressed in centimeter-gram-second units).

An inexpensive version of the Cavendish apparatus, modified to include electrostatic shielding, has been constructed and used successfully for evaluating *G* within 1 per cent of the currently accepted value by Sam Epstein of Los Angeles.

Epstein writes: "Essentially the Cavendish apparatus is a sensitive torsion balance and a balance arm suspended at the middle by a slender steel wire. A small lead weight suspended from each end of the arm is attracted to larger weights by mutual gravitation. The rotation of the arm varies with the intensity of attraction and is measured by the deflection of a light beam from a small mirror fixed to a pair of hooks that support the balance arm, as shown in the accompanying illustration [*below*].

"The complete balance assembly including the case is supported from the ceiling by a length of 3/4-inch pipe that terminates in flanges. The structure is braced by a set of three guy wires. The torsion wire attaches at the upper end to a special fitting that rests in the top end of the pipe: a brass flange and cap nut drilled and threaded to receive a small rod with a hook at one end for attaching the wire. The flange is centered in the pipe by four adjusting screws and can be rotated for adjusting the orientation of the wire and balance arm. The lower end of the torsion wire attaches to an S-fitting that engages a pair of wire hooks to which a small mirror is fixed.

"The remaining apparatus, including the large weights, is mounted on a wooden platform that in turn rests on legs in the form of inverted lag screws, which serve as leveling adjustments. The platform carries two metal pails filled with sand; these act as massive supports for a pair of turntables used to shift the position of the heavy weights. The turntables roll on casters of the nonswiveling type that ride on Masonite disks laminated to plywood atop the metal pails. A 3/8-inch pivot anchored in the center of each plywood disk engages a companion hole in the center of the turntables. The



Cavendish apparatus as modified for amateur construction

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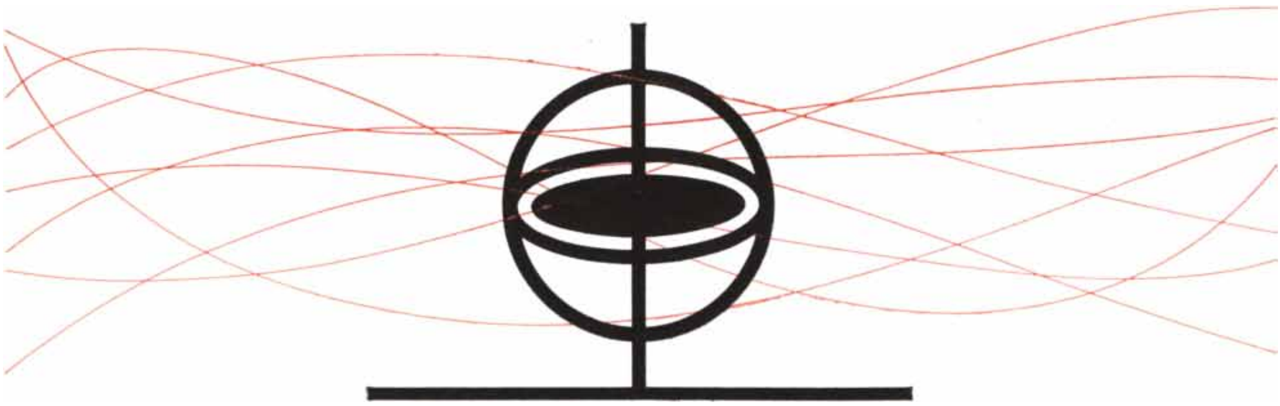

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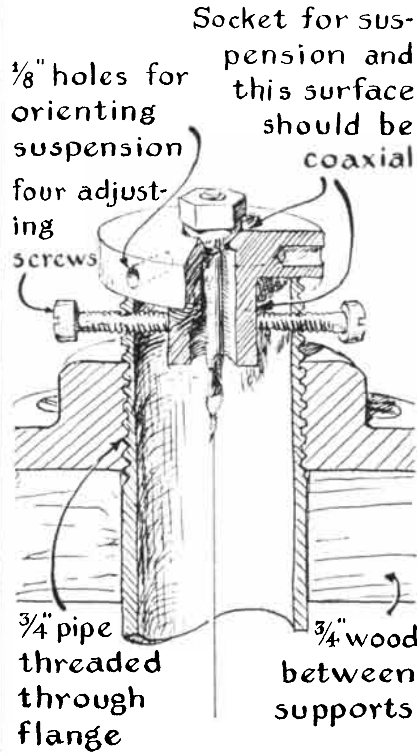

Details of top of torsion-wire suspension

pivots keep the turntables centered when the position of the attracting weights is altered. The gravitational attraction of the mass represented by the sand in the metal pails acts vertically on the small weights and therefore exerts no turning force on the balance arm. The attractive force of the brackets from which the large weights are suspended, however, can influence the motion of the arm and must be minimized. This is accomplished by making the brackets in V-sections of thin aluminum sheeting and providing the necessary strength by means of wire braces.

"Lead is an ideal material for the weights because of its high density, cheapness and low melting point. (Any other substance can be used, however, because all matter exerts gravitational attraction.) Lead can be bought in most plumbing establishments, where arrangements might also be made for melting and casting the weights. The construction requires about 75 pounds of lead. Standard fruit-juice cans of 46-ounce capacity serve as forms for the large weights. Make the castings by embedding clean, dry cans almost to the top in moist sand or earth and filling them to the brim with molten lead. Lead shrinks on cooling, so that more than one pouring is necessary. The sand absorbs heat

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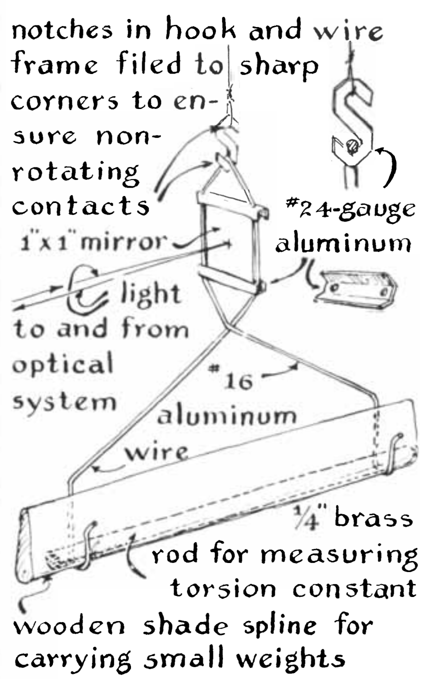
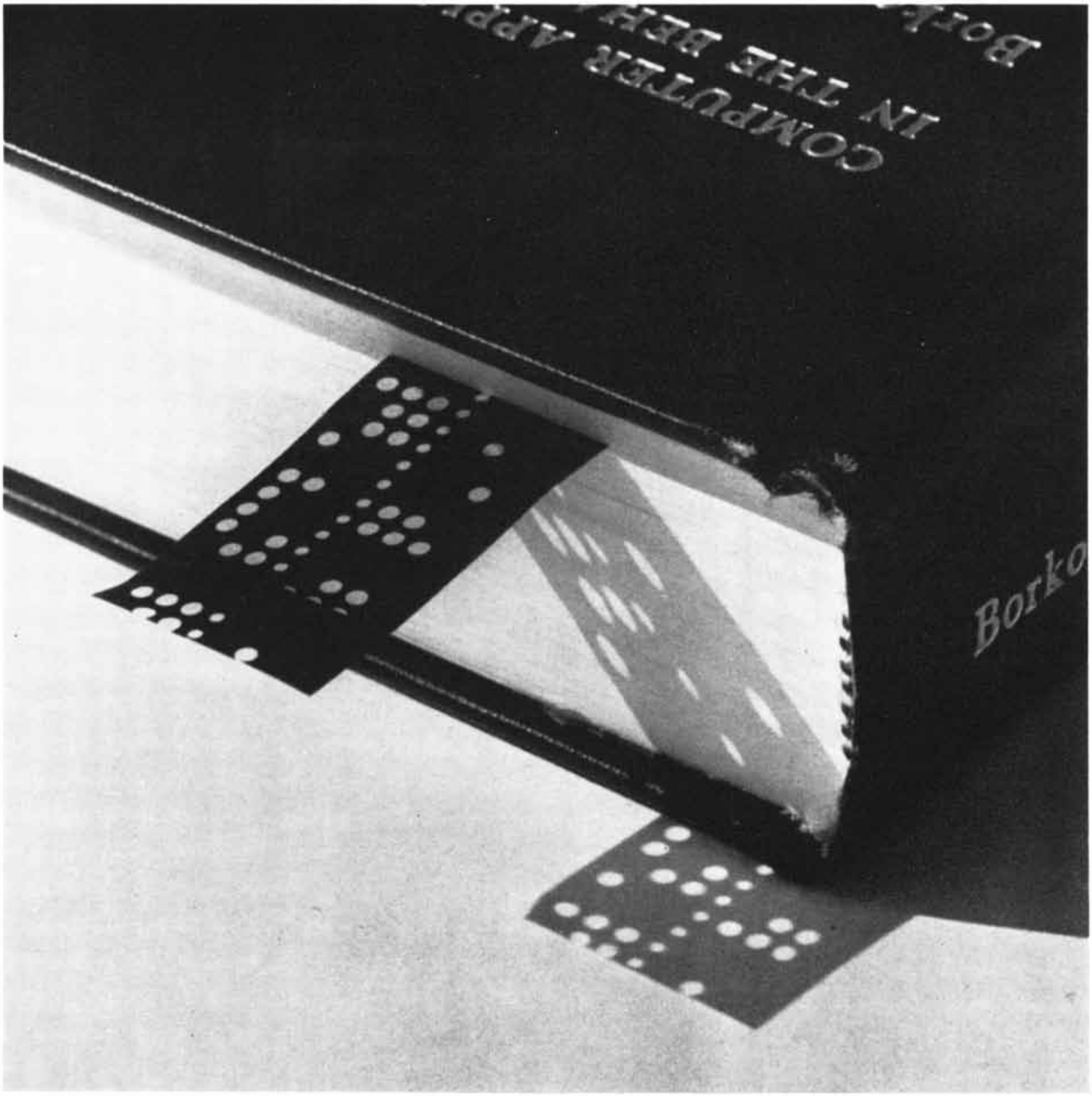
from the sheet metal and keeps the soldered joints from melting. If the cans are not completely dry, the molten lead may spatter and cause severe burns. A face shield, hat, gloves and a garment with long sleeves should be worn for safety. Do not melt more lead at one time than can be safely carried and poured. Let the castings cool for at least an hour before removing them from the sand or earth. Then drill and tap the lead to take an accurately centered screw to which suspension hooks are attached. Each completed unit should weigh 16.3 kilograms. Although their weight need not be precisely this amount, the weights of each must be the same and should be determined to within 100 grams. The weights are equalized by filing lead from the heavier of the pair. After the weights have been suspended from the aluminum brackets and mounted on the turntables, measure and record the distance between the suspension wires and the center of the turntable to the nearest millimeter.

"The small weights carried by the balance arm are much easier to make. Simply stand two 1/2-inch brass tubes with 1/32-inch walls on a smooth metal surface and pour in the lead. The tubes should be about four inches long to allow for shrinkage when the lead solidifies. When the lead is cool, saw an inch from the tops and square the ends with a file. Each weight is then drilled and



Lower end of suspension



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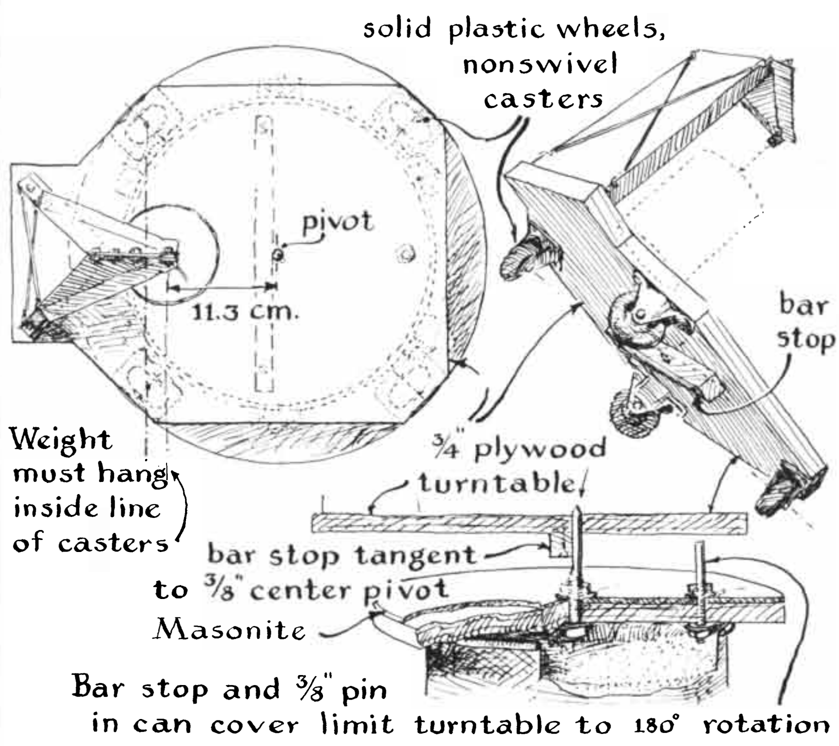
fitted with a small screw eye; these must be accurately centered because the suspension wires are presumed to pass through the center of mass of each weight and the distance between the centers of mass of the large and small weights must be subsequently determined by measuring the distance between the suspending wires. The small weights, of about 100 grams each, must be equal and measured to the nearest gram.

"The balance-arm assembly is enclosed by an airtight case that includes a pair of metal-lined tubes for shielding the small weights. These shields can be made of clear plastic sheeting rolled and cemented. The electrostatic shielding that lines the tubes can be made of copper fly screen and is electrically connected to the grounded pipe support and guy wires. One side of the case is hinged for a door and sealed with weather stripping.

"Any optical system that can project a reasonably sharp image of a cross hair can be used to indicate the position of the balance arm. I improvised a system that uses a clear Mazda lamp for the source and a common reading glass and spectacle lens for focusing the image of a fine wire on the screen, as illustrated in the accompanying drawing [*bottom of page 278*]. Doubtless a satisfactory substitute could be constructed around a 35-millimeter slide projector.

"When the balance has been assembled as illustrated, carefully center the balance arm on its suspension hooks and hang the small weights in their shields. Measure and record the distance between the small weights to the nearest millimeter. If the arm is properly centered, this will be twice the length of the lever arm through which the force of gravitational attraction is exerted on the torsion wire as a moment, or twisting force. Now turn the adjustment head at the top of the suspension pipe to position the balance arm longitudinally with respect to the case. If the torsion wire has been twisted during installation, several turns may be required to align the balance arm. The balance arm can be considered properly aligned when the small weights remain centered in the shielding tubes following an adjustment. Because the balance is sensitive and oscillates at a frequency on the order of only about one cycle per 10 minutes the inexperienced operator may tend to overshoot in making this adjustment. Make the final adjustments in small increments and wait at least 10 minutes between adjustments for the arm to respond. After centering the arm, align the optical system and thereafter observe the movements of the balance by meas-



Details of the turntable construction

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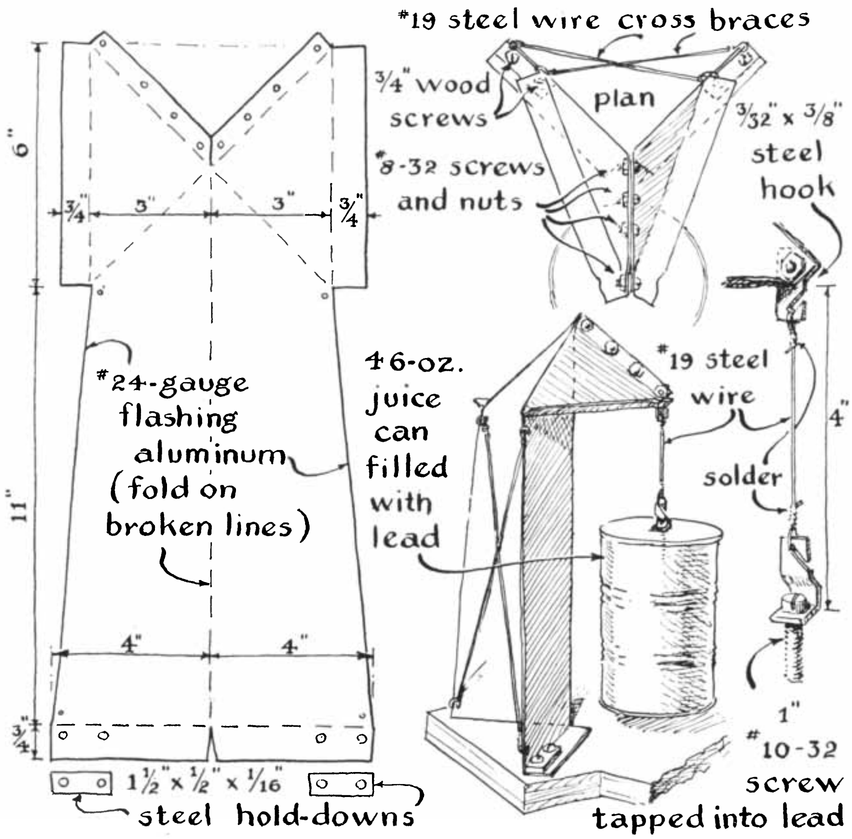
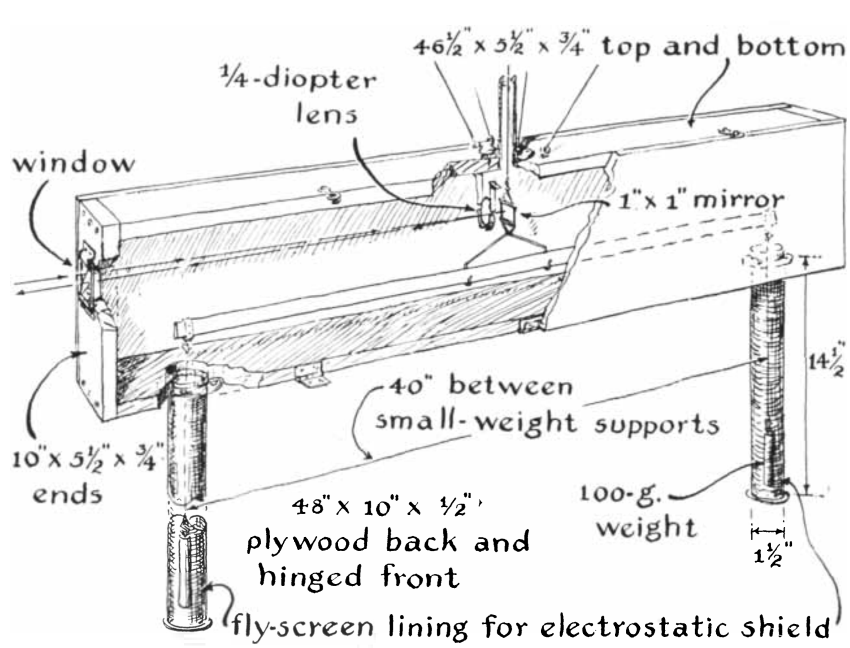


Suspension system for the large weights

uring the movements of the cross hair on the scale.

"In order to measure the force required to twist the torsion wire, first carefully mark on the arm the points at which the balance arm rests in the suspension hooks; then remove the balance arm and small weights and replace the assembly with a brass rod a 1/4-inch in diameter that equals the total weight of the balance-arm assembly to within a gram. (The balance-arm assembly of my apparatus weighs 239 grams and the length of my 1/4-inch brass bar of equal



Case for shielding the balance-arm assembly

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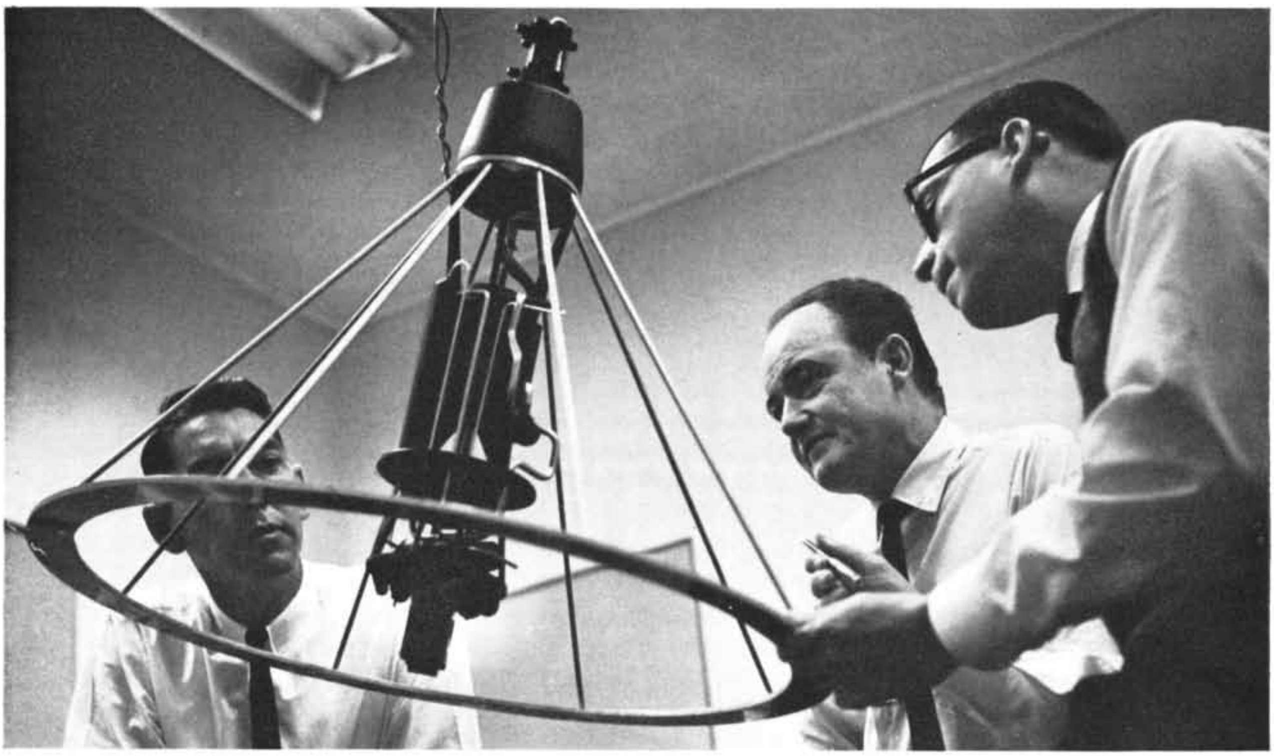

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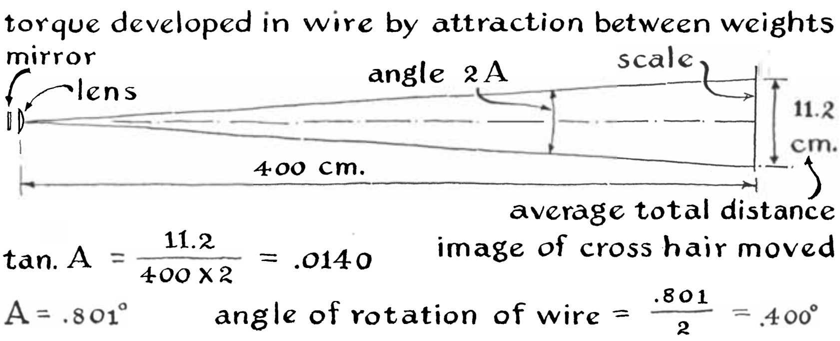


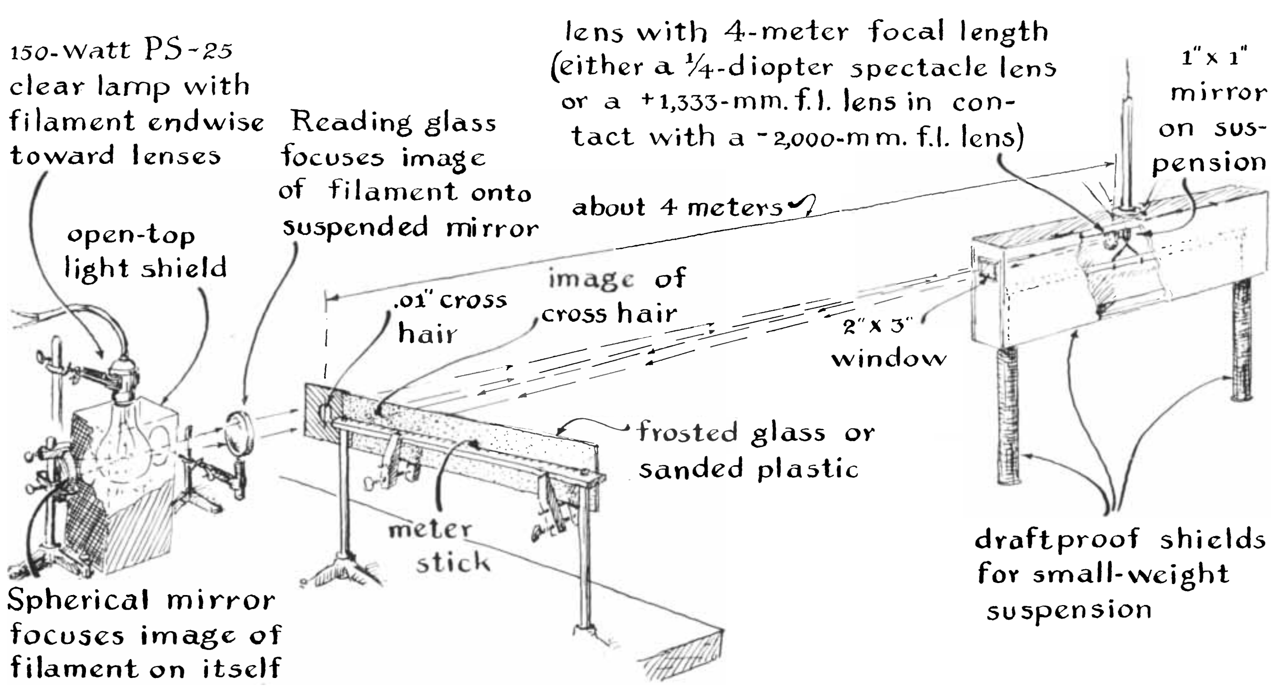
Geometry of the light beam

weight is 35 inches.) Center the brass bar carefully on the suspension hooks and, after the image of the cross hair has come to rest on the scale, give the brass rod a slight impulse to set it in oscillation and then close the door of the case.

"The objective is to determine the period of oscillation of the balance when the torsion wire is loaded with the weight of the balance-arm assembly and from the period of oscillation to calculate the force, or moment, required to twist the wire. The brass rod is substituted for the balance-arm assembly because the subsequent calculation requires that the moment of inertia of the load be known, and it is much easier to compute the moment of inertia of a simple geometric form, such as a brass rod, than that of a complex shape such as the balance arm. The brass rod must oscillate smoothly in a horizontal plane without evidence of swinging, conical rotation or teeter-totter. The period of the system, or the time required for the cross hair to move from one extreme position to the other and return, must be measured to the nearest second. Time at least 10 oscillations and record the average. Remove the brass rod, reinstall the balance-arm assembly according to the guide marks previously placed on it and check to be sure that the small weights are properly centered and in precise axial alignment with the pivots of the turntables. If they are not so centered, align them by shifting the turntables. The centers of mass of the large and small weights must be at the same level, a position that is determined by the length of the suspension wires.

"In order to determine the force of gravitational attraction between the large and small weights, first rotate the turntables until all four weights are in a straight line. This is the neutral position in which the large weights exert no force tending to rotate the balance arm. Record the position of the cross hair on the scale. (The cross hair may move erratically from time to time but excursions of less than a millimeter may be ignored.) Next, rotate the turntables 90 degrees so that the two heavy weights are on opposite sides of the case. Observe the cross hair. It will oscillate slowly for a time and come to rest about five millimeters from the previously recorded neutral position. Stay at least three meters from the balance assembly to minimize the influence of your own gravitational attraction on the small weights. Record the position of the cross hairs when the balance reaches equilibrium. Then rotate the turntables 180 degrees to shift the large weights to the other sides of the case and record the position at which the cross hair comes to rest at the side opposite the neutral position. Keep shifting the large weights 180 degrees until a good average value for the total deflection of the cross hair—the distance between the extreme rest points—has been recorded.

"Simple arithmetic then makes it pos-



Optical system of the apparatus

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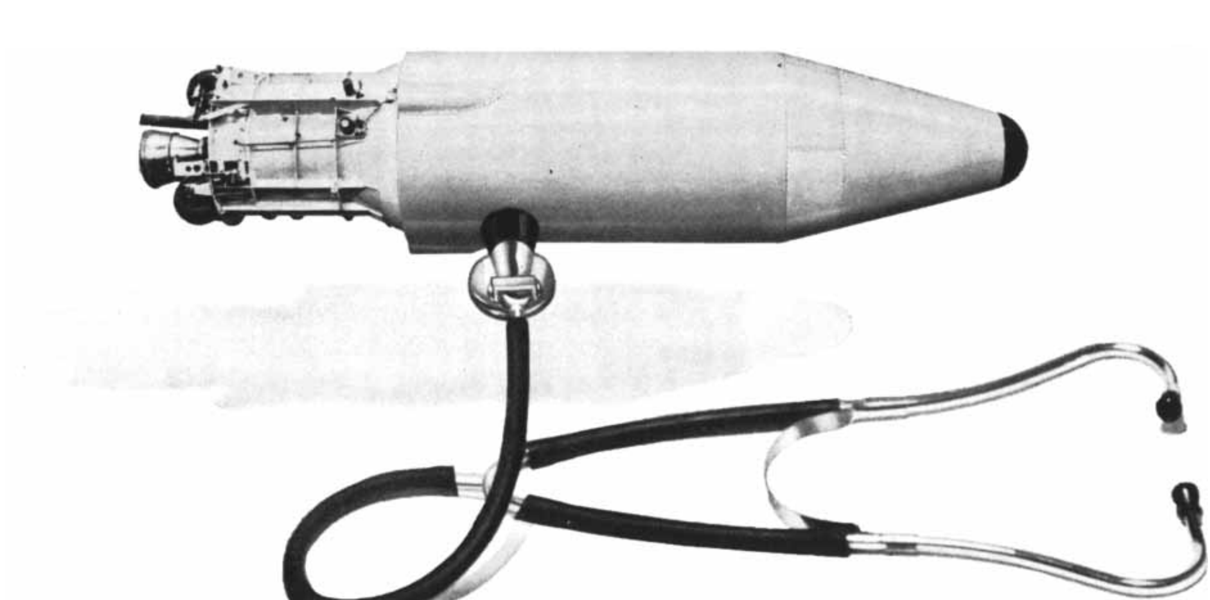
Reducing data reduction



sible to solve for the value of G and the 'weight' and density of the earth [*see box below*].

"The attractive force exerted between the large and small cylinders of lead used in this apparatus does not equal so much as the weight of a small gnat's wing. (It amounts to about a hundred-billionth of an ounce.) Even a relatively crude torsion balance responds easily to forces of this order, however, as indicated by the closeness to the generally accepted values of the values derived by the experiment."

Dimensions of the apparatus:

M = mass of large weight = 1.63×10^4 grams
m = mass of small weight = 1.01×10^2 grams
a = distance of small weight from center of balance arm = 50.8 centimeters
ϕ = angle of rotation of torsion wire = .4 degree
d_n = distance between M and m when weights are in neutral position = 11.3 centimeters
d_r = distance between M and m when m is attracted to M = $d_n - a$ [tangent ϕ] = 11.3 − .352 = 10.9 centimeters
W = weight of brass rod = 239 grams
R = radius of brass rod = .318 centimeter
l = length of brass rod = 88.9 centimeters
T = period of oscillation of brass rod = 678 seconds

Computed constants of the apparatus:

I = moment of inertia of the brass rod = $W[R^2/4 + l^2/12]$
= $239[.318^2/4 + 88.9^2/12] = 1.58 \times 10^5$ gram-centimeters^2
L_r = torque per radian of rotation of wire = $4\pi^2 I/T^2$
= $4 \times 3.14^2 \times 1.58 \times 10^5/678^2 = 13.5$ dyne centimeters/radian
L_o = $L_r/57.3 = 13.5/57.3 = 2.36 \times 10^{-1}$ dyne centimeter/degree
L = wire torque = $L_o\phi = 2.36 \times 10^{-1} \times .4 = 9.45 \times 10^{-2}$ dyne centimeter
F = force of gravitational attraction between M and m
= $L/2a = 9.45 \times 10^{-2}/2 \times 50.8 = 9.28 \times 10^{-4}$ dyne

Value of G from Newton's equation ($F = GMm/d^2$):

G = gravitation constant = Fd^2/Mm
For this experiment $d = d_r$
Therefore $G = 9.28 \times 10^{-4} \times 10.9^2/1.63 \times 10^4 \times 1.01 \times 10^2$
$= 6.7 \times 10^{-8}$ dyne centimeter$^2/g$
Where g = gravitation acceleration (at location where experiment was performed, assumed to be 980 centimeters/second^2)
Accepted value for $G = 6.670 \times 10^{-8}$ dyne centimeter$^2/g$

Mass of the earth:

F_g = gravitational attraction of earth for any body of mass m_b
= $m_b g = GM_e m_b/r^2$
Where M_e = mass of the earth
r = radius of earth = 6.37×10^8 centimeters
$M_e = gr^2/G = 980 \times [6.37 \times 10^8]^2/6.7 \times 10^{-8} = 5.93 \times 10^{27}$ grams or 6.5×10^{21} tons
Accepted value for mass of the earth = 6.60×10^{21} tons

Average density of the earth:

D = density of earth = M_e/V
V = volume of earth = $4\pi r^3/3$
Therefore $D = 5.93 \times 10^{27}/[4 \times 3.14 \times (6.37 \times 10^8)^3/3]$
= 5.5 grams/centimeter^3
Accepted value for earth's density = 5.52 grams/centimeter^3

Calculations to determine the value of the constant G

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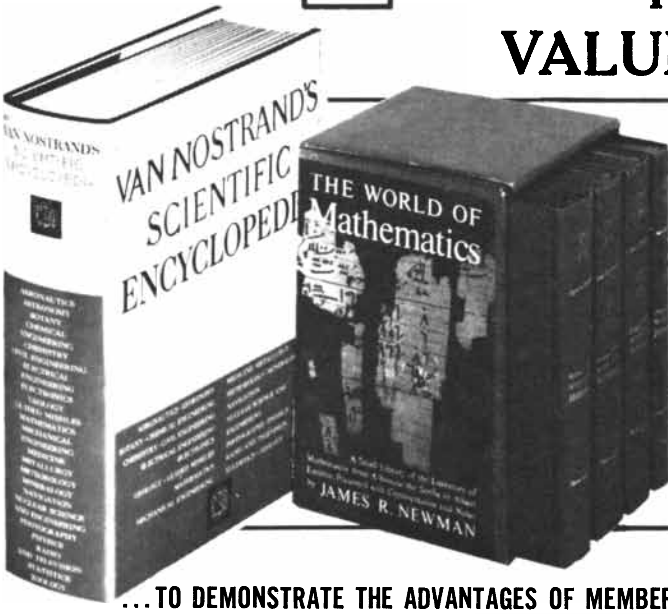

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BOOKS

C. G. Jung: prophet of the unconscious

by Erich Fromm

MEMORIES, DREAMS, REFLECTIONS, by C. G. Jung. Recorded and edited by Aniela Jaffé. Translated from the German by Richard and Clara Winston. Pantheon Books ($7.50).

"The older I have become the less I have understood or had insight into or known about myself.... I have no judgment about myself and my life. There is nothing I am quite sure about. I have no definite convictions—not about anything, really."

These words were spoken late in life by C. G. Jung, a man who claimed to have found a way to self-knowledge that was superior to Freud's psychoanalysis. Jung's posthumously published autobiography gives us an answer to this and other questions that have puzzled many of Jung's readers. The autobiography, by revealing the man, shows that Jung's emphasis on the collective unconscious and his opposition to Freud's personal unconscious had the function of protecting him from becoming aware of his own repressed experiences by making his unconscious part of a mythical entity that rules all men alike and knows no good or evil. Jung, a man relentlessly pursued by the furies of uncertainty, destructiveness and loneliness, found a modicum of peace in what he thought were the revelations and commands of a mythified unconscious.

Jung's life from childhood on was dominated by the quest for certainty. Was God real? Was he, Jung, real? Was evil real? Eventually he believed he had found an answer in the concept that his visions, dreams and fantasies were all manifestations of the unconscious and that he was the first to have discovered this ultimate reality, to have submitted to it in full awareness and so tamed it. His autobiography is illuminating and impressive. It would arouse deep compassion, at least in this reader, if it were not for the fact that Jung combined an incapacity to see the truth with such a degree of opportunism that as a tragic hero he often resembles the Pied Piper of Hamelin.

His doubts began early. At the age of three or four he had a dream that, as he later interpreted it, expressed his doubt whether or not Jesus was devouring little children. A similar and even more troubling experience of his childhood occurred when he was 12: he felt a compulsion to think that God, sitting on his golden throne, defecated and shattered a beautiful church. Fearing that if he allowed himself to think this, he would be committing a most frightening sin, he tried to avoid the terrifying thought. Eventually, when the torture was unbearable, he decided that if he was obsessed by the blasphemous temptation, it must be God's will. He then gave in to the thought and felt that he had experienced the miracle of grace by such complete submission to God's will. (In this experience as well as in many traits of his personality Jung showed a remarkable kinship to Luther.) "I had experienced a dark and terrible secret. It overshadowed my whole life and I became deeply pensive." Indeed, uncertainty, submission and the hate/love ambivalence toward God (and, incidentally, toward his father) remained the theme of his life.

In the period when he was a young psychiatrist, particularly during his close association with Freud, Jung was to some extent liberated from the tortures of uncertainty. Science seemed to give him the certainty he had been seeking so desperately. Freud's purity and intellectual power impressed him deeply; moreover, it must have meant a great deal to him to be chosen by Freud as the "crown prince" over the heads of a number of rivals who had served Freud faithfully for many years.

Nonetheless darkness won out over Jung's rational tendencies. He felt compelled to break with Freud—and with scientific thought. The break must have been more surprising to Freud than to Jung. Freud had been troubled by Jung's belief in occult phenomena: premonition, extrasensory perception and the like. Freud sensed Jung's unconscious death wishes against him and tried to analyze them, without success. Persuaded by the hope of having found a Germanic Paul to spread the gospel to the Gentiles, Freud was not aware of Jung's insincerity toward him. Although Jung told Freud his dreams, he lied to him about his associations with them, rationalizing this behavior by saying, "It would have been impossible for me to afford him any insight into my mental world," and excusing his insincerity with the words "*À la guerre comme à la guerre!*" Freud had no idea that Jung was waging war against him.

The two men differed over the psychic role of sex, but the reasons for their break were much deeper. Jung thought that for Freud sexuality was "a hidden God." The fact was that Freud insisted so vehemently on the role of sex because to him, rightly or wrongly, it was the only explanation of neuroses. The real reason for their incompatibility was the conflict between Freud's rational approach and Jung's romantic obscurantism.

Nothing illustrates this conflict better than a dream Jung had at the time of his break with Freud. The gist of it was that Jung saw Siegfried appear on the crest of a mountain and knew that he, Jung (together with a dark savage), had to kill him. Siegfried was struck dead by Jung's bullet. Disgusted with his deed, Jung turned to flee, impelled by the fear that the murder would be discovered. Suddenly a tremendous rainstorm began and wiped out the traces of the murder. ("I had escaped the danger of discovery ... but an unbearable feeling of guilt remained.") In spite of Freud's repeated suggestion that Jung wished his death and the fact that the name Siegfried so closely resembled Sigmund, Jung had no idea what the dream meant. After he had awakened, a voice had said to him: "If you do not understand the dream you must shoot yourself!" How did Jung "understand" the dream? To him the dream meant that he had killed the hero Siegfried within himself, that "my heroic idealism had to be abandoned for there are higher things than the ego's will, and to these one must bow." Thus he explained his murderous impulse toward Freud as an expression of his own humility.

The break with Freud—and with rational thought—ended in a new and severe personal crisis for Jung. ("It would be no exaggeration to call it a state of disorientation.") He withdrew from the University of Zurich and found himself "utterly incapable of reading a scientific book." He gave himself completely to work on his fantasies. Aided by his ability to perceive hypnagogic images and by his increasing acquaintance with mythology and the history of religion, he produced fantasies and even saw visions. Still he was plagued by doubt. Was his guru Philemon, who enlightened him during their "walks," real or only a product of his imagination? Was he, as a psychopathic patient tried to convince him, only a modern artist who seeks "to create art" out of the unconscious? Were the fantasies he was producing "really spontaneous and natural and not ultimately my own arbitrary inventions?" At the height of this crisis salvation came. He broke with the patient who maintained that his visions were "art," and he saw everything in terms of circular "mandala" images. His conclusion was: "There is no linear evolution; there is only a circumambulation of the self. Uniform development exists, at most, only at the beginning; later, everything points toward the center. This insight gave me stability and gradually my inner peace returned. I knew that in finding the mandala as an expression of the self I had attained what was for me the ultimate." In addition his study of alchemy and of the Chinese *The Secret of the Golden Flower* helped him to convince himself that his own visions and fantasies were not merely subjective but constituted an objective reality shared by and governing all men.

Jung had finally achieved what he had hoped for: "I myself had to undergo the original experience and moreover try to plant the results of my experience in the soil of reality; otherwise they would have remained subjective assumptions without validity.... My delivering myself over to [the service of the psyche], as it were, was the only way by which I could endure my existence and live it as fully as possible." After his childhood experience of God's grace Jung had again found a way to salvation. Now the unconscious had become God, and Jung was the first to become its prophet.

This isolated man had found a way to relate himself to others. "It was clear to me from the start that I could find contact with the outer world ... only if I succeeded in showing ... that the contents of psychic experience are real, and real not only as my own personal experiences but as collective experiences which others also have.... I knew that if I did not succeed, I would be condemned to absolute isolation."

Why did he make such an extraordinary effort to escape an awareness of his inner personal reality? First of all, his suspiciousness and isolation made it impossible for him to be psychoanalyzed by somebody else and even, as we have seen, for him to be frank with Freud. This incapacity for frankness, which Jung explained as the necessity of having a secret, was rooted in his narcissism (an orientation in which only subjective experience, as opposed to the outside world, is fully real). Jung's narcissism was also the condition for his claim that his visions and fantasies represented an objective and independent reality. If he dreamed, for example, that he was kneeling in front of an attractive woman patient, it meant that she was saintly—how else could he have had the dream?

Yet since Jung was not insane, he was never entirely convinced. Because of his doubts he had to take refuge in elusive language and naïve philosophical statements. Thus he wrote in *Psychology and Religion* that psychology is only occupied with the fact that a certain idea exists (for example, the idea of virgin birth) and not with whether or not its content is true. "The idea is psychologically true inasmuch as it exists," just as "an elephant is true because it exists." In spite of these cautious statements Jung proceeds to say that psychological existence is subjective inasmuch as an idea occurs only in an individual but that it is objective in that it is "shared through a consensus gentium by a large group." In his autobiography Jung goes even further by ascribing objective reality to his fantasies.

Jung did not perceive that the same fantasies can be shared by millions of people because of common irrational needs, or that such multiplied fantasies are no proof that their contents have any logical validity or reality in themselves. The more Jung persuaded himself of the reality of his visions the less he knew about himself. This is expressed in the last sentence of the book: "In fact, it seems to me as if that alienation which so long separated me from the world has become transferred into my own inner world, and has revealed to me an unexpected unfamiliarity with myself." Jung's autobiography shows the basis for

his emphasis on the point that the phenomenon of belief is a "truth." He had to reassure himself against his continuous doubts. Even if the contents of his visions were not real, the visions themselves constituted a truth.

There was another reason for Jung's inability to make his unconscious conscious; it lay in the fact that the contents of his unconscious were extremely frightening. The reader of this autobiography does not have to be a psychoanalyst to be impressed by Jung's deep affinity for death, destruction, the past, the dark, ice, stones and everything that is not alive. Blood and corpses, skulls and murder are the repetitive theme of his dreams. Granted that no one is free from murderous impulses, this picture, in its emphasis and consistency, constitutes a psychological syndrome that is found in persons with an affinity for destruction, the past, the inorganic. Jung was a man deeply attracted by the dark, not by the light. But this was not all of Jung. He was also extremely productive, imaginative and in many ways alive. He could not accept his necrophilous complex. He had to fight it, partly by repressing it, partly by transforming it into a lively interest in the powers of darkness.

What I have said so far may suggest the difference between Jung's and Freud's views of the unconscious and of therapy. On the surface it appears that Freud emphasized the personal and sexual aspects of the unconscious, whereas Jung emphasized its collective and nonsexual aspects. Although this is more or less correct, it is not the main difference. Freud had an evolutionary—as Jung called it, "linear"—concept that implied value judgments and goals for human development. Man historically and individually develops from archaic (narcissistic, destructive, cannibalistic) impulses to higher forms of behavior in which reason and independence are achieved; this process occurs by repression and sublimation and also by the transformation of the libido itself from the narcissistic to the genital level. Mental illness is the result of the failure to solve the conflict between archaic-regressive and progressive-rational tendencies. By becoming aware of the irrational tendencies within himself the individual can gain the ability to overcome them. Freud's therapy was based on the concept "The truth shall make you free." His aim was to replace the archaic by the rational, fixation by independence, the id by the ego.

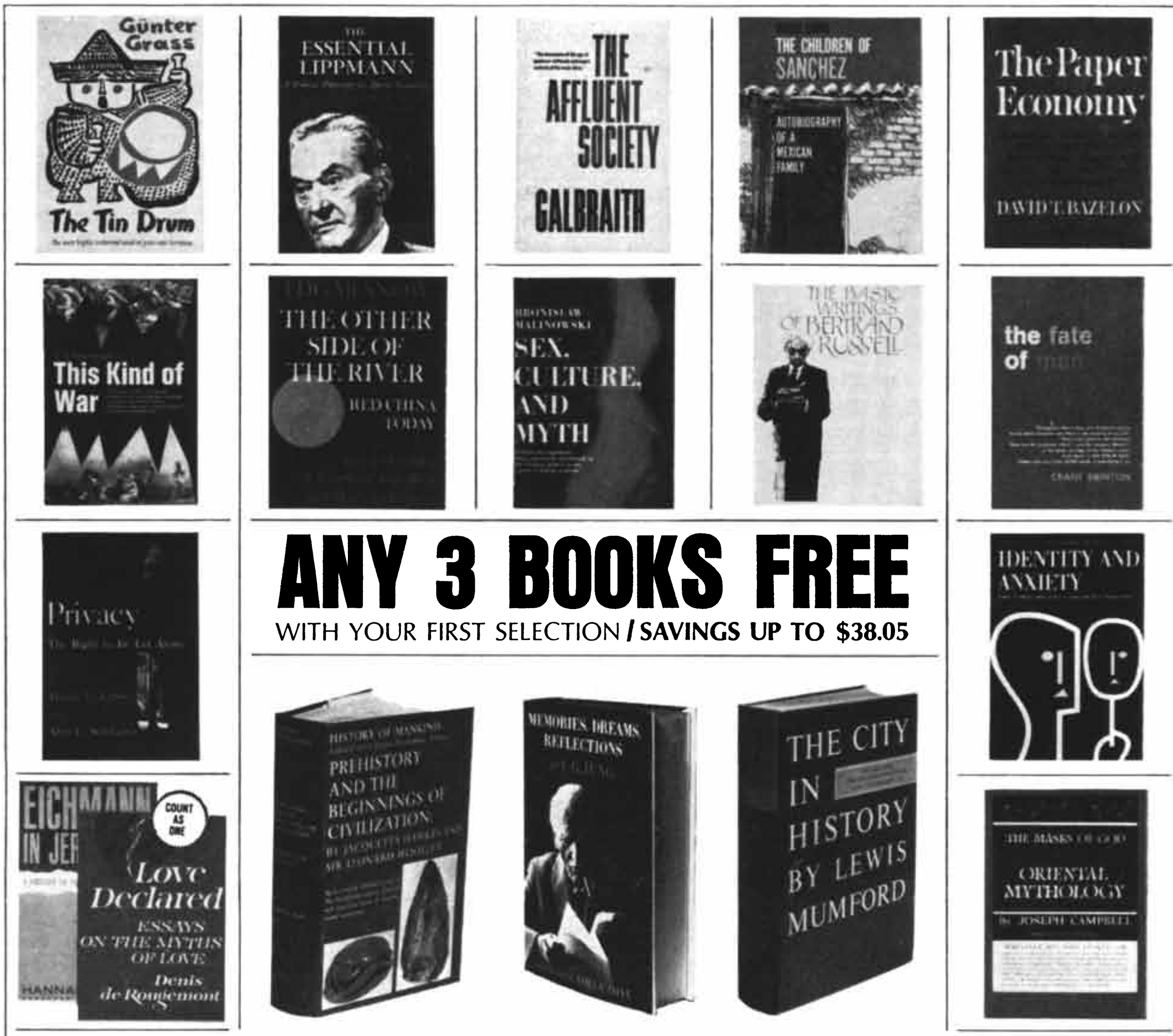
For Jung there was no such evolutionary concept and no value judgments; there was "circumambulation." The unconscious corresponds "to the mythic land of the dead, the land of the ancestors"; it represents the past, the most primitive layer of man. For Jung analysis meant seeing the forces of the past and the dark in man, finding names and images for them and weakening the dark and evil powers by mythifying them. But the unconscious is also the source of all wisdom and vitality, it can be equated with God, and man must surrender to it. The unconscious rules man mercifully if he has tamed it by words and images, cruelly if he fails to do so. Jung's unconscious is God and the Devil, and man is ridden by it.

The collaboration of Freud and Jung was a misunderstanding; they shared an interest in the unconscious but their aims and intentions were opposite. For Freud uncovering the unconscious was essentially a critical task, the criticism of illusions and self-deceptions. Jung, on the other hand, said: "The more the critical reason dominates, the more impoverished life becomes." For Freud criticism was liberating; for Jung it was a menace to life. The mystery is not why they parted but why they ever had the illusion that they had the same aim.

Jung was certainly not a religious man in the Christian, Jewish, Moslem or Buddhist sense. He was essentially a pagan, more specifically a worshiper of evil gods and goddesses rather than those of the Olympian religion. But he lacked Nietzsche's boldness and honesty. He never admitted to himself that he had no faith in God. He speaks of the "Creator"; he put an inscription at the entrance of his house that said: "Summoned and not summoned, God will be there." He wrote: "Hence I prefer the term 'the unconscious,' knowing that I might equally well speak of God or 'daimon' if I wish to express myself in mythic language."

Why this ambiguity? Why did this religious relativist who never understood the significance of truth as a religious category go on talking about God? One psychological explanation could be that he never dared to deny God because he was too much bound to his father, to his past and to convention. Another explanation may lie in the fact that in spite of considerable philosophical and some theological erudition, Jung was philosophically and theologically a naïve man who could "unify the contradictions" out of sheer lack of clear thinking.

There is still another factor that contributed to Jung's elusive and ambiguous statements: his opportunism. There is perhaps no more striking example of his opportunism than his attitude toward



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ORIENTAL MYTHOLOGY
JOSEPH CAMPBELL

Germany between 1933 and 1945, and the fact that there is no mention of this in his autobiography. In 1932 Jung, a Swiss, was still able to write an article praising Freud as a prophet "who overthrows false gods and mercilessly exposes to the light the rottenness of the contemporary soul." Soon afterward he expressed his sympathy for National Socialism, not only by accepting the editorship of the German *Central Review of Psychotherapy* in 1933 but also by writing in 1934 that Freud "could not understand the Germanic soul, as little as all his Germanic followers. Have they not been taught better by the tremendous phenomenon of National Socialism to which the whole world looks with astonished eyes?" He also wrote about the difference between Germanic and Jewish psychology, qualifying his comment by saying "that it does not imply underevaluation of Semitic psychology." In one newspaper interview he called Hitler "a spiritual vessel"; in another he said that he considered it a mistake that England and France tried to prevent Germany from expanding to the East.

Although these and similar statements can be interpreted as naïve expressions of a reactionary romantic, Jung's opportunism manifested itself *after* the German defeat. Without referring to his former sympathies he said in an interview with the Swiss magazine *Die Weltwoche* that the German nation had a collective guilt from which no German was exempt. Later he clarified the interview by saying: "If [the Germans] want to insist on their responsibility and mental sanity, I have no objections, but in this way they make their moral position worse; for in this case the German nation has simply devastated Europe with intention and deliberation. I am more tolerant and at least concede to them, as an extenuating circumstance, psychopathic inferiority." But even as he condemned the Germans he subtly implied that anti-Nazism had not been better than pro-Nazism. He described his experience with two anti-Nazi German patients and said that unconsciously they harbored the same violence and cruelty characteristic of the Nazis.

Jung's opportunism was not limited to his attitudes toward Germany. On one occasion he wrote a letter to Freud suggesting that the importance of sexuality be minimized in order to make psychoanalysis more acceptable. Above all, his pronouncements had an elusive quality that made them all things to all men. Everyone could take what he liked: the believer could choose God; the unbeliever, the unconscious.

The fact remains that Jung made important contributions to Freud's thought. He perceived that there are certain intense desires and certain possible responses inherent in the conditions of human existence ("archetypes") and that these archetypes can be found in all men. He freed Freud's energy concept of libido from its narrow sexual confines. He built a bridge between personal experience and myths, rituals and symbols.

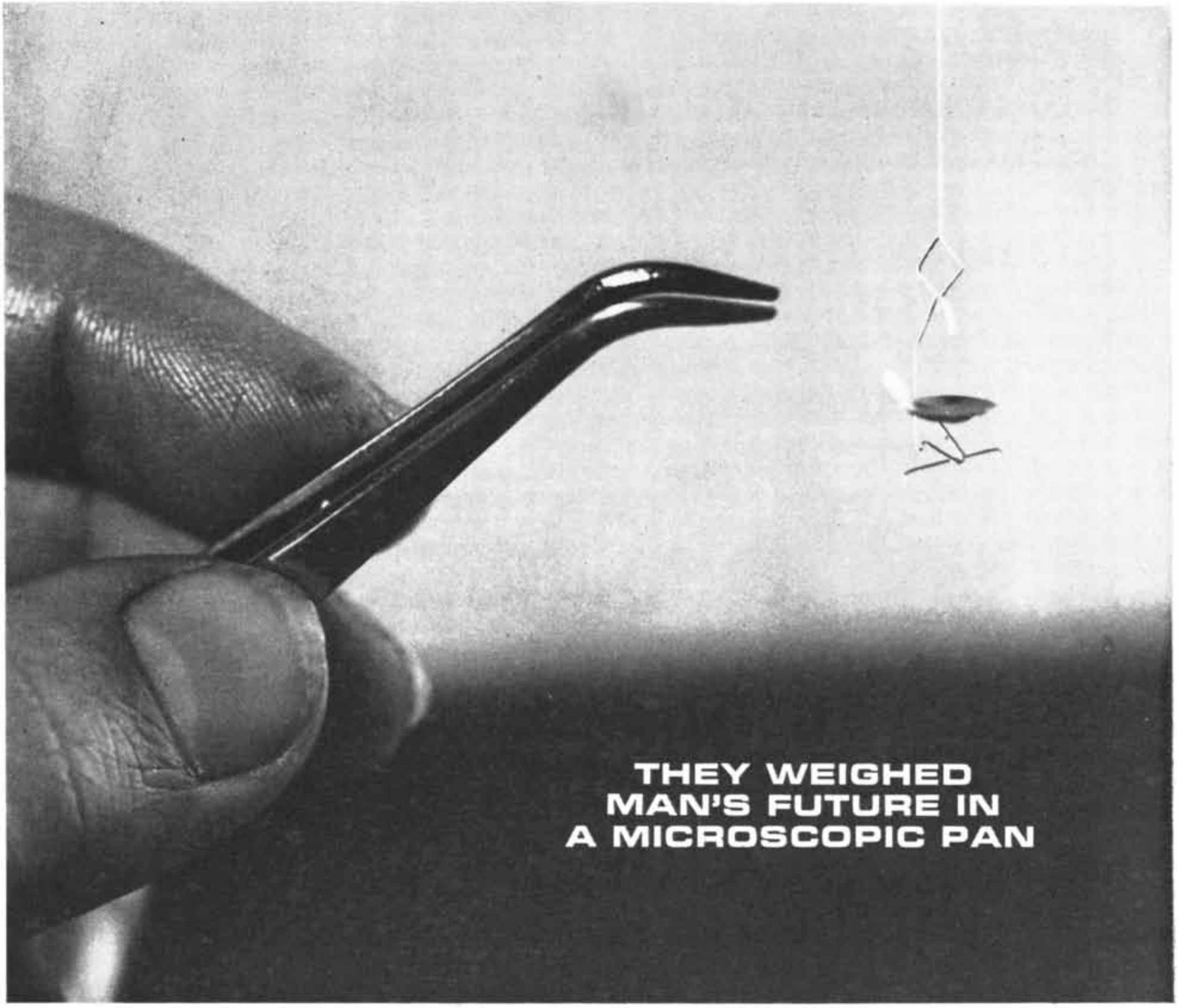
These achievements, however, cannot explain Jung's extraordinary influence in contemporary culture. The Western world is in a state of spiritual crisis. The majority of men still hold on to religious concepts, but for most of them these concepts have become empty formulas and not the expression of a reality to which one is committed. Under such conditions Jung's lack of commitment and authenticity become attractive to those who find themselves in the same position. Jung, with his mixture of sophisticated superstition, vague pagan idolatry and equally vague talk about God, together with his claim that he was building a bridge between religion and psychology, offered the right mixture to an age of little faith and little reason.

In another sense Jung was truly modern. His concept of the unconscious partakes of the extreme alienation of contemporary society. The unconscious as a "psychic reality" governing man is the alienated form of man's own desires and fears, particularly the archaic and regressive ones. We are not responsible, Jung taught, for these impulses. They rule us and the best we can do is to recognize them and so weaken their power, while at the same time worshiping them. All these features of Jung's personality become transparent in his autobiography. Much as psychoanalysis owes Jung for his contributions, he essentially eliminated its core—the search for truth and for the liberation from illusion—and replaced it by meretricious spirituality and brilliant obscurantism.

Short Reviews

A TREATISE ON PROBABILITY, by John Maynard Keynes. Harper Torchbooks ($2.45). PROBABILITIES AND LIFE, by Émile Borel. Dover Publications, Inc. ($1). AN INTRODUCTION TO MATHEMATICAL PROBABILITY, by Julian Lowell Coolidge. Dover Publications, Inc. ($1.35). AN ELEMENTARY INTRODUCTION TO THE THEORY OF PROBABILITY, by B. V. Gnedenko and A. Ya. Khinchin. Dover Publications, Inc. ($1.45). LADY LUCK: THE THEORY OF PROBABILITY, by

GREAT MOMENTS AT CHICAGO



February 24, 1941: the first appearance of an unknown element, created in a cyclotron, sparks a top priority project at Chicago headed by Nobel prize physicist A. C. Compton. *September 10, 1942:* man weighs the first synthetic isotope – *Plutonium.* The sample weighed only 2.77 millionths of a gram – 1/900,000 the weight of a dime, but the key to unlimited electrical power had been found.

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Warren Weaver. Anchor Books ($1.45). CHANCE, LUCK AND STATISTICS, by Horace C. Levinson. Dover Publications, Inc. ($1.75). Anyone interested in the theory of probability—and who among us, from poker players to astronauts, from philosophers to physicists, from social scientists to storekeepers, is not?—finds that there are never enough books on the subject. It has an intrinsic fascination and a persistent elusiveness; one keeps hoping that this very book, whatever it may be, will clear up a conceptual difficulty, dissolve a nagging doubt or open a new horizon. These six paperbacks, five of them established works, one a fresh venture, are likely to satisfy many tastes and give pleasure and enlightenment to a wide audience. Keynes's brilliant treatise was first published in 1921. His central notion is that probability is a primitive idea, with the terms "certain" and "probable" describing "the various degrees of rational belief about a proposition which different amounts of knowledge authorize us to entertain." In addition to analyzing the fundamental ideas and theorems, the book discusses induction and analogy, the philosophical applications of probability and the foundations of statistical inference. Mathematics is freely used but there are many sections that even the nonmathematician will find engrossing.

The small volume by Borel, a preeminent and prolific French student of the subject, is a readable essay, the emphasis being on the applications of the calculus of probabilities to questions that, for the most part, are related either to everyday living or to illness and death. Life expectancy, the perverse chanciness of the weather, events of small probability, problems of heredity and the miracle of the typing monkeys are among the topics discussed.

Coolidge's book is a sound and respected introductory text, his approach being based on the statistical interpretation of probability. A knowledge of elementary calculus is needed to follow the discussion.

The Gnedenko and Khinchin, translated from the fifth Russian edition, is described as suitable for those who have little mathematics; this is misleading, because many sequences demand considerable experience and sophistication in mathematical manipulation. A gifted high school student could get much out of the book, but it is in no sense a popularization.

Both Levinson's and Weaver's volumes, however, meet the need of the nonspecialist. Levinson's essay, formerly titled *The Science of Chance*, is diverting and relaxed in its discussion of a wide variety of questions, from the mathematics of games to the manifold uses (and misuses) of statistics. Freshly written for the "Doubleday Science Study Series," Warren Weaver's *Lady Luck* is a lively, amusing and authoritative introduction. For years Weaver has gathered anecdotes and examples of the vagaries of chance, and he uses them here to good effect in explaining the fundamental concepts of mathematical probability, the basic rules of the calculus, the measurement of hopes and mathematical expectation, the law of large numbers, the mathematics of rare events and coincidences, the nature of gambling systems and the reign of statistical reason.

SIR THOMAS BROWNE: A MAN OF ACHIEVEMENT IN LITERATURE, by Joan Bennett. Cambridge University Press ($5.50). A pointed and illuminating study of the man and his works. Sir Thomas Browne (1605–1682) was a physician of Norwich. He was a practitioner and an experimenter and, although he was not a fellow of the Royal Society, his interests and the spirit that animated his inquiries into natural philosophy were close to those of the men who founded that body. As evidence of the seriousness of his scientific pursuits we have the opinion of Joseph Needham, who in *A History of Chemical Embryology* acclaims him as the first to make experiments in this field, conducted in the "elaboratory" in Sir Thomas' house. He was by no means free of the errors and prejudices of his time, however, and even as a medical practitioner the following entry in one of his *Commonplace Books* shows that he was not in all respects the perfect healer: "Trie the magnified amulet of Muffetus of spiders leggs worn in a deers skinne or Tortoyses leggs cutt off from the living Tortoys & wrapped up in the skinne of a kid."

Browne, as Mrs. Bennett points out, "lived at the meeting point of the medieval and modern worlds," which helps to explain why he both clung to the old and welcomed the new, was a skeptic and a believer, embraced science and was the disciple of superstition. He is remembered, of course, as a great writer of prose, not only for the incomparable *Religio Medici* but also for such masterpieces as *Urne-Buriall* and *The Garden of Cyrus*. Less read in our time but often mentioned is his longest and most erudite work, *Pseudodoxia Epidemica*, usually known as *Vulgar Errors*. In this remarkable book, which Browne spent years composing, are embodied the fruits of much thought, enormously wide and diversified reading, observation and experiment. It displays for the reader an astounding assortment of human error, of mistaken beliefs that occur and impede progress in different branches of knowledge. Errors about animals, vegetables, minerals and man himself all fall under Browne's scrutiny. He discusses, among other things, lightning and thunder, the custom of saluting a person who has just sneezed, the tenet that mineral crystals are merely congealed water, the alleged medical efficacy of powder made of a unicorn's horn, the effect of garlic on the attractive powers of the lodestone, the opinion that an elephant has no joints ("based on the gross and somewhat cylindrical composure of the legs"). He examines the belief that snails have no eyes; that camphor "begets in men an impotence unto Venery"; "that storkes will live only in republics or free states"; that the blackness of Negroes is "a curse of God derived unto them from Cham, upon whom it was inflicted for discovering the nakedness of Noah." He exposes the errors themselves, shows their origins and makes a general analysis of the prejudices and infirmities of human thinking that make man particularly susceptible to vulgar errors.

No better example can be found of Browne's divided response to contemporary views, his scorn for certain types of nonsense and his hospitality to others than in his opinions about cosmology. Having scored men for their obstinacy and irrational skepticism, as a result of which new discoveries discomfited them, he makes it clear that he is himself still a follower of the Ptolemaic hypothesis. Copernicus had published the *De Revolutionibus* in 1543, more than a century before Browne published *Vulgar Errors.* Galileo had already poked his little telescope at the sky and seen things the Church had proved could not possibly be there. Browne, however, like others of his learned and thoughtful contemporaries, found Copernicus too hard to take. Yet he was a mild and kindly man who was willing to concede the possibility "that the earth doth move," and he would not quarrel with Copernicanism simply because it stretched imagination. As Mrs. Bennett amply demonstrates, both by quotations and by skillful analysis, no one can read Browne carefully without a growing confidence in his "basic good sense," and it is this fact that accounts in large measure for the pleasure to be derived from *Vulgar Errors.* Browne was an inspiring figure as a literary artist, independent and often courageous in his thought. In our own time, in which, for all the dazzling advances of science, vulgar errors and irrationalism continue to enthrall men's minds in matters of utmost human concern, it is well to think back on the work of this most unusual man.

Santos-Dumont: A Study in Obsession, by Peter Wykeham. Harcourt, Brace & World, Inc. ($5.75). An anecdotal biography of the small, frail, dapper, eccentric, wealthy, flamboyant and gifted Brazilian aviation pioneer who spent a large part of his life in Paris, flying balloons, designing and flying fantastic airships and finally building and successfully operating a series of tiny dragonfly heavier-than-air craft—the "Demoiselle" type—that looked and behaved much like their inventor. Santos-Dumont was overpraised during the early part of his life and has been depreciated ever since. There can be no doubt of the importance of his contribution to the progress of aviation, but after a few years of creative work he simply dropped out of the picture. This was in large part owing to the peculiarities of his personality, which on the one hand led him to crave publicity and adulation and on the other hand made him almost pathologically secretive, disdainful and quite unable to learn from the work of others. It was his way or none. Like many other European and American aviation enthusiasts, he took no notice of the major innovations of the Wright Brothers. At first he could not bring himself to believe that they had really flown, that this pair of Ohio bicycle mechanics had achieved what no man had ever achieved before. Thus they had no direct influence on him, and even when their accomplishments were widely accepted and wildly applauded, he sulked in his tent. Within a few years aviation had passed him by and the latter part of his life was unproductive, marred by a lingering, painful illness and by increasing melancholia. For the Brazilians he remains to this day, as Air Vice-Marshal Wykeham tells us, the hero of aviation, the true inventor of the airplane.

Ancient Egyptian Materials and Industries, by A. Lucas. St Martin's Press ($30). This scholarly monograph, first published in 1926 and now issued in a fourth edition revised by the Oxford Egyptologist J. R. Harris, deals with every aspect of Egyptian materials and technology. It includes chapters on cementing materials; the brewing of beer, wine making and distillation of spirits; animal products such as bone, feathers, leather, mother-of-pearl, ostrich egg

shell, parchment, tortoise shell; the making of brick; stoneworking; the uses of wood, mortar and plaster; cosmetics and perfumes; the elaborate art of making inlaid eyes; glazed ware; glass and glass manufacture; metals and alloys; mummification; painting and writing materials; pottery; precious and semiprecious stones. Reviewers of earlier editions of this unique contribution to archaeology complained that the book had no illustrations and that it lacked an index of the Egyptian and Coptic names for the various materials that are described. The reviser explains the fact that neither of these criticisms has been met in the new edition because of the expense involved in the illustrations and the extreme difficulty of preparing an accurate index, since few names of materials are to this day known with any degree of certainty. Considering the price of the book, the reference to the "disproportionate expense" of illustrations is unimpressive, and the absence of any pictorial material must continue to be seriously disappointing, particularly in an otherwise completely engrossing volume. One wishes that a foundation or private Maecenas could have been found to do for this book what was done so splendidly for Charles Singer and E. J. Holmyard's *History of Technology*.

METHODS OF AIR DEODORIZATION, by W. Summer. American Elsevier Publishing Co., Inc. ($16). There is an old joke about a man who went into a delicatessen and asked, "What smells around here?" to which the storekeeper replied, "The business." This book is concerned with a more pervasive problem, namely the increasingly serious contamination of the air by odors due to industrial activity, the growing volume of waste products, sewage-disposal difficulties and so on. It may be true that man's olfactory sense is becoming less acute, but his awareness of atmospheric pollution is not, a circumstance that has led to numerous studies by local authorities of ways to combat the distressing effects of odor-producing particles. The author examines the psychophysiological and engineering fundamentals involved.

FLATLAND, by Edwin A. Abbott. Barnes & Noble, Inc. ($1). It is hard to explain why this rather heavy-handed Victorian satire about life in a land of two dimensions should have survived and still be of interest today. Among the reasons may be that it is unique, that it works out an abstract idea with unshakable determination, that it has to do with mathematics—a seductive subject

even for those who abhor it. Also one is intrigued by the bizarre and quite unforeseeable implications of a simple mathematical hypothesis. Modern science has made the world seem a queer place and about *Flatland* it can be said, at the very least, that it is in complete consonance with this queerness. Here Abbott's book appears as a paperback with all the original illustrations.

FRONTIERS OF SCIENCE AND PHILOSOPHY, edited by Robert G. Colodny. University of Pittsburgh Press ($7.50). A series of lectures given at the University of Pittsburgh in 1960–1961 by several philosophers of science: Carl G. Hempel, Wilfrid Sellars, Michael Scriven, Ernst Caspari, Adolf Grünbaum and P. K. Feyerabend. The value of the papers differs considerably. For example, Scriven's discourse on psychoanalysis and parapsychology is glib and pretentious, whereas Feyerabend's survey of the problems of microphysics and of the controversy surrounding Copenhagen orthodoxies affords a searching and admirably illuminating analysis.

THE IDEAS OF BIOLOGY, by John Tyler Bonner. Harper & Row, Publishers ($4.95). This volume in the "Harper Modern Science Series" seeks to explain certain of the larger themes of modern biology, among them the workings of the cell, the mechanics of evolution, genetics and the processes of development from simple to complex organisms. A well-illustrated, attractively written book that manages to introduce the reader to a broad field in a brief compass but without any sense of strain or hurry.

BIOTECHNOLOGY: CONCEPTS AND APPLICATIONS, by Lawrence J. Fogel. Prentice-Hall, Inc. ($22). The subject of this book is essentially a new one that has arisen in recent years as men move higher and faster, as their machines grow much more complex and as it becomes necessary to consider not only what mechanical systems can be made to do but also what the human organism is able to tolerate when subjected to severe stresses and strains. Machines have an increasingly disagreeable way of placing demands on their operators that are hard to anticipate when the machine is designed.

Notes

THE JOURNALS OF THE EXPEDITION UNDER THE COMMAND OF CAPTS. LEWIS AND CLARK, edited by Nicholas Biddle. The Heritage Press ($12.50). An attrac-

tive two-volume reissue of Nicholas Biddle's early 19th-century edition of the great journals of Lewis and Clark, supplemented by journals kept by two of the sergeants accompanying them on the expedition. Illustrated with water colors and drawings by Carl Bodmer and other contemporary artists.

RUSSIAN-ENGLISH CHEMICAL AND POLYTECHNIC DICTIONARY, by Ludmilla Ignatiev Callaham. John Wiley & Sons, Inc. ($19.50). A second, revised and updated edition of a standard work intended chiefly for the chemist and chemical engineer.

THE PRACTICAL COGITATOR, selected and edited by Charles P. Curtis, Jr., and Ferris Greenslet. Houghton Mifflin Company ($6.95). A third, revised and substantially enlarged edition of a "thinker's anthology" incorporating favorite passages from the wide readings of two cultivated men. Both Curtis and Greenslet died in 1959.

HANDBOOK OF ANALYTICAL CHEMISTRY, edited by Louis Meites. McGraw-Hill Book Co., Inc. ($47.50). A reference volume that embraces the fundamental data and practical procedures most useful in analytical chemistry.

SELECTED PAPERS OF KAJ LINDERSTRØM-LANG, edited by Heinz Holter and others. Academic Press ($17). A selection of the scientific papers of the late Kaj Linderstrøm-Lang, a leading Danish biochemist.

ATOMS AND THE UNIVERSE, by G. O. Jones, J. Rotblat and G. J. Whitrow. Charles Scribner's Sons ($4.50). A second and revised edition of an able popularization of physics and astronomy. Photographs and diagrams.

INSECTS IN RELATION TO PLANT DISEASE, by Walter Carter. Interscience Publishers, John Wiley & Sons, Inc. ($25). Intended for reference and as a source book, this monograph deals with insects and their activities as transmitters of plant-disease-producing organisms, with plant diseases caused by the toxic secretions that insects inject into the plant and with their role in transmitting plant viruses.

THROUGH ALCHEMY TO CHEMISTRY, by John Read. Harper Torchbooks ($1.75). The late John Read's palatable and instructive historical account of the transformation of alchemy into chemistry. A paperback.

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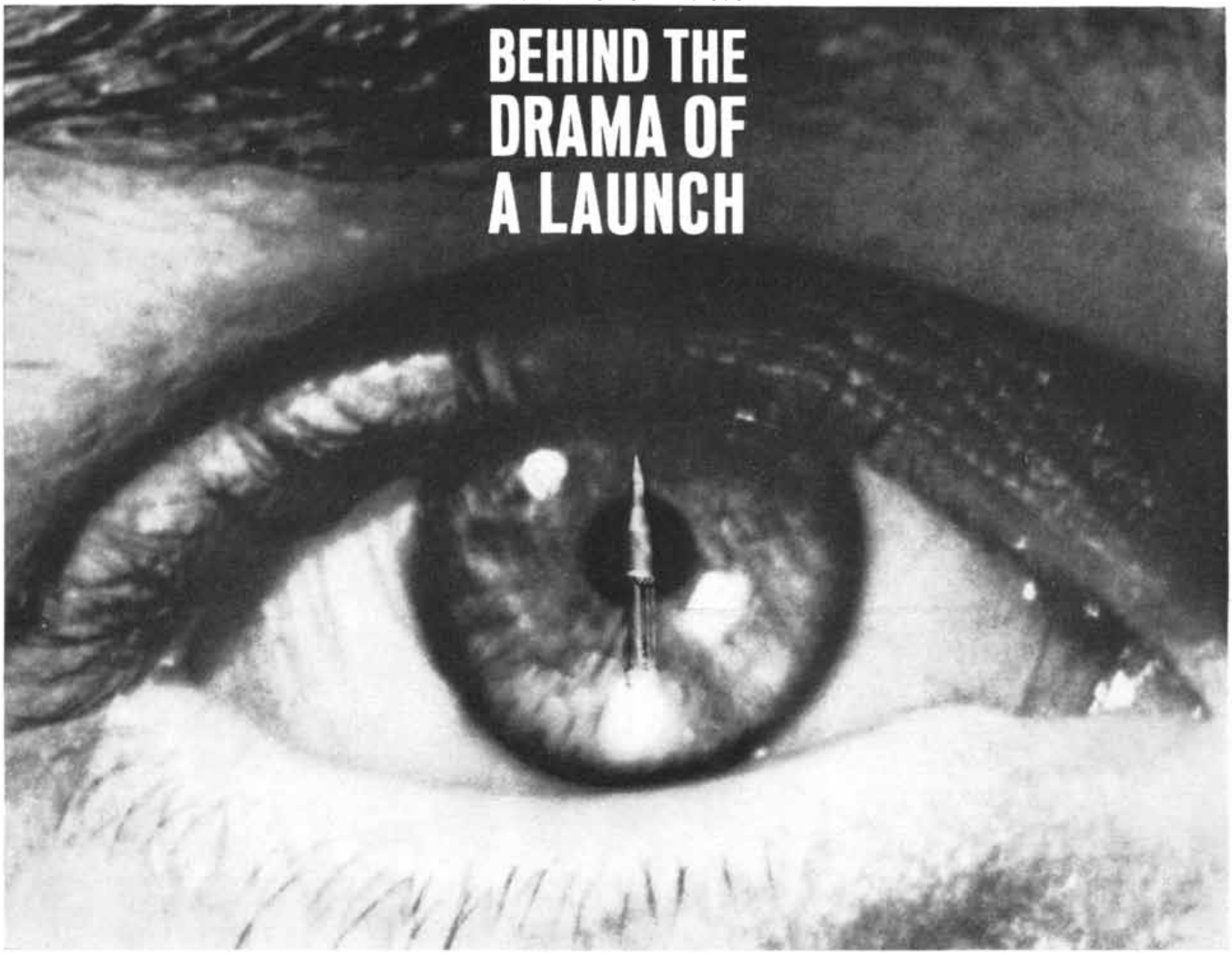

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