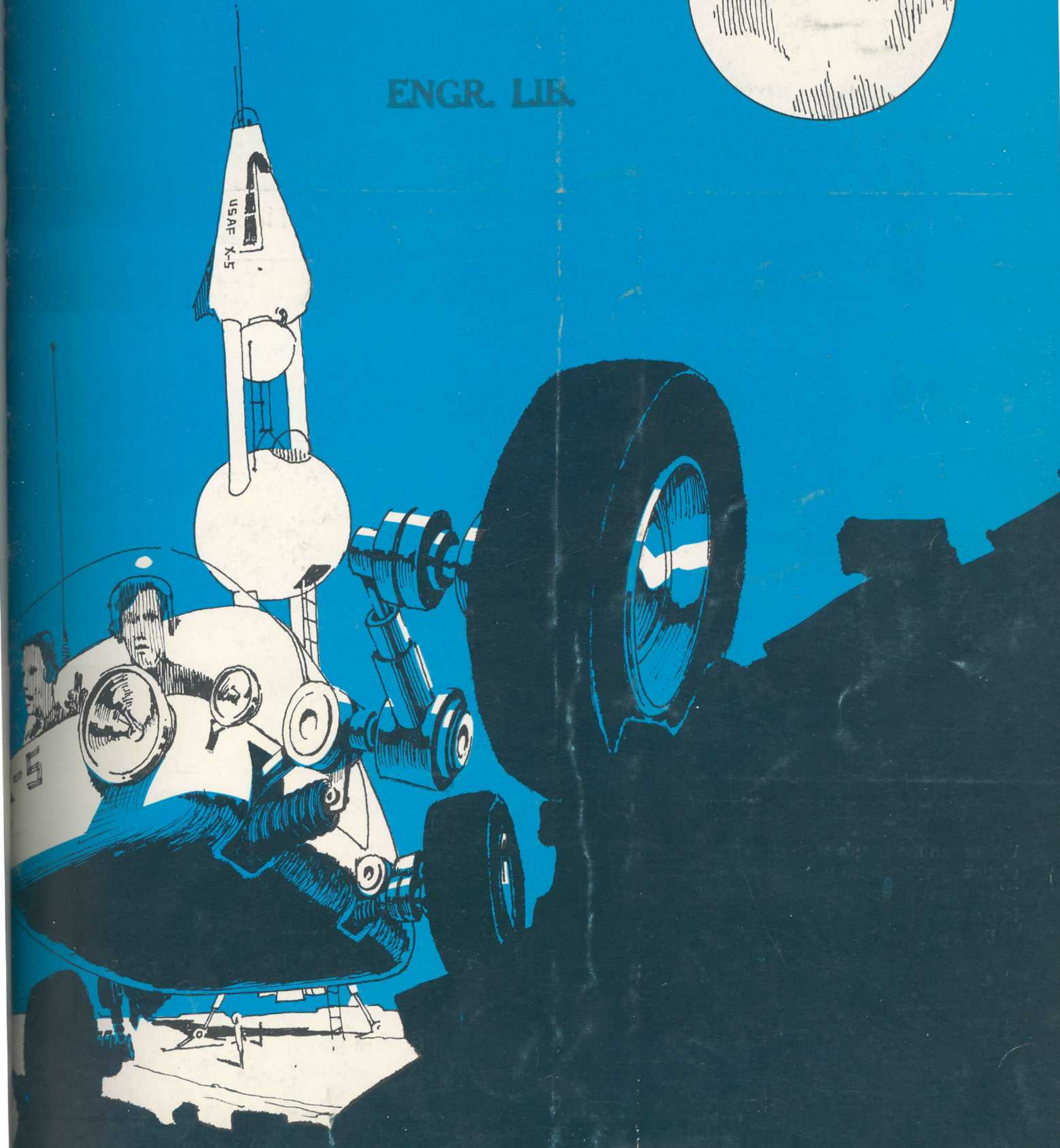
# SPARTAN ENGINEER

NUARY, 1966



**Seven-tenths of the earth's surface is water but 97% of it is salty**

## Westinghouse desalting plants can make the sea an endless source of fresh water

Where can the earth's expanding population get the fresh water it needs? We can get it from the endless supply in the sea.

Desalting plants offer one of the most practical solutions to the problem.

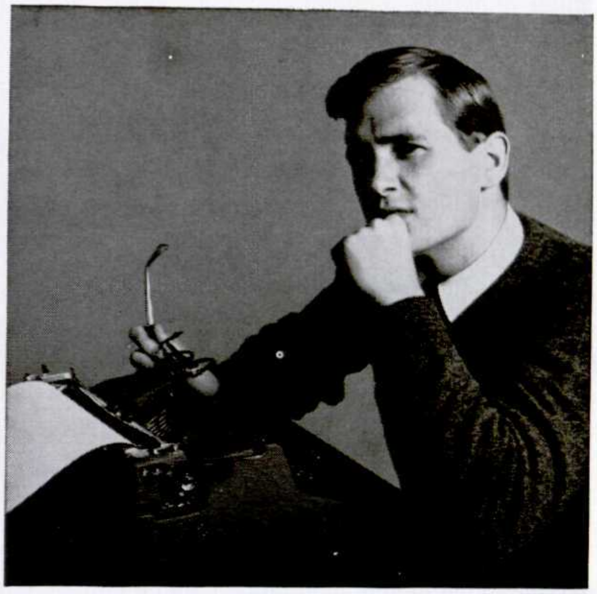
Since 1951, 57 Westinghouse desalting units have been installed around the world. They are desalting millions of gallons of water a day.

Westinghouse is prepared to start building water-desalting facilities to help solve water deficiencies for coastal cities of any size—anywhere in the world.

**You can be sure if it's Westinghouse**

For information on a career at Westinghouse, an equal opportunity employer,
write L. H. Noggle, Westinghouse Educational Department, Pittsburgh, Pa. 15221.

Engineers & Scientists



# With all the companies making the same promises, how do you tell the difference?

It is difficult! Perhaps the best and only way is to study the company carefully—to see if its structure, range and operational modes permit it to make good its promises. If you scrutinize Sylvania Electronic Systems, you'll discover a number of salient facts that may help clarify the matter for you.

Note first that Sylvania employs the small group form of organization—within its nationwide complex of research and development groups, manufacturing plants and world-wide field engineering operation. This makes swift individual progress and development possible within a wide choice of current in-house projects.

Note particularly the diversity and breadth of SES projects. You may advance in a technical or administrative capacity in any of these areas: ground electronics equipment for Minuteman missile sites...research and development in electronic warfare field...electronic security systems...ASW systems...special purpose airborne computers for incorporation into U.S. Air Force large scale electronic systems...laser systems...design of spaceborne electronic and optical systems...plus world-wide engineering support systems.

Note that SES has worked out three distinct routes for advancement, all with equal rewards—technical specialist, technical manager, program/project manager.

Finally, note how SES encourages ambitious individuals to accelerate their development through participation in Division-wide conferences, in-plant courses and seminars and post-graduate study plans conducted on an unusually generous scale.

The success of the SES mission—to manage government systems programs for General Telephone & Electronics, the parent corporation—depends on the professional and intellectual growth of its personnel. In every respect, SES has created an environment to foster that growth. Be sure that any prospective employer you consider has established a growth climate of like specifications.

**Making promises is one thing. Making progress is another.**

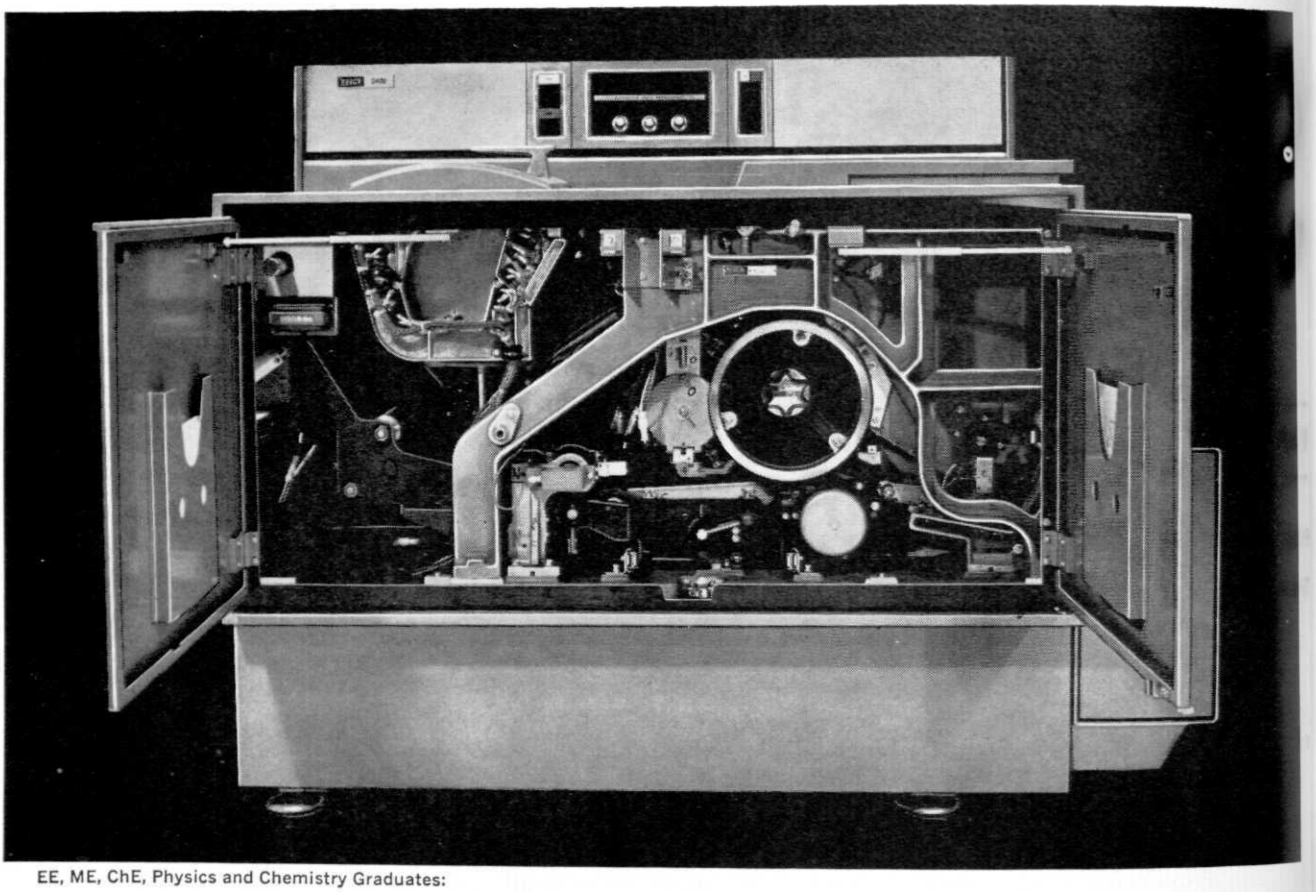
GT&E

GENERAL TELEPHONE & ELECTRONICS
Total Communications from a single source through

SYLVANIA ELECTRONIC SYSTEMS

SES LABORATORIES ARE LOCATED SUBURBAN TO SAN FRANCISCO, BUFFALO AND BOSTON

For further information about any of these locations, see your college placement officer or write to:
Manager of College Relations, 40 Sylvan Road, Waltham, Massachusetts 02154. An Equal Opportunity Employer.



EE, ME, ChE, Physics and Chemistry Graduates:

# How soon after graduation will somebody give you a chance to invent something?

**It could happen on your first job.**

Some very young engineers and scientists at Xerox helped our "old timers" invent the electro-mechanical-optical-chemical machine pictured above—the Xerox 2400. On its patent documents you'll find names like John Wirley (BSEE Univ. of Detroit '60), Henry P. Jankowski (BSEE Rensselaer Poly '62), and Larry H. Warren (BSEE Clarkson '63). They all joined Xerox right after graduating.

The 2400 is no fluke. It's just a recent example of a tradition that began in 1959, when Xerox revolutionized the office copying field by introducing the now world-famous 914 Copier. From the 914 onward, every new piece of equipment or system we've developed has had no real counterpart already on the scene from any competitor.

What about the future? It gets even more interesting. Because as advanced as today's systems may appear, they don't yet fully reveal the true technology Xerox is pursuing—graphic communications.

Born out of the global information explosion and its incredible potential for helping to solve man's oldest problems (as well as his newest scientific riddles), graphic communications at Xerox encompasses the entire spectrum of communications in a graphic sense: the formulation, reception, transmission, recording, storing, retrieving, processing, copying and presentation of any meaningful images.

And if you don't think all this has a habit of creating continuing opportunities to "invent something," ask John, Henry, Larry . . . or some of your own alumni who started their careers here...or your Placement Director. If you prefer, write directly to Mr. Stephen G. Crawford, Xerox Corporation, P.O. Box 1540, Rochester, New York 14603.

XEROX

An Equal Opportunity Employer

XEROX, 2400 AND 914 ARE TRADEMARKS OF XEROX CORPORATION

**Performance Note:** The Xerox 2400 (illustrated) can produce copies on ordinary paper directly from an original document at the rate of 2,400 per hour. No "master" need be prepared first. An operator simply places the original on the machine, dials the number of copies wanted, and presses a button.

# SPARTAN engineer

**VOLUME 19** **NUMBER 2** **JANUARY, 1966**

FRED GEORGE . . . . . . . . . . . . . . . . . . editor
TOM Mc CLURE . . . . . . . . . . . . . . . . . . artist

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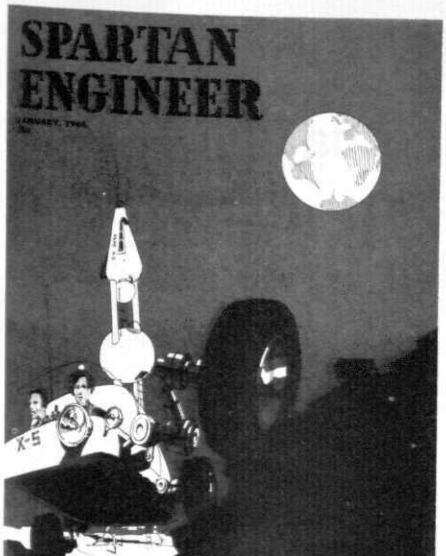

Our artist's conception of the first Lunar explorers on the surface of the moon.

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ALABASTER STATUETTE—SUMERIAN. THE METROPOLITAN MUSEUM OF ART, ROGERS FUND, 1950.

# He was a great scientist in his day

This Sumerian was minding our business five thousand years ago.

Like Olin, he specialized in chemicals and metals. He smelted copper and tin to make bronze. He made an iron axle, put it between two wheels, and off he went.

Men have always been trying to find the answers to important problems. Today, Olin is at it, harder than ever.

Our pioneering research in liquid chlorine helped eradicate typhoid and other water-borne diseases.

Our anti-tubercular drug, NYDRAZID® is a major reason TB deaths decreased 60% in the last eight years.

Olin's ammonium phosphate fertilizer (Ammo-Phos®) makes it possible for farmers to grow more food than ever before.

And to prevent the tremendous waste in food spoilage, we're working on an antibiotic-coated plastic wrapping.

To take a big sting out of life, Olin is developing a high speed cartridge that enables medicine to be injected without the use of hypodermics.

But none of these advances could have been made without our scientists.

Every division of Olin seeks the creative, scientific mind for the answers to the research problems of our day. If this is the kind of work that interests you, call Olin or write to M. H. Jacoby, College Relations Officer, Olin Mathieson Chemical Corporation, 460 Park Avenue, New York 22, N.Y.

Olin

"An Equal Opportunity Employer"

*Editorial..*

# What about the People on the Curb?

I don't understand people. Maybe it's because I'm only 19 years old, or maybe it's because I'm an engineer. I just don't understand people at all.

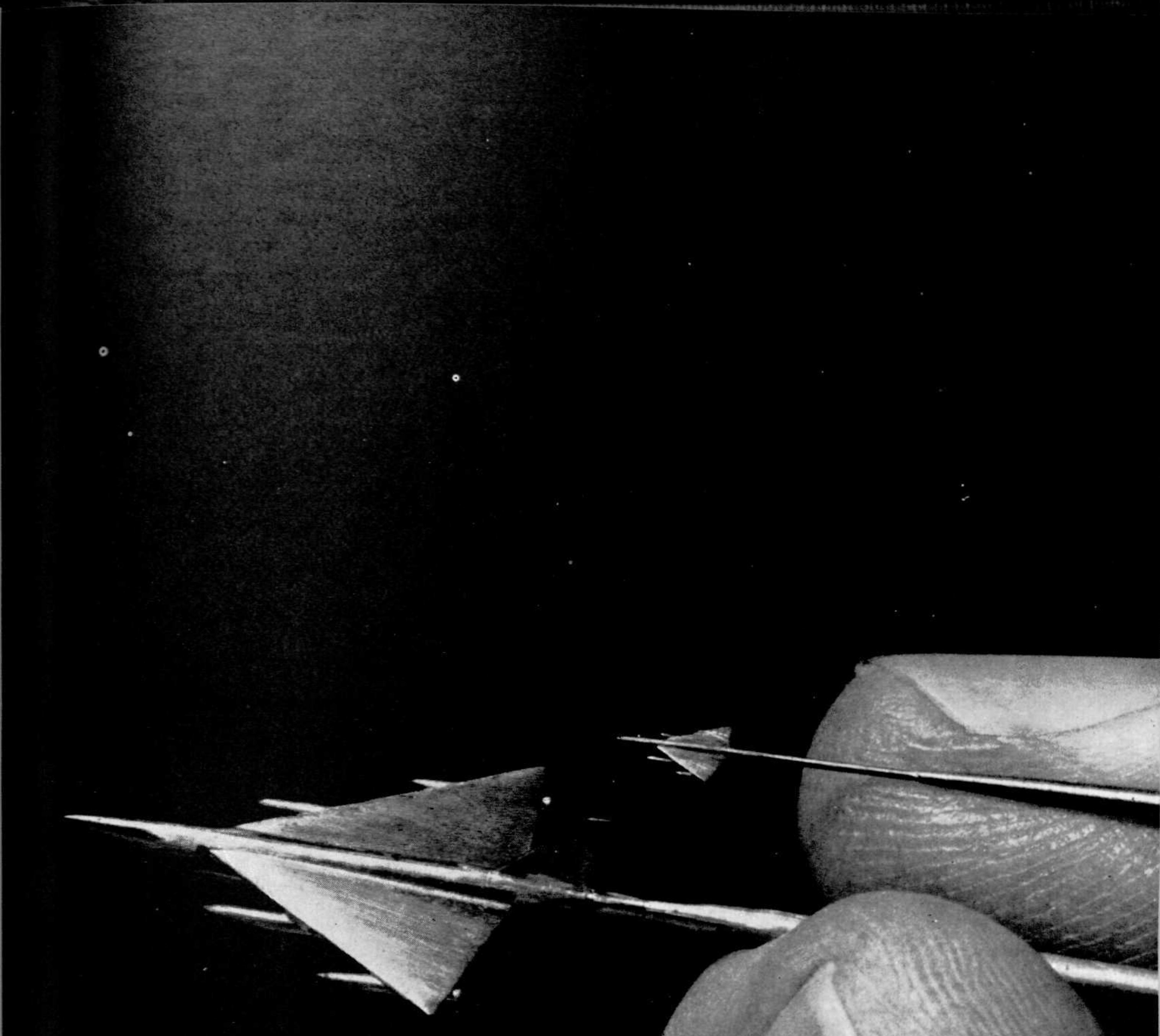
A campus bus seats 53 people, with standing room for 50 or 60 more. I got on a bus today, across from the Brody complex. When the bus left, 15 people were left standing at the curb in the cold to wait for the next bus. Yet there would have been room for 20 more people if those on the bus had moved to the back and filled in the empty spaces between them. Despite three requests by the bus driver, those standing in the aisles would not move back fully, but continued to leave unnecessary empty space. They left 15 people standing in the snow on the curb.

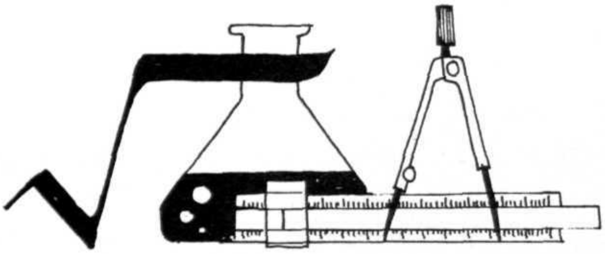
Why will people force others to stand in the cold, when moving three or four feet would prevent it? Why do their egos require a space four or five times the size of the space their bodies require? Are they afraid that someone will actually bump against them (horrors) when the bus turns a corner? Could it be that these people aren't even aware of the discomfort of those who are being forced to wait for another bus?

Furthermore, these "mature" people grumble if asked to move as far back as possible. Is it unjustified for the bus driver to try to carry as many people as he can? I watched a girl stand in the middle of the aisle, with six feet of unused space behind her, inaccessible to those wishing to board the bus. Five or six people could stand in that area, six feet long and three feet wide, but she stood there expressionless while the driver asked twice for people to move back. The third time the driver asked, she scowled and moved back a foot and a half!

Why, when a student responds to the bus driver's plea by saying, "C'mon, let's move back and make room," does he receive dirty looks and not even half-hearted cooperation? Why don't people have any consideration for others? I don't understand at all.

--B.G.





# PLACEMENT BUREAU

(Note: This is only a list of those employers scheduled to visit MSU as of January first. This does not mean that additional employers will not come to MSU on a given date, or that the employers listed here will not add to or revise their scheduled visits.)

January 12
Marshall Space Flight Corp.
National Electric Welding
National Home Corp.
Peerless Division of the American Cement Corp.
Pitt. Plate Glass
Sealright Corp.

January 13
Carnation
Cities Service Oil Co.
Illinois Bell Telephone
Packaging Corp. of America
U.S. Corrugated Fiberbox Co.

January 14
Ansul Co.
Carnation
Cities Service Oil Co.
Food Machinery Corp.
Naval Ordinance Laboratory
Morse Chain Co.
Pock Corp. of America
U.S. Rubber

January 17
Abitibi Corp.
Continental Can Co.
Heath Survey Consultants
McLouth Steel
Sylvania Electric System

January 18
Alleghany Ballistics Laboratory
Ex-Cel-O Corp.
Interlakes Steel Corp.
Leeds & Northrup Co.
Ohio Edison Co.
Penn Salt Chemical Co.
Raytheon Corp.
West Virginia Pulp and Paper
U.S. Geological Survey

January 19
Alleghany Ballistics Laboratory
B F Goodrich
Bulldog Electric Division of I.T.E.
Congall Corp.
Esso Research
Interlake Steel Corp.
Raytheon Corp.
Union Carbide
U.S. Atomic Energy
Xerox Corp.

January 20
General Telephone and Electric
Hamiliton Standard Division of United Aircraft
Sealed Power
Whirlpool

January 21
Giffels & Rossetti Consulting Co.
Hamilton Standard Division of United Aircraft
Northrup Corp.
Whirlpool
Wyandotte Chemical Co.

January 24
Abbot Labs
Applied Physics Laboratory
Federal Mogul Corp.
U.S. Naval Missile Center

January 25
Abbot Labs
Applied Physics Laboratory
DuPont
Fairbanks Morse
General Tire & Rubber
Upjohn

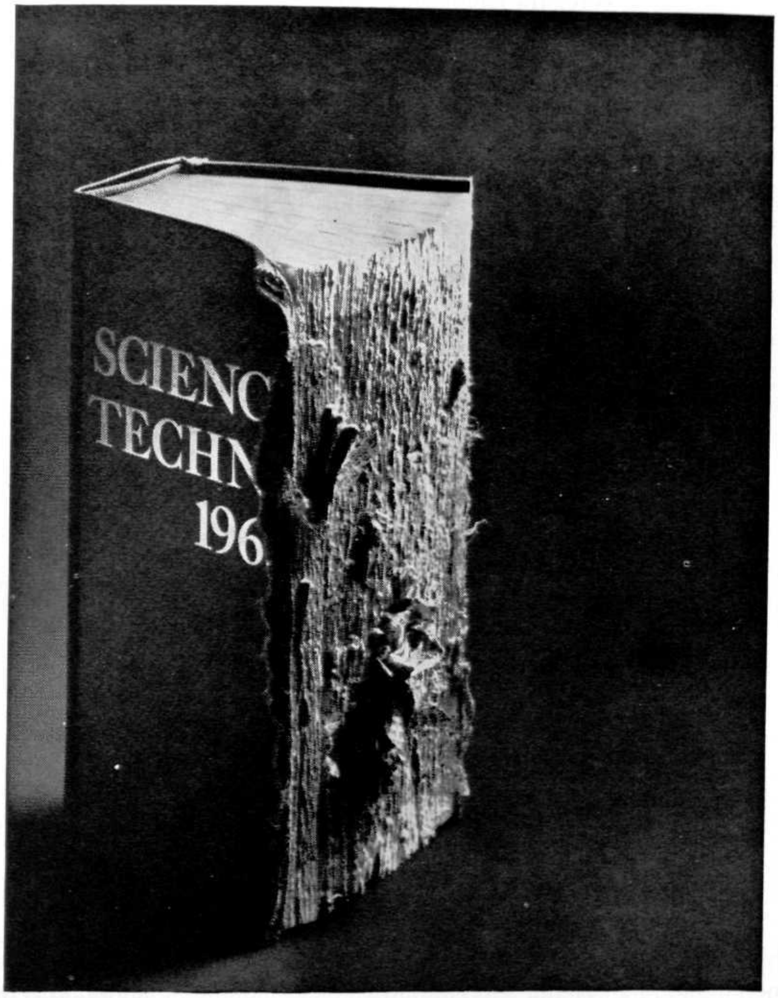
January 26
Boeing
DuPont
Reynolds Metals
Union Carbide

January 27
Boeing
John Deere and Co.
Reynolds Metals
Swift & Co.
Union Carbide

January 28
Boeing
Desoto Chemical Coatings
E. W. Bliss
Vick Chemical Co.

January 31
Lear Siegler
Lockheed-California
March & Co.
North American Aviation
U.S. Department of Public Health
U.S. Naval Ordinance Test Center
General Motors

February 1
General Motors
North American Aviation
Hercules Powder Co.
Jones & Laughlin Steel
Minnesota Mining & Manufacturing
Socony Mobil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196

February 2
Radio Corp. of America
General Mills
Cummins Engine
Square D
General Motors

February 3
Radio Corp. of America
General Mills
General Motors
Bell Telephone
Cornell Aeronautical Lab.
Alleghany Ludlum Steel Corp.

February 4
Anchor-Hocking
Gulf Research & Development
Scott Paper
General Motors

February 7
General Electric
Dow Corning
J. I. Case
Owen-Ames-Kimball

February 8
General Electric
U.S. Steel
Rockwell Standard
Nalco Chemical Co.
Babcock & Wilcox

February 9
Standard Oil
International Harvester
Kimberly-Clark
Goss Co.

February 10
Standard Oil
Kimberly-Clark
General Foods
Control Data Crop.

February 11
Inland Steel
Pfizer & Co.
Hewlett-Packard Co.

February 14
Sinclair
Bendix
General Dynamics
Factory Mutual Engineering Div.

February 15
Bendix
General Dynamics
Fischer Governor
Burrows
McDonald Aircraft
Sylvania Electric Systems

February 16
Olin
McDonald Aircraft
Power Controls-Midland Ross
U.S. Army Tank Automotive Center
West Virginia Pulp & Paper

February 17
Motorola
Douglas Aircraft
International Milling
Honeywell Inc.
Firestone Tire & Rubber

February 18
Douglas Aircraft
Firestone Tire & Rubber
KVP-Sutherland
Ohio Dept. of Highways
Grummend Aircraft

February 21
Caterpillar Tractor Co.
The Martin Co.
Texaco
Glidden Co.

February 22
Caterpillar Tractor Co.
The Martin Co.
Ford
Texas Instruments
Goodyear Atomic
Bell Arrow Systems

February 23
Ford
The Martin Co.
Texas Instruments
Alcoa
Indiana & Michigan Elec. Co.
I.B.M.

February 24
I.B.M.
Allis-Chalmers
Sundstrand Corp.
Magnavox
Youngstown Sheet & Tube

February 25
U.S. Rubber
Weyerhauser
Standard Oil
California State (Personnel Board)

February 28
Shell Oil
Kodak
New Holland
Rex Chain Belt

March 1
Owens-Illinois
Hughes Aircraft
Inland Container Corp.
Ameco Chem. Co.
U.S. Army Corp of Engineers

March 2
Ownes-Illinois
Falk Corp.
Industrial Nucleonics
Humble Oil
Proctor & Gamble

March 3
Collins Radio Co.
Proctor & Gamble
Kellogg Co.
U.S. Gypsum
B. F. Goodrich
NASA

March 4
Collins Radio Co.
NASA
Dura Corp.
Washington State Highway Commission
Miles Lab.

March 7
Sperry Phoenix
Miss. Valley Structural Steel Co.
Navy-Marine Engineering

March 8
Surface Combustion
Libbey-Owens-Ford
Westinghouse Elec.
Air Force Logistics Command

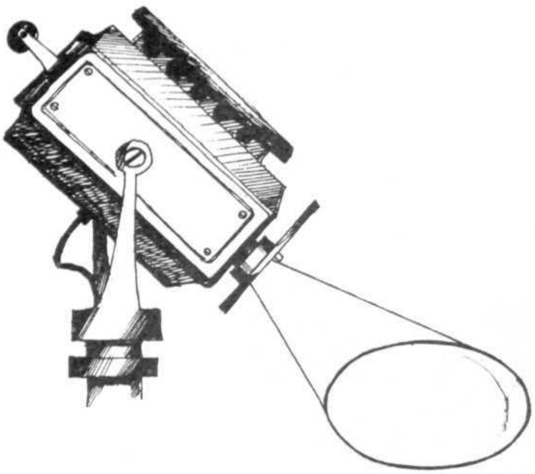
March 9
Interstate Elec.
M. W. Kellogg
U.S. Army Material Command

March 10
Continental Oil
Interstate Minerals & Chemical
Worthington Corp.
Pan-American Petroleum

March 11
Interstate Minerals & Chemical
Hyster Co.
Aeroneutronics


MECHANICAL ENGINEERS AT DU PONT
CHEMICAL ENGINEERS AT DU PONT
DU PONT
ENGINEERS AT DU PONT

# *INDUSTRIAL SPOTLIGHT*



# SCOTT INDUSTRIES, INC.

**edited by Richard Marett**

One of the major problems facing the engineering programs of many universities today is the expense and space availability of conducting regular programs of student experimentation. This problem is being eased greatly by the Scott Professional Development System for Engineering Education, a division of Scott Industries, Inc.

Scott Professional Development Systems (18 in all and more planned) are small, usually bench-sized or portable, pieces of apparatus. They incorporate, either integrally or as accessory equipment, everything needed to interest engineering students in setting up and observing experiments, in various fields of engineering. Scott Systems are used in Senior and Junior Colleges throughout the country. Currently many are also finding their way into Vocational schools, into Adult Education, and into First-Class Technical High School Programs.

Recently five new or improved Systems for Engineering Education have been announced to the educational systems market.

SCOTT SUBSONIC WIND TUNNEL SYSTEM-Model 9059: Self-contained unit (70 inches high, 130 inches wide and 33-1/2 inches deep) delivers horizontal laminar air flows at velocities from 15 to 110 feet/second to 6-inch square transparent plastic test section capable of open or enclosed operation. It can also deliver up to 15 feet/second positive or negative direction vertical laminar air flows to 18 inch open test sections. Vane-axial blower speed is infinitely variable between 438 and 1750 rpm.

SCOTT ANALOG-FLUID CIRCUIT-Model 9012: Bench-sized unit is electrically analagous to flow conditions that develop in piping circuitry under various input conditions.

Plug-in modules simulate various sizes of numerous types of commercial valves, fittings and pipes. Voltage simulates pressure drop through system or component. Current simulates flow. Inputs are manipulated by master control to electrically

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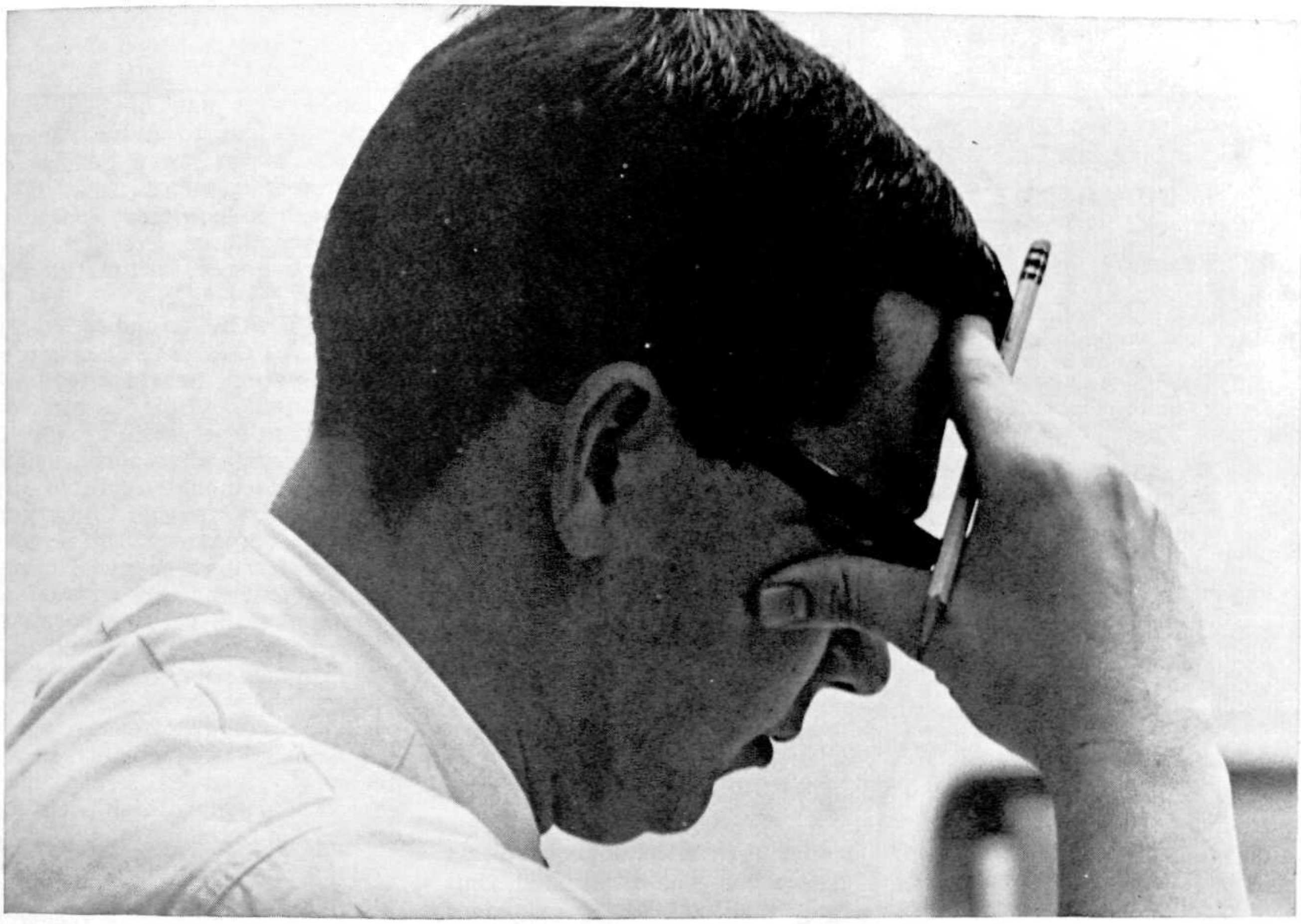
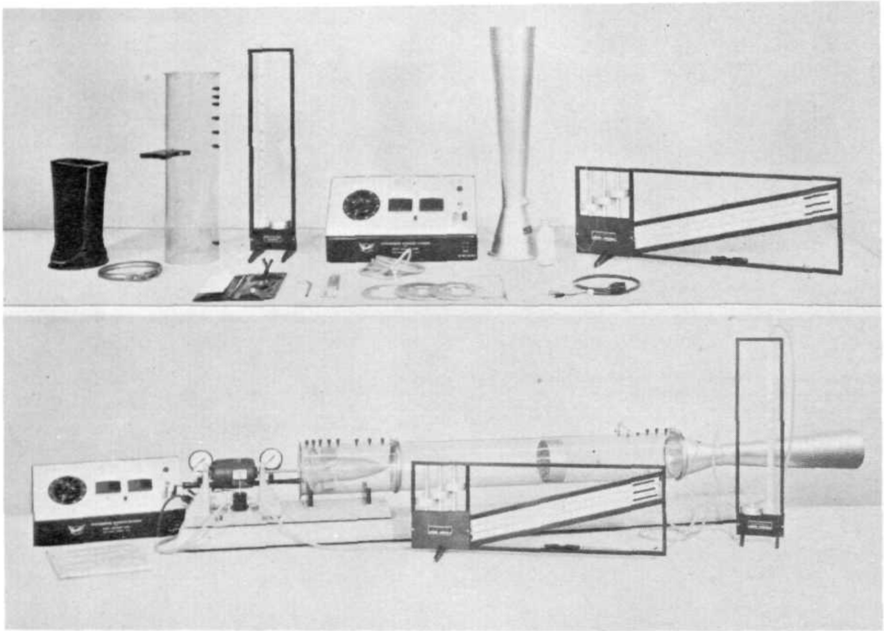
SCOTT SUBSONIC WIND TUNNEL SYSTEM – MODEL 9059





SCOTT TUBOFAN SYSTEM – MODEL 9005

CONTINUED FROM PAGE 12

duplicate hydraulic situations. Immediately readable measurements summarize the complex calculations of incompressible fluid flow (current) through an entire simulated piping system, thus elimating need for individual calculations which can become tedious as components are added.

SCOTT STRAIN INDICATOR SYSTEM-Model 9083: This benchtop, cabinet unit is designed as an economic means of introducing the student to strain gage investigation of stresses and strains in materials. Accuracy is 3% of full scale (10,000 microinches per inch). Current is fed to the bridge from an ac rather than a dc source so that drift problem is eliminated. Unit is fully silicon transistorized for reliable operation and long life. Positive burn-out protection makes unit electrically student-proof. It is intended for use with standard bonded resistance wire strain gages and complements other Scott units designed to load-test materials and structures.

SCOTT TURBOFAN SYSTEM-Model 9005: This bench-top unit enables student determination of laminar versus turbulent flow properties, pressure and veleocity relationships, turbine blade properties, aerodynamic principles, manometer usage, many more. Dynamometer effects are attained with use of high velocity air-jets to drive fan and operate motor as a generator. Instrumentation includes pitot tube with manometer, load cell with manometer, venturi with pressure gages, voltmeter and ammeter.

SCOTT FORCE and MOMENT INDICATOR SYSTEM-Model 9032: System provides precise determination of forces and moments resulting in lift, drag, roll, pitch and yaw when aerodynamic shapes are mounted on thin column in air streams of various types. Comparison of aerodynamic behavior of various model shapes and demonstration of floating shafts is also possible. This bench-sized unit utilizes virtually friction-less air-supported shafts and can be null set. Accordingly measurements are obtained by manometers connected to load cells and calibrated to read to high accuracy directly in force units.

Each Scott System is designed specifically for its task of inducing original student research as well as demonstrating fundamental laws in classical areas of the engineering curricula...the behavior of structures under stress (Scott Structures Test System-Model 9004), the properties of materials (Scott Materials Test System-Model 9014), fluid flow characteristics (Scott Fluid Circuit System-Model 9009 and Analog-Model 9012), thermodynamics (Scott Double Pipe Heat Exchangers-Models 9052 and 9052B; Radiation and Tempature Measurement System-Model 9053) are only a few in Scott's

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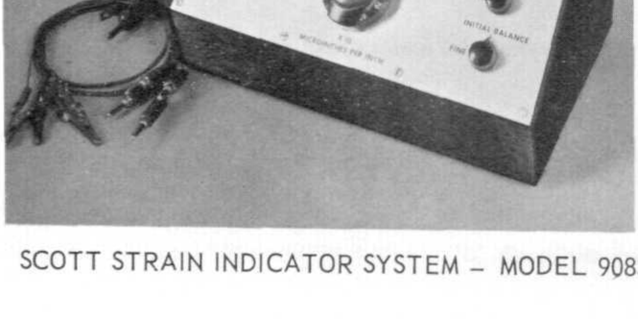
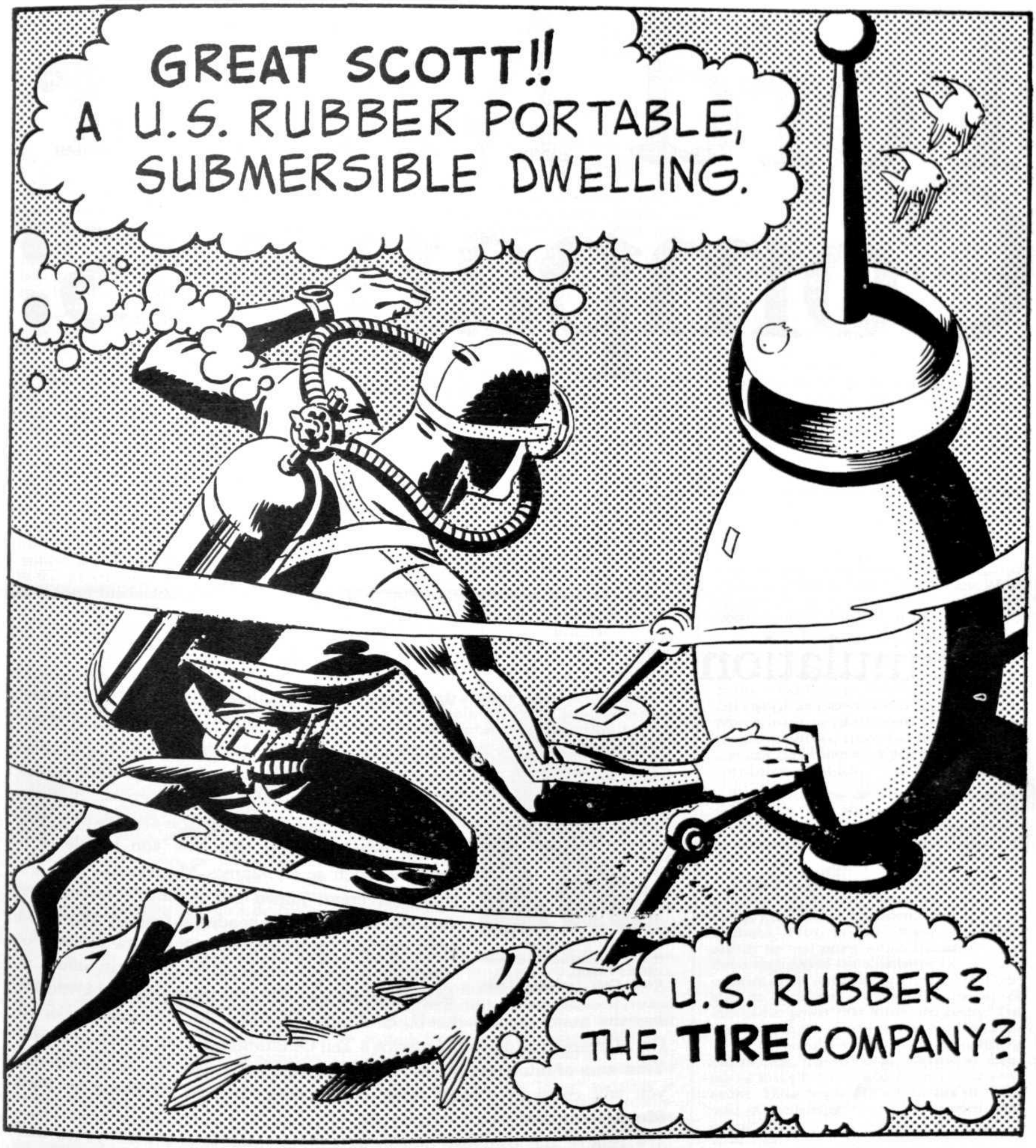


SCOTT STRAIN INDICATOR SYSTEM – MODEL 9083

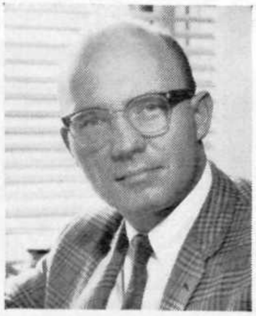
SCOTT ANALOG – FLUID CIRCUIT – MODEL 9012



GREAT SCOTT!! A U.S. RUBBER PORTABLE, SUBMERSIBLE DWELLING.
U.S. RUBBER? THE TIRE COMPANY?

# Ford Motor Company is:

## stimulation



*James E. Mercereau*
*B.A., Physics, Pomona College*
*M.A., Physics, Univ. of Ill.*
*Ph.D., Calif. Institute of Tech.*

What does it take to "spark" a man to his very best . . . to bring out the fullest expression of his ability and training? At Ford Motor Company we are convinced that an invigorating business and professional climate is one essential. A prime ingredient of this climate is the stimulation that comes from working with the top people in a field . . . such as Dr. James Mercereau.

Jim Mercereau joined our Scientific Laboratory in 1962. Recently, he headed a team of physicists who verified aspects of the Quantum Theory by creating a giant, observable quantum effect in superconductors. This outstanding achievement was the major reason the U. S. Junior Chamber of Commerce selected Dr. Mercereau as one of "America's Ten Outstanding Young Men of 1964." Your area of interest may be far different from Dr. Mercereau's; however, you will come in contact with outstanding men in all fields at Ford Motor Company.

We believe the coupling of top experience and talent with youth and enthusiasm is stimulating to all concerned. College graduates who join Ford Motor Company find themselves very much a part of this kind of team. If you are interested in a career that provides the stimulation of working with the best, see our representative when he visits your campus. We think you'll be impressed by the things he can tell you about working at Ford Motor Company.

Ford

The American Road, Dearborn, Michigan

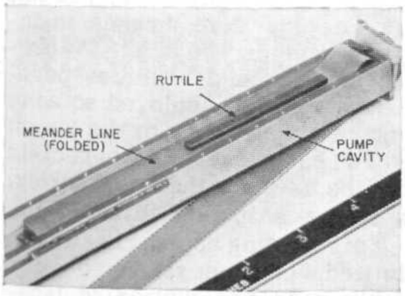
*An equal opportunity employer*

# Engineering and Science at RCA

## Traveling Wave Masers

RCA's recent maser research and development has yielded systems with outstanding low-noise microwave amplifier performance along with adaptability for field use. These amplifiers exhibit ultra-low noise temperature (8-10°K) and high gain (30-40 db) with extreme gain stability. Wide tunability (up to 50%) and large instantaneous bandwidth (up to 150 MHz) have been achieved.

Several technique areas involved with this work are of particular interest. Iron- and chromium-doped rutile (titanium dioxide) are employed as active paramagnetic materials, in a "meander-line" slow wave structure, providing wide bandwidth and high gain. Ferrite reverse isolators function to provide a high degree of gain unidirectionality. The requisite magnetic field is provided by a superconducting magnet within a cryogenic enclosure, and the entire system is operated by a closed-cycle refrigerator requiring no helium replenishment, so that field use in radar systems, satellite communications and radiometry is practical. Sectionalized magnet structures with independent controls permit "stagger-tuning" the maser, so that its very high gain can be traded for even greater bandwidth.



The illustration shows the active elements of a maser amplifier typical of such a high-performance system. The meander line, seen as a zig-zag conducting path on a flexible insulating sheet, goes down one side of the pump cavity, folds over, and returns on the other side. The cavity is the terminal portion of a waveguide assembly, with microwave pump energy being introduced at the other end. One of two rutile paramagnetic crystals is shown in close proximity to the meander line, the ferrite isolator being on the opposite side of the meander line and not visible. In operation, the entire structure shown in the photograph lies between pole faces of the superconducting magnet, which provides a precisely controlled and distributed transverse field, typically, of a few thousand gauss. The assembly including the magnet is enclosed in a chamber maintained at 4.2°K.

Amplifiers with performance as described above are by no means the end, however. New advances are in the offing through research in areas including optical inversion (pumping), operation at temperatures above 4.2°K, higher frequency operation, and the use of active materials in powder rather than single-crystal form.

---

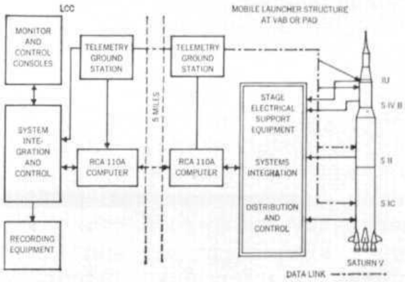
*References:*

*(a) L. C. Morris, "A New Class of Traveling Wave Masers," International Conference on Microwave Circuit Theory and Information Theory, Tokyo, Sept. 11, 1964.*

*(b) L. C. Morris and D. J. Miller, "Traveling Wave Masers Employing Iron-Doped Rutile," Proc. IEEE, Vol. 52, #4, p. 410, 1964.*

## Integrated Launch Control and Checkout Systems for Saturn Lunar Vehicles

Highly sophisticated Saturn automatic ground checkout and launch sequencing equipment has been under development by RCA since late 1960 for the National Aeronautics and Space Administration, Marshall Space Flight Center. The original Saturn Ground Computer System (SGCS) was used on the highly successful Saturn I program; an advanced version of the SGCS is currently being readied for the Saturn IB and Saturn V programs. The RCA 110 computer was the heart of the Saturn I SGCS; the RCA 110A is the heart of the Saturn IB and Saturn V SGCS.



The block diagram shows the tandem, two computer configuration for Saturn V at Complex 39, the lunar program "space port" at NASA's Kennedy Space Center. Complex 39 is based on a mobile launch concept to gain high efficiency in launch operations. Vehicles are assembled in the Vehicle Assembly Building (VAB) on a Mobile Launcher structure. After the Saturn V with its Apollo Spacecraft is completely checked out, the vehicle in its Launcher is transported to one of three launch pads for a remotely controlled launch. The computer in the Launch Control Center (LCC) controls the activities of the "slave" computer in the Mobile Launcher via a 250 kilobit/sec digital data link. The configuration thus remains the same for both VAB and pad operations; only the length of the data link changes. The complex umbilical interface between the vehicle and ground support equipment remains undisturbed until launch. The LCC computer controls the sequence of checkout and launch countdown programs performed by the Mobile Launcher computer via commands transmitted over the data link. The "slave" computer in turn performs the detailed testing and sequencing, performs evaluation and data compression of test results, and transmits the data back to the LCC computer which relays it to the correct operator for display. LCC operators can override, via their console request keyboards, the predetermined sequence of programs stored in the Mobile Launcher computer or handle unusual test situations.

In addition to conventional serial computer functions, special parallel input/output capabilities are included for control of 1008 discrete (relay driver) outputs, monitoring of 1512 discrete (contact closure) inputs, a wide range of DC and AC analog outputs (72 in quantity), a wide range of DC and AC analog inputs (300 in quantity), telemetry interface, 3 internal interval timers, several external clock inputs, and an interface with the spaceborne computer.

In line with the developmental nature of the total Saturn program, the role of RCA's Saturn Ground Computer System is continuing to expand in factory and static testing, as well as launch operations, as automation techniques are applied to other Saturn subsystems.

*Reference—J. E. Sloan and J. F. Underwood, "Systems Checkout for Apollo"—Astronautics and Aerospace Engineering, March 1963.*

## A Light Detector That Makes Laser Communications Practical

RCA has developed a photoconductive device that operates on an alternating current that can sense up to 100 million changes in light intensity per second. This is sufficient to distinguish as many as 25 separate television programs, all carried on a single laser beam. This major breakthrough in light detection is extremely fast, enormously sensitive and is responsive to the whole range of optical frequencies, ranging from infra-red through the visible spectrum to ultra-violet.

By contrast, previous means of detecting laser light employed photoconductors operated by direct current, photoelectric cells, semiconductor photodiodes and electron photomultiplier tubes. The major drawbacks were that these methods were either too slow, too insensitive, or too limited to the portions of the electromagnetic spectrum where most lasers operate poorly, if indeed, at all.

The laser is, to state it simply, a high frequency transmitter with the capacity to carry a fantastic amount of information. The real problem has been to develop a receiver both fast enough and sensitive enough to detect and process incoming information. This new device has the sensitivity, speed and frequency range that can make possible a practical system for laser communications.

This radical new detector is a tiny speck-sized piece of photoconductive material mounted in a small cavity continuously bathed in microwaves oscillating at 10 billion cycles per second.

When a laser beam bearing information in the form of intensity variations enters the cavity, it strikes the photoconductor and frees electrons. They, in turn, begin to oscillate rapidly up and down within the material, in direct response to the alternating electric field inherent in the surrounding microwaves. These electron oscillators control the amount of microwave power that leaves the cavity. The variations in the incoming light are then converted to intensity variations in the outgoing microwaves. Conventional microwave techniques make it possible to process these variations. These techniques are similar to those used in modern radar and commercial television systems.

*Reference—H. S. Sommers, Jr. and E. K. Gatchell, presented at Annual Meeting, Optical Society of America, Philadelphia, October 5-8, 1965, Paper WE-1.*

These are only a few of the recent achievements which are indicative of the great range of activities in engineering and science at RCA. To learn more about the many scientific challenges awaiting bachelor and advanced degree candidates in EE, ME, ChE, Physics or Mathematics, write: College Relations, Radio Corporation of America, Cherry Hill, New Jersey.

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# ON PLANETARY LANDINGS BY SPACECRAFT

**by Tom Heppenheimer**

One of the most important and difficult problems facing engineers today is the problem of planetary landings by spacecraft, or, more specifically, the motions of spacecraft in the immediate vicinity of a planet. In its full generality, this problem deals with such diverse aspects as the motion of winged craft in atmospheres* and the landing of the LEM on the surface of the moon. Few results can be stated which are completely accurate in this field, and inadequacies of knowledge are rather common; recall how the spacecraft Molly Brown failed to develop its theoretically predicted aerodynamic lift and landed short of its target, and how the Russians' soft-lunar-landing attempt of last October failed because the retros were barely off in their reduction of the craft's velocity.

The purpose of this series is to approach this topic in an introductory manner. We shall consider the problem of landing a spacecraft on a planet which posesses an atmosphere, using a fairly general sort of landing orbit. In order to deal with the problem on an undergraduate level, however, we will find it necessary to introduce a good many simplifications and simplifying assumptions. It must be stressed at the outset that our results can claim little or no accuracy in describing the physical situation, for our assumptions will often only be gross approximations and the mathematics will be restricted to elementary differential equations. Nevertheless, this discussion may help give readers an introduction to the subject, which they will later follow up with more advanced study.

The landing approach we will consider has the following characteristics:

1) The ship approaches the planet: in its immediate vicinity it can be considered to be under the influence of only the planet's gravity and its orbit with respect to the planet is a hyperbola. It passes through the atmosphere and is slowed to under parabolic velocity; if its velocity when on the fringes of the atmosphere is so high that drag would not slow it sufficiently, rockets may be fired to slow the ship somewhat.

2) Having passed through the atmosphere, the ship swings outward in an elliptical orbit of high eccentricity with perigee lying within the atmosphere. Thus the orbit will decay rapidly and will be reduced to a circular orbit lying entirely within the atmosphere. (Fig. 1.)

3) This circular orbit will then decay extremely rapidly as the ship is braked strongly. The ship may deploy dive brakes to increase the deceleration. At proper speeds and altitudes parachutes may be deployed so as to reduce the velocity to the lowest possible level. Retro-rockets may be used for the final braking; then the ship will touch down.

This landing approach, suitably limited, can be taken to be a fairly good description of landing approaches which are in use now or are to be used in the immediate future. For example, Step 3 (except for the suggestion of dive brakes) is a fair description of the landing approach of all U.S. and Soviet manned spacecraft launched thus far. Also, the landing approach of the Apollo moonship may be taken to be described by Parts 1 and 3, if we

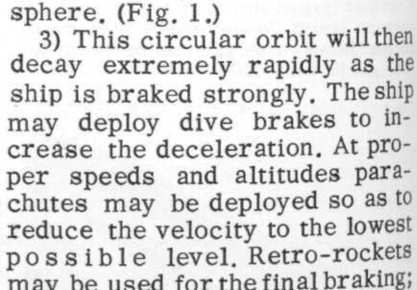

Fig. 1. Braking ellipses, by which the spacecraft's orbit rapidly decays to circularity.

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* For example, the satellite Titan of Saturn is known to have an atmosphere of methane. This suggests a novel form of jet plane, which would carry liquid oxygen in tanks and get its fuel from the atmosphere. The aerodynamics of such a craft in Titan's 100° Kelvin atmosphere would be quite an interesting problem to study.

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CONTINUED FROM PAGE 18.

tie them together by asserting that the spacecraft is braked so strongly in its first encounter with the atmosphere that its orbit is reduced to circularity without the ship leaving the atmosphere again.

Step 2 could be useful in the case of a planetary exploration party landing on their planet. They would want to conduct systematic investigations of the features of the planet, and artificial satellites could be extemely useful tools in this exploration. These satellites could be launched quite easily, into any desired orbit, merely by ejecting them with a small boost at the proper time in the proper ellipse. This would be analogous to antarctic explorers setting out overland to the Pole and leaving instruments behind at various places on the trail to monitor conditions and radio them to the party of explorers.

Of course, the descriptions of land approaches in use today are highly idealized and limited in their usefulness. For instance, with regard to Part 1 we made the "two-body assumption" that we need only consider the two bodies of planet and spacecraft, neglecting gravitational influences of other bodies. Thus, any description of an Apollo landing approach based on our model could only have any sort of validity within a dozen or so radii from either Earth or Moon. Moreover, Step 3 is somewhat limited by the fact that it ignores lifting effects, which are important in the control of a returning Gemini. In addition, we will ignore heating effects on the spacecraft. Thus Parts 1, 2, and 3 should be considered to represent an idealized model of the gross characteristics of a landing spacecraft. However, this model has one great advantage over a more exact (but more complicated) model: it can be treated using physics and mathematics which are entirely familiar to the undergraduate reader.

We will treat the three steps in detail in the second article of this series. Before this, however, we shall consider certain principles and results which will be useful in our discussion. These preliminary results concern the nature of a planet's atmosphere, the nature of orbits, drag forces drag forces on its velocity and distance traveled, and the effect of using retro-rockets. Some of these results will be familiar, or can be found in well-known references and texts; these results we will do little more than state. Other results, less familiar, we will derive in full. The references for the more familiar results are as follows:

Halliday & Resnick, Physics for Students of Science and Engineering (1952), John Wiley & Sons

Yeh & Abrams, Principles of Mechancis of Solids and Fluids (1960), McGraw-Hill

Consider the variation in density with increasing altitude of an atmosphere. It can be shown[1] that the variation in pressure with altitude is given by:

$$p = p_0 e{=}(\rho o/P_0)gy$$

where p is pressure, $\rho$ density, g the acceleration due to gravity, y the altitude and the subscript $-_0$ denoting the initial condition of y = 0. We can apply the Ideal Gas Law twice to obtain the form we require. This very familiar law may be written: pV = nRT. We note that n is number of moles and therefore represents the mass of the gas under consideration. Take V = 1 meter$^3$; then V drops out of the equation, and we write: p = nRT.

From this, we see that the number of moles per unit volume = p/RT. But (no. of moles) (mol. wt.) = density; let m be the mol. wt. and we have $\rho$ = pm/RT. If we take T to be constant (isothermal conditions throughout the atmosphere) we have $\rho$ proportional to p. Then

$$\rho = \rho_0 e\text{-}(\rho_0/P_0)gy$$

But consider the term $\rho$o/po. We have written $\rho$ in terms of p; divide both sides by p and we have that $\rho$/p - m/RT. This is a constant. Our final result, then, is:

$$\rho = \rho_0 e^{-(m/RT)gy} \tag{1}$$

In using Eq. (1) we shall ordinarily be concerned with ranges of altitude which are small compared to the radius of the planet; hence we may take g as a constant.

The implications of Eq. (1) are extremely interesting. Let us compare the variation in density for the planets Earth and Mars. For Earth a typical value for surface density is 1.2 kg/-meters$^3$, for temperature 300° K, and for g 9.8 meters/sec$^2$. The atmosphere of Earth is about 80% nitrogen (m = 28) and 20% oxygen (m = 32); hence we take a weighted average and have for the Earth's atmosphere m = 29. For Mars a typical value for temperature is 250° K and for g 3.9 meters/sec$^2$. Its atmosphere is

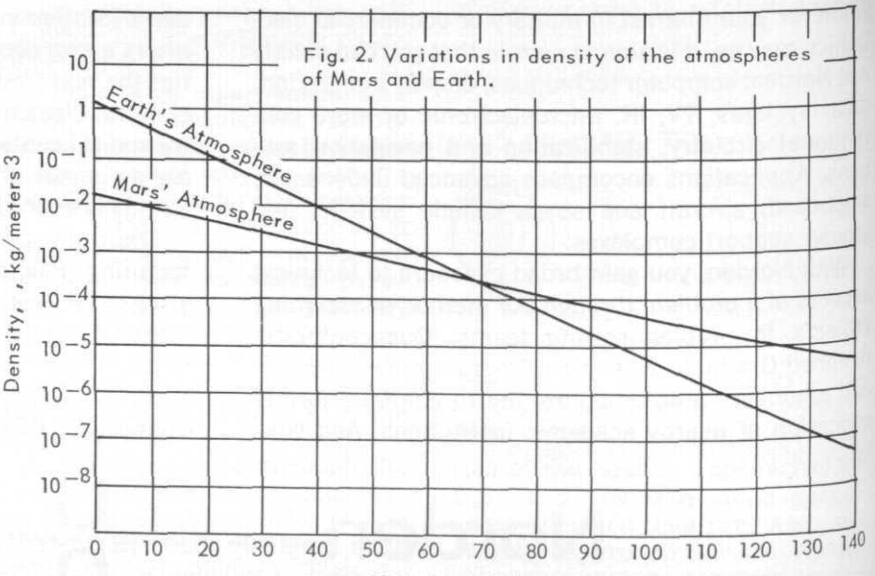

Fig. 2. Variations in density of the atmospheres of Mars and Earth.

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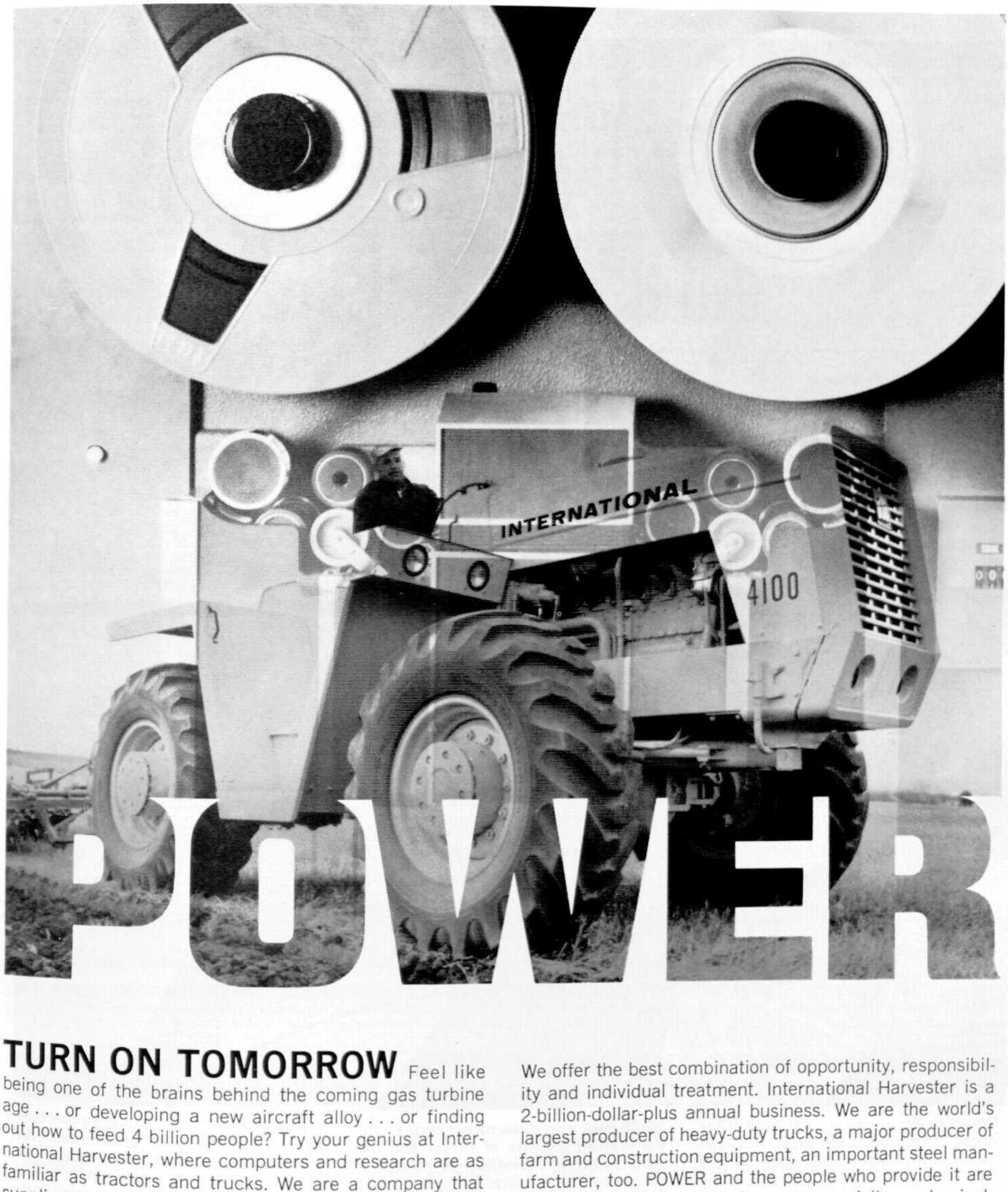
[1] Halliday & Resnick, pp. 357-60



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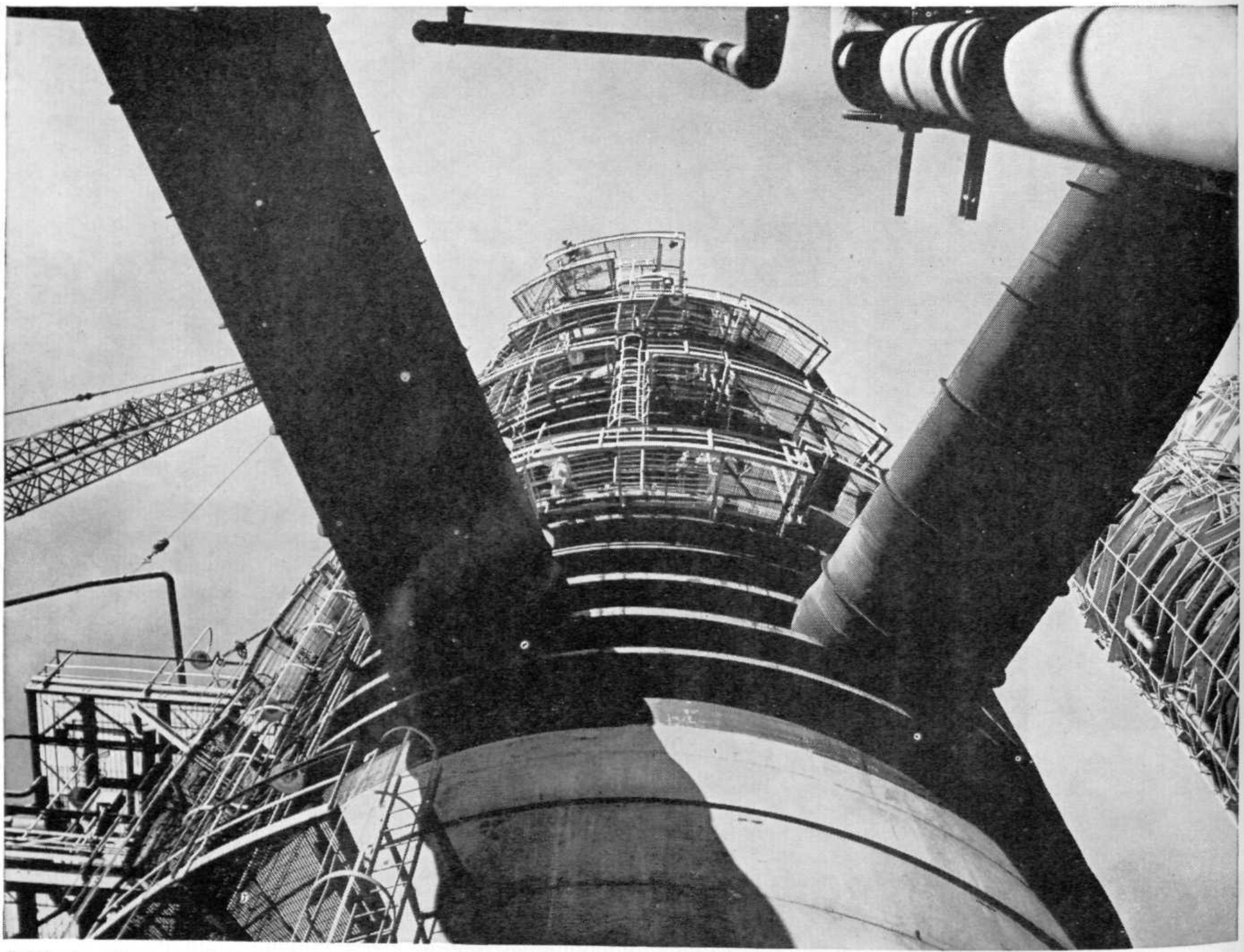

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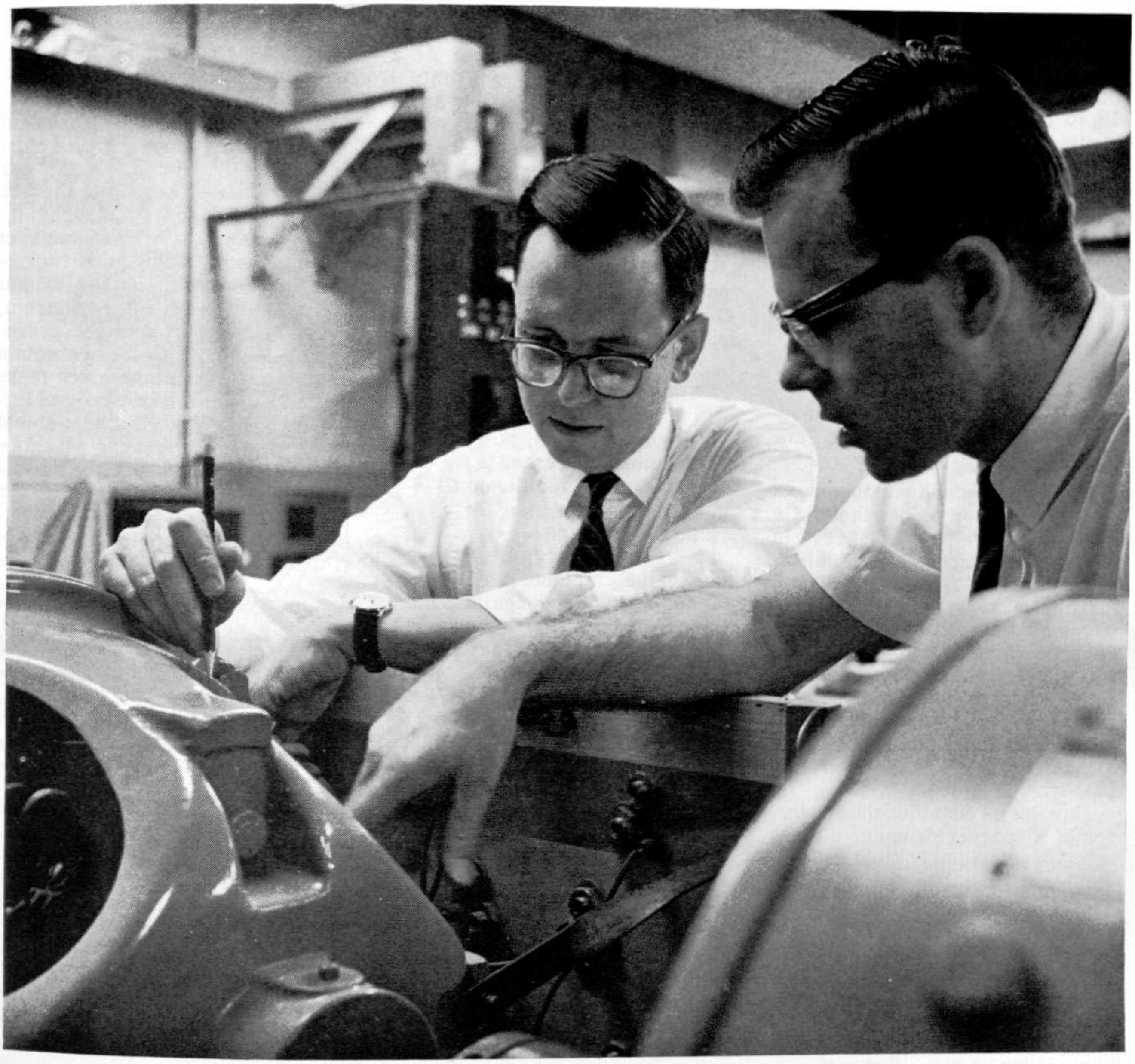

Detroit Edison and Consumers Power Company are jointly sponsoring research at the University of Michigan, devoted to advanced mathematical methods for power system stability analysis and generator field control. Shown are Professor Anthony J. Pennington (left), director of the project, and James Bennett, a graduate student.

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- Analysis of Conductor Vibration
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- Mathematical Models for Peak Load Forecasting
- Block Diagram Representation of a Power Generating Unit—a first step in stability analysis
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almost pure nitrogen; hence $m = 28$. Measurements by the space probe Mariner IV indicate a $\rho_0$ of 1% to 2% of the Earth's; taking the median value of 1.5%, we have Mars' surface density as $1.8 \times 10^{-2}$ kg/meters$^3$. We have R, the universal gas constant, as 8.32 joules/mole-°K. Then we may put these values into Eq. (1) to get the variation of density for the two planets:

For Earth: $\rho = 1.2\ e^{-0.116y}$ kg/meters$^3$

For Mars: $\rho = 0.018\,e^{-0.0525y}$ kg/meters$^3$

where y is measured in kilometers. These equations are graphed in Fig. 2.

From this graph we observe a very interesting result: that while initially Mars' atmosphere is much thinner than Earth's, above 67.2 km (41.7 mi., or 220,000 feet) it is actually denser. This suggests that if we could build a vehicle which would do most of its decelerating above the 42-mile limit in landing on Earth, then this vehicle would also do most of its decelerating in Mars' atmosphere in landing on that planet.

Now let us consider the dynamics of a spacecraft under a planet's gravitational field. From Kepler's first law we know that in the absence of dissipative or drag forces, the orbit of the spacecraft will be a conic of eccentricity E with one focus at the center of the planet. The equation of such an orbit is:[2]

$$r = \frac{L}{1 - E\cos\phi}$$

where r is distance from the center, o is measured from the perigee of the orbit, and L is a constant, called the semilatus rectum of the conic. It can be seen from this equation that r takes its minimum value at the perigee; denote the perigee by rmin. Then L - (1- E)rmin and we may write as our equation of the orbit:

$$r = r_{\min}\frac{1 + E}{1 - E\cos\phi} \quad (2)$$

As an application of this equation, we note that for an elliptical orbit the apogee, $r_{\max}$, is to be found at $\phi = \pi$ ; hence we find that

$$r_{\max} = r_{\min}\frac{1 + E}{1 - E}$$

Now let us consider the eccentricity E of the orbit. We will use the following notation: At a particular time, v is the ship's velocity (measured with respect to the center of the planet), r its distance from the center as above, R the planet's radius, g the acceleration due to gravity at its surface, and O the angle between the ship's velocity vector and the radius vector (vector from ship to center of planet). The eccentricity may be found from[3]

$$E^2 = \frac{v^4r^2}{g^2R^4}\sin^2\Theta - \frac{2v2r}{gR^2}\sin^2\Theta + 1$$

For our problem, however, we will be most interested in the case of near-normal incidence, $\theta \approx \pi/2$. Then the $\sin^2\theta$ terms are close to unity and we have:

$$e = \pm(v^2r/gR^2 - 1)$$

where the ambiguous sign is determined by the stipulation that $E \geqslant 0$. (3)

Suppose a ship, far out in space, is approaching a planet with velocity $v^o$, the velocity vector pointing approximately in the direction of the planet. Let the ship fall to a distance r from the center; its velocity will be equal to the sum of $v_o$[4] and the value of the escape velocity at that distance r. It can be shown that $v_{escape} = \sqrt{2}\,v_c$, where $v_c$ is the circular velocity (velocity required for a circular orbit) at that altitude. But this velocity may be found from Eq. (3), by setting E = 0 and solving for v. The $v_c = \sqrt{2gR2/r}$. So we have for the velocity of the ship

$$v = vo + \sqrt{2gR^2/r} \quad (4)$$

Let us now consider the dynamics of a ship in flight through the atmosphere. The most important drag force is proportional to the square of the ship's airspeed*; this force arises from a physical model of the ship, with its blunt heat shield, pushing aside gas which it encounters and thereby transferring momentum from itself to the gas. The shape of the spacecraft is quite important; the optimum shape is that of a cone or conic frustrum. Such a shape places the center of gravity close to the heat shield and makes the shape much more stable and less likely to tumble.[5]

Let the area of the heat shield be S, and let the heat shield be fairly flat. The density of the atmosphere at the point under consideration is $\rho$ and the airspeed of the ship is U. Thus in time t the ship will sweep out a volume SUt, and will encounter a mass of gas $\rho$SUt; the ship's rate of mass encounter is then PSU. Each element of gas, in being pushed aside, has its velocity relative to the ship, along the direction of the ship's motion, reduced an amount kU, where k is a constant that represents the average reduction for all the elements of gas that the ship encounters. Then the rate of momentum gain by the gas is $k\rho SU^2$. But this is then the drag force on the ship. We call $F_d$ the drag force and write

$$F_d = k\rho SU^2$$

As a point of interest, a modification of this equation is used quite extensively in the field of aerodynamics. The modification is as follows:

$$F_d = 1/2\rho U^2SC_D \quad (5)$$

where S is taken to be the total surface area normal to the direction of flight and $C_D$ is a constant, called the coefficient of drag. As concerns our problem, $C_D$ has been calculated for the case of subsonic flight through an atmosphere; it has a value of 1. It can also be calculated for the case of flight through an atmosphere that cannot be treated as a continuum but must be treated as a collection of discrete particles; from the theory of elastic collisions it can be shown that for this case $C_D = 2$. For the highly important case of hypersonic flight through a continuum, however, $C_D$ has not been calculated; it must be determined

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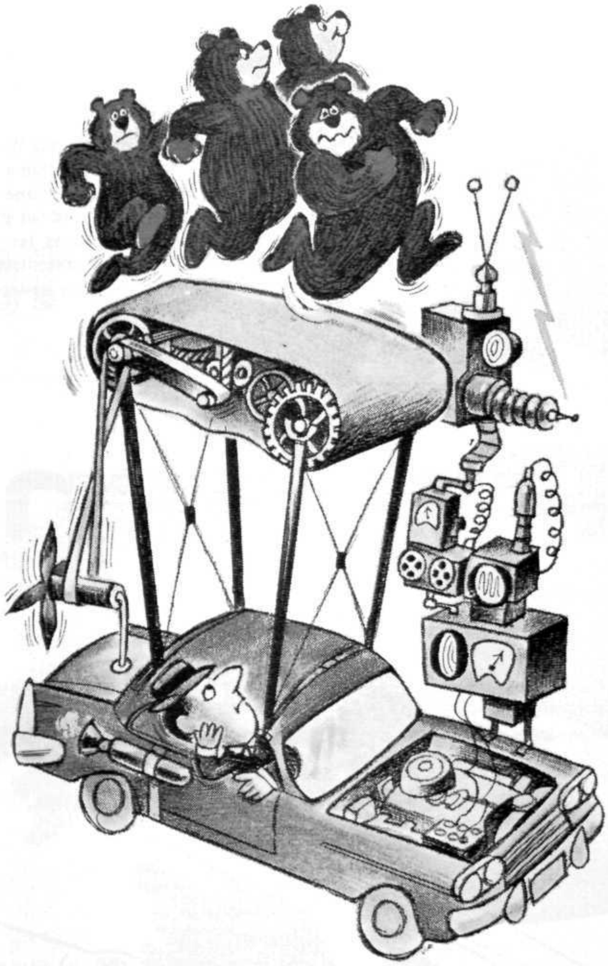
[2] Yeh & Abrams, pp. 166-167

[3] Yeh & Abrams, pp. 167-168

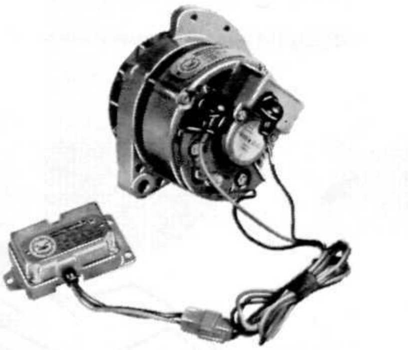
[4] Yeh & Abrams, p. 169

[5] The author is indebted to Mr. Gary Irving of Douglas Aircraft Corp. for this discussion of the stability and optimum shape of spacecraft.

* The airspeed is the velocity realtive to the atmosphere; it is the velocity v plus a correction for the speed of rotation of the planet. We will denote the airspeed by U. The concept of airspeed will be discussed at greater length in the second article of this series.



Hitch it to a herd of grizzlies . . .



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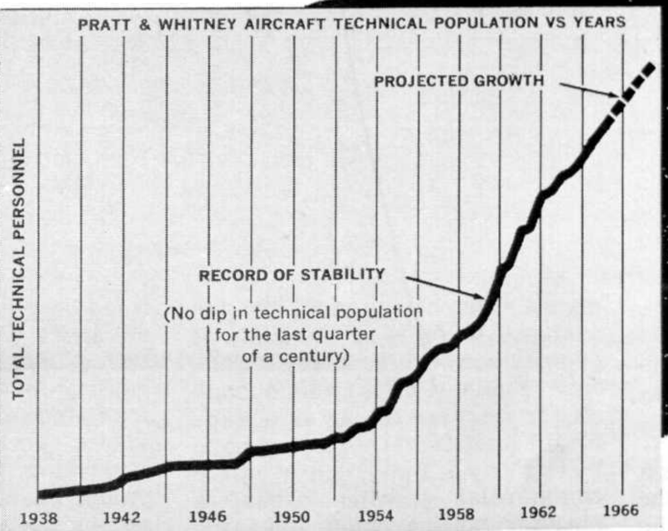
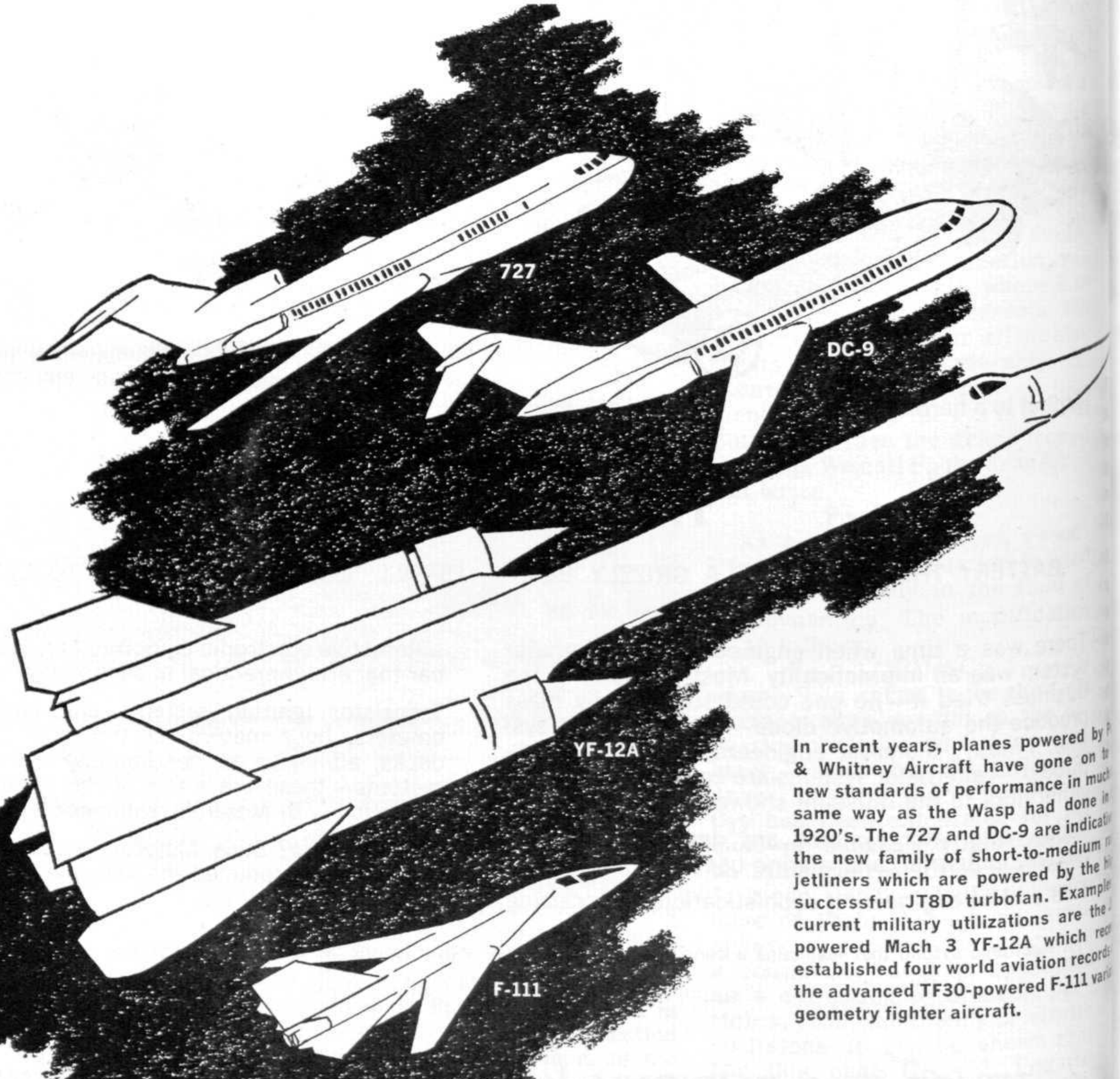


# Present



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# MEASURING THE GASOLINE RATING SEVERITY OF TEST AUTOMOBILES

**by Thomas Hewett**

ABSTRACT

In order to meaningfully interpret the results of a gasoline antiknock rating program, a measure of the rating severity of the test automobiles must be used. A method comparing the rating of a standard fuel to the cars' basic requirements was found to account for the manifold distribution differences of the cars in the analysis. This method also indentified the cars which are best suited for rating the antiknock quality of gasoline to be used in normal production cars.

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48823

A basic requirement of any gasoline antiknock rating program is that a meaningful interpretation of the calculated results is possible. The lack of repeatability of the road octane rating of a single fuel by different cars has tended to cloud the meaning of road octane numbers. Also the fact that there is no standard method for determining the suitability of a particular car for road rating had lead to additional confusion in this area.

An analysis of the differences in road octane rating of different cars should first be directed at the reference base from which the road octane numbers are assigned. The octane numbers are assigned to fuels on the basis of comparison with Primary Reference Fuels (PRF's) which consist of varying mixtures of isooctane and normal heptane. These reference fuels, quite unlike commercial gasolines, have a singular boiling point. An automobile with manifold distribution problems has trouble performing on the PRF's. A high road octane rating for a particular test fuel may not necessarily imply a high antiknock quality for the fuel, but rather a "dislike" of the PRF's by the car in which it was tested. The differences in the manifold distribution characteristics of cars can then be held to account for much of the inconsistency in road ratings on a particular fuel.

In order to best interpret the octane number results of a given gasoline rating program, some means of measuring the rating severity of the test cars should be used. In a recent program consiting of sixteen test fuels which were run in seven test automobiles, an ASTM standardization fuel was used for this purpose.

The road octane rating of the fuels was done by the Modified Uniontown method. This method consists of top gear, maximum throttle (without downshift) accelerations at different spark advance settings. The spark advance at which knock is present at a trace intensity is defined as the knock-limited spark advance. The relationship between spark advance and octane quality is found by running various Primary Reference Fuels of known octane number and determining the knock-limited spark advance of each. By comparing these spark settings with those of the test fuels, the test fuel road octane numbers are found.

The standard fuel which was also run in each of the cars was an ASTM 99.6 RON Standardization Fuel. This fuel was 24% toluene and had an 11.5 sensitivity. A measure of the rating severity of each car may best be shown by comparing the PRF octane requirement at basic timing with the road octane number of standardization fuel. A car which rates the fuel much above its requirement is not considered severe, while one which rates the fuel near or below its requirement may be regarded as quite severe. This method, in effect, compares the knock-limited spark advance of the standardization fuel to basic timing on an octane scale. Simple comparison of the knock-limited spark advance would not be effective because the difference in spark advance for a one octane number fuel difference varies between cars. The effectiveness of comparing the PRF requirement of each of the cars is limited by the manifold distribution problems indicated earlier.

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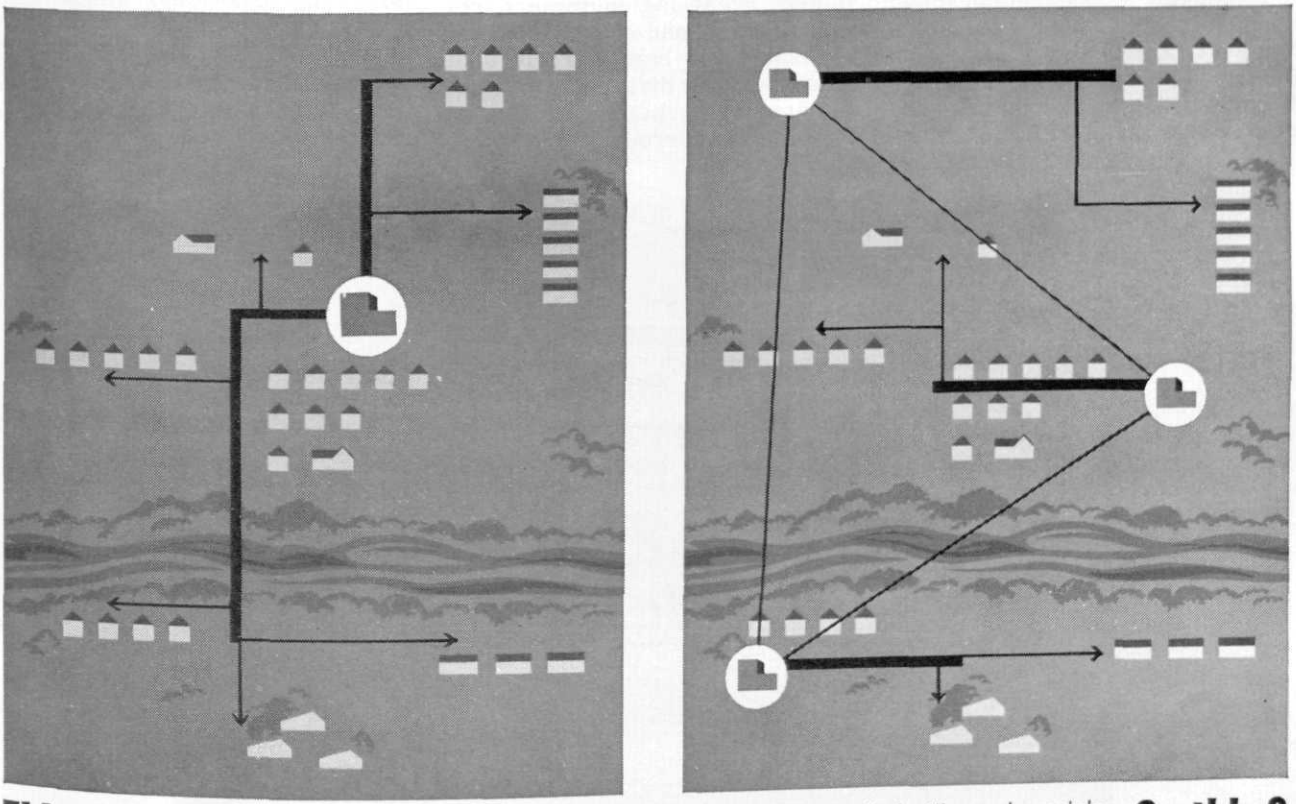

**This?** In this hypothetical geographical area, communications could be supplied with one large telephone switching office and a network of cables (left), or with three smaller offices and a different network (right). Many other combinations of offices and cable networks might be possible. This situation, although hypothetical, is typical of the complex telephone engineering problems that are being solved with the aid of computer programs designed at Bell Laboratories. **Or this?**

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The results of this type of comparison for the seven cars used in the program are shown in the following table. The cars are listed in order of decreasing severity with the difference between the standardization fuel rating and the PRF octane requirement shown for each.

ORDER OF RATING SEVERITY
IN TEST CAR FLEET

| NO. | AUTOMOBILE | St. Fuel Rating Minus PRF Req't |
|---|---|---|
| 1 | 1965 Buick Electra 225 | 0.2 |
| 2 | 1965 Pontiac Catalina | 1.0 |
| 3 | 1965 Chevrolet Impala | 2.1 |
| 4 | 1964 Buick Special | 2.1 |
| 5 | 1965 Ford Galaxie 500 | 3.2 |
| 6 | 1964 Ford Fairlane 500 | 4.1 |
| 7 | 1965 Dodge Custom 880 | 4.8 |

Examination of this table reveals that the Buick Electra and Pontiac Catalina are particularly well suited for evaluating fuels. These two cars rate the test fuels in a spark advance range which is quite close to basic timing, or under conditions quite close to normal customer usage. Thus, the antiknock quality information generated by these cars provides a good prediction of the fuel performance which customers will find in normal car operation. The cars further down the rating severity scale evaluate the fuels in a spark advance range which is quite different from basic timing, or normal operating conditions. Antiknock quality information derived from ratings in these cars does not have much significance for predicting the performance of a fuel in normal cars on the road.

The importance of having a measure of a car's rating severity can now be seen. If gasoline antiknock quality information is to be used for determining gasoline production standards, then ratings which are relevant to customer usage must be employed. The advantage of a method like the one described above is that the effects of the manifold distribution characteristics of the cars are eliminated. By considering the antiknock ratings of the test fuels in conjunction with the test cars' rating severity, a meaningful interpretation of the calculated results can be made.

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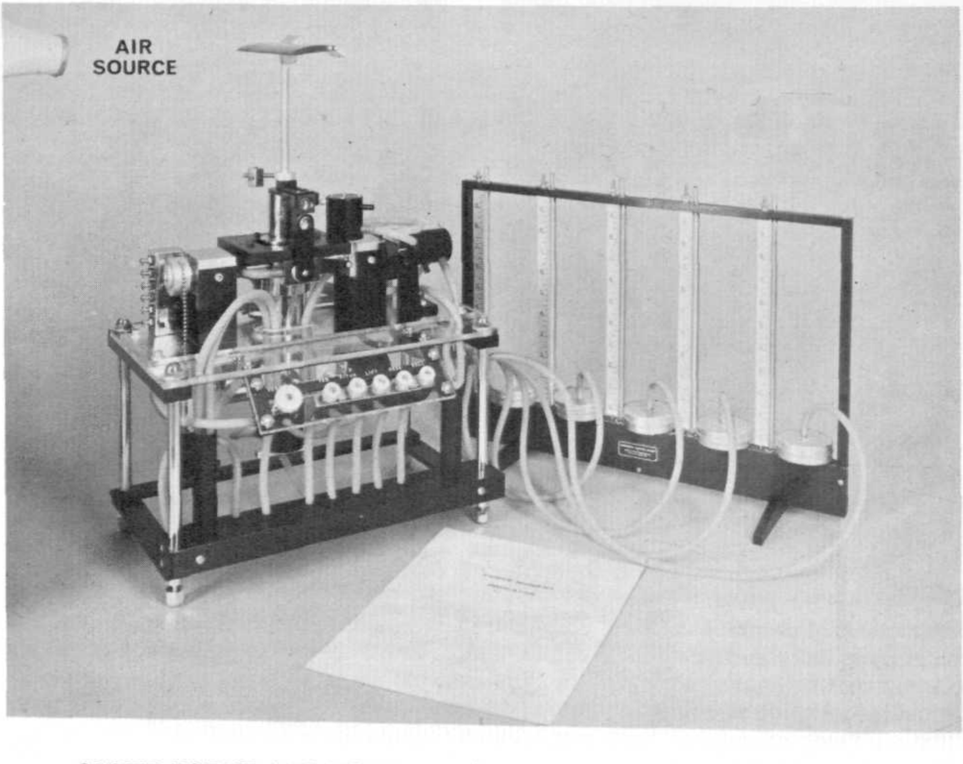

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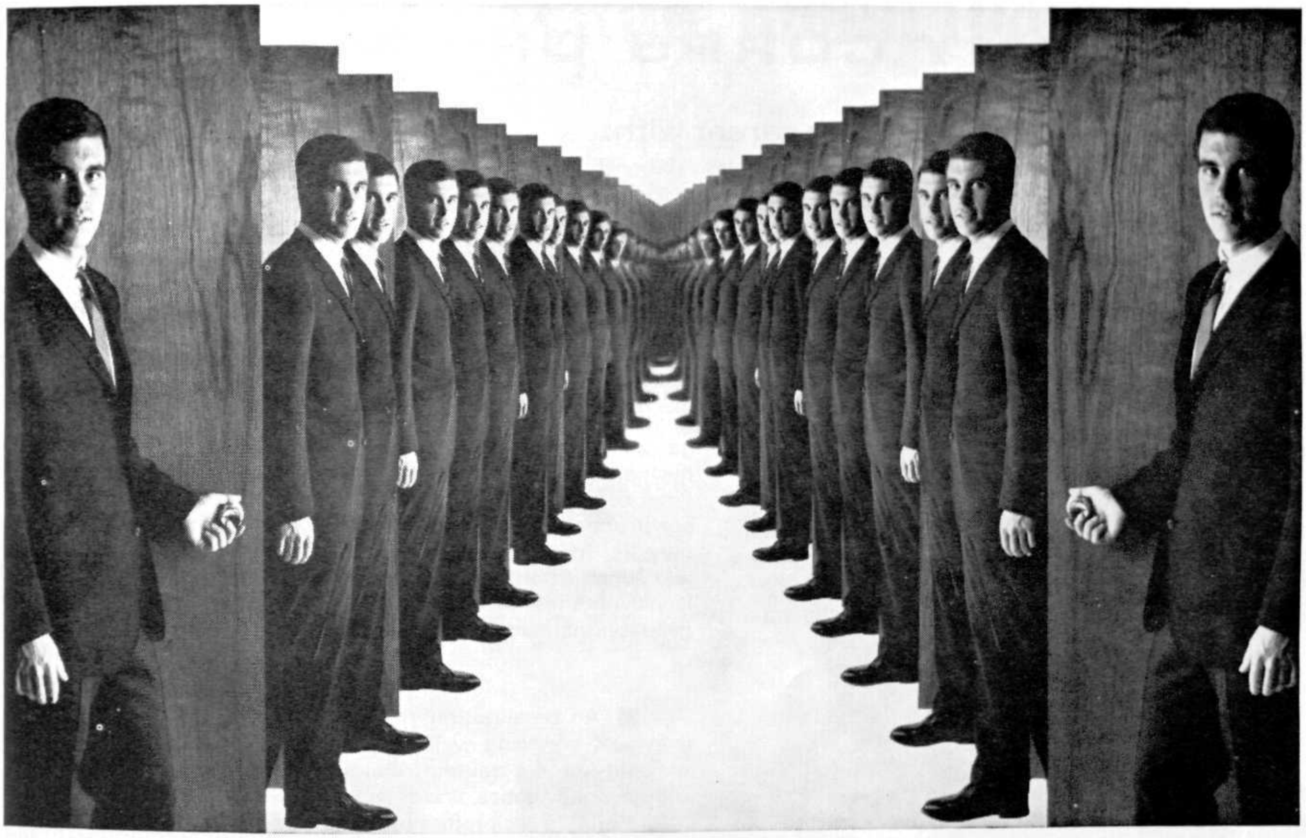

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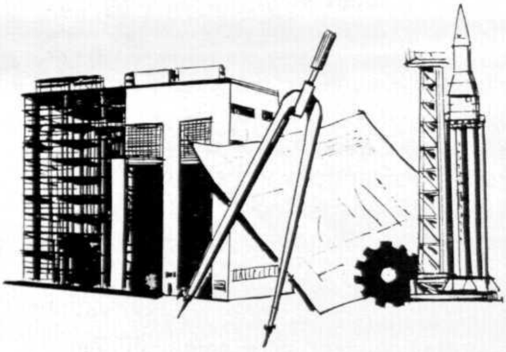

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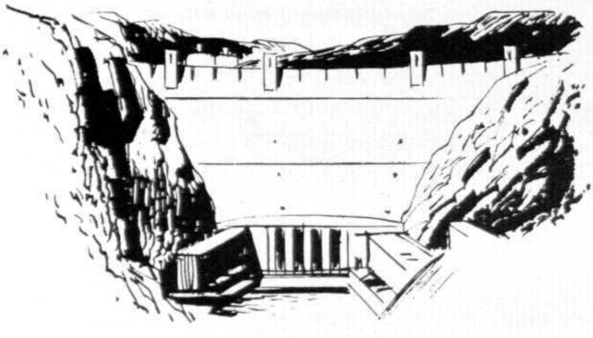

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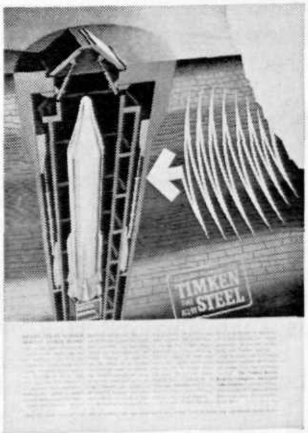

# LAY THAT SLIDE RULE DOWN,

OR

## *"Using The Gears Between the Ears!"*

## PART TWO

# FUN WITH RECIPROCALS,

OR

## *"Putting One Over!"*

Often a problem upon solution will reduce itself to the reciprocal of a certain number. Insofar as a course in mathematics is concerned, it is common to leave the expression in that form. We recognize, of course, that the reciprocal of any given number is in itself a precise number and can represent the exact answer to a particular problem. For example, an exhaustive nationwide survey may show that one doctor in thirteen smokes cigarettes. It is graphic, dramatic, and accurate to state that only 1/13 of the nation's doctors smokes cigarettes. It makes little more sense to say that only 7.69 per cent of the nation's doctors smoke cigarettes. However, there are many instances when the decimal fraction form of answer is to be preferred despite the loss of an exact solution when the conventional three or four significant figures of the answer are shown.

The decimal equivalents of all integer fractions fall into two rather obvious classes. They are either exact decimal fractions which may be expressed in a finite number of places, or they are never-ending decimals. It may not be so obvious, however, that the never-ending decimals invariably settle down to the endless repetition of a certain sequence of one of more integers.

Some examples of exact decimal fractions are:

$$1/5 = 0.2.$$
$$1/16 = 0.0625.$$
$$1/125 = 0.008.$$
$$1/4{,}096 = 0.000244140625.$$

The exact decimal fractions are relatively uncommon. They stem from just those denominators that contain no prime factors other than two and five. There are but 40 such exact decimal equivalents of the reciprocals for all integers up to and including 4,096, the last example cited above. This is one of the liabilities resulting from the use of 10 as the base of our number system. If we used either 12 as the base of our number system, for example, the frequency of exact reciprocals would increase very substantially.

Some never-ending decimals that repeat the same integer after one or more places are:

$$1/3 = 0.3333333333...$$
$$1/45 = 0.222222222...$$
$$1/576 = 0.0017361111...$$

These decimal fractions appear only if the integer three is one of the prime factors of the denominator; although the mere presence of three as one of the prime factors does not assure a constantly repeating single integer as it does in the examples mentioned here.

Another form of never-ending decimal fraction repeats a certain small group of integers.

$$1/11 = 0.09\ 09\ 09\ 09......$$
$$3/22 = 0.136\ 36\ 36\ 36......$$
$$1/55 = 0.018\ 18\ 18\ 18......$$

Nevertheless, the decimal fractions which repeat a somewhat lengthy sequence of integers over and over again are more interesting. We have reference to decimal fractions of the forms:

$$1/7 = 0.142857\ 142857\ 142857\ ......\ ......$$

$$1/13 = 0.076923\ 076923\ 076923\ ......\ ......$$

These decimal fractions are particularly unusual. They appear as the reciprocal of a prime number. The preceding statement may be challenged as not applying in the instances of the prime numbers 2, 3, 5, and 11 that have been referred to above. Nevertheless, this has been found to be true of a large number of primes. We shall soon see why this must be true.

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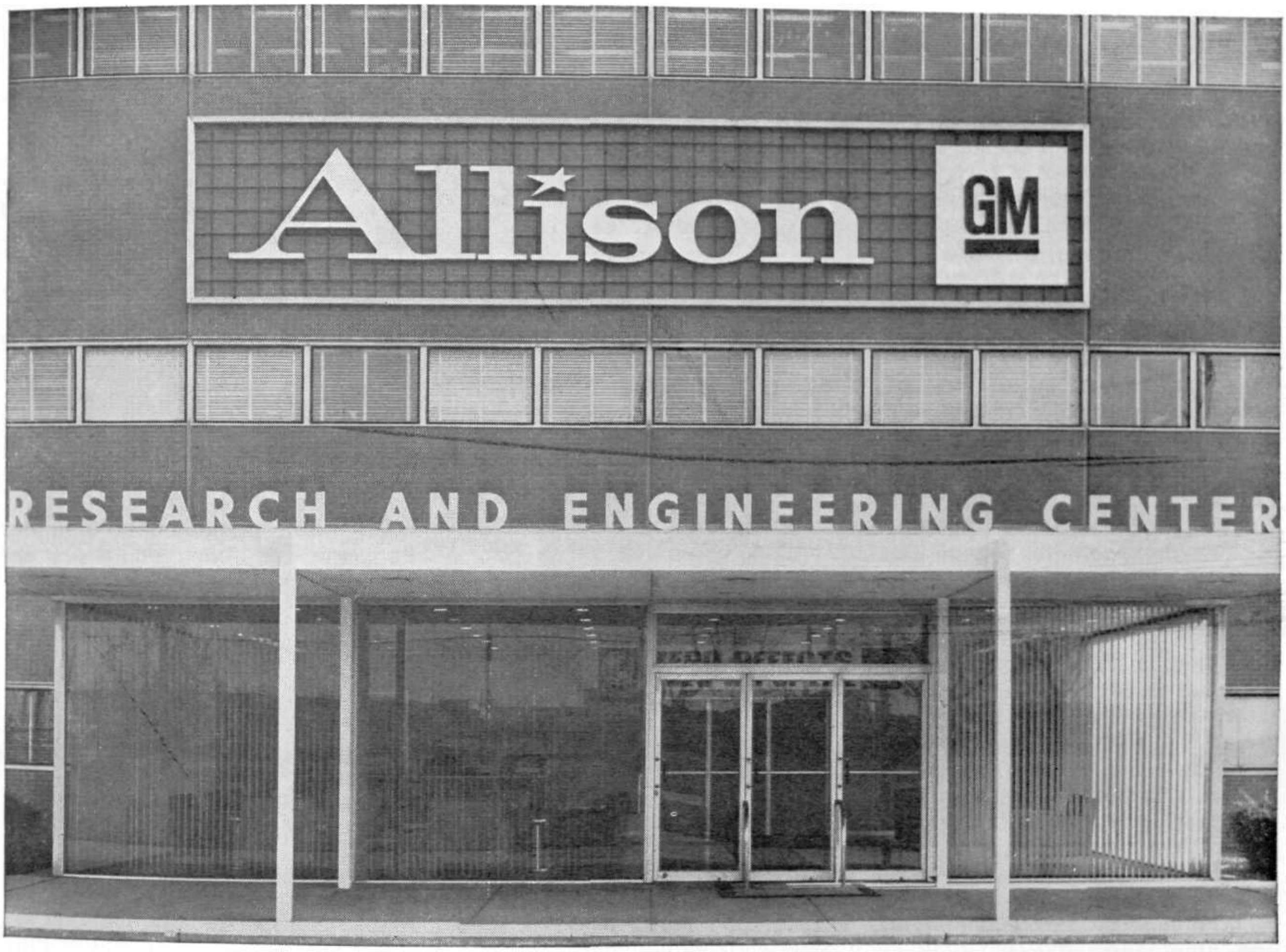
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Imagine the example of 1/7. The largest remainder that can be brought down from a step of division is the number 6. The smallest remainder is the number 1. A remainder of zero would indicate that 1/7 can be expressed as a finite decimal fraction. We realize, of course, that this cannot be true. It stands to reason, therefore, that the remainder from a step of division will be forced to repeat after not more than six steps. You see, above, that this is precisely the case.

In the example of 1/13, the remainder after six trial divisions is the number 1. But this is how the problem began! The cycle simply must repeat itself.

Another property exhibited by these repeating decimals is that the fraction begins to repeat itself after the *n*th place in the example of 1/*n*, where *n* is a prime number. The decimal fraction of 1/13 repeats itself in the thirteenth place, the "double frequency" notwithstanding. Similarly, the decimal fractions representing 1/17 and 1/19 repeat themselves in the seventeenth and nineteenth places, respectively.

The interval of the cycle always involves an even number of decimal places. This would appear to be a condition imposed by meeting the requirements of beginning to repeat in the *n*th place, where *n* must necessarily be odd if the number is to be any prime other than two.

Having established that these cyclic groups always contain an even number of digits, we may divide them into two equally long integer groups and demonstrate another property which we shall call "being complementary with respect to nine about the midpoint." We recall the sequence, 142857, representing the decimal equivalent of 1/7. The sum of the two parts, 142 and 857, is 999. The six-figure group which repeats in the instance of 1/13 may be written in two parts, 076 and 923. Again, they add up to 999. The same may be said for the reciprocals of 17 and 19 which appear below with the second half of the sequence arranged under the first half:

1/17 = 0.05882352 94117647
05882352 94117647 ........

$$\frac{94117647}{99999999}$$

1/19 = 0.052631578 947368421
052631578 947368421 ....

$$\frac{947368421}{999999999}$$

This feature, when put to work, makes it possible to express the final $\frac{(n - 1)}{2}$ places of the decimal sequence for the prime number, *n*, simply by inspection.

From the foregoing it is hoped that a little interest has been aroused that will cause you to familiarize yourself with the first dozen reciprocals. From a working knowledge of a few reciprocals, a great many others can be found.

For instance, the reciprocal of 15 is merely one-third of the reciprocal of five. We may readily establish,

$$1/15 = (1/3)(1/5) = \frac{0.2000}{3} = 0.0666\ldots$$

Similarly,

$$1/14 = (1/2)(1/7) = \frac{0.142857\ 142857}{2}\ldots$$

$$= 0.07\ 142857\ 142857\ldots$$

and

$$1/18 = (1/2)(1/9) = \frac{0.11111}{2}\ldots$$

$$= 0.055555\ldots$$

Note the persistence of the sequence, 142857, in reciprocals involving seven as a prime factor of the number.

Once the form of the cycle has been established, it may often be applied in expressing decimal fractions where the numerator is an integer other than one. The following sequences are illustrative:

1/14 = 0.07 142857 142857 ..,
2/14 = 0.142857 142857 ..,
3/14 = 0.02 142857 142857 ..,
4/14 = 0.2857 142857 ..,
5/14 = 0.3 57 142857 ..,
6/14 = 0.42857 142857 ..,

1/18 = 0.055555. . .
2/18 = 0.111111. . .
3/18 = 0.166666. . .
4/18 = 0.222222. . .
5/18 = 0.277777. . .
6/18 = 0.333333. . .

Thus, once the repetitive sequence is recognized, the result may be written down to any desired number of places.

A working knowledge of the decimal equivalent of integer fractions may be used to good advantage on a great many applications. We will recall PART I, FUN WITH SQUARES, where it was pointed out that the difference between the squares of two consecutive integers is simply the sum of the two integers. Turning the same statement around, we have a method at hand that is useful in finding square roots rather than squares. We might reason that $\sqrt{13}$ lies somewhere between three and four; being very nearly $\frac{4}{3 + 4}$, or 4/7, of the interval from three to four. Our new interest and experience in handling decimal fractions indicates the answer to be close to 3.6. Ordinarily, one would not be interested in extending the approximation into the third significant figure since the data furnished and the approximation method involve only one and two place numbers. The actual root, to five significant figures, is 3.6056.

Another example is $\sqrt{158}$. This number lies between 12 and 13. We expect it lies near $\frac{14}{12 + 13}$, or 14/25, of the interval toward 13. Expressing three significant figures, the answer is quickly estimated to be 12.6. Attempting to stretch out a fourth yields 12.56. The actual root is 12.5698.

We sense now that our method results in answers that are slightly in error, a fact which can be verified by comparing the actual parabolic function, y = x2, between any pair of consecutive integers with the straight-line approximation method we are substituting in its place. The comparison will also reveal that the accuracy improves when bigger numbers are involved.

A simplifying, and often corrective, step that can be taken when working with larger numbers such as $\sqrt{927}$ is to assume that (30 + 30) in the fractional

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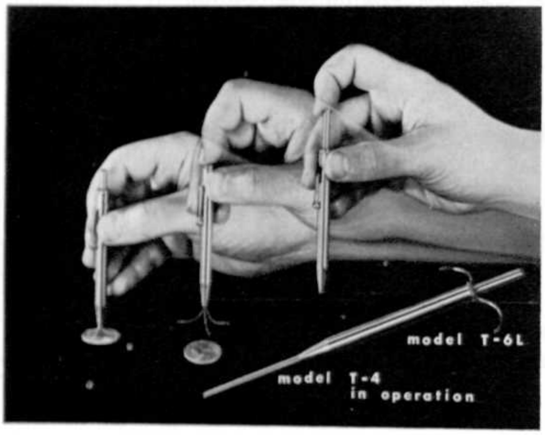
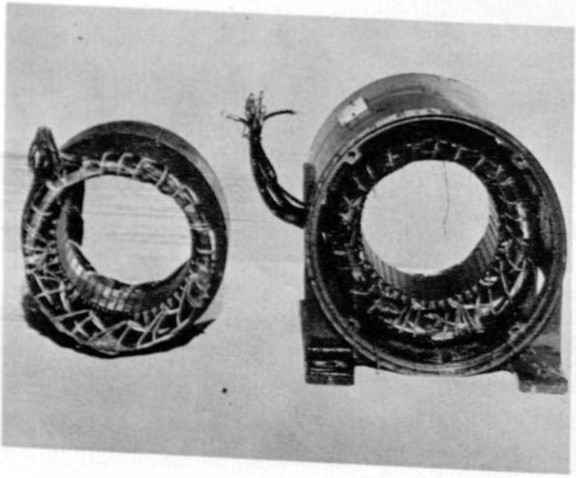
# Industrial News



The Universal Technical Products Co. announces a new universal hand tool . . Triceps. This remarkable, all stainless steel instrument eliminates many of the problems encountered by those who work with very small, delicate, oddly shaped, or otherwise difficult to handle objects. Depressing the Triceps plunger causes three resilient, hooked fingers to flare out from the tip. By properly positioning the extended fingers and releasing the plunger, the fingers retract and an object is firmly but gently grasped. This instrument is ideal for handling small parts in cramped locations or for holding components during soldering operations. It is very effective in applications where it is necessary to pick up flat objects from a flat surface, and is most advantageous when minimum contact area between the tool and and an object is desired.

A new solventless varnish from General Electric has greatly eased the varnishing operations involved in the production of electric motors. The stator on the left has been treated with new G–E "Series 700" Solventless Varnish. Because the varnish is applied only where it is needed, there is no excess varnish to be removed and stator can be assembled directly into a motor. The stator on the right was treated by dipping into a solvent containing varnishes. The strings caused by draining must be removed and the stator must be cleaned before assembly.



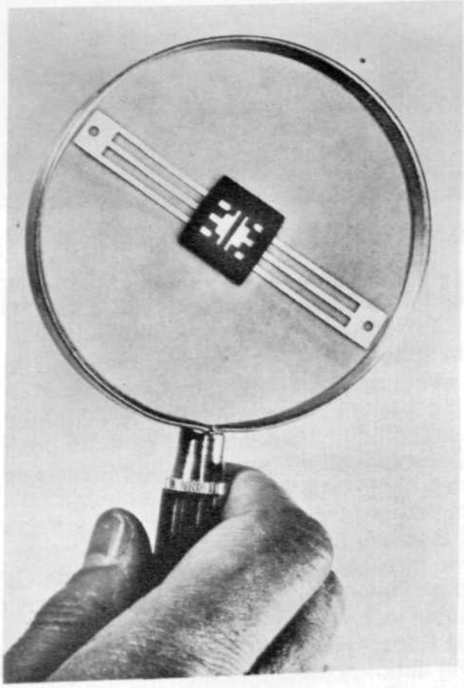
Scientists of International Business Machines Corp. have found that by rolling different sized balls into an inclined tray, they can duplicate what happens when atoms from metallic vapors are frozen directly onto a cold surface. Such films do not follow the traditional rules of metallurgy because they are deposited directly from a vapor without going through a liquid stage. The model shows for example that if the diameter of the balls differs substantially, the balls will arrange themselves into an amorphous or homogeneous structure. These and other insights gained from the model are in Qualitative agreement with behaviour of atoms in the formation of these new films.

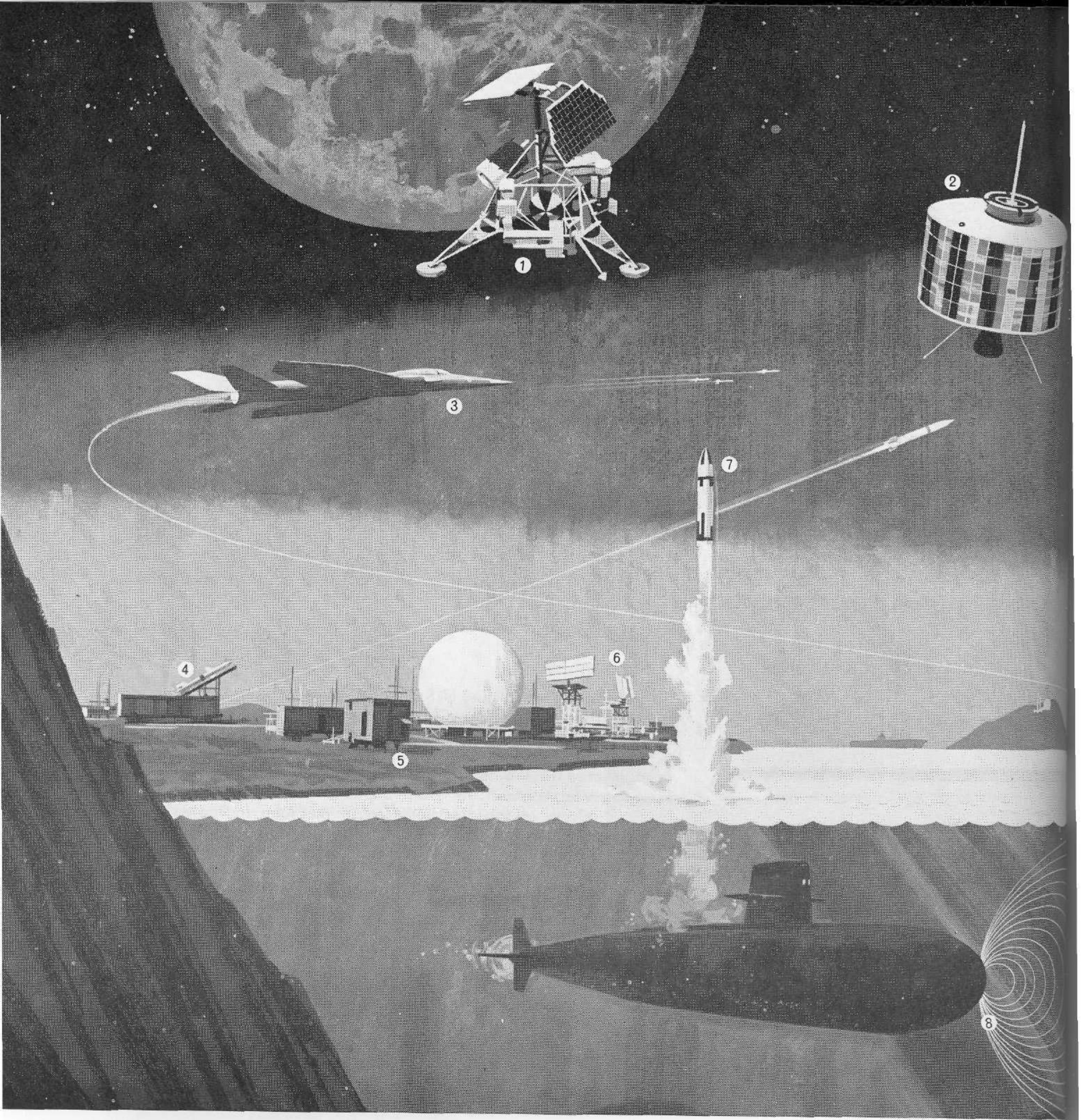
# Industrial News

The Fairchild Controls Stan system for determining an aircraft's take-off gross weight and center of gravity has completed intensive testing aboard a Pan American World Airways cargo jet. These tests were highly successful. Shown in the upper left photo is the location of the Stan pressure transducers on the landing gear. Lower left is a close-up of the left main landing gear showing the transducer installation. Pressure from the hydraulic fluid in the struts is sensed by the transducers and translated into electrical signals. Upper right photo shows nose gear installation of transducers. Electrical cabling from the transducers runs directly to flight station and into the Stan indicator box shown in lower right photo. Here two digital indicators display the Take-Off Gross Weight in pounds and the Center Of Gravity in Percent of Mean Aerodynamic Chord.

Manufactured in the U.S. under license from the Socony Mobil Oil Co., this Unico Chloride-ion Test Kit is an inexpensive, reliable, and rapid method of measuring chloride-ion concentration in many applications. When testing the sample is collected in the test vial. An indicator tube is inserted into the vial. A yellow stain appears if the ion is present and the length of the discoloration in the tube indicates the concentration present. The Unico Chloride-ion Test Kit will measure potassium, magnesium, and manganese chlorides as well as sodium chloride.

A two-transistor glass flar pack has been introduced by the Electronic Products Division of Corning Glass Works. The customer made a hermetic seal between the glazed lid and the glass case after inserting the devices. The package uses Corning Code 7052 glass, black so that it blocks our infrared and visible radiation. Besides transistors, the package can be used for hermetic protection of other miniature devices. Dimensions are .240-inch square and .060-inch thick after sealing.

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denominator is very little different from (30 + 31). Hence, $\sqrt{927} = 30 + 27/60$, or 30.45. Actually, to four decimal places, the answer is 30.4467.

Similarly, if we desire the solution of $\sqrt{888}$, we may conclude the number lies close to 30, but is nearly 12/60 of the interval toward 29. Our solution suggests 29.80 as the root. The more exact solution obtained by extraction of the root is 29.7993. A typical slide rule answer for the above problem will be no better than the results obtained by the suggested method.

As a general rule, the approximation is both easier and more accurate in working from the perfect square nearest to the number given under the radical. As an example, $\sqrt{248}$ may be estimated as being 15 + 23/30, or 16 - 8/32. The solutions are respectively, 15.77 and 15.75. The actual root is 15.748.

Having observed that the accuracy of the approximation method improves when working with larger numbers, we have reason to return to the original example, $\sqrt{13}$. Should we be able to extract the square root of 1,300, additional significant figures will be obtained. It is a simple matter to point off the decimal place that represents the difference between $\sqrt{13}$ and $\sqrt{1300}$.

Recalling methods from PART I, FUN WITH SQUARES:

$$35^2 = (3)(4)100 + 25 = 1{,}225$$

and $$36^2 = 35^2 + 35 + 36 = 1{,}225 + 71 = 1{,}296$$

Thus
$$\sqrt{1{,}300} = 36 + 4/72 = 36 + 1/18 = 36.0555\ldots = 36.056.$$

Removing the factor of ten, our solution now checks precisely with the four-place calculation cited heretofore: $\sqrt{13} = 3.6056$.

Returning now to finding reciprocals, mention is made of two other types which can be handled with relative ease after a little practice. They are of the form,

$$\frac{1}{1 - x} \quad \text{and} \quad \frac{1}{1 + x}$$

where x is a small number when compared with one. We may establish identities helpful in these instances by carrying out the indicated division for each of the algebraic fractions.

$$\frac{1}{1-x} = 1 + x + x^2 + x^3 + x^4 + \ldots + x^n + \ldots$$

$$\frac{1}{1+x} = 1 - x + x^2 - x^3 + x^4 - \ldots + (-x)^n - \ldots$$

Thus, $$\frac{1}{0.99} = \frac{1}{1.00 - 0.01} = 1 + 0.01 + 0.0001 + \ldots \simeq 1.0101$$

And, $$\frac{1}{1.02} = \frac{1}{1.00 - 0.02} = 1 - 0.02 + 0.0004 - \ldots \cong 0.9804$$

Application may be made with problems involving 9.9 and 102, or any other similar values, where proper regard is given to the location of the decimal point.

To show the limit of these methods where four significant figures are desired, several values are tabulated below. The identities involve geometric series where each additional term increases the number of decimal places by two. We have shown three terms of each series so that we may properly appraise the effect of the third term upon the last significant decimal place.

| x = 0.05 | x = 0.07 | x = 0.09 |
|---|---|---|
| 1/0.95 | 1/0.93 | 1/0.91 |
| 1.000000 | 1.000000 | 1.000000 |
| 0.05 | 0.07 | 0.09 |
| 0.0025 | 0.0049 | 0.0081 |
| 0.000125 | 0.000243 | 0.000729 |
| 1.053 | 1.075 | 1.099 |

It is not until x = 0.09 that the third place of the decimal is affected by the third term of the series. Actually, because of common familiarity with the squares and cubes of 11 and 12, the method may be used to determine

| 1/0.89 | 1/0.88 |
|---|---|
| 1.11 | 1.12 |
| 0.0121 | 0.0144 |
| 0.001331 | 0.001728 |
| 1.123 | 1.136 |

A further interesting method for determining reciprocals may be explained by assuming the problem of 1/41. We first reason that the desired reciprocal is close to 1/40. We readily recognize the latter as being 0.0250. Just how far removed from 1/40 are we? Performing the subtraction to see what difference there actually is,

$$\frac{1}{40} - \frac{1}{41} = \frac{41 - 40}{41 \times 40} = \frac{1}{1{,}640} \simeq 0.0006$$

Therefore,

$$\frac{1}{41} = \frac{1}{40} - \frac{1}{1{,}640} = 0.0250 - 0.0006 \cong 0.0244$$

Calculating the reciprocal to a few more places reveals 1/41 = 0.024390.

Similarly, we may estimate the reciprocal of 79,

$$\frac{1}{79} = \frac{1}{80} + \frac{1}{6{,}320} = 0.01250 + 0.00016$$

$$\frac{1}{79} \cong 0.01266.$$

It matters little whether the product of 79 x 80 is evaluated or whether 6,400 is used in determining the difference between these two reciprocals. In the more recent instance the magnitude of the second term is but little more than one per cent of the first term. A 10 percent to 20 per cent error in the determination of this increment scarcely affects the significance of the answer as ordinarily reported.

Fun with reciprocals need not be limited to these few methods. Imagine the example of 1/47. As a first approximation, we can treat this as 1/50, for which we know the reciprocal to be 0.02. Now, in making this rash substitution, we have used a denominator that is too large by 3 parts in fifty or 6 per cent. Is it not true, then, that the numerator is too small by 6 per cent? Again, it is a simple matter to increase the approximate answer of 0.02 by 6 per cent, yielding 1/47 ≅ 0.0212. The answer to four significant figures is 0.02127.

If we return to the reciprocal of 7, we note another unusual feature in the sequence of integers, 142857 142857. Starting with the first pair, "14," we note that each succeeding pair

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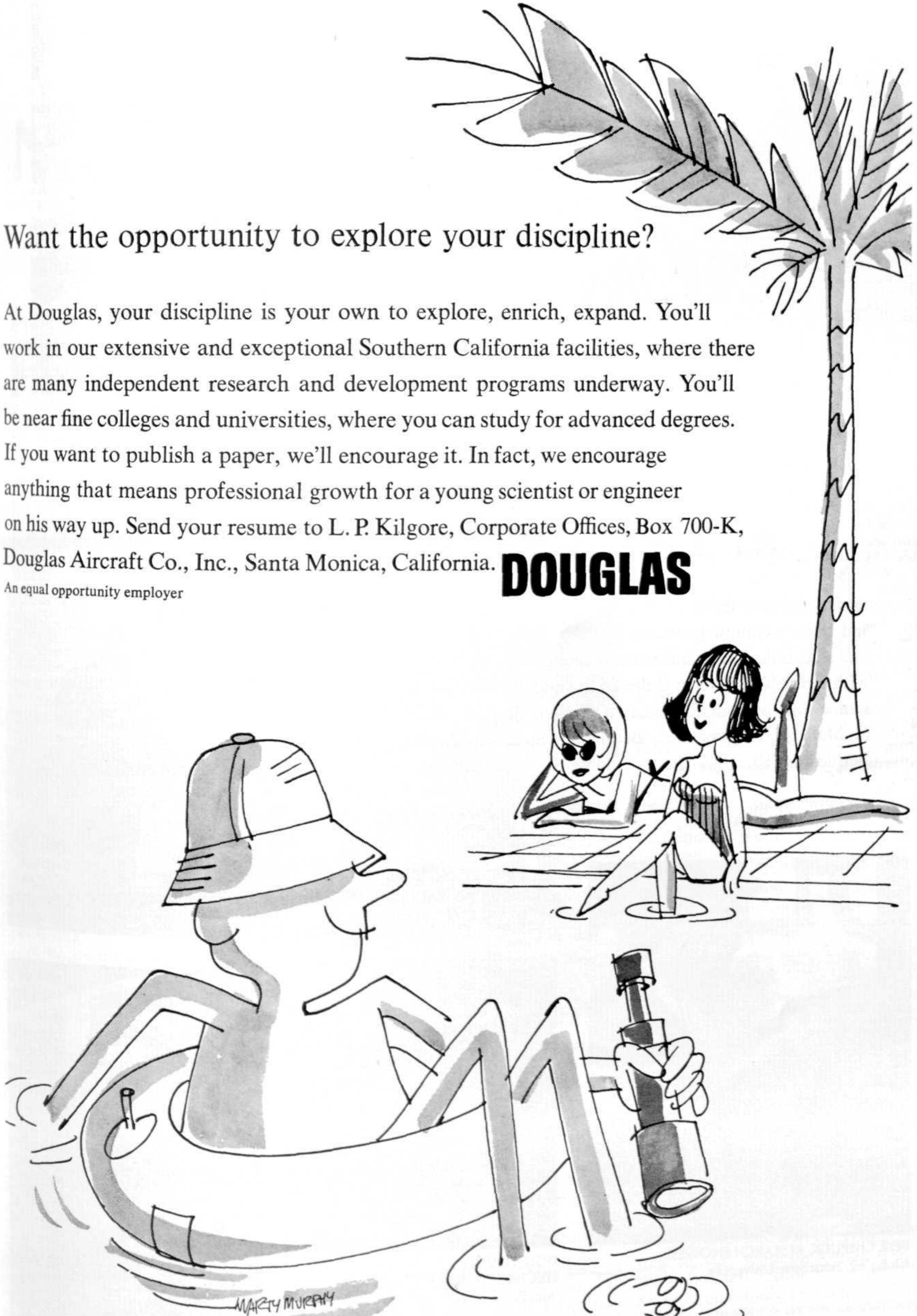
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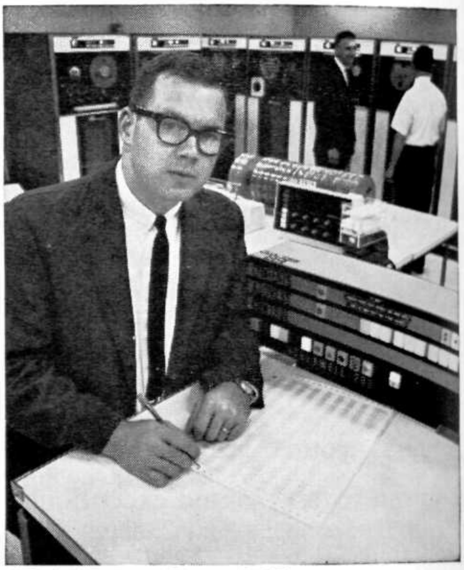

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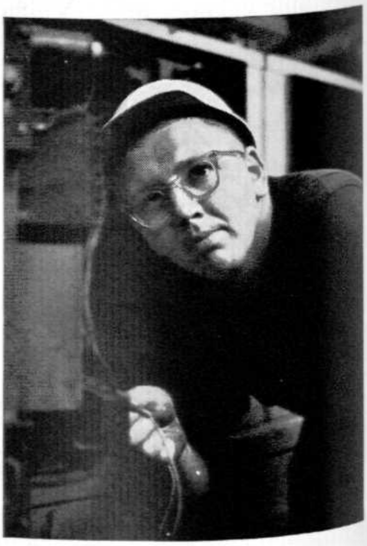

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CONTINUED FROM PAGE 42

can be generated by a process of continuous doubling:

1/7 = 0.14
28
56
112
224
448
896
1792
3548

1/7 = 0.14285714285728....

Why is this so? Upon further reflection, we wonder why we haven't tumbled upon this before! Notice that 7 goes into 100 fourteen times and leaves a remainder of 2! It follows then that 7 goes into 200 twenty-eight times and leaves a remainder of 4! Similarly, 7 goes into 400 fifty-six times and leaves a remainder of 8! This type of insight gives one a little of the feeling that Archimedes must have known when he discovered in his bath that the volume of an irregular solid could be determined by measuring its displacement.

But don't run shouting into the street just yet. We have need to look further for the key to the real utility of this discovery. Take the example of the reciprocal of 23. We recognize by inspection that 23 goes into 100 four times and leaves a remainder of 8. Therefore, 23 goes into 800 thirty-two times and we see that the remainder (which happens to be 64) is not important to us. All that we need to do is to multiply 32 x 8 = 256 and then add it to the developing series of terms. The reciprocal of 23 follows immediately.

1/23 = 0.0432
256
2048
(approximately) 16400

1/23 ≅ 0.043478......................

The convenient desk calculator shows the answer:

1/23 = 0.04347828

We are doing all right now with our ability to carry out such divisions to six places with a minimum of mental effort.

Let's try these methods on an example from above.

1/79 = 0.01
21 (The remainder is 21.)
(20 x 460 for approximation) 441 (From FUN WITH SQUARES)
9200
(20 x 9200) 184000

1/79 ≅ 0.01265.....

Accurate calculation yields 1/77 = 0.01266, as we have seen. We know, of course, that the answers derived by the series method are small by virtue of the terms that should be included on the right. There is little practical difference, however, in the two answers above as obtained by two different methods.

Some practice examples follow:

1/31 = 0.03 (remainder is 7)
21
(these need not be labored over for precision) 147
1029
7200

1/31 ≅ 0.03225801

The answer is correct through seven decimal places.

The number need not be prime as have been used in the several examples above.

1/48=0.02
08
32
128
512
1024
2048
4096
8200

1/48≅0.02083333333......

This results may be confirmed

$$1/48=(1/4)\ (1/12) = \frac{0.08333\ ....}{4}$$

$$= 0.020833...$$

Notice how frequently two or more of these methods are available in the attack upon any given problem. For example:

1/48=2/96
=2 (0.01+0.0004+0.000016 +0.00000064+...)
= 2(0.01041666...)
=0.0208333...

The more you work with these methods in unison, the more quickly you will see alternate methods of solution. Since most of the methods are mental, the mind tends to congratulate itself upon getting the same answer by two separate methods. Your confidence in the methods grows as you discover that you "know" a certain answer is correct, having "seen" it develop mentally by alternate methods. This is an example of the redundancy that space-age designers try to build into their equipment for added reliability. You should practice redundancy, seek it, and use it, as a method of achieveing greater reliability in your work. When properly applied by your mind, it takes virtually no extra time.

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Madison, Wisconsin
February 13,1964

Professor Paul J. Grogan, Chairman
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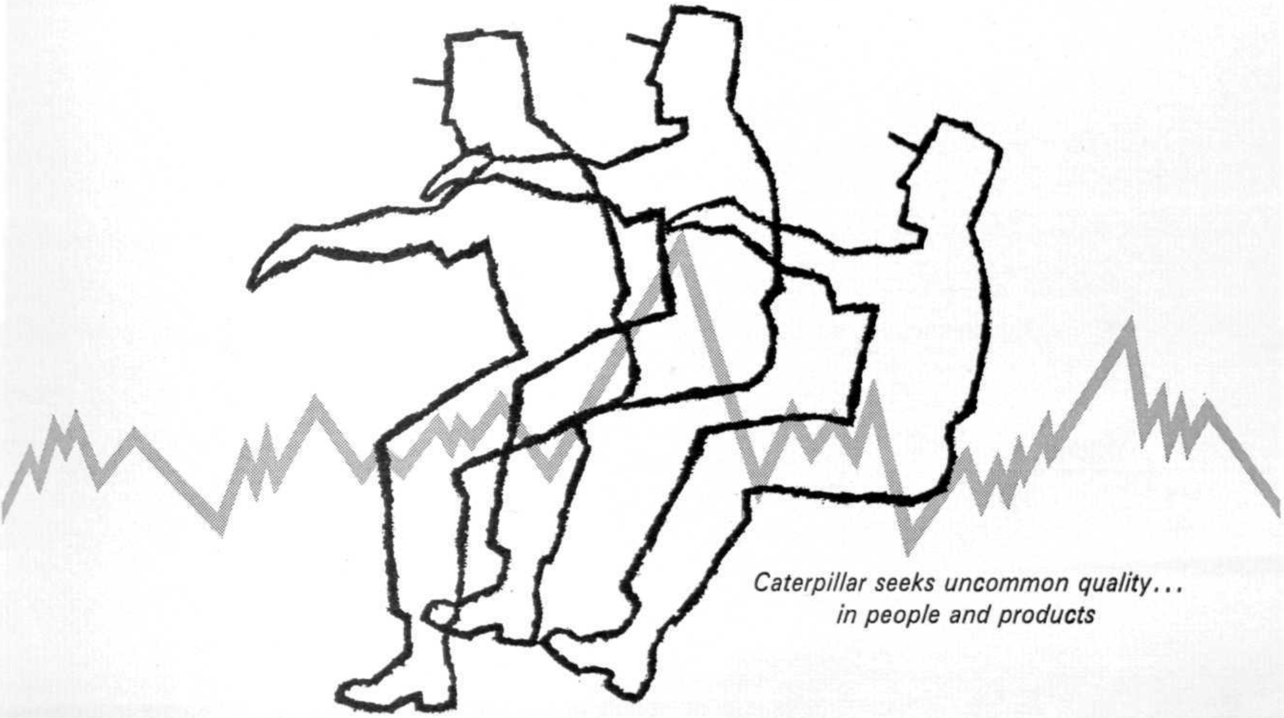
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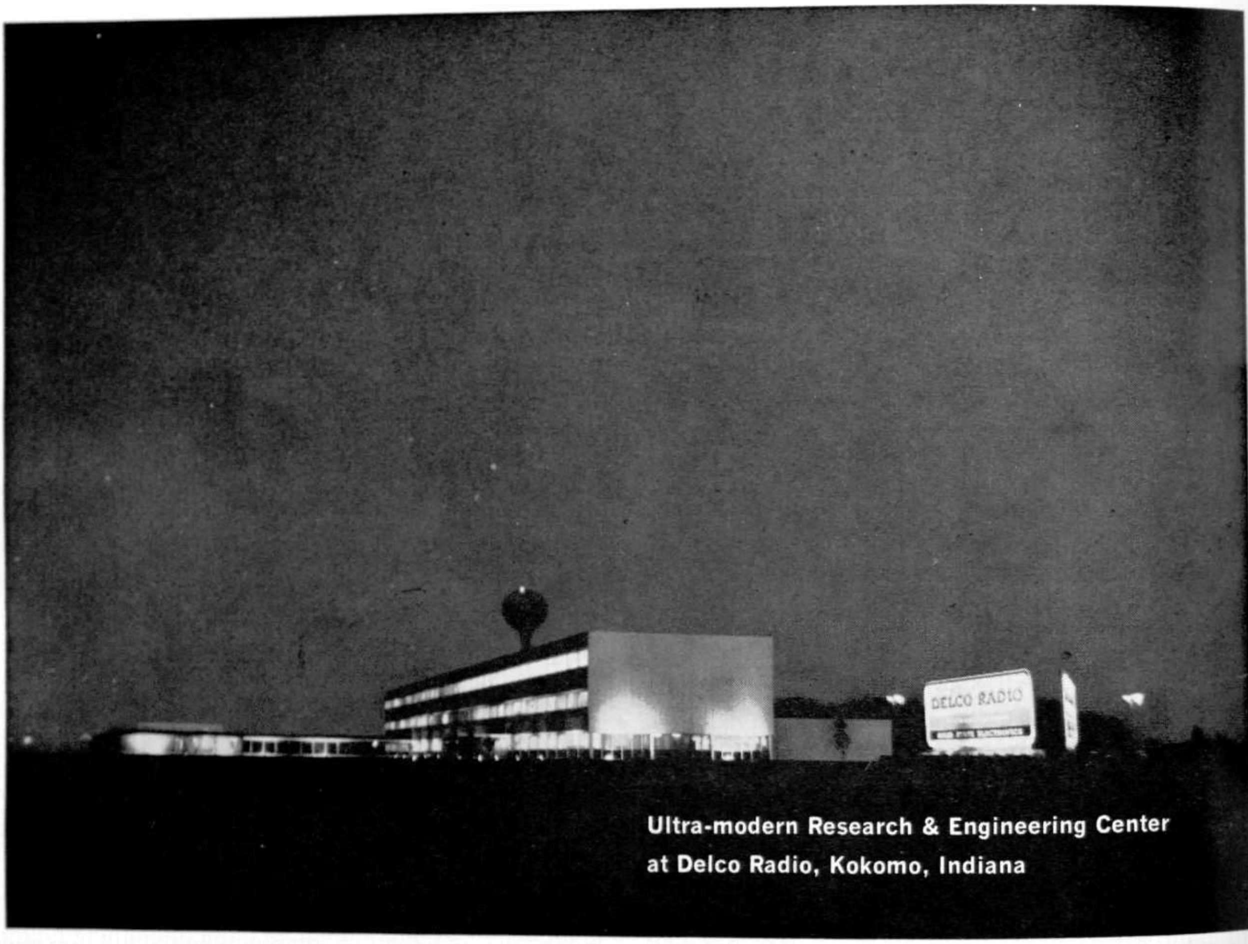

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31

CONTINUED FROM PAGE 24

experimentally by means of a wind-tunnel test.

Eq. (5) allows us to put an upper limit on the atmosphere. A convenient upper limit is the altitude at which $F_d$ is sufficient to cause a deceleration of 1.0 meter/sec$^2$. (If the ship moves through the upper layers fairly rapidly, the total deceleration produced by the layers above this upper limit will be negligible.) We should expect this upper limit to be fairly close to the surface: denoting the upper limit by $y_{max}$, we expect $y_{max} \ll R$. Thus in Eq. (4) we may set $r = R$ and be quite close. Then, using Eqs. (1) and (5) and letting M be the mass of the ship, the desired $y_{max}$ can be found. There is no need to write an explicit equation, as this is just one of several criteria that could be used. The important thing is that a reasonable value of $y_{max}$ be used, and used consistently in any particular problem.

In the absence of atmosphere, the orbit of the ship in the range below $y_{max}$ would be a conic section. We may consider its motion to be given by two parametric equations, with time as the parameter: $r = r(t)$, $\phi = \phi(t)$. Let us consider the nature of these equations without actually performing a parameterization. We know the range of r is small-- from R to $(R + y_{max})$. Consider now Kepler's second law, which states: For constant r, $\phi$ = constant, where $\phi$ is the ship's angular velocity with respect to the planet. From this it follows that for constant r, $\ddot{\phi} = O$. Now in fact r is very nearly constant; the range of variation is small in comparison to R and $\ddot{\phi} \approx O$. If we take r to be constant, $r = r_{eff} = (R + 1/2y_{max})$, then we can take $\ddot{\phi} = O$ to a high degree of accuracy. But $\ddot{\phi} = a/r$, where a is acceleration; hence in the absence of atmosphere we may say that in passing below $y_{min}$ we have $a = O$.

So much for $\phi(t)$. Let us consider r(t). At any time the ship's radial motion is subject to two forces, in the absence of atmosphere: the force of gravity and the "centrifugal force" $v^2/r$, where in this case v is the tangential velocity of the ship. In our case the "centrifugal force" will be $v^2 r_{eff}$. Thus we have that $\ddot{r} = g - v^2/r_{eff}$. This equation predicts results that are in reasonable agreement with actual occurrences within our narrow range of r.

Now let us put in an atmosphere, an atmosphere of constant density. (In the second article of this series we will extend results obtained for a constant-density atmosphere to real atmospheres of variable density.) The tangential acceleration a, or $\dot{v}$, is the sum of the acceleration due to drag forces and whatever acceleration there would be in the absence of atmosphere. But we have seen that in the absence of atmosphere we would have $\dot{v} = O$. Consider the acceleration due to drag forces. We combine Eq. (5) with Newton's second law and, remembering that M is the mass of the ship, we have

$\dot{v} = -F_d/M = -U^2(1/2\rho SC_D/M)$

where the minus sign indicates that the direction of the force is opposite in sense to the direction of acceleration.

Let us solve this differential equation. We separate the variables and integrate:

$$-1/v = (-1/2\rho SC_D/M)t + C$$

$$v = \frac{1}{(1/2\rho SC_D/M)t + C}$$

Multiply top and bottom by $v_i$, the initial velocity:

$$v = \frac{vi}{(1/2v_i \rho SC_D/M)t + C}$$

We require the initial conditions to be that v = vi at t = O. This allows us to evaluate the constant C: C = 1. Thus our final result is:

$$v = \frac{vi}{(1/2v_i\rho SC_D/M)t + 1} \quad (6)$$

We will perform another integration, but it will be convenient to express the resulting equation in terms of $\phi$. We have v = ds/dt where s is distance along the orbit, but $s = \phi r_{eff}$. With this change of variable we may write Eq. (6) as a differential equation and solve immediately. Our initial condition will be that at t = O we have $\phi = \phi_o$, $\phi_o$ being the angular position at which the ship first dips below $y_{max}$. Then we have

$$\phi = \phi o + \frac{M}{1/2 \ SC_D r_{eff}} \ln (1 + 1/2 \ v \cdot \rho SC_D t/M) \quad (7)$$

We can now finish our preliminary consideration of the dynamics of spacecraft in an atmosphere by considering its radial motion. Let the ship's surface area normal to the radius vector be S'. The differential equation for radial motion is then found by adding a drag force to the gravitational and radial forces already mentioned:

$$\ddot{r} = g - v^2 r/r_{eff} - (1/2\rho S'C_{D/M}) \dot{r}^2$$

We want for intial conditions that $\dot{r} + \dot{r}_o$ at t = O. To solve this equation, it will be useful to make the following changes of variable: $(g - v^2/r_{eff}) = G$; $(1/2\rho S' C_D/M) = c^2$; $\dot{r} = d(\dot{r})/dt$. Thus we rewrite the equation as:

$$\frac{d\dot{r}}{dt} = G - c^2\dot{r}^2$$

Separating the variables and integrating,

$$t + C_1 - \frac{1}{2c \sqrt{G}} \ln \frac{\sqrt{G} - c\dot{r}}{\sqrt{G} - c\dot{r}}$$

$C_1$ is evaluated from the initial condition:

$$c_1 = \frac{1}{2c \sqrt{G}} \ln \frac{\sqrt{G} + c\dot{r}_o}{\sqrt{G} - c\dot{r}_o}$$

Let us introduce a new variable: $t' = t + C_1$. Now we may solve the result of our first integration for $\dot{r}$:

$$\dot{r} = \frac{\sqrt{G}}{c} \frac{e^{2ct' \sqrt{G}} - 1}{e^{2ct' \sqrt{G}} + 1} = \frac{\sqrt{G}}{c} \tanh \sqrt{G}\, ct \quad (8)$$

We could replace the new variables c, G, and t' by the old variables, but doing so would merely complicate the equation. We may integrate Eq. (8) now, subject to the initial condition that $r = (R + y_{max})$ when t = O:

$$r = (R + y_{max}) - \frac{1}{c^2} \ln \cosh \sqrt{G}\, ct' \quad (9)$$

This finishes our preliminary treatment of the motion of a spacecraft in an atmosphere. The final result we will want to consider is that of the effect on a spacecraft's velocity if it fires retro-rockets. The differential equation for velocity during retrofire is the following: (6)

$$v = -g + \frac{T}{Mo - \mu t}$$

where T is the thrust of the retros, $M_o$ the spacecraft's mass at retro ignition, and $\mu$ the rate of mass ejection by the retros. We solve this equation subject to the initial condition of $v = -v_o$ at t = O (instant of retro ignition) and find

$$v = \frac{T}{\mu} \ln \frac{Mo}{Mo - \mu t} - gt - v_o \quad (10)$$

where the minus sign in front of the $v_o$ indicates the direction of velocity is downward.

Now we have established our preliminary results. In the next article of this series we will apply these results to a detailed study of our landing approach.

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[6] Yeh & Abrams, pp. 233-35

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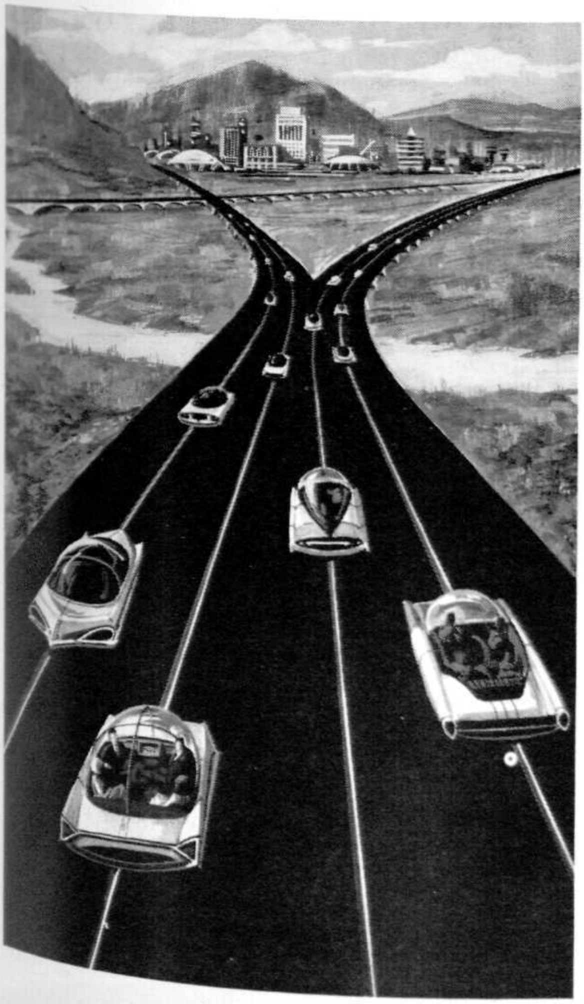

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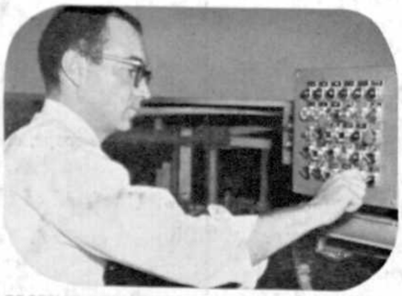

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