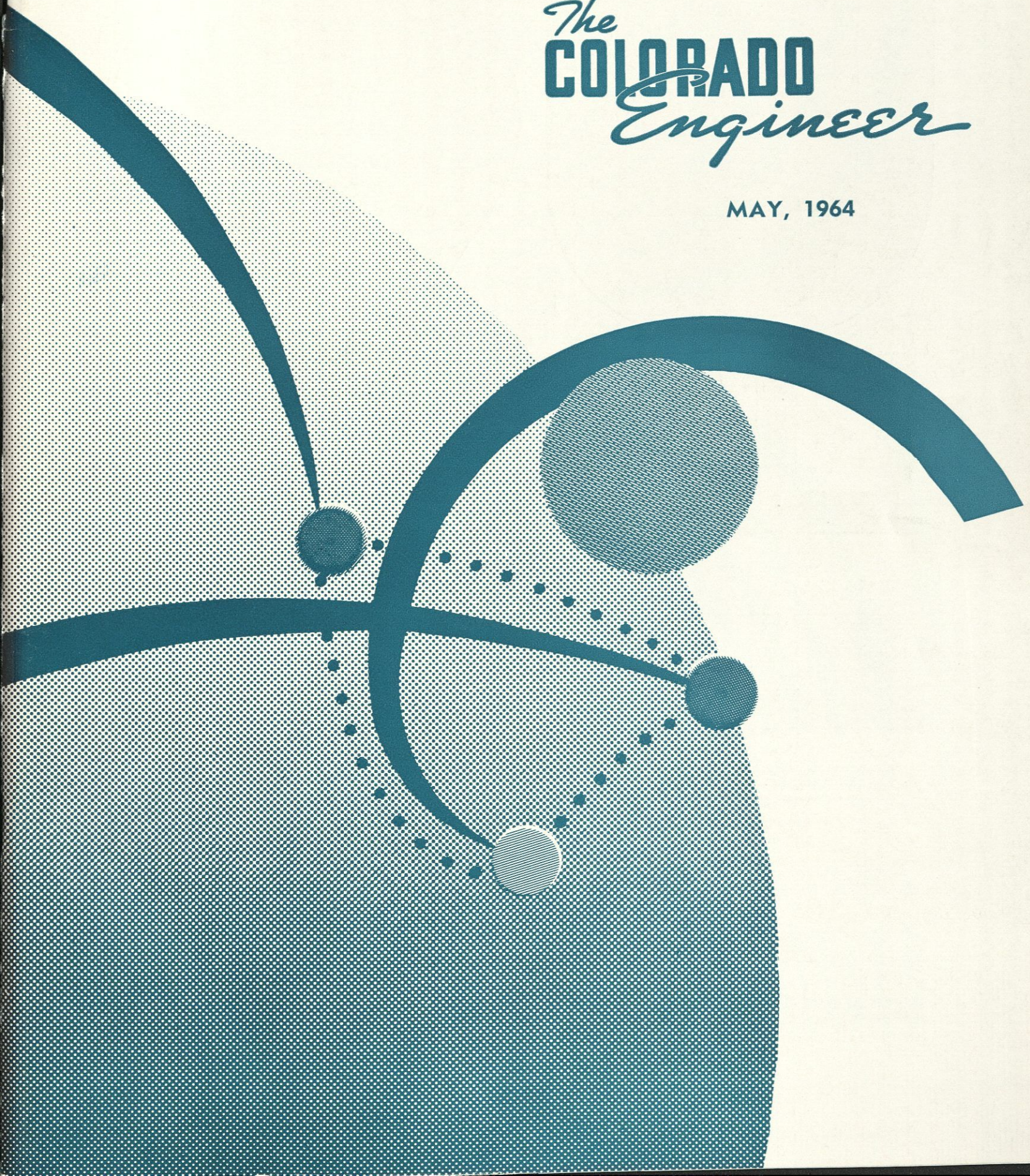
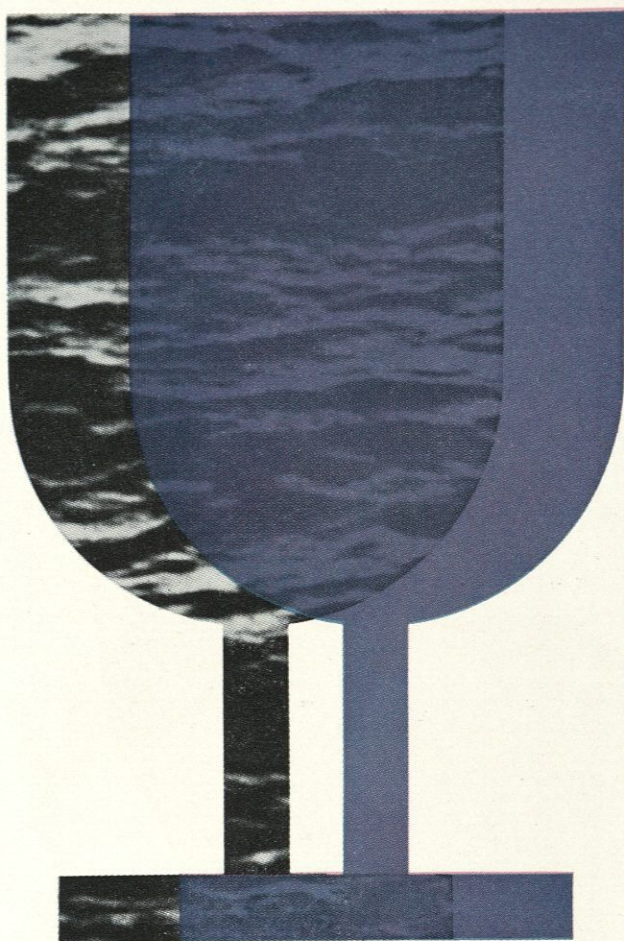


The
COLORADO
Engineer

MAY, 1964





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Imagine a modern factory that can produce 500,000 kilowatts of electric power—and at the same time take water from the sea and make it drinkable at the rate of 50 million gallons a day. That's enough power and water for a population of half a million.

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DEVELOPING NEW DESIGNS

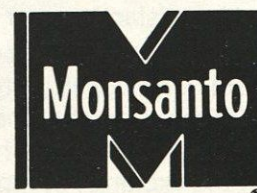
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The COLORADO Engineer

UNIVERSITY OF COLORADO, BOULDER, COLORADO

VOLUME 60

NUMBER 4

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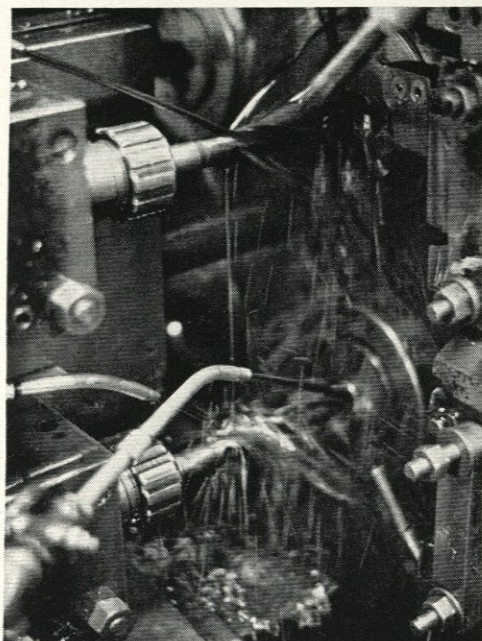
This month's cover is our artist's concept of future communication satellites relaying information between themselves and the earth. One is in orbit around the moon and the others around the earth.

Member of Engineering College Magazines Associated, J. Chumley, Chairman, Louisiana Polytechnic Institute, Ruston, Louisiana.

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Bob Turley, on right, American Oil Company Sales Engineer discusses cutting oil problem with Walter Binkley of Schwinn Bicycle Company.

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**what do you
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Bob's a mechanical engineer. Yet, he might have been working for us if he were a metallurgist, chemist, mathematician or physicist. Petroleum takes on a multitude of uses and requires people of every skill. For information regarding a career in sales engineering or other fields, write to C. L. Wells, Room 1036, American Oil Company, 910 S. Michigan Avenue, Chicago, Ill. ZIP Code 60680

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The Dinosaur Problem

What grunts, groans, gesticulations, and contortions would one cave man have had to perform to convince another, whom he had never before seen, that the dinosaur in the corner of the cave had no inclination to eat either of them? How would the first caveman convey the difference between eating a dinosaur, and being eaten by one? Without a common frame of reference, communications of this or almost any other nature are totally hopeless. Unfortunately, ideas themselves cannot be transmitted. They must be translated into some language, either audio or visual, before they can be conveyed. This is the problem that faced our two cavemen and that faces each of us.

It is primarily through communications that this modern world came about. While science has advanced through the efforts of individual scientists, those efforts would not have been possible without communication with other scientists. Scientific and technological advances alone are not sufficient; they must be communicated not only to other scientists, but to the whole world. As the volume and quality of communication between groups of scientists increases, so does their overall productivity. In return, that productivity increases the volume of communications and improves their quality by providing on expanded frame of reference on which to fasten new ideas. This sort of technological feedback has resulted in cooking ware made from nose cone materials, antibiotics made from rocket fuel, and advanced communication methods such as satellites.

Communication is of vital importance not only on this highly technical level, but also on the very personal level. Every advance, whether on the job or off, is made by means of and because of communications. On the other hand, disputes with wife, girl friend, or buddy may arise not from a real difference of opinion, but, all too frequently, from a communication breakdown. This breakdown is not usually of the sort that ends communication, but rather the sort that leaves information gaps.

On the professional level, contracts, jobs, and salary raises are lost or delayed because of similar breakdowns. These problems have a solution, but each individual must find it himself, just as the caveman found his. Ironically, the means to the solution have been available to us since grade school — reading, writing, and speaking. They are relatively easy to practice and someday may save you from being eaten by a dinosaur — or the Boss.

LARRY L. HUSTON

DEVELOPMENT OF MANAGEMENT IS OUR MOST IMPORTANT FUNCTION

At the 1963 stockholders' meeting, Arjay R. Miller, President of Ford Motor Company, emphasized the Company's far-sighted recruitment program and its accent on developing management talent:

"Obviously, our long-run future will be determined by the development of our management. Here, every one of us—at all levels of supervision—recognizes this as his most important function. Since 1946, the Company has recruited widely varied talent—talent that can be blended to give us the required combination of tight administration and creative scope.

"Under a carefully conceived management development program, we try to recruit the best personnel available, both in training and experience. Once we get them, we have a program for giving them varied opportunities and increasing responsibility. This program is in force in all parts of the Company—in manufacturing, finance, styling, engineering and marketing.

"The program is paying off. We have developed a real depth of management talent in the Company, and we are dedicated to seeing it continued and reinforced. Because of this, I feel not only very fortunate in being associated with this management group, but also very confident of its long-run success. We know our goals and how to achieve them."



MOTOR COMPANY
The American Road, Dearborn, Michigan



Arjay R. Miller, President of Ford Motor Company, and Henry Ford II, Chairman of the Board, at 1963 Annual Stockholders' Meeting.



An equal opportunity employer

COMMUNICATIONS SATELLITE

BILL CHENWORTH

Although satellites have only recently made their grand entrance into the communications arena, the idea of using spacecraft to relay radio waves is not new. Almost twenty years ago, this idea was conceived and published by a British science writer, Arthur C. Clark. His specific proposal was to orbit three elaborate manned space stations each packed with radio broadcasting and relaying equipment and traveling in the plane of the equator about 22,000 miles from earth. Clark maintained that such a system would provide a relay network capable of handling signals from virtually any joint on the globe. Even though Mr. Clark's idea is now dated by twenty years, the concept of communications satellites is very much alive today and three distinct systems are getting off the ground and into the laboratory of space.

The three systems undergoing intensive development have been identified as follows:

- (1) synchronous active satellite
- (2) non-synchronous active satellite
- (3) non-synchronous passive satellite

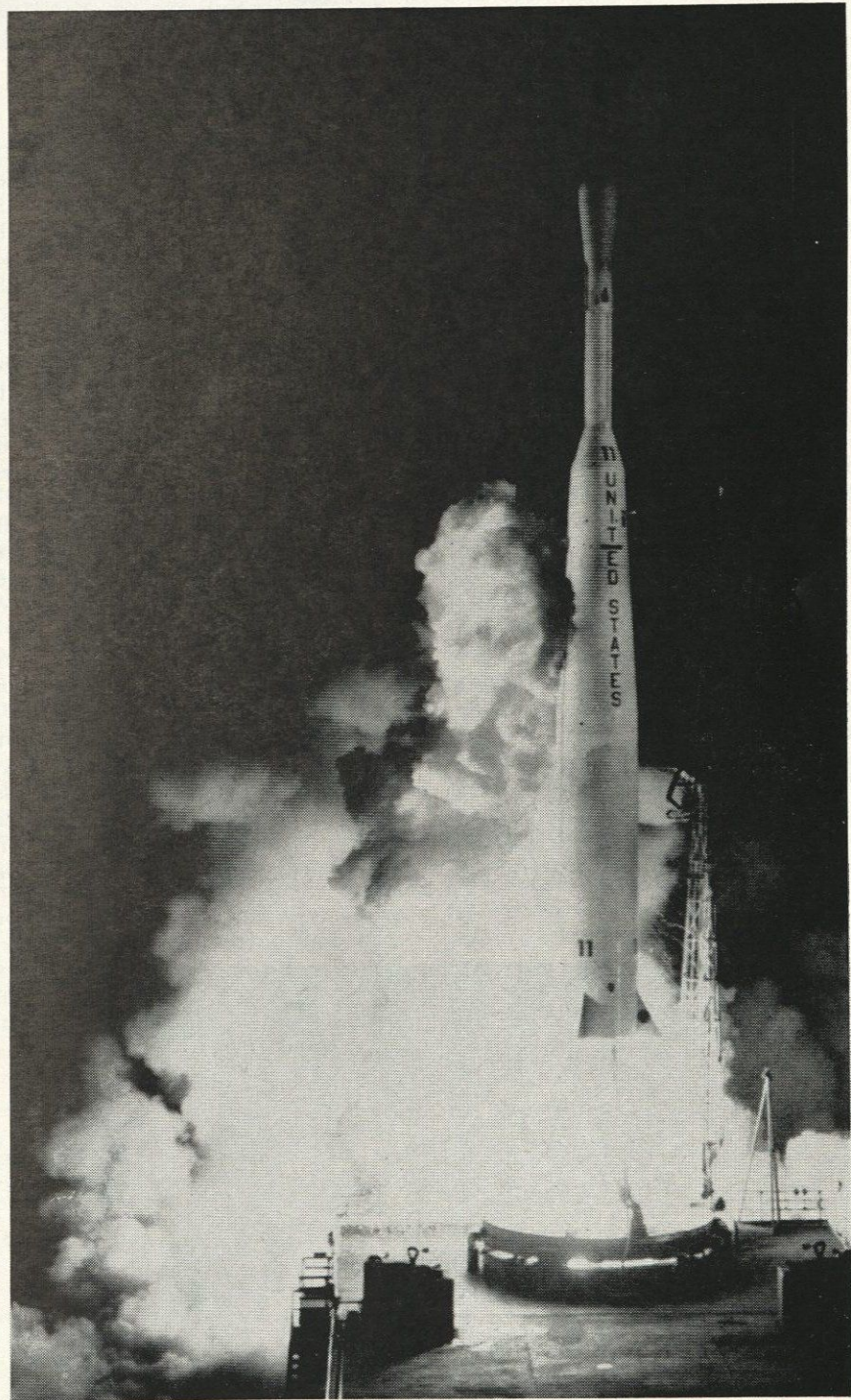
Note that the first two systems employ an "active" satellite, whereas the last uses a "passive" type. There is a vast difference between the two. An active satellite receives, amplifies and transmits radio signals. Syncom, Relay, and Telstar are examples of this type. A satellite which is passive merely intercepts radio signals and reflects these back to earth. Echo is of the passive variety.

Synchronous Active Satellite

The orbit configuration of the synchronous active satellite system is the simplest of the three. This system is composed of three satellites spaced 120 degrees apart in the equatorial plane, rotating with the earth at an altitude of about 22,300 miles.

(See Fig. 3)

Notice that the angular velocity of each satellite is equal to (synchronized with) that of the earth about its axis of rotation. In theory, synchronization is achieved by simply placing the satellite in a circular orbit



TELSTAR I AT LIFTOFF ABOARD A DELTA ROCKET

at the indicated altitude. If we investigate the centrifugal and gravitational forces acting on the satellite, this fact is readily apparent,

$$F_c = \frac{v^2}{r} m = \omega^2 r m \quad F_g = G \frac{mM}{r^2}$$

In order to maintain orbit $F_c = F_g$

$$\omega^2 r m = G \frac{mM}{r^2}$$

$$\text{Or } r = \left(\frac{GM}{\omega^2} \right)^{1/3}$$

Setting $\omega = 2\pi \text{ rad} / 24 \text{ hr.}$, we have $r \approx 22,300 \text{ miles} + \text{radius of earth}$

As of this writing, two satellites, Syncom I and Syncom II (refer to photograph) have been orbited as preliminary steps in developing the synchronous active satellite system. Primary objectives of these shots were to spin stabilize the satellite; to obtain a synchronous orbit using the satellite's own rocket motor and a nitrogen or hydrogen peroxide velocity pulse jet; to orient the spin axis normal to the orbital plane; and to utilize the spacecraft in communications experiments. Ground command was essential for the fulfillment of these objectives and it is for this reason that Syncom II was far more successful than its predecessor, Syncom I. After Syncom I's rocket had burned for 20.077 sec. all contact with the spacecraft was lost. It should also be noted that neither vehicle was programmed for an equatorial orbit primarily because of the limited capability of the hardware involved. Nevertheless, both launchings were successful in that near 24 hour orbits were achieved and much data was obtained to evaluate the techniques employed at this stage of development of a synchronous active satellite system.

The techniques and components developed to meet Syncom's program objectives will now be briefly pre-

sented. Before separation of the satellite from its rocket booster, a 150 rmp spin is imparted to Syncom by the booster's third stage. This spin serves to stabilize the spacecraft in the same manner that a gyroscope is stabilized. The satellite then enters a highly elliptical orbit with an apogee of about 22,300 miles. After the satellite reaches this apogee, a ground command or on-board timer ignites the rocket motor to break away from the elliptical orbit and establish a circular orbit at the 22,300 mile altitude. Spin axis precession is then accomplished by pulsing the nitrogen (or hydrogen peroxide) orientation jet in synchronism with the spin of the satellite, producing a net average precession torque. This torque positions the satellite so that its spin axis is normal to the orbital plane. This maneuver is required for correct antenna altitude. Small adjustments to the satellite's velocity may then be effected by periodically firing the nitrogen (or hydrogen peroxide)

velocity pulse jet. Both the velocity and orientation pulse jets must thereafter be fired periodically in order to maintain the synchronous orbit and proper orientation; therefore, the life of the satellite is determined by the amount of fuel on board. In order to handle communications via radio wave, Syncom is equipped with a 2 db skirted-dipole receiving antenna, a receiver, frequency translation transponders, a 2.0 watt traveling-wave tube amplifier and a 6 db skirted-dipole-array transmitting antenna. Voice, facsimile, and both simplex and multiplex teletype messages may be relayed by Syncom. In order to provide the necessary electrical power, 35 watt-hour rechargeable nickel-cadmium batteries are employed in conjunction with a solar cell array. Reliability of much of the electronic gear is questionable and backup components have been provided to a large extent. In review, Syncom is spin-stabilized before separation; a self-contained, apogee, rocket motor is used to circularize the initial elliptical orbit; pulse jets are used to establish and maintain a synchronous orbit and satellite altitude; radio signals are boosted by a traveling-wave tube amplifier; electronic component redundancy is common and electrical power is provided by batteries and solar cells.

Non-Synchronous Active Satellite

If you were to place a satellite in an altitude below 22,300 miles, synchronization would be impossible. This is precisely what is done in the non-synchronous active satellite system. Obviously, this type of system needs more satellites to provide the same amount of global coverage that is obtained with the synchronous type; therefore, the orbit configura-

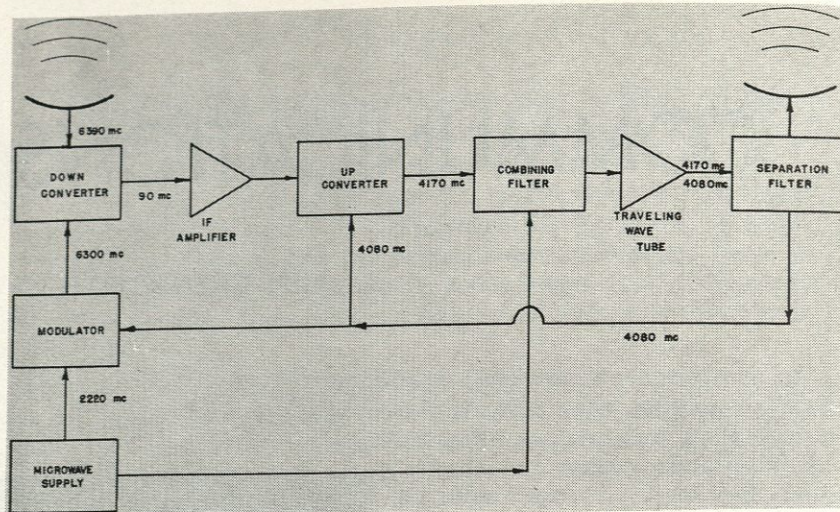
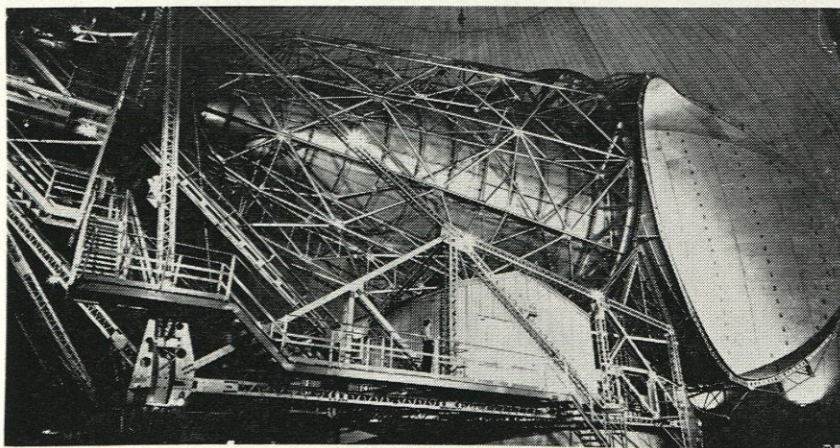


FIG. 1. SCHEMATIC DIAGRAM OF THE TELSTAR SATELLITE RELAY SYSTEM



THE HUGE HORN REFLECTOR OF BELL'S SATELLITE COMMUNICATIONS ANTENNA AT ANDOVER, MAINE.

tion of the non-synchronous system is substantially more complex and this complexity is directly proportional to the quality of service desired; i.e., the larger the number of satellites in orbit, the greater the probability of one of them being in a usable position for any two ground antennas. (Some proposals have been advanced which would use well over 100 satellites). Another factor contributing to this complexity is that the non-synchronous system is not restricted to an equatorial orbit but may employ this type along with polar and inclined orbits. On the other hand, a non-synchronous satellite is simpler than the Syncom type in that it is not burdened with position control equipment. Thus trademarks of the non-synchronous system are orbit complexity and satellite simplicity.

The complexity of the orbit configuration is revealed in the following diagram which depicts a non-synchronous system proposed by the American Telephone and Telegraph Co.

(See Fig. 4)

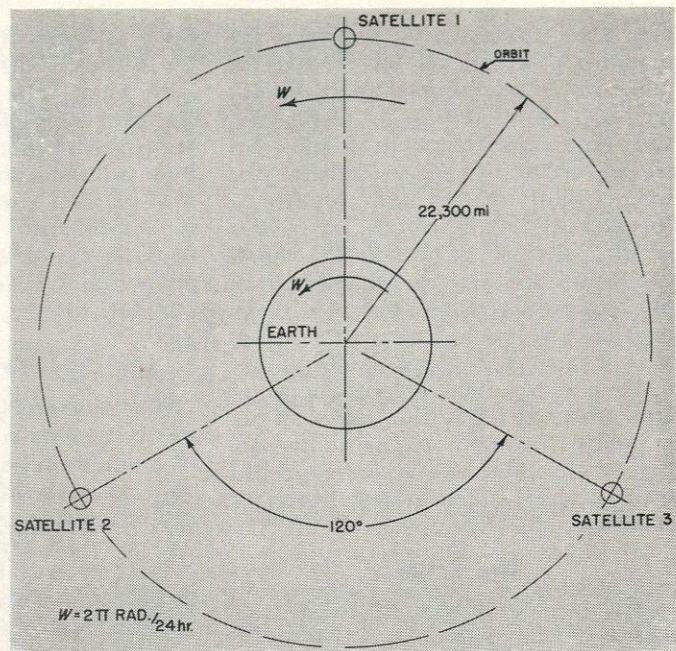
This system would employ 55 active satellites, 40 in polar orbits and 15 in equatorial orbits, in order to provide communication service 99.9 percent of the time to any region on the earth. The altitude of these orbits would be about 7,000 miles.

Another system proposed by A.T. and T. would consist of 24 satellites in 6000 mile circular orbits. Each orbital plane would contain four equally spaced satellites. Three of the planes would be polar and the other three would be inclined 28° to the earth's equatorial plane. The ascending nodes (points on the ascending portion of the orbit where it crosses the equator) of the three planes in each group would be 120° apart. This system would provide essentially uniform service throughout the world with a modest number of satellites.

These examples merely serve to demonstrate the relatively complex nature of a non-synchronous orbit configuration and no attempt has been made to discuss this in detail, as this is beyond the scope of this article. A more comprehensive presentation of the non-synchronous orbit characteristics may be found in reference (1).

To date, three spacecraft, Relay, Telstar I and Telstar II, have been placed in medium altitude orbits as prototypes of the future non-synchronous active satellite. Differences between the Relay and Telstar designs are subtle and therefore the remainder of this discussion shall be devoted to the latter. Both Telstar

FIG. 3.
A
PROPOSED
ARRANGEMENT
FOR THREE
SYNCOM
SATELLITES



vehicles were boosted into highly elliptical orbits inclined to the equator at about 45° . As was the case with Syncom, both satellites were spin-stabilized by the last stage of the booster. Neither satellite was equipped with pulse jets or any position-control hardware. Consequently, the spin axis does not remain fixed relative to the earth or sun. This fact had to be taken into account in the design of the antenna and solar-cell array. Two equatorial bands of rectangular ports and L-shaped diagonal probes make up the microwave antennas. This design provides a nearly isotropic pattern. The solar cells are distributed approximately uniformly over the satellite's surface in order to best collect whatever sunshine is available. Nickle-cadmium storage batteries are charged by the solar cells and are the satellite's primary source of electrical energy during an eclipse. One interesting point is that Telstar cannot be operated continuously because of power limitations and consequently it is turned on and off by ground command. The following diagram illustrates the transmission of radio waves through the satellite: Signals are received at 6390 mc, converted to 90 mc and amplified by an IF amplifier, which supplies most of the repeater gain. The signals are then converted to 4170 mc, amplified by the traveling wave tube and radiated by a separate antenna with a power of 2.0 watts. It is interesting to note that the separation filter is deliberately made "leaky" to the 4080 mc signal so that a portion of it provides a microwave beacon to be used by

ground antennas in acquiring and tracking the satellite. Telstar is capable of transatlantic transmission of high quality television, or the equivalent of 600 one way telephone channels. In summary, Telstar is spin-stabilized; its spin axis is not fixed; the antenna pattern is isotropic; electrical power is provided by solar cells and batteries; it is activated by ground command and its microwave repeater network employs a traveling wave tube.

Non-Synchronous Passive Satellite

The non-synchronous passive satellite system is simply a modification of the preceding system—the fundamental difference being that a "passive" satellite is employed rather than an "active" type. However, once again the orbit radii are below that required for synchronization and a variety of orbits—polar, equatorial and inclined—may be used. Thus orbit complexity is a characteristic, but on a larger scale since the orbits must be closer to earth in order for a passive satellite to radiate a signal of the same strength obtainable with an active satellite at a higher altitude. This is understandable, if you recall that a passive satellite merely reflects the radio signal whereas an active type amplifies this signal before returning it to earth. Moreover, passive satellites presently being developed are necessarily restricted to low altitudes due to the mammoth size which they must take on at higher altitudes in order to be effective. An enormously powerful booster would be required to place such payloads into high or-

bits and consequently cost of such magnitude would be incurred as to make this operation economically unfeasible. One approach to placing this type of satellite in high orbit would naturally be to lower the weight, but this would require a formidable breakthrough in passive satellite design. Thus, at the moment, it appears that the non-synchronous passive satellite system will be restricted to low altitudes. Of course at low altitudes, more satellites are needed to cover the same amount of land areas as high-orbit types. Consequently the orbit configuration of a non-synchronous passive system would be akin to the active system but more complex.

The Echoes

The passive satellite is an entirely different animal than the active type. It is essentially a big balloon with radio beacons. Two of these, Echo I and Echo II have been successfully orbited (see photograph). Echo I was placed into a 900 n. miles orbit inclined 47° to the equator on 12 August, 1960. Echo II was launched in January of this year.

Echo I was constructed for short-time use to demonstrate the feasibility of large, inflatable spheres as communication reflectors. It was made of strips of Mylar, 0.0005 in. thick, coated with vapor deposited aluminum for radio wave reflectivity. It weighed 136 lb. and was folded into a small 26 inch diameter container. Fully inflated, it assumed a spherical shape with a diameter of 100 feet. The folded balloon was ejected into space and became partially inflated by the residual air it contained. Complete inflation was achieved by using two sublimating powers, benzoic acid and anthroquinone, of very low vapor pressure. It was calculated that 10 lb. of anthroquinone and 20 lb. of benzoic acid would provide a final skin stress of 150 psi in the Echo I structure. The stiffness of the structure was considered marginal in its ability to maintain a spherical shape once the gases have escaped due to punctures.

Echo II was designed to resist the space environment almost indefinitely and consequently was more rigid than its predecessor, Echo I. It was made from laminate strips each composed of two layers of aluminum foil, 0.00018 in. thick, bonded to a central skin of Mylar, 0.00033 in. thick. Fully inflated, it measured 135 feet across and was folded into a 44 inch diameter container. As was the case with Echo I, initial deployment was accomplished by residual air. Com-

plete inflation however, was achieved by 72 bags of acetamide, sealed closed with wax. The melting point of the wax slightly below the equilibrium temperature of the fully inflated balloon so that until this temperature was reached the acetamide was free to sublimate. This structure also contained two solar-cell-powered 25-mw. radio beacons located at the equator of the sphere, 180 degrees apart.

Problems

The non-synchronous passive satellite system, at a glance, is composed of numerous balloon structures capable of reflecting radio waves and located in low-altitude orbits which may be polar, equatorial or inclined.

Now that we have some concept of the communications satellites systems being tested today, let's take a look at some of the advantages and drawbacks of each. To provide constant global coverage the synchronous system would employ only three satellites, if no backups are used. Since the position of each satellite is stationary relative to the earth, the ground antennas may be fixed thereby alleviating the necessity for costly acquisition and tracking equipment. On the other hand, each satellite must be equipped with intricate position-control equipment in order to stay put. The nonsynchronous active satellite system would consist of numerous non-stationary satellites. Consequently the ground equipment

would have to be more complex in order to acquire, track, and switch between satellites. Also, since the orbits are subject to drift, there may be times when no satellite is "visible" between two ground stations, thus causing an outage. However, the type of satellite employed in this system is simple in that position-control equipment is not used. The disadvantages of this system also apply to the non-synchronous passive satellite type. An additional disadvantage is that more satellites would have to be used to provide equivalent earth coverage since they must be placed in low-altitude orbits. The primary advantage of the passive system is that the satellites are simple balloon structures. In addition, since both of the non-synchronous systems are located in low altitudes, the satellites are subject to proton bombardment which plays havoc with transistors.

In conclusion, intensive activity is now being directed to establish the role of satellites in world-wide communications. Some practical experience has already been obtained with the launchings of Syncom, Telstar and Echo and these launchings have demonstrated the feasibility of a satellite communications system. We have come a long way since Clark first advanced this concept but much work remains to be done until a commercially acceptable system is achieved.

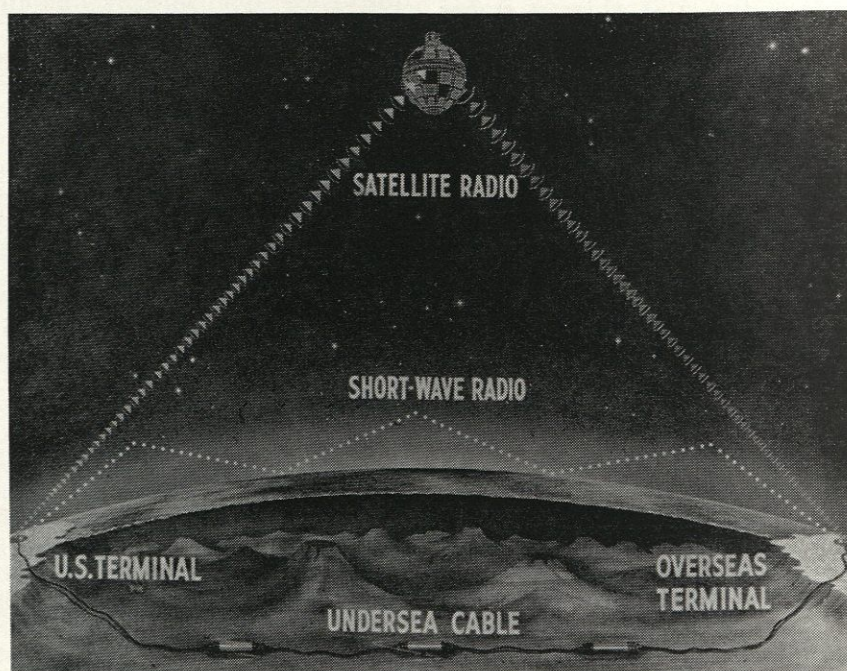


FIG. 4. AN ARTIST'S REPRESENTATION OF EXISTING OVERSEAS COMMUNICATIONS CIRCUITS

THE BELL TELEPHONE COMPANIES

SALUTE: CHUCK SCHNORENBERG

Chuck Schnorenberg (B.S., 1957) is plant manager for Pacific Northwest Bell at the communications center in Roseburg, Oregon. He is responsible for the economical and efficient operation of all communications in the area.

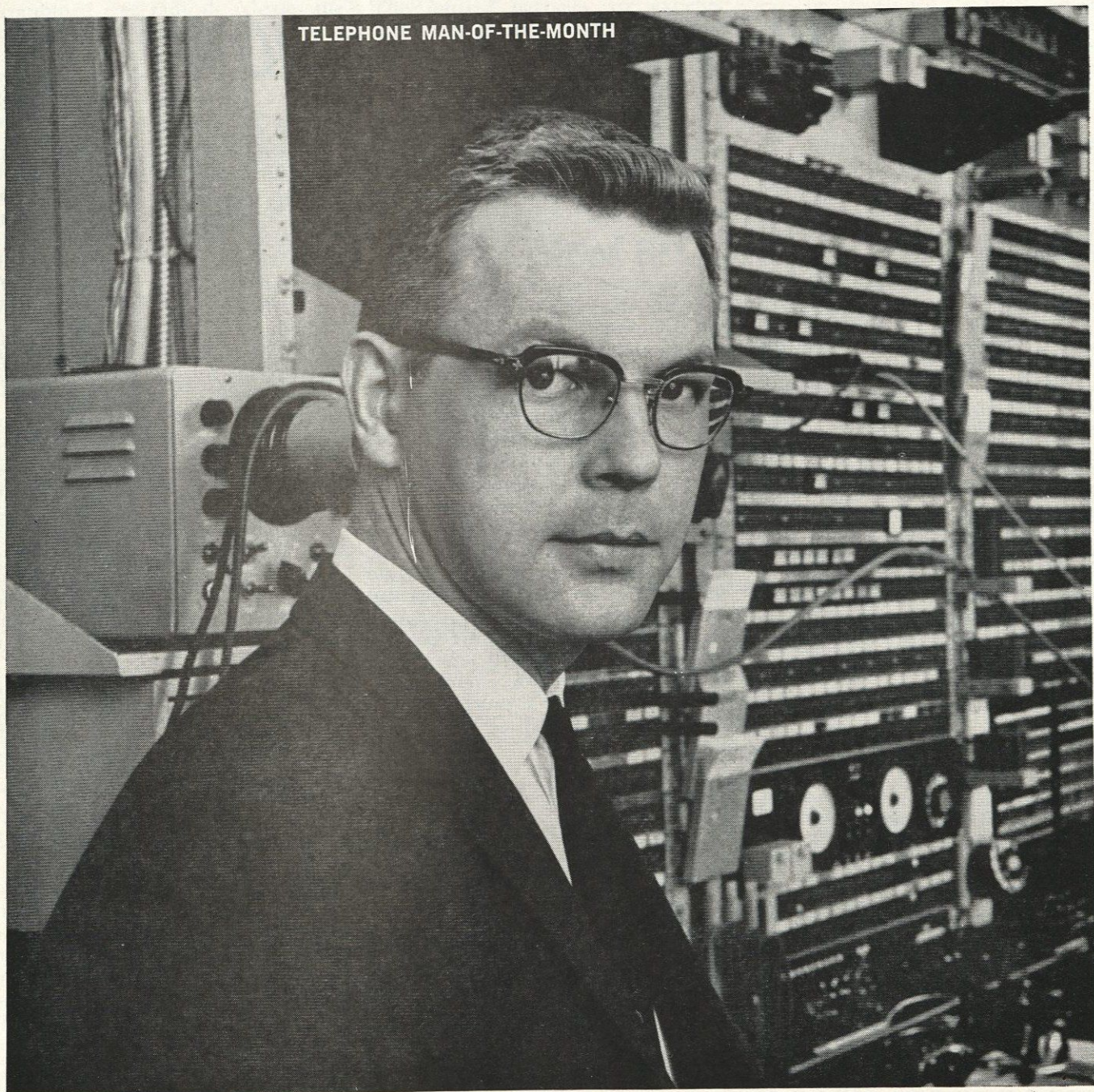
This is quite an assignment for a man less than 3 years with the company. But Chuck's career has been based on increased knowledge of the company and its operations, which has been followed logically with the increased responsibility and authority he has proven he can handle.

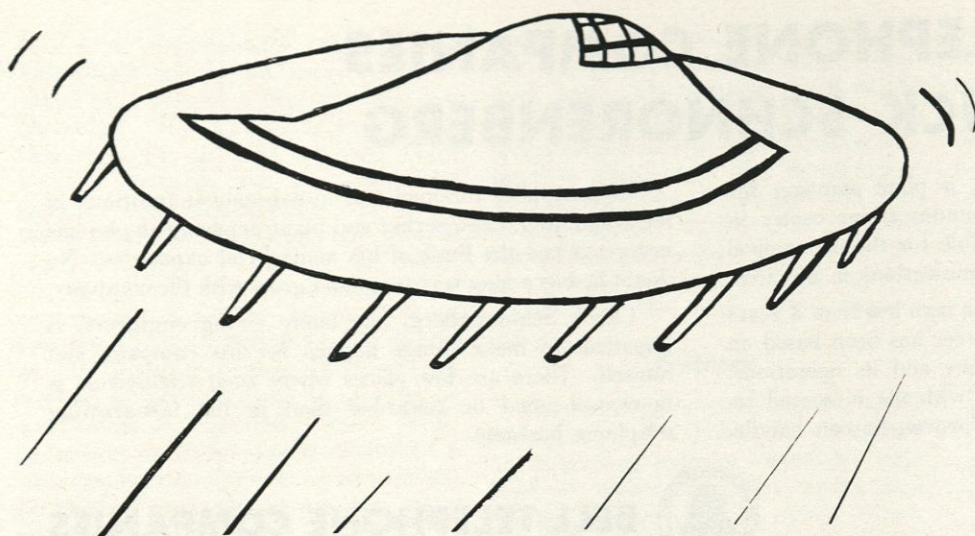
As a supplies foreman and in subsequent positions in the accounting, engineering and plant departments, he has never reached the limit of his managerial capacities. No doubt he has a long way to go and grow with the company.

Chuck Schnorenberg, like many young engineers, is impatient to make things happen for his company and himself. There are few places where such restlessness is more welcomed or rewarded than in the fast-growing telephone business.



BELL TELEPHONE COMPANIES





FRED LOVE

ADVANCED PROPULSION

For the present, rocket propulsion by chemical means is sufficient, but the time is rapidly approaching when space exploration will demand more advanced sources of power. A chemical-burning rocket is capable of producing very high thrusts, but it does so by burning large quantities of fuel in a very short time. While this high thrust is needed to overcome the downward acceleration of gravity here on earth, such extravagance is not feasible for long journeys into space. With this problem in mind, much research has been done to find a more efficient method of propulsion.

The specific impulse (I_{sp}) of a rocket engine is defined as the pounds force of thrust produced, divided by the mass flow rate in pounds mass per second of the propelling steam. This is sometimes expressed in terms of seconds by assuming pounds force and pounds mass to be equal. The maximum I_{sp} for chemical propellants appears to be about 400 lbf-sec/lbm, with present rockets being capable of specific impulses of about 350 lbf-sec/lbm. Research in advanced propulsion systems indicates that an I_{sp} of over 20,000 lbf-sec/lbm is possible with other methods.

The space probe of the future will most probably be launched from an orbiting satellite. Thus it will not require the large thrust to overcome gravitational attraction that can only be provided by chemical propulsion systems. The space probe will instead need a propulsion system that can produce enough power for the journey's requirements without ex-

pending large amounts of energy. Some of the more promising attempts to satisfy this need are described below.

FREE RADICAL SYSTEMS

Any rocket propulsion system relies upon Newton's Third Law, i.e., it pushes itself forward by expelling mass in the other direction. When the mass expelled is a gas, it is found that the lighter the gas, the higher will be the I_{sp} produced by its expulsion. For example, gaseous hydrogen at 3000°K will produce an I_{sp} of 707 lbf-sec/lbm, while CO_2 (a common result of combustion) produces an I_{sp} of only 197 lbf-sec/lbm under the same conditions. Of course the energy released must come from somewhere. In the case of CO_2 , this energy was provided by the chemical reaction which produced the gas. In other words, if an efficient means could be found to add energy to the gaseous hydrogen, a much superior rocket engine for space exploration could be obtained.

One source of this energy could be

the combining of unstable free radicals. For example, the gaseous hydrogen could contain some monatomic hydrogen. The H will release 24.4 Kcal/gm when it recombines to H_2 . This released energy will be absorbed by the surrounding gas and later released as the gas is expelled.

Because of the free radical's high instability, it is very difficult to preserve as a distinct species. However, this free radical may be stored for a period of time by trapping it among inert atoms. This is done by supplying energy to a stream of H_2 (either with an electric arc or with radiation) in the vicinity of a cold surface (the temperature of liquid N_2 or He). As some of the H_2 molecules are broken into atomic hydrogen, they become surrounded by inert H_2 molecules. Because the low temperature prevents much migration, the free radicals remain trapped. If the temperature of the inert mixture is increased sufficiently, the free radicals will be able to diffuse through the now active H_2 and recombine with other free radicals.

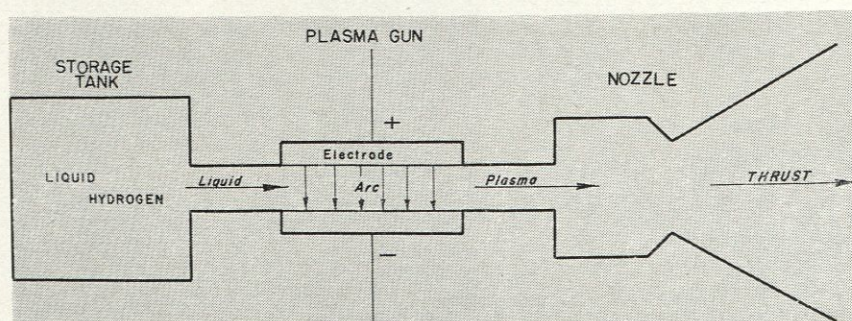


FIG. 1. A PROPOSED PLASMA ROCKET

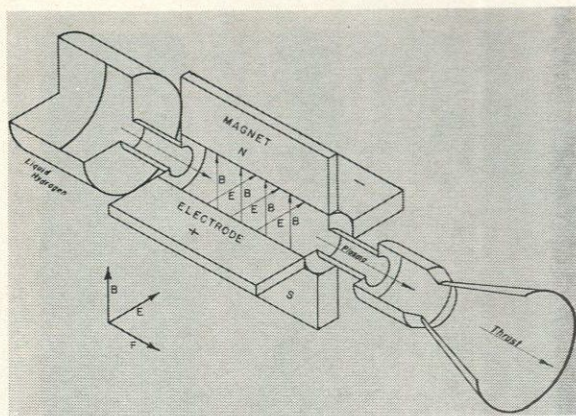


FIG. 2.
AN MHD
PROPULSION
SYSTEM

The low temperature mixture of inert H_2 and atomic hydrogen is pumped to the reaction chamber. Here some of the energy of previously recombined free radicals releases the trapped free radicals, allowing them to recombine to H_2 . The energized stream of gaseous H_2 then flows from the nozzle, providing thrust. While such an engine is years in the future, it is, nevertheless, a promising solution to the problems of rocket propulsion.

NUCLEAR AND SOLAR PROPULSION

The much publicized nuclear rocket engine is very similar to the free radical engine. In this case, however, the energy required by the propelling H_2 stream is provided by a nuclear reactor. The liquid H_2 is pumped through the reactor where it picks up thermal energy from the atomically active core. The H_2 then expands through the nozzle to provide thrust. The Kiwi-A nuclear rocket presently being tested is essentially this type.

Another type of heat-utilizing rocket engine relies upon solar energy. In this engine, a heat exchanger is placed at the focal plane of a large collecting mirror. Radiant energy from the sun is directed upon the heat exchanger, where it supplies the energy to vaporize and heat the H_2 that propels the craft. This design is very interesting in that it requires no self-contained energy supply. The engine literally pulls energy out of space to provide the thrust.

PLASMA AND MHD PROPULSION

There is also research being done on a propulsion system that uses the above two sources of power in an indirect way. The nuclear or solar energy is converted to electrical energy. This electric power is then used to produce an arc (see fig. 1). The arc then transmits the necessary energy to the H_2 stream, and in so doing, creates a thermally ionized plasma. Thrust is produced as the plasma expands through a nozzle.

When a relatively dense plasma is produced by the arc, it may be further accelerated by magnetohydrodynamic (MHD) action (see fig. 2). The ionized particles are expelled by the arc. This technique is capable of producing specific impulses of up to 10,000 lbf-sec/lbm.

ION ROCKET ENGINES

A completely different type of engine uses electrostatic expulsion of ions as a means of producing thrust (see fig. 3). Liquid cesium is pumped to a boiler and vaporized. The gaseous cesium then passes through a porous tungsten disc where electrons are literally "scraped off," leaving cesium cations. The cations are then accelerated across a potential and expelled from the engine, much like particles in a linear accelerator. The electrons scraped off are also accelerated and expelled. Thus both the positive and negative ions provide thrust.

The ion engine is both the most promising and the least developed of the advanced propulsion systems. Specific impulses above 5×10^5 lbf-sec/lbm have been theorized, but such power is far from a reality.

PROBLEMS TO BE SOLVED

Like any evolving ideas, all phases of advanced propulsion are filled with severe problems that must be solved before the systems can become practical realities. In most cases,

these are "state of the art" problems without any apparent solution. That is, man is unable to solve these problems with what he now knows. However, in the past, thorough investigation has always provided knowledge, and eventually solutions.

There is, as yet, no way to produce a sufficiently high concentration of stabilized (trapped) free radicals in a mixture to provide the energy for a free radical propulsion system. The best attempts in this direction have resulted in only trace amounts of free radicals in the inert liquid.

The nuclear propulsion system has a weight problem. Reactors mean radiation and radiation means bulky shielding to protect the crew. Thus unless a light-weight radiation shield can be developed, a workable and efficient atomic rocket cannot be a reality. Like its namesake, the Kiwi-A nuclear rocket cannot fly. Technology must advance considerably before the Kiwi can be changed into an eagle.

This technological gap is especially great in the propulsion systems using electrical power. Although great strides are being made in the efficient production of electricity from other sources of power, we still rely upon bulky mechanical generation or inefficient chemical and physical sources (batteries—solar and chemical, fuel cells, etc.). The promising ion propulsion systems require very high potential differences to create thrust. While this power could be supplied by a steam turbine-generator system, complete with boiler, condenser, heat exchangers, and other equipment, the resulting vehicle would be too cumbersome for its purpose.

The outlook is not completely black. Work is continuing on all of the problems, and one by one they will be solved. Interplanetary and even interstellar travel will one day be a reality. With man's curiosity about his universe as a driving force, nothing is impossible.

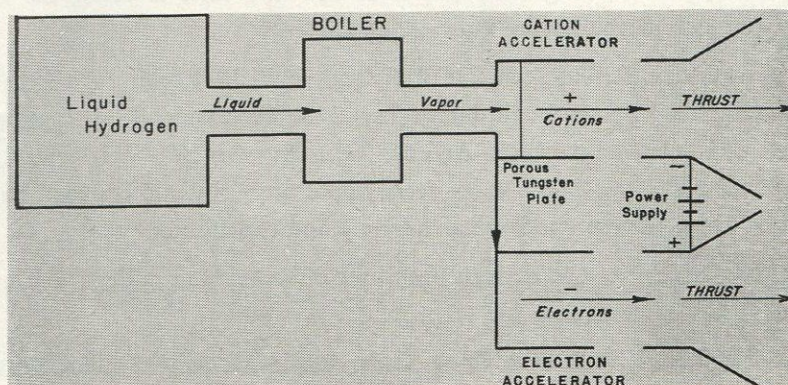


FIG. 3. AN ION ENGINE FOR SPACE TRAVEL



a man
likes to
know
where he's
headed

False career starts are frustrating from both an achievement and an advancement viewpoint. Getting the right start the first time is often the most important step in your entire engineering career.

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LASER

DEVELOPMENTS

DODD PRICE

The laser is a little over three years old. At present, by conservative estimate there are approximately 500 organizations engaged in laser research or exploitation.

Lasers have progressed to the point where their basic principles are well understood, but the engineering and application work has just begun. It is predicted that a split between the scientific work and the applied technological work will take place in the next few years. The effort put into the development of laser collateral equipment, such as modulation and demodulation apparatus is increasing rapidly.

Operation

The laser is a high frequency device operating in the visible and infrared portion of the electromagnetic spectrum. Unlike conventional high frequency devices, the klystron for example, which obtain their output from a decrease in the kinetic or potential energy of free charged particles such as electrons, the laser output is derived from the transfor-

mation of the internal energy of excited neutral atoms to the electromagnetic field.

The basic parts of a laser are a resonant cavity, an active medium, and a pump. The first part, the resonant cavity, is usually formed by two reflecting surfaces, ground to a fraction of the operating wavelength, set precisely parallel to one another with one surface slightly less reflecting than the other. The second part, an active medium which passes gain at the desired wavelength, is placed in the resonant cavity. Some active mediums are (1) gas—a noble gas such as helium mixed with neon and contained in a glass or quartz tube, (2) crystal—such as high purity ruby, or (3) liquid—an organic liquid such as benzene or pyridine. The third part, the pump, is the source of power that is applied to the active medium to stimulate laser action. The pump may consist of high power flash tubes used with crystal lasers, or a radio frequency source as used with gas lasers. The configuration of the laser must be such that the energy

supplied by the pump is absorbed by the active medium. The idea is that some of the energy supplied by the pump will be stored in the active medium and later released as laser or coherent light.

Photons

The pumping energy is made up of photons or quanta that are sent into the active medium. Atoms inside the active medium absorb some of the photons of the pumping source, and in so doing, a number of their orbital electrons are raised to an energy level above the normal position. The normal energy level is ordinarily the lowest possible, and hence is called the ground state. The level to which the electrons are driven, usually two energy levels above the ground state is not very stable, and the electrons fall back to a position only one energy level above the ground state. This middle energy level is known as a metastable level or state. The electrons tend to stay in this position for a relatively long time (a few microseconds).

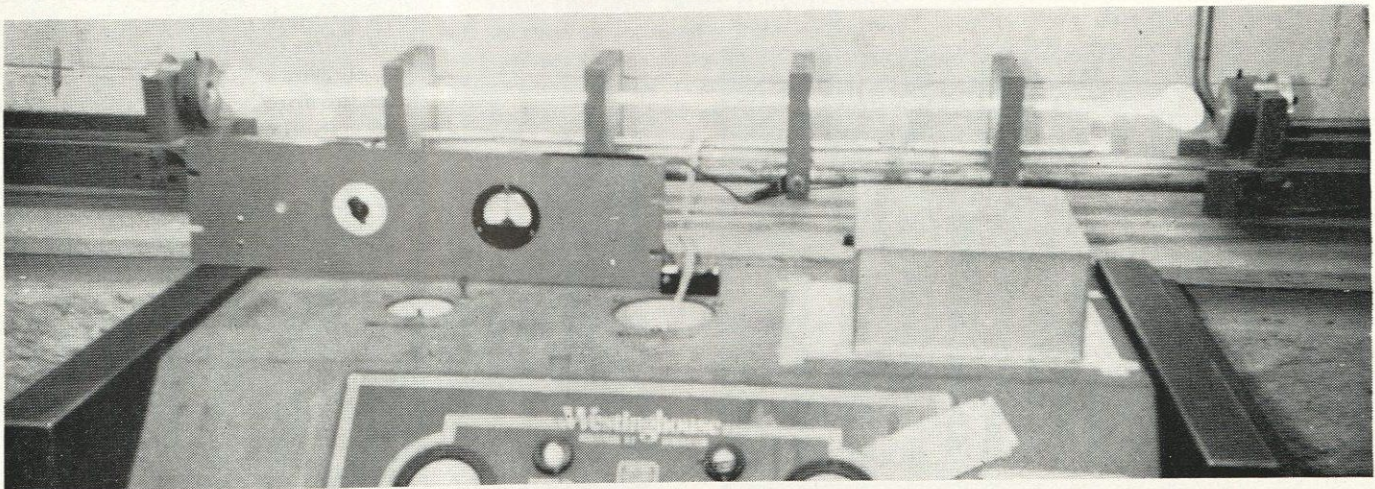


FIG. 1. A LASER IN OPERATION IN THE E. E. LABS

When most of the electrons are in the metastable state, a population inversion is said to have taken place. As electrons fall from the metastable state to the ground state they give off photons. Most of these photons are lost through the sides of the active medium, but if some happen to be traveling parallel to the axis of the resonant cavity in such a manner that they will be reflected between the two reflecting surfaces, they will encounter electrons still in the metastable state. The photons will induce these electrons in the metastable state to return to their normal ground state and in so doing, the electrons will give off photons that are exactly the same as the ones that stimulated their return to the ground state. This process continues as the photons bounce back and forth between the reflecting surfaces until the light waves "gain" enough energy to pass through the less reflecting of the resonant cavity surfaces as a beam of coherent light. This light produced by the laser is termed coherent because it consists of electromagnetic energy which is all of the same frequency, direction, and polarization.

If the pumping power comes from a flash tube as in the ruby crystal laser, and the flash is too powerful, the tube will destroy itself. Dr. Frank A. Barnes and Kenneth R. Lang of the Electrical Engineering Department of the University of Colorado have done some research in shock waves in xenon flashtubes in an effort to determine what ways the tube may be constructed and operated to produce a more powerful flash without causing permanent damage to the tube itself.

Semiconductor

One of the newest types of lasers is the semiconductor or gallium arsenide diode laser. Semiconductor lasers were developed almost simultaneously by I.B.M., G.E., and M.I.T. late in

1962. The semiconductor or diode laser is constructed of a gallium arsenide crystal. Two opposite sides of this crystal are perpendicular P-N junction planes, and form the reflecting surfaces for the resonant cavity. The top and bottom surfaces, which form the P and N portions of the diode are connected to the electrodes. A forward bias causes electrons and holes to be injected into the junction region where they occasionally recombine emitting a photon. Under proper conditions enough photons will be induced from the electron-hole recombinations to produce a coherent laser beam from the plane of the P-N junction (See figure 3). Some of the advantages of the semiconductor laser are: (1) it is jumped directly by an electric current, and therefore does not require any of the bulky optical pumping apparatus, (2) it can be made to operate with an efficiency approaching 100%, compared to a few per cent for gas, liquid, and crystal lasers.

Power

Jim Reynolds of the Electrical Engineering Department of the University of Colorado is working on a scheme to operate three lasers in series which should produce one or two joules of energy in one millisecond. As a comparison, a flashlight bulb will produce about one joule in several seconds of operation. This is enough energy to burn a hole thru a 1/32 inch thick piece of sheet steel if it is transmitted in a concentrated burst of about a millisecond, as in the pulse laser. The American Optical Company has under development a laser that should have an output somewhere between 2000 and 3000 joules. It is predicted that lasers with outputs of 10,000 joules will soon be a reality. There is a laser scheme which could theoretically generate a billion or more joules. This is enough energy to destroy an ICBM.

The laser beam has extremely small spread, that is it tends to remain as a narrow beam even a long distance from the source. For example, one second of laser beam width, spreads only 1/3 inch for every mile it travels from the transmitter. Because the laser beam can carry a large amount of energy and the beam has minute spread, it may be feasible to transmit power using lasers. Theoretically, a system utilizing a point source with a minimum beam spread of 0.005° can be used together with optical antennas to transmit power via laser beam with a loss of only 1/30 of one per cent over a distance of twenty miles. This is far better than present day transmission lines. Power transmission will be even better if the medium separating the transmitter and receiver is not absorbent, as in outer space. Again theoretically a beam with an aperture of 10 seconds of arc would be completely intercepted at 100 kilometers by an aperture of 5 meters in diameter. Such a system could transfer several kilowatts of power. These theoretical systems are possible in the future, but there is a tremendous amount of research and engineering work to be done first. For example, a system has to be devised to convert light energy received into usable energy, such as electricity.

Since the laser beam has a frequency that is in the visible or near-infrared part of the electromagnetic spectrum, it is susceptible to attenuation caused by atmospheric conditions. A laser beam will be absorbed and scattered by rain, snow, clouds, and fog. Even clear weather will bend the beam, because differences in temperature produce deviation in the index of refraction in various air masses.

Communication

The laser is well suited for communication systems. In fact it is possible that a single laser beam could carry as much information as all communication channels now in existence. Put another way, using optical frequencies for communications would open a frequency band of 250 million million cycles per second. This is thousands of times more space than is presently available in all the crowded radio frequency bands combined. A realizable communications system here on earth would have to be protected from the atmosphere which would attenuate and disperse an information filled laser beam. It would be possible to contain the laser beam in a pipe filled with non-absorbent dry air or nitrogen. Such a system certainly would have many difficulties to overcome. One of the biggest

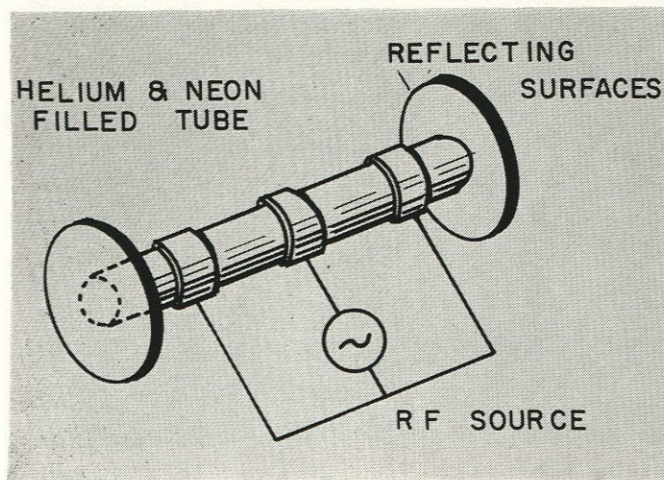


FIG. 2.
A RECENTLY
DEVELOPED
VARIATION
OF THE
RUBY LASER
IS THE
GAS
LASER

problems would be ground stability since the position of the laser beam in the pipe would be critical. An even better application of the laser beam would be in a space where there is no atmosphere to attenuate or disperse the beam. A realizable system with a range of 100 million kilometers could have a receiver with a light gathering area of only one square meter.

Non-Linear Optics

One of the problems in communications using lasers is the modulation and demodulation of the beam. The Ford Motor Company has reported progress in this field. They have achieved second and third harmonic generation using non-linear optics. In general two types of modulation are under experimentation. The first type could be called internal modulation. That is, modulation is achieved as the laser beam is generated inside the active medium. One method of internal modulation involves changing the Q, or optical alignment, of the laser cavity by using an electro-optical shutter between the laser material and one reflecting surface of the cavity. This introduces a variable loss which causes large variations in the operating power somewhat akin to amplitude modulation of radio signals. Internal frequency modulation may be obtained by subjecting the laser material to a transverse electric or magnetic field.

External Modulation

The second general type of modulation is external modulation applied to the beam as it leaves the laser. Electro-optical materials are being examined for use in modulating beams in this manner. These materials change their light transmitting characteristics when subjected to an electrostatic field. An example is ammonium dihydrogen phosphate, which has been used successfully for relatively low frequencies. One difficulty in using the electro-optical crystals is the high voltage required for modulation. The voltage is on the order of 17,000 volts, and it is difficult to handle at the re-

quired high frequencies. Semiconductor lasers are excited, or pumped, directly by an electric current hence modulation may be effected simply by varying the excitation current.

Demodulation presents another problem, here the light energy must be converted to electrical energy. One possibility is heterodyning. This may be accomplished by beating two laser beams together and obtaining an intermediate frequency in the microwave band. If this can be done effectively, existing microwave equipment may be used to work with this intermediate frequency. In general, however, the same techniques apply to laser signals as to microwave signals, so that the difference is in detail, not principle.

Radar

High resolution radar systems have already been developed. Currently various types of laser radar are being investigated by Hughes, R.C.A., G.E., and Sperry. The R.C.A. tracking system is expected to have a range accuracy of 6 feet over 70 miles.

The Doppler shift frequencies for laser beams reflected from moving objects are quite high even if the object is moving very slowly. Sperry is developing a system, using the Doppler effect, that can measure the frequency shift caused by vehicles moving from 18,000 mph to 0.2 inch per hour. Such systems which possess great accuracy are expected to be used in spacecraft rendezvousing.

Long-range radars are also feasible. A system using 1 megawatt in pulses of one microsecond could detect a target having one square meter effective surface area at a distance of 4500 kilometers. It is expected that by 1965, laser radars will produce high resolution maps of the moon and Mars, making it easier for man's first landing on their surfaces.

Since the laser beam is light—usually of one, or at most a relatively few, frequencies or colors—it can be concentrated quite readily by optical means to a spot whose concentration

of energy will produce energy densities greater than on the surface of the sun. This intense power in small areas is usable in small dimension welding, such as connecting leads to semiconductors, fusion of any material, and in local chemical reactions. Lasers are presently being used in production lines to cut components to size for use in micro-circuits.

The laser affords a tool for the surgeon that is precise enough to cut a single human cell. A ruby laser has been used by ophthalmologists to coagulate a human eye retina to prevent it from becoming detached. Such an operation can be performed in 0.001 seconds, thus eliminating the possibility of damage due to eye motion during the operation.

Lasers in Biology

At the University of Colorado, experiments have been performed by Dr. Frank A. Barnes and Kenneth R. Lang of the Electrical Engineering Department in conjunction with Joseph C. Daniel of the biology department to determine the possibility of using lasers for tools in embryology and cytology (the study of cells). This team has used a laser beam to effectively stop growth of selected portions of a chicken embryo without damaging the other parts. They were also successful in killing the nucleolus of a HeLa cell, which is an animal cancer cell used for research purposes, without damaging adjacent parts of the cell. This experiment was performed by directing a laser beam through one ocular of a binocular microscope onto the cell and using the other ocular for viewing the work. The spot size obtained was only one micron in diameter, which was even smaller than the nucleolus.

In order to study the absorption characteristics of the various cell structures the wavelength of a laser beam could be changed using a device known as the Roman cell. Then beams of various frequencies could be used with the binocular microscope system to determine how much energy of a specified wave length is required to stop growth.

Theoretically, the laser has practically unlimited applications. However, from an engineering and economic point of view many of these applications may not be practical or even possible. It may be more feasible to apply a somewhat less glamorous and older concept to some of these theoretical applications. Nevertheless, the engineering student of today should prepare himself fully in order to utilize this new and powerful tool effectively.

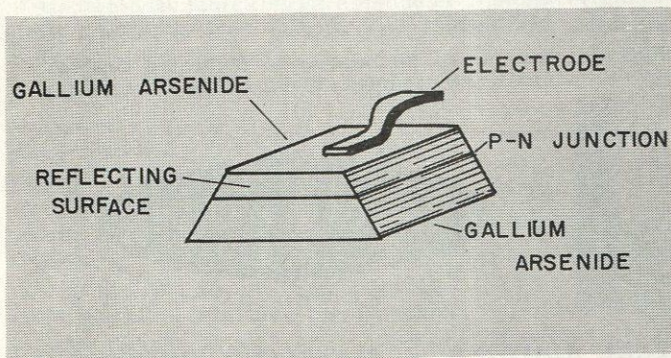
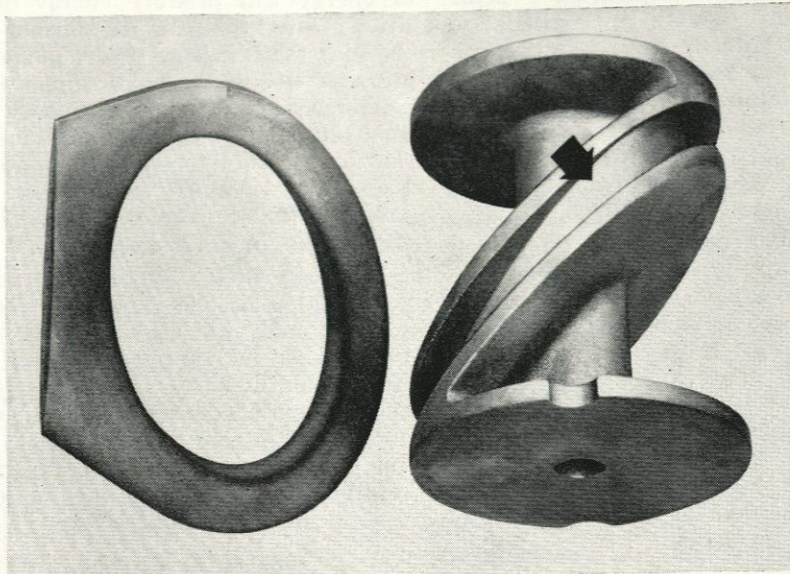
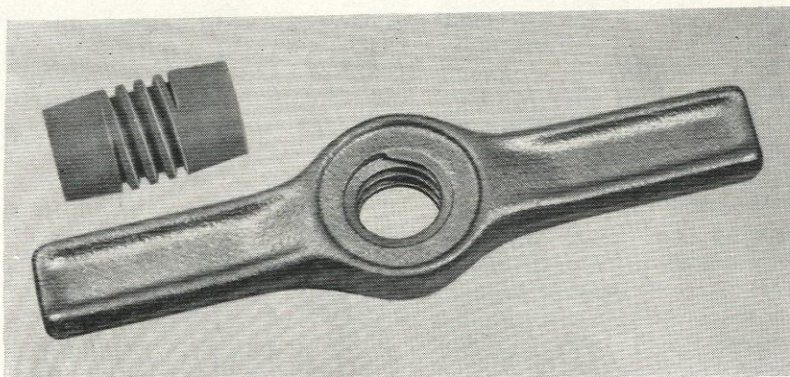


FIG. 3.
THE NEWEST
LASER IS
A P-N
JUNCTION
DIODE



The groove on this Malleable iron cam for a packaging machine requires a fine finish. A shell core used on the outside of the part produces such a smooth, accurate surface that no machining is required.



Shell coring produces such exact detail that the acme thread on this Malleable iron trench brace wing nut is used without any machining. Previously produced with a standard oil sand core, it required reaming and tapping.

Solve Design Problems, Reduce Machining with Shell Cored Malleable Castings

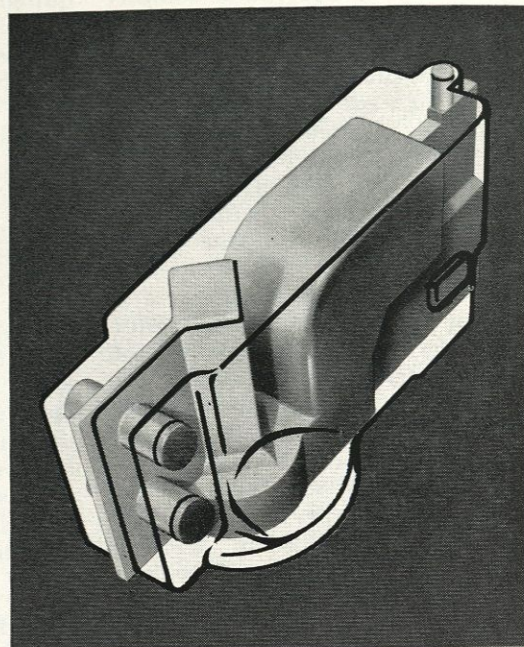
Shell cores are most often used to create interior surfaces but, in addition, they can be utilized at other locations in a green sand casting to impart smoothness, provide closer tolerances, reduce machining, and solve a variety of design problems.

Shell cores create surface finishes of 50 to 250 microinch rms. Thus, excellent detail can be obtained in Malleable castings for gear teeth, holes, dove-tails, mating surfaces and threads with this modern casting technique.

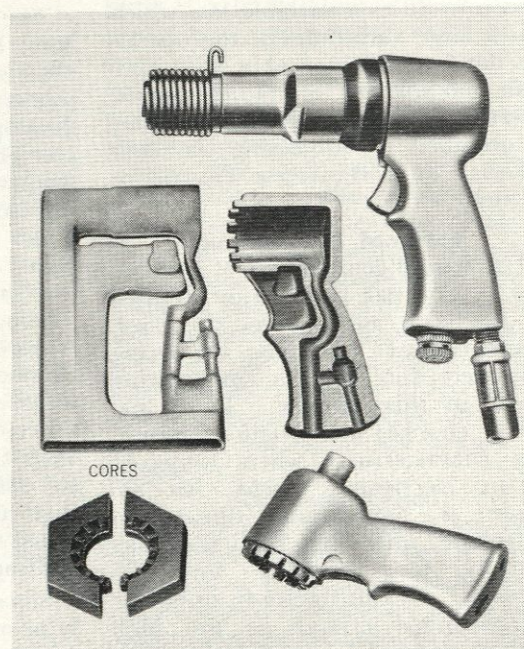
The internal air passages and chambers in the pneumatic wrench handle, shown at right, are excellent examples of the amazingly complex details which can be created accurately and economically in Malleable castings with shell coring. They are produced—completely finished except for tapping—in the basic casting.

The advantages obtainable from shell coring in selected applications, combined with Malleable's high strength, ductility, easy machinability and reliable uniformity, make Malleable castings an outstanding choice for high-quality, low-cost parts.

Send for your free copy of this 16-page "Malleable Engineering Data File." You will find it is an excellent reference piece.



The machining once required to produce this lever bracket included broaching the square hole, milling the slot, drilling and reaming the two large bolt holes, and drilling the small hole. All machining has been eliminated through the use of a single shell core.

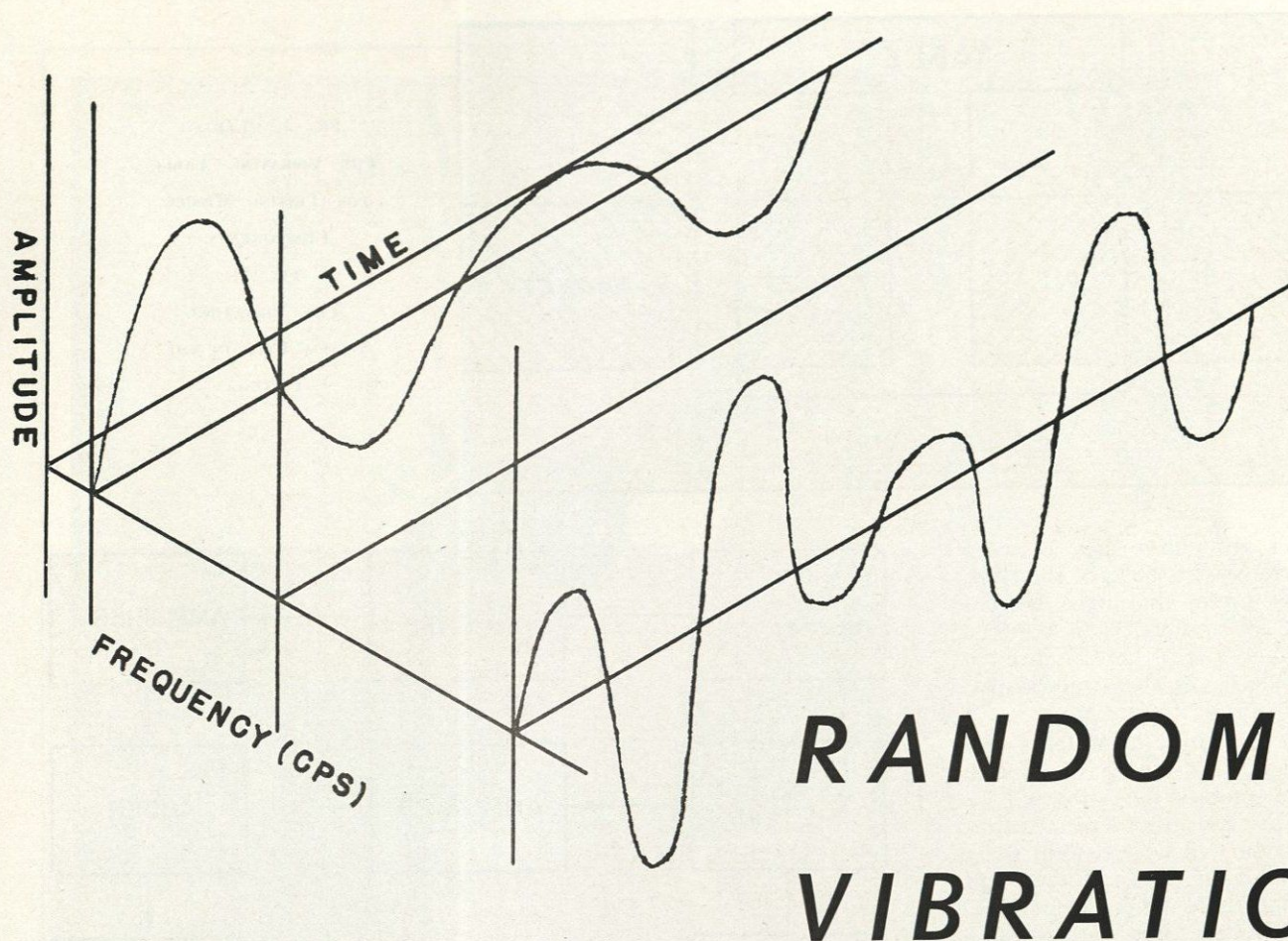


Precise dove-tails, intricate air channels and other interior details of this impact wrench handle are produced in the Malleable casting by the three shell cores shown. A variety of machining operations is eliminated by this relatively low-cost technique.

For further information on Malleable castings, call on any company that displays this symbol—



MALLEABLE FOUNDERS SOCIETY • UNION COMMERCE BUILDING • CLEVELAND, OHIO 44114



RANDOM VIBRATION

The jet and missile age has created many new environments that mechanical and electrical components must endure. The speeds at which modern aircraft and missiles travel create problems in the structural and thermal design which arise from air friction, temperature, and pressure changes of outer space. Another design problem is the magnitude and frequency at which vibrations may occur and the damage to components which might result. A vibration of one magnitude and frequency could result from the vibration of the engines, another from the fuel pumps, and still another from skin vibrations. Many more could be caused by any of the moving parts in the aircraft or missile. Since a large number of different amplitudes and frequencies are possible at the same time, it has been necessary to develop a test to insure the success of the subsystem components. This is the purpose of the random vibration test.

Random vibration can be understood with greater ease if first a common sinusoidal vibration is investigated. Sinusoidal vibration is determined when the displacement, velocity, and acceleration follow a sinusoidal curve as time varies. This vibration has a single frequency and given double amplitude displacement (at any specific time).

The standard method of measuring the force that is exerted on a test item during sinusoidal vibration is in "G's", the force or acceleration of gravity that is felt by the test item. This is measured as a multiple of the pull of gravity at sea level. Sinusoidal vibration is normally expressed in peak G's, although it is sometimes more convenient to express the acceleration in terms of GRMS, (root, mean, square), as in random vibration.

At a certain frequency, there is also a possibility that the component may experience resonance. Resonance occurs when the frequency of vibration approaches the natural oscillation frequency of the component. This causes relatively large amplitudes and can destroy the component if the amplitudes are too large. A component must therefore be designed so that resonance occurs above the range of frequencies to which this part is subjected.

As mentioned before, the possibility of an infinite number of frequencies, each at an infinite number of amplitudes, may occur simultaneously. Random vibration would be the com-

RICHARD LUBINSKI

posite of all the possible wave forms. There are three factors that must be considered: namely, amplitude, time, and frequency (see above).

Since it is not possible to determine what actually will occur in random vibration, statisticians have used the Gaussian Distribution Curve (see figure 3) to represent what will happen if time is to go to infinity while an infinite range of amplitudes are considered. The Gaussian Curve represents the amplitudes of one frequency, although this curve is used for all frequencies.

The 0 , $\pm 1\sigma$, $\pm 2\sigma$, and $\pm 3\sigma$ calibrations on the horizontal axis represent the deviation from a nominal amplitude of vibration, infinitely high deviations would be represented at the far right and the far left of the curve.

The area under the Gaussian Curve, as applied to random vibration, represents time. Since 68% of the total

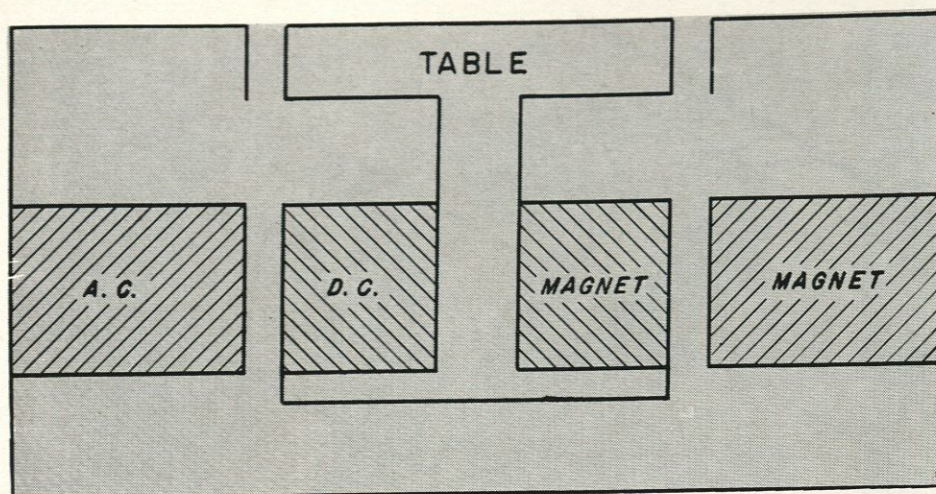


FIG. 1. (LEFT)
THE VIBRATING TABLE
FOR TESTING MISSILE
COMPONENTS.

FIG. 2.
THE VIBRATION
SYSTEM USED IN THE
TESTING.

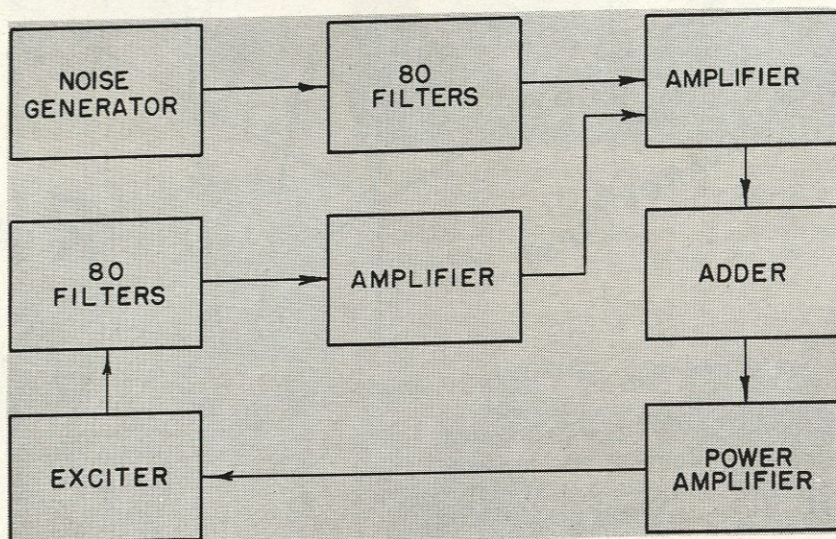
area under the curve lies between $\pm 1\sigma$, this represents 68% of the time. Of the area under the curve, 95% is between $\pm 2\sigma$, and 99.7% is between $\pm 3\sigma$. Therefore, these represent 95% and 99.7% of the time, respectively.

Because the curve represents one frequency of vibration, it shows that 68% of the time the deviation will be less than one times the nominal value. The deviation will be less than twice the nominal value 95% of the time, and less than three times the nominal value 99.7% of the time. Statistically, all of the possible frequencies will have the same amplitude distribution curve.

Since 3σ includes 99.7% of the time, the manufacturers of vibration equipment feel the test is sufficient for any component, therefore they limit the machinery so that the amplitude of vibration will not exceed this value. The possible frequency input is also limited to the range of 10-200 cycles per second, since the designers feel these frequencies are most probable to occur. A block diagram of the vibration circuit is shown in figure 2.

The noise generator consists of a "noisy" thyratron, which generates a completely random noise signal at all frequencies. This noise signal is then fed into eighty frequency filters. Each filter has a band width of 25 cycles per second, thus limiting the frequency input to that required by the designers. An automatic gain-control amplifier is connected to each of these filters, and the desired power is applied to the frequency band at this point. These signals are then added and transmitted into another amplifier and are sent into the exciter where the actual vibration is performed (see figure 1).

The armature of the exciter is supported by a large amount of D.C. power and the vibration is created by



the A.C. signal as described above. This system is very similar to that acting on the cone of a radio speaker.

Two accelerometers, piezo electric crystals that transform pressure to electric current, are generally placed on the exciter. One is connected directly to an RMS voltmeter to measure the GRMS that is felt by the test item. The other is connected to an amplifier, to eighty more filters

and amplifiers, and is then fed back into the automatic gain control amplifiers. This acts as an equalizer and completes the feedback system.

Random vibration is an essential test in an age of jet aircraft and missiles. Practically every engineer that makes his career in the aerospace industry will come in contact with it at some time during his career.

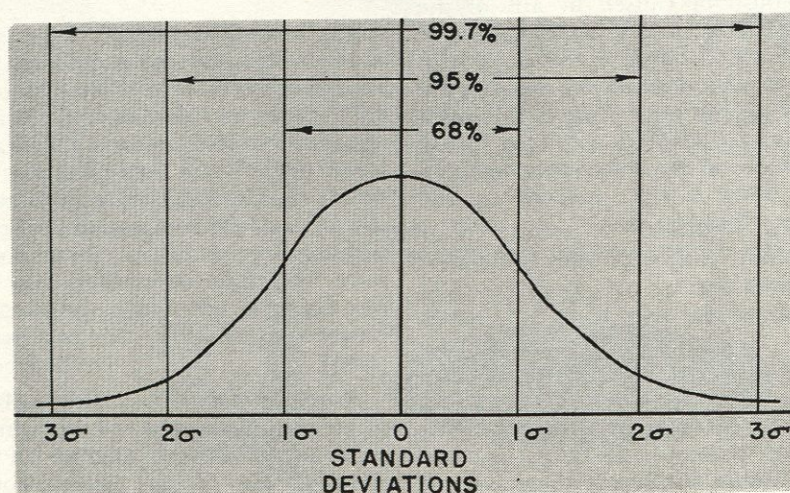


FIG. 3.



Is it news that a leading maker of spacecraft alloys had a hand in dolling up Mildred Kinne's potting shed?

It isn't really surprising that a single U.S. corporation provided the metal for the outer skin of Mercury space capsules. It's perfectly natural to be called in on that kind of a job when you lead the nation in developing a line of alloys that resist extreme heat, wear and corrosion.

You'd also expect that a leading producer of petrochemicals could develop a new base for latex paint—called "Ucar" latex—since paint makers are among its biggest customers. Now Mildred Kinne can paint right over a chalky surface without priming. It's dry in minutes. And her potting shed will look like new for many New England summers and winters.

But it might indeed be surprising if both these skills were possessed by the same company. Unless that company were Union Carbide.

**UNION
CARBIDE**

Union Carbide also leads in the production of polyethylene, and makes plastics for packaging, housewares, and floor coverings. It liquefies gases, including oxygen and hydrogen that will power rockets to the moon. In carbon products, it has been called on for the largest graphite shapes ever made. It is the largest producer of dry-cell batteries, marketed to millions under the trade mark "Eveready." And it is involved in more atomic energy activities than any other private enterprise.

In fact, few other corporations are so deeply involved in so many different skills and activities that will affect the technical and production capabilities of our next century.

It's already making things a great deal easier for Mildred Kinne.

UNION CARBIDE CORPORATION, 270 PARK AVENUE, NEW YORK, N.Y. 10017. IN CANADA: UNION CARBIDE CANADA LIMITED, TORONTO
Divisions: Carbon Products, Chemicals, Consumer Products, International, Linde, Metals, Nuclear, Olefins, Ore, Plastics, Silicones, Stellite and Visking

Everything we learned from building 10,000 small gas turbine engines has been packed into this new 600-horsepower turboprop engine —and it shows!

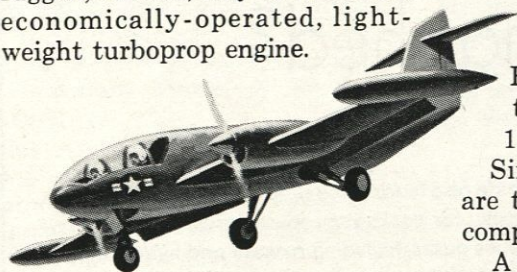
You'd probably expect the world's largest manufacturer of small gas turbine engines to turn out the world's finest small turboprop job.

And we have.

We call our new engine the TPE-331. (The military version is designated T-76.) It is a versatile turbine capable of powering many vehicles. Its 600-horsepower category makes it particularly suitable for the new generation of executive and military fixed-wing aircraft.

More specifically, our new prime propulsion engine is designed to fill the gap between reciprocating engines and larger turboprops.

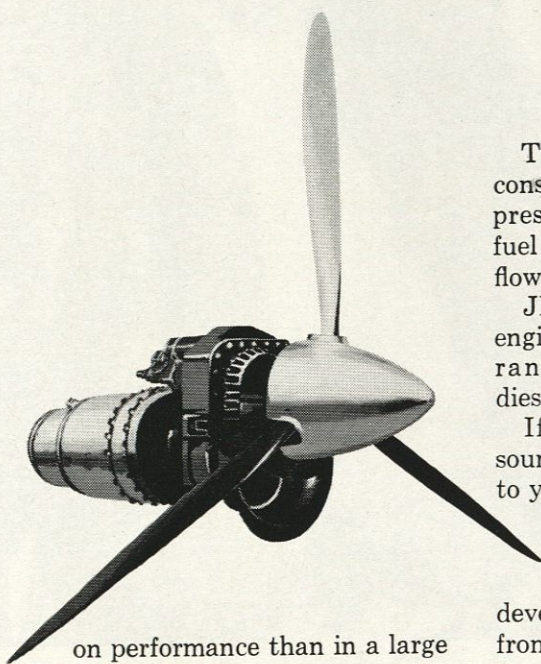
And the reason we built it, is because both civil and military sources have asked for a simple, rugged, reliable, easy-to-maintain, economically-operated, light-weight turboprop engine.



The Garrett-AiResearch TPE-331 more than fills the bill.

Obviously, building such an engine is a specialized art that demands experience, especially in miniaturization of controls, oil pumps, and starter motors.

Manufacturing tolerances are precise and have a greater effect



on performance than in a large engine. Scaling down big engine techniques is not the answer.

The TPE-331 has a specific fuel consumption of .62 pound per shaft horsepower hour. Its weight to power ratio is .45 pound per horsepower. Response rate from flight idle to full power is approximately 1/3 of a second.

Single-casting turbine wheels are typical of the simple, rugged components of this new engine.

A two-stage centrifugal compressor is driven by a 3-stage axial turbine. Propeller drive is through a 2-step reduction gear box offset for flexibility of aircraft design.

The fuel system of the TPE-331 consists of a fuel filter, single high-pressure pump, speed-governing fuel control, manual shutoff valve, flow divider and fuel nozzles.

JP-5 is the normal fuel, but this engine will take all kinds of fuel, ranging from AV-gas to light diesel fuel.

If this new turboprop engine sounds like something very special to you, we've made our point.

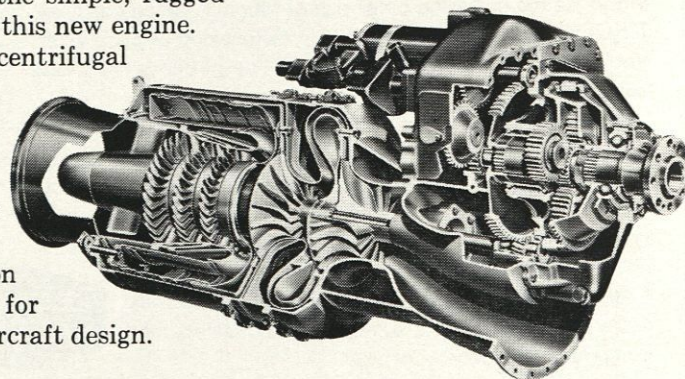
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Engineer's Days



Miss Vicki Craig

19



*Miss Janey Criswell
Queen of Engineers'
Days -- 1964*



Miss JoAnn Cram

64



Miss Jacki Faust



Miss Bonni McGrew

—PORTRAITS BY MARKAY



THE ENGINEER'S ANSWER TO REGISTRATION —
THE ANNUAL E-DAYS PICNIC.

E-Days, as always, falls just when the engineer is in need of a study break. The weekend provides a welcome relief from the strain of lab reports, hourlies, eyeballing, and other assorted miseries that seem so common in the spring. It is also a time for honoring outstanding members of the college, attending seminars, and having fun.

CONVOCATION

Engineers' Days 1964 officially began with the convocation in Macky Auditorium. At this time, scholarships and awards were presented. As in years past, Dean Hutchinson was called upon to make these presentations. The Dean is noted for the speed and efficiency with which he distributes awards. A coffee was held Saturday morning in honor of the recipients.

Lynn Kramer, the out-going President of the Associated Engineering Students, was named "Outstanding Senior" by the Colorado Engineering Council. Runners-up were Ross Fraker and Larry Huston. Keys were presented to the incoming AES officers—Marshall Silver, Bob Joselyn, JoAnn Cram, and Dean Peed. The Associated Engineering Students Faculty Appreciation Award was presented to Professor R. C. Rautenstrauss, of the Civil Engineering Department. A letter of appreciation was also given to Professor Maler of the Electrical Engineering Department in appreciation for his work as Faculty Advisor to AES.

The keynote speaker at the Convocation was Mr. Robert D. Lilley of Western Electric Company. Mr. Lilley spoke on the advances in our society that have both directly and indirectly resulted from engineering achievement. The list is long and impressive. Mr. Lilley concluded his talk with a few predictions about the role of the engineer in the years to come. He felt that the modern society would come to depend more and more upon the engineer.

LUNCHEON

Immediately following the convocation, a luncheon was held in the UMC Ballroom. After the meal, entertainment was provided by the Hustlers. Fortunately, laughter does not interfere with digestion, as the group interspersed their folk music with jokes and comedy. The luncheon also gave the engineers a chance to display their success in the Beard-Growing contest. Appropriately, the award was an electric shaver.

SEMINARS

The ASME seminar proved to be an extremely interesting presentation of the Leyden Mine Gas Storage Project. This was given by G. Paul Cook, a C.U. graduate in Chemistry, and the head of the gas storage project. In this project, gas is stored in a completely sealed, abandoned coal mine. Water, which is constantly leaking into the mine, prevents the gas from escaping through the floor, and an impermeable layer of shale prevents leakage upwards. A crew patrols the area every two days to look for any leakage. To date, no

BALMY WEATHER HAS BECOME A TRADITION
AT THE PICNICS.





FACULTY PARTICIPATION WAS ENTHUSIASTIC, AS USUAL.

leakage has been found, and the project has been perfectly satisfactory.

At the ASCE seminar, Arthur Krill, president of the Ken R. White Consulting Engineers, Inc., spoke on the 47th Ave. Freeway Project in Denver. In this interesting and informative talk, Mr. Krill told of the role of the consulting engineer in the Interstate Highway Project. Today about fifty percent of the work in the IHP is performed by consulting engineers. In this respect, the Civil Engineer is reaching his greatest potential to contribute to society. This point was illustrated with a description of the Afghanistan Highway Project. Mr. Krill then presented a film which explained the 46th Ave. Project and the role of the consulting engineer in its construction.

The president of IEEE was unable to attend the seminar presented by that department, but he wasn't missed, as some 70 of the EE's appeared to hear the talk given by the Hewlett-Packard Company. The seminar began with a photographic history of the instruments made by the Hewlett-Packard Co. since their beginning. This series of slides was followed by a survey, via slides, of the various HP plants. The rest of the time was spent in a discussion of the philosophies and the practicalities of manufacturing electronic instruments. The talk ended with a brief discussion of how to package instruments for shipment. The trick here was to outwit the US Post Office. At this point the EE's got their chance

to speak, and a discussion period concluded the seminar.

At the A.I.Ch.E. Seminar, Mr. David Furakawa spoke about various methods of purifying unpotable waters for human use. In his very interesting talk, Mr. Furakawa discussed the most promising methods of desalting water, together with the problems encountered in each method. A rough economic evaluation of each process pointed out the rapid gains

that have been made toward a purification system that is competitive with fresh water from natural sources. Among the more promising techniques are: evaporation, freezing, and ion exchange. Mr. Furakawa's specialty in his work at the Bureau of Reclamation is electrodialysis as a desalting process. In this system, the ions of the dissolved salts are drawn through ion selective-membranes — away from the water to be purified — by an electric current.

As is their tradition, the Society of Women Engineers conducted a seminar on one of the more general lines of engineering. This year the speaker was Dr. W. D. Weir of the Honors Department. Dr. Weir's topic was "Ignorance is Bliss—Or is it?" In his presentation, Dr. Weir stressed the need for more individuality in our society. This is the basis upon which a better education can be built. He also discussed the role of understanding through education in the world today. Dr. Weir felt that the only way to reach world peace is through this better understanding. The presentation also included a discussion of the role of the woman in society, much to the members' enjoyment. A question and answer period followed the seminar.

The A.I.A.A. Seminar was conducted by a panel of engineers from Martin Company of Denver. The topic was "Educating the Engineer." The panel discussed the quality and



HEY!! SOMEBODY MOVED THE GROUND.

quantity of education necessary in the development of the engineer. At the S.I.A.M. Seminar, Dr. Hultquist from Ball Brothers Research spoke on "Aspect Determination of Satellites." The presentation covered the description of satellite position and orientation through numerical analysis.

ENGINEERS' BALL

The 1964 Engineers' Ball was held in the Glen Miller Ballroom. The engineers and their dates danced to the music of Duane Kramer under decorations of balloons and streamers. During the intermission, Dean Hutchinson crowned Miss Janey Criswell, a freshman from Lakewood, Queen of the 1964 Engineers' Days. Miss Criswell's court consisted of Vicki Craig, JoAnn Cram, Jacki Faust, and Bonnie McGrew. Miss Criswell and Dean Hutchinson led the first dance after the intermission.

The results of the Meanest Professor contest were also announced during the intermission. This culminated a week of enthusiastic campaigning, including a television appearance. Professor Robert Branch of the Electrical Engineering Department won this dubious distinction, and was awarded the "Purple Screw" as a symbol of his popularity, or lack of it. Smaller "Purple Screws" were presented to the other candidates—Retcher Ron West, the Raging Rat-Fink, Chopper Chinn, the Un-Civil Camikaze, Wicked Wagner, the Whip Wielding Warden, and Viscous Vlasses, the Vicious Varlet.



THE BACK-STRETCH OF THE WHEELBARROW RACE.

E-DAYS PICNIC

Saturday morning, students, faculty, friends, wives, and children all assembled at Chautauqua Park for the annual E-Days Picnic. A lunch of hamburgers and potato salad was provided, along with coke for those who had not come equipped. Immediately after the lunch, the field events were begun. There was hot competition between the various departments in the Tug-O-War, the Four-Legged Race, the Egg Toss, the Wheelbarrow Race, and the Bat Race. Once again, the Civil Engineers came

out on top, as they outscored the Mechanical Engineers and the Electrical Engineers by a wide margin.

The final event of the day was the selecting of the Most Beautiful Body. This award went to Miss Carol Lee Thorpe, of Santa Monica, Calif. Other contestants were Ginny Ann Penn, Penny Goldstein, Norma Ackermann, Gloria Hillman, Marilyn Algyer, and Barbara Krebs. Spectator enthusiasm was quite high as the contestants were introduced. A cool, windy day is no match for a girl in a bathing suit.



ALL OF THE BODIES LOOK PERFECT FROM HERE.

VORTICITY

RON BLACKWELDER

With the advent of the nuclear rocket, the propulsion field has gained a radically new type of propulsion which has a much larger specific impulse. One of the drawbacks of the nuclear rocket is that there must be a considerable amount of shielding to protect the other hardware and the personnel involved. This shielding, which is normally lead, accounts for a large portion of the engine's weight. Since the nuclear rocket is usually planned as the propulsion unit for the second or third stage of a missile, the problem becomes one of designing a nuclear rocket light enough to be boosted into the upper atmosphere and yet large enough to accomplish its mission once it is placed there. Thus the consideration of thrust/weight becomes a critical one.

This paper presents a new method of increasing the thrust to weight ratio by increasing the heat transfer coefficient in the nuclear heat exchange. The same thrust can then be generated by using a smaller and lighter reactor.

The beneficial effects of turbulence promoters on heat transfer have been recognized by many observers, (7, 11). However, none of these authors have undertaken an analysis of the application of these results to the nuclear rocket. The physical size and weight, and therefore the cost, of a

nuclear rocket depends on the heat transfer coefficient. Hence, by increasing the heat transfer coefficient, the weight of the nuclear rocket can be decreased for a given thrust level.

Promoting Turbulence

During the course of an experimental investigation at the University of Colorado, turbulence promoters were consisting of twisted tapes of 3 different twist ratios: $H/D=3.54$, 8.5, and 22.0 (where H is the length required for a 360° rotation of the tape). These are shown in figure 1.

The insertion of these tapes into the air stream has several effects on the flow characteristics. First the density gradient is altered from that which normally exists for straight flow. The centrifugal force generated by the vortex motion will tend to force the more dense (cooler) gas outward to the larger radius while the less dense (hotter) gas is displaced inward. This density gradient is more favorable for heat transfer. Also, in the case of swirling flow, the velocity relative to the wall is greater than for flow without swirl. This larger velocity will tend to reduce the boundary layer thickness. In particular the laminar sublayer where the heat is essentially transferred by conduction will be decreased. The thinner laminar sublayer will tend to increase the rate of heat transfer.

In general, it was believed that the

swirl flow should increase the rate of heat transfer. This was subsequently shown to be true.

The equipment used in this investigation consisted of a high pressure air supply, a metering section, a test section and associated instrumentation. The arrangement of these items is shown in figure 2.

The air supply was a 2500 psi compressor from which air passed through a de-oiling chamber and desiccation tube containing silica-gel and was stored in a receiving tank. From there it passed through a pressure regulator, which maintained a constant supply pressure of 500 psi, and then went to the metering section.

The results indicated that the rate of heat transfer was significantly increased for the swirl flow. The Nusselt number for the tightest twisted tape, $H/D=3.54$, was increased by more than a factor of two. The other two tapes affected the Nusselt number to a lesser degree.

Calibration of Equipment

As a check on the experimental apparatus, runs were made with the straight flow. The Nusselt numbers for these runs were calculated and compared with those of previous investigations, (3, 5). Humble et. al. (5) presented Nusselt numbers for a wide range of heat fluxes. The present results agreed within $\pm 2.6\%$ of

their data. However, the results of the present investigation lay from 1.1-7.3% below that of Deissler and Finn's (3). It should be noted that they evaluated their fluid properties based on the wall temperatures, whereas the fluid properties in this investigation were based on the fluid bulk temperature, which was found by assuming a linear temperature increase between inlet and outlet. Hence Deissler and Finn's different approach would tend to make their results lie above those of this investigation.

After the temperatures and pressure drop were obtained, the Nusselt number and the Darcy-Weisbach friction factor was calculated based on the fluid bulk temperature. The pressure drop, Δp , increased as H/D increased. This is expected because of the increased restriction to the flow for the more tightly twisted tapes. From the pressure drop data and the static pressure data, the Darcy-Weisbach friction factor, $4f$, was calculated by the following equation.

$$4f = \frac{2gc}{pV^2} \frac{D}{L} \Delta p$$

Here again the friction factor was increased for the more tightly twisted tapes.

The most important result was the effect of the tapes on the heat transfer coefficient, the greatest increase being for the tightest twist ratio, $H/D = 3.54$. This increase agrees within 6.2% of the data found in Smithberg and Landis (10).

It was found for the straight flow case, that the equation

$$Nu = .021 R_N^{0.8} Pr^{1/3} \left(\frac{T_B}{T_w} \right)^{.575}$$

fit the data with a mean deviation of 4.9%. The Nusselt numbers for swirl flow were compared with equation 2, and equations were obtained along with their deviations.

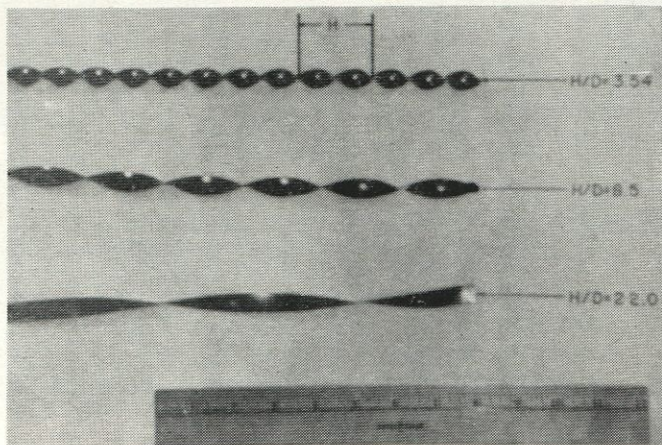


FIG. 1.
THE VARIOUS
TAPE
CONFIGURATIONS
USED TO
PROMOTE
TURBULENCE
IN THE
GAS
STREAM.

This method of approximation was reliable for $H/D = 8.5$ and 22.0 . However, for the tightest twisted tape, $H/D = 3.54$, the data lay above this approximation at the lower Reynolds numbers and below the approximation for the higher Reynolds numbers. This suggests that the Reynolds number plays a greater role in the determination of the Nusselt number for the increased twist ratio. Therefore the tightest twist ratio must decrease the boundary layer thickness considerably more than the two other twist ratios. For $H/D = 8.5$ and 22.0 , the Nusselt number ratio is 18% above that of reference (7). For $H/D = 3.54$, the present results are 35% greater than those cited in the above reference.

The solid nuclear rocket achieves its thrust by heating gaseous hydrogen in the nuclear reactor. The hydrogen is heated to approximately $5000^\circ R$ as it passes through tubes embedded in the reactor core as shown in figure 3. By inserting twisted tapes in these tubes the heat transfer coefficient is increased and hence, for the same amount of thrust, the reactor size and shielding weight can be reduced.

To compare the case of swirling flow to that of straight flow in the reactor, it is assumed that the fluid properties at the reactor's exit are the same in both cases. This can be accomplished by increasing the size of the pump and by reducing the length, L , of the reactor. Since the weight of the pump is small compared with the weight of the reactor (9), the increased weight of the larger pump will still be less than the decreased weight of the reactor. This assumption remains valid until a point is reached such that the increased weight of the pump equals the decreased weight of the reactor.

To generate the same thrust at a given altitude with the same mass

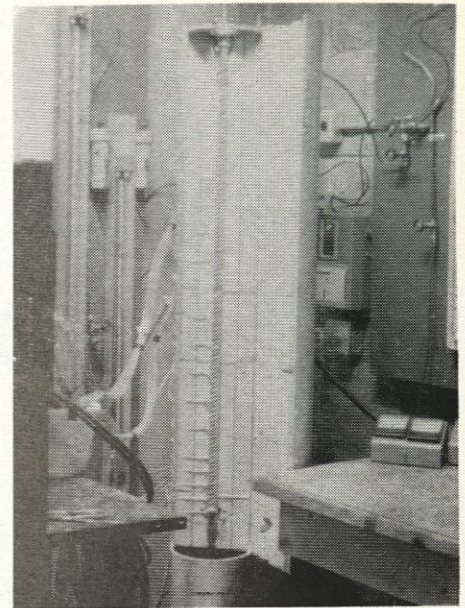


FIG. 2.
THE APPARATUS USED IN
THE EXPERIMENT.

rate of flow, the exit velocities must be equal. This is accomplished by letting $T_1 = T_1'$ where the prime superscript indicates the case of swirling flow. Neglecting end effects, T_1 can be found from the heat transfer equation

$$h = \frac{q}{T_w - T_1}$$

where q is the heat flux, T_w is the wall temperature and h is the heat transfer coefficient. Since the wall temperature in both swirl flow and straight flow will be the maximum temperature imposed by the materials, equation 3 and 4 yield

$$\frac{q'}{h'} = \frac{q}{h}$$

The heat flux per tube, q , is given by the following expression:

$$q = \frac{c_p (T_1 - T_{in}) \dot{m}}{\pi DL}$$

If the temperature of the gas at the reactor's inlet is assumed to be the same in both cases, and the weight of the reactor is assumed to be a linear function of the length, it is found that:

$$\frac{h'}{h} = \frac{1}{(W'/W)}$$

Thus an increase in the heat transfer coefficient will promote a decrease in the weight of the reactor for a given thrust level. This will also

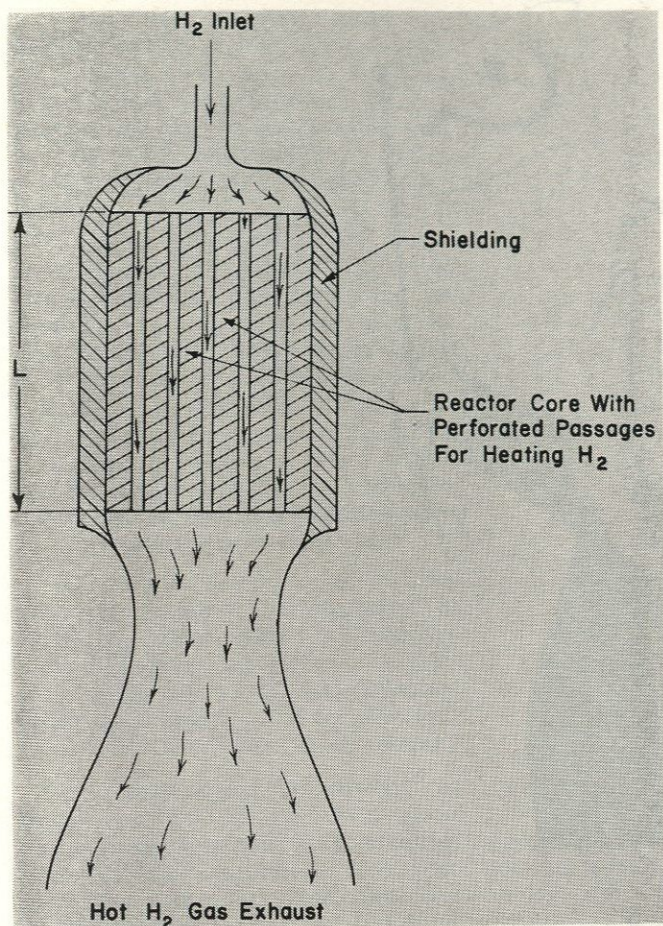


FIG. 3.
SCHEMATIC
OF A
FISSION
REACTOR
FOR A
NUCLEAR
ROCKET

promote a further reduction of the shielding weight.

Assuming that the weight of the tapes is negligible compared to the weight of the reactor and shielding, the substitution of the above relations into the thrust equation yields

$$F = (P_e - P_a) A_e + \dot{m} \sqrt{\frac{2g\gamma R T_e}{\gamma - 1}} \left[T_w - \frac{c_p (T_e - T_{in}) \dot{m} \delta}{\pi D h W} \left(\frac{Nu}{Nu_w} \right) \left(\frac{W}{W_w} \right)^{1/2} \right]$$

Theoretical considerations indicated that the heat transferred to the fluid should be increased due to the decrease of the boundary layer thickness imposed by the swirling motion. Experimental results proved that as the amount of twist of the tapes was increased, the pressure drop, friction factor and the heat transfer coefficient increased. Equations were found for the Nusselt number in swirling flow with a maximum mean deviation of 11.7%. It was found that the weight of the nuclear rocket engine could be reduced by the insertion of twisted tape into the heat exchanger tubes. The tightest twist had the most effect on the weight ratio and the thrust.



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THE RUSE

TOM DAVEY



The recent claim by Soviet Premier Khrushchev that the Soviet Union did not intend to compete any longer in the race to the moon came not only as a surprise, but as a relief to the American people. The people thought that as long as the Russians were not interested in going to the moon, we might just as well quit also and save ourselves a tremendous amount of tax-financed expense. At the same time the military planners of the United States recognized Premier Khrushchev's proclamation for what it was: an attempt to make the United States slow down its military programs in space while the Russians are still ahead.

The ruse Premier Khrushchev is trying to put on the American people is that the exploration of the moon is strictly a peaceful venture, that can wait until the future when the Russian economy is improved. However, few people recognize more than the military that throughout history, peaceful exploration has generally followed only after military exploration, and usually, exploitation. This has been true not only in geographical exploration, but in scientific endeavors as well. The greatest example of peaceful use of military scientific studies has been the development of

the aircraft in the twentieth century. The jet transport would never have been economically feasible without the development of the B-47 and the B-52 by the Air Force. We will never go to the moon until we understand much simpler problems, such as space rendezvous and identification of space vehicles. The Air Force is primarily responsible for basic studies such as these at this time. It is the fear of the military that this proclamation of Khrushchev will develop a state of euphoria in our people reducing our vigilance and our willingness to extend our resources to space exploration. They fear that the demands of the people for budget cuts will severely disrupt not only our moon projects, but also space projects that are necessary for our security in this period when militant communism remains committed to the destruction of our society.

Before the people of the United States spend money on any space project, they must be convinced that the programs are necessary. It is therefore up to the military leaders of the United States to chart the future in

space operations. They must also make the people realize that even though detailed forecasts of most military operations in space cannot be clearly made now, the people must not believe that there will be no such requirement in the future. We can find a parallel from the early days of aviation when there were no well defined trends in aerial warfare. Large elements of conjecture and imagination at that time, however, enabled us to build the greatest aerial force in history.

I therefore believe that we should not let ourselves be fooled by this Russian ruse. We should re-emphasize our military space projects and hope that one day they can be put to peaceful use. We should always be reminded of the words of President Lyndon B. Johnson, "We go into space as pioneers came into the West, for one purpose only: to find for ourselves and our families a better life on Earth and to assure the ultimate success of the cause of freedom we uphold. If we do not succeed in these efforts—as one great American has put it—we will not be first on the Moon; we will not be first in space; and one day soon we will not be first on Earth."

"I hold that the architectural profession should assume responsibility for nothing less than the nation's *MAN-MADE ENVIRONMENT*, including the use of land, water, and air, *AN ENVIRONMENT IN HARMONY WITH THE ASPIRATIONS OF MAN.*" These words, of Philip Will, former president of the American Institute of Architects, express the demand, the challenge, that lies before every nation today. The demand is not new; however the attack is now under the direction of the architectural profession. Never before in history has America so needed the design professions. Never before has the opportunity for leadership by the architects and city planners been so overwhelming and self-evident.

Since the profession is using what is called "modern architecture" to create an environment in harmony with the aspirations of man, an outsider might ask why it was necessary to invent a new kind of architecture. Wasn't the Parthenon good enough?

The question may be answered in three ways; first, our era had come to need two entirely new types of buildings—the first completely new types since the cathedral. We have developed a need for the tall building, a building which could not take the shape of the Parthenon nor be satisfied in function by a Chartes Cathedral. An entirely new expression was needed and Louis Sullivan gave that expression to America with the first steel structured, multi-story buildings. The second new type of building was the modern factory with its one story coverage of large areas to allow for modern machinery and conveyor systems. A good example of this type is the Dodge truck plant by Albert Kahn in Detroit, Michigan. Walter Gropius was a definite leader in the design of factories with the Fagus Works in Alfred, Germany, which is believed to have been the first use of what is now called "curtain-wall construction."

MODERN ARCHITECTURE

T. L. TURMAN

Second, our era—and our architecture—had to respond to the remarkable change in modern man's life, a change from a slow-moving to a fast-moving society. Frank Lloyd Wright understood and expressed this change with his concept of "space in motion" as early as 1909 with his Fredrick C. Robie house.

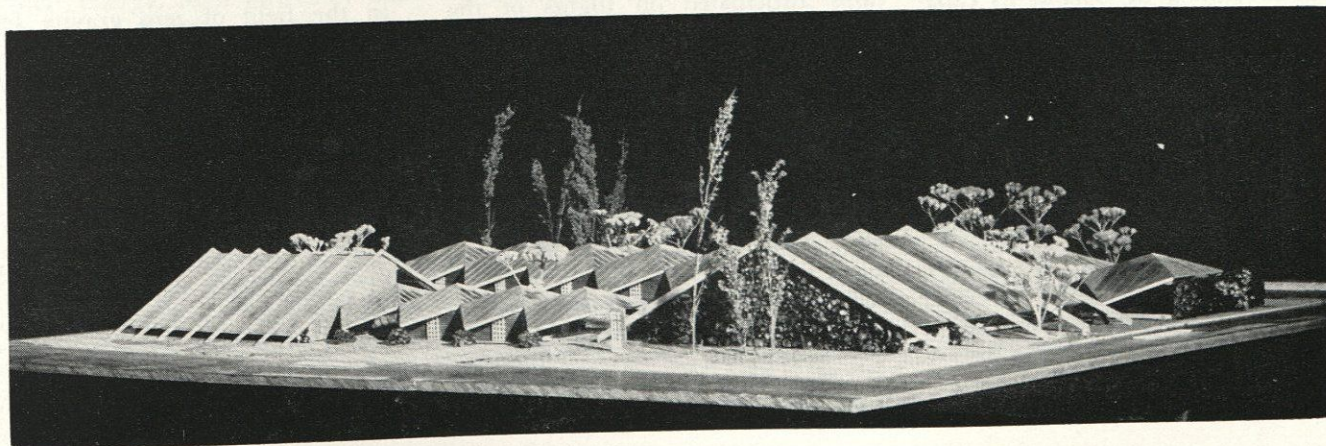
Finally, the world needed a more mechanized building technology to keep pace with the expanding population. The fact that the population tripled in the one hundred years from 1850 to 1950 was responsible for every major change in the way we live today.

These three developments—larger scale, faster motion, and more efficient technology—are usually associated with America. Thus modern architecture is related to America where freedom and space have allowed it to mature. America was by no means the birthplace of the modern movement, but in the United States,

with its seemingly unlimited space resources, the development was more pronounced. The United States' nickname "the continuing revolution" serves as a good title for the chapter of advance in architecture written by America.

The creation of an environment is not attained overnight nor is it gained by letting communities grow as they may. It is created by great architects working together in spirit to mold the tools, influences, and ideas into a system of order. Such architects were Richardson, Sullivan, and Wright in America and Machintosh, Wagner, and Le Corbusier in Europe. They recognized the impending crisis of the individual in a mass society; and they all had an intuitive grasp of the technical tools that had been placed into their hands, and, more important, of the technical tools that would soon become available.

Who needs modern Architecture?
Only the human race!



COLORADO INDUSTRIES

LARRY FOWLER

Back in 1954, three years before history's first earth satellite hurled into orbit, Beech Aircraft Corporation started preliminary studies of ways to contain a new rocket propellant — liquid hydrogen.

The work performed under a classified USAF contract, involved insulation development, component evaluation and material compatibility evaluation and material compatibility. They called it cryogenic engineering.

Cryogenics is the realm of super cold where the temperature range begins at about -200 degrees F. and descends to absolute zero or -459 degrees F. Over the past decade what happens physically at these low temperatures has grown from a purely scientific interest to a practical technology.

Founded in 1932 at Wichita, Kan., Beech is traditionally known as a leading builder of business and utility aircraft. Yet today it is also widely known as a major participant in some of the nation's most advanced space programs, such as Apollo and Gemini.

As a result of its liquid hydrogen investigations ten years ago, Beech became one of the first aircraft companies to develop cryogenic systems for space vehicle applications. And it has continued to expand its capabilities in the space sciences, notably in cryogenics, ever since.

To vigorously pursue diversified projects relating to rockets, missiles and space exploration, Beech in 1955 established a new division at Boulder, Col. This division now employs nearly 400 specialists and maintains a fully integrated space systems research, engineering and production complex on some 15,000 acres of Beech-owned property four miles north of Boulder in the Rocky Mountain foothills.

With ten years of experience in

cryogenics, Beech technical innovations in a number of areas have immeasurably advanced the state of the art.

Boulder Division scientists, engineers and technicians, in fact, work on solutions even before they know if actual problems exist. The ability to convert research projects from test prototypes to operational hardware has made Beech a principal source for complete programming in highly specialized space fields.

Environmental Testing

Boulder's environmental testing and contamination control facilities are among the finest in industry.

Complete space vehicle systems, components or subsystems—including storable, cryogenic, pneumatic, hydraulic, electrical and electronic types—are evaluated under conditions of vibration, altitude, radiation, acceleration and temperature extremes.

Such capability enables engineers to duplicate on earth the alien conditions anticipated on flights of the moon and beyond.

Boulder operates America's first transient heat laboratory capable of thermal testing liquid hydrogen fuel systems, including boost stage tanks with capacities up to 20,000 gallons. To duplicate the effect of aerodynamic heating, tank skin temperatures are instantly elevated to 1,000° F. or more.

The test complex, which is used in the Apollo program, features a 20,000-pound-force shaker. Other individual chambers simulate alien conditions of outer space, such as

climatic, radio frequency interference, high vacuum, acceleration, altitude and tensile loads — even explosions.

Functional and environmental tests are monitored by a battery of precision electronic instruments and automatic control mechanisms. Investigations of a hazardous nature are performed through use of closed-circuit television and windows of bullet-proof glass which permit direct visual observation.

Advanced analytical techniques and modern high speed electronic computing and recording devices provide fast, accurate data reduction, theoretical correlation and solutions to complex problems.

Boulder engineers have also turned liquid hydrogen into icy slush. These experiments were aimed at determining the feasibility of further reducing hydrogen volume and thus increase fuel loads without increasing tank sizes and weights.

Weightlessness

In the field of zero gravity feed systems, Beech has experimented with gelatinous fluids. Pre-jellied fuels would save weight by eliminating pressure requirements. Beech also leads the industry in development of positive expulsion systems for delivering cryogenic fluids in zero gravity environments.

And in the not-too-distant future, electric propulsion may power vehicles in the most prodigious undertaking ever attempted by man — first-hand exploration of deep space.

Beech is already working on systems for these exotic propulsion



A BEECH-BUILT MOBILE STORAGE DEWAR FOR LIQUIFIED GASES

modes, such as electrostatic, electromagnetic and electrothermal engines. Drawing power from either nuclear or solar energy, high efficiency and long life of electric engines makes them ideal for orbit adjustments, space stations and altitude sustainer missions.

Other low acceleration space systems projects include those which will constitute a natural outgrowth of current electrothermal propulsion programs. And in addition to chemical fuels, Beech has considerable research experience in solid propellants.

A broad background in cryogenics proved a key factor in selection of Beech by NASA and North American Aviation's Space and Informa-

tion Systems Division for the development of Apollo's "cryogenic storage subsystem."

Forming the heart of the Apollo environmental control and electric power systems, Beech's subsystem installs in the spacecraft's service module. It consists of four storage vessels and the required flow lines for supplying the gases used to operate the fuel cell (electric power generation equipment) and to provide the three astronauts with breathing oxygen during the mission.

North American awarded Beech its Apollo contract in July, 1962. The task includes the design, development, evaluation and manufacture of the complete cryogenic storage subsystem.

The Beech Boulder Division is performing the bulk of the work, with support from the main plant in Wichita.

The subsystem's four spherical tanks, each about two feet in diameter, contain hydrogen and oxygen at 300 to 400 degrees below zero and at pressures as high as 1,000 pounds per square inch. The amount of gas in the four tanks would occupy 20,000 cubic feet at room temperature and normal pressure — or enough volume to fill two average size five-room houses.

To keep the hydrogen and oxygen utracold, and thus in a fluid state, the tanks or pressure vessels are insulated with Beech-designed mater-

ial, a special form of fiberglass interspersed with layers of aluminum foil.

Space available for the insulating material between inner vessel and an outer sphere is less than an inch and a half. If the glass fibers in this insulation were placed in a straight line they would reach from the earth to the moon. Also, all air is removed from the insulation in much the same way as in a vacuum bottle.

The vacuum must be so hard that for every 75 million molecules of air between inner and outer spheres, 74,999,999 must be removed. And to maintain this vacuum, the tanks must be built so perfectly that it would take more than 65 years for a thimbleful of air to leak in.

Put still another way, if the tanks were filled with boiling coffee, the insulation would keep the beverage too warm to drink for at least nine months or more of storage.

Beech has achieved several significant technical breakthroughs in connection with subsystem development. One involves a small electric motor that will operate in temperatures as low as -425 degrees F. and at pressures as high as 1,000 psi. Tests indicate the motor would be capable of running on the planets Jupiter and Saturn.

Boulder Division technicians have

also successfully developed a method of electronic beam welding similar to the principle used in projecting pictures on home television tubes.

Additionally they have perfected new techniques for welding different metals, such as aluminum to titanium.

Last December, Beech shipped to North American the first oxygen and hydrogen assemblies. Concurrently with hardware production and deliveries, the company is conducting rigid qualification testing at Boulder, including evaluation of each individual component part of the entire subsystem. Reliability goals far exceed the standards for most aerospace projects.

Beech is also involved in other important work for NASA. For NASA's Launch Operations Center, it is performing cryogenic engineering studies and design verification of spacecraft launch systems.

Advanced insulation evaluation studies of quarterscale Saturn S-II boost stage tanks are in progress at Boulder under subcontract to North American. This activity is being carried out in the company's thermodynamics facility.

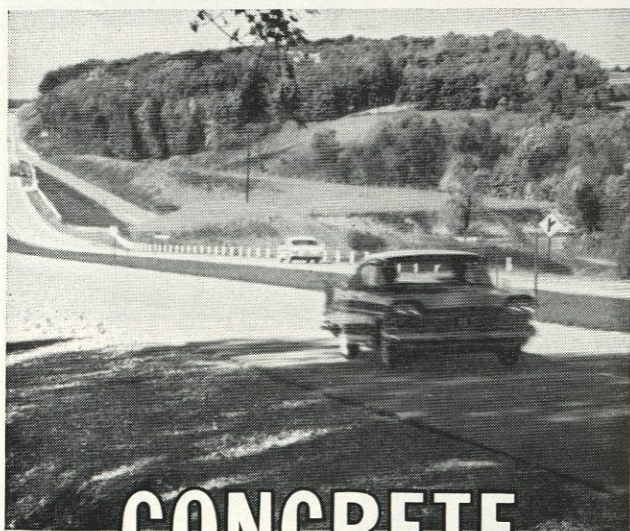
For McDonnell Aircraft, Beech is building the propellant loading system for the Gemini launch complex

at Cape Kennedy. Beech has also been engaged in flight qualification testing of major Centaur cryogenic systems components for General Dynamics/Astronautics.

The company designed and built the nation's first non-refrigerated liquid hydrogen dewar (a double-wall vessel for storing and transporting cryogenic fluids) and the first all-aluminum liquid oxygen dewar. It constructed and tested the largest titanium assembly ever built, a 460-pound tank designed to hold 7,000 gallons of pressurized liquid hydrogen.

For Titan II, first missile to use storable propellants, Beech has been active in development and reliability programs on various systems. The firm also performed literally thousands of environmental tests on both Titan I and Atlas ICBM propulsion system components. It built fuel transport trailers for Titan missile sites and liquid oxygen "topping units" for the Atlas.

Already making vital contributions to America's goals in space, Beech will intensify its activities in these challenging areas as man continues to push the limits of his environment.



saves up to 60% on upkeep!

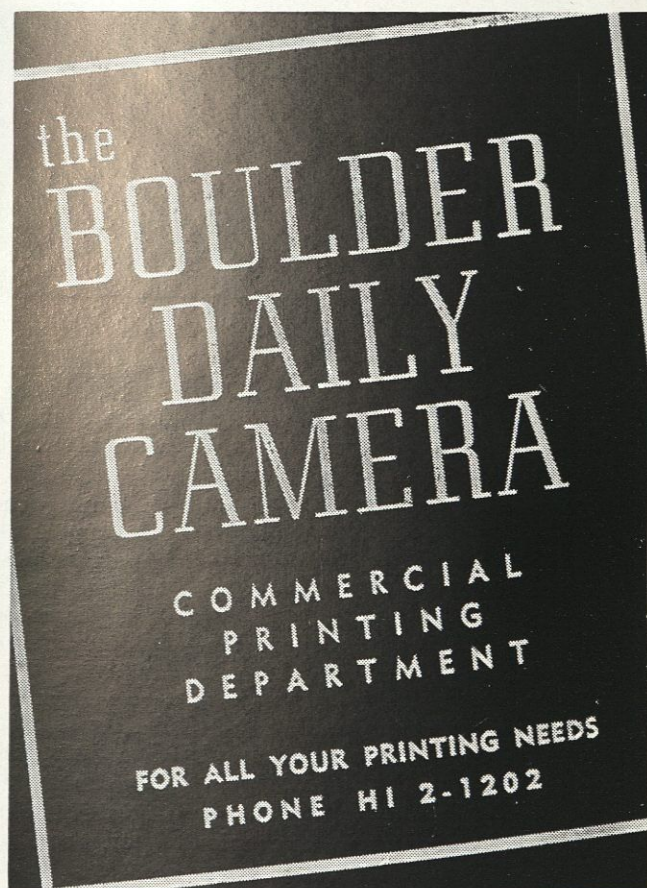
Another Interstate System highway that won't be wearing detour signs! Only concrete has load-bearing strength that can be computed *mathematically* to match future traffic. There are no "moving parts" in concrete to cause hidden wear. Concrete can't oxidize. It doesn't dry out, lose strength and need expensive surface build-up treatments every few years. Then, too, concrete actually grows stronger year by year.

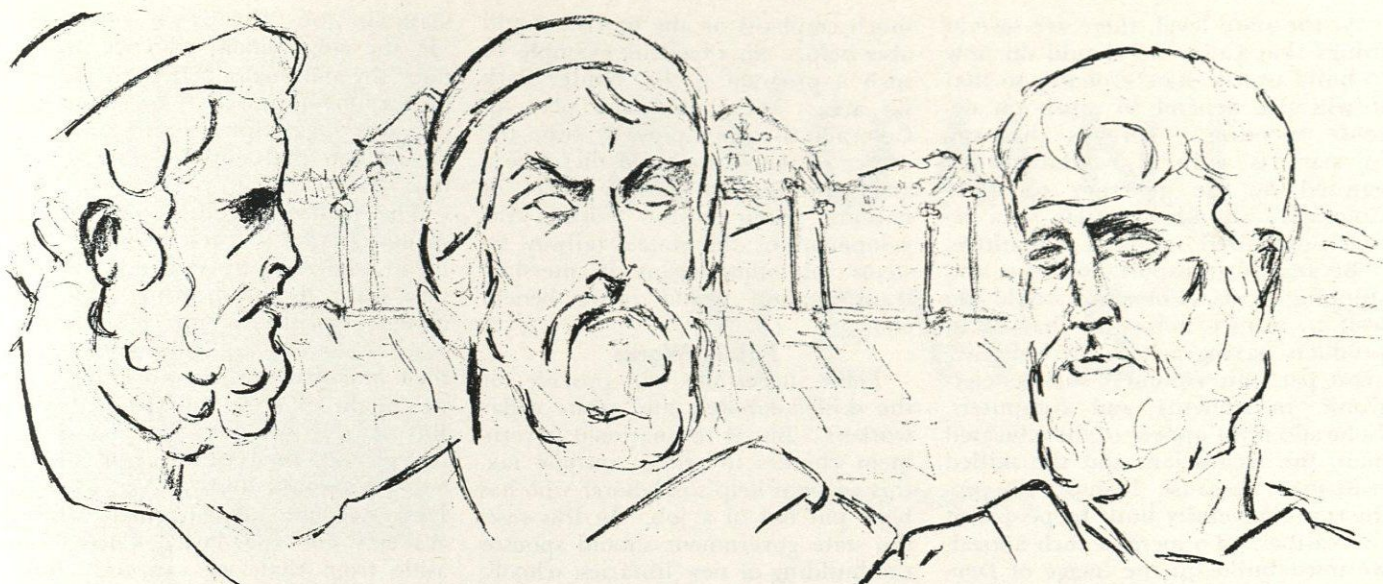
All this adds up to built-in thrift. Upkeep costs will run as much as 60% lower than for asphalt.

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DISARMAMENT AND DEPRESSION

JIM TOEVS

This paper is a discussion of the economic effects of a drastic cut in national defense spending that will accompany the disarmament that the author feels is already in its early stages, as discussed in an earlier paper, ("Keepers of the Peace," *Colorado Engineer*, Nov. 1964). This paper suggests steps that should be taken by the State of Colorado to protect her economy in the event of such a budget cut.

The steps are based on the three most probable methods the government would use to balance the budget: (1) by a tax cut (both income and corporate), (2) reduction of the National Debt by retirement of bonds, (3) by increasing government spending in other fields, such as Foreign Aid, nationally administered research grants, state aid, domestic welfare, and government loans.

Looking at these three methods in view of the national economy, it seems that the last method could result in an uneven distribution, of the surplus funds helping some parts

of the economy and some sections of the country more than others. For instance, increasing foreign aid will be an advantage to agriculture, farm equipment industries, and coastal states because of the shipping involved and the proximity of the product to the transportation. Expanding the basic research programs (A.E.C., N.S.F., etc.) could be quite fair if the government tried to let contracts and give grants to the corporations most dependent on defense contracts. This would present problems, however, because research and mass production do not go hand in hand, and many companies would not be able to employ their full labor force for work under research contracts and grants.

It appears that the tax cut would be the most inflationary of the remaining two methods. With reduction of the debt, money would be paid both to the banks, increasing

their loan capabilities, and directly to corporations holding bonds. This would increase the available capital, encouraging expansion and new development. The tax cut would also increase capital insofar as corporate taxes might be lowered, but the consumer would benefit directly from the income tax cut. The producer might well take advantage of the extra dollar in the consumer's pocket by raising prices. With the debt reduction, the first direct benefit to the consumer would be the creation of jobs through industrial expansion.

Of the three methods, the author favors debt reduction, possibly coupled with low interest government loans made available to the industries hardest hit by the defense cut.

At the state level, there are several things that Colorado should do now to build up the state economy so that it will not depend so much on defense spending. Perhaps the way to start is with a committee organized by the governor to study Colorado's situation, similar to a recently-organized national committee.

Because of transportation costs and shipping costs, Colorado would do well to attract industries that build products having a high price density (cost per unit volume), such as electronic instruments and computers. Colorado must appeal to the educated man, the technician, and the skilled craftsman, because high-priced products are generally built by people of this caliber. To increase such appeal, we must build up the image of Denver and northern Colorado as a scientific and cultural center. National recognition of state colleges and universities will help, but the universities find it difficult to become great when the state legislature is so frugal with its educational budget. State work to make Colorado accessible to Coloradoans, instead of placing so

much emphasis on the tourist, would also help. An excellent example of such a program is the Winter Park ski area. We should also play up Colorado as geographically near the center of the nation, and therefore a good location for home offices of national chain stores. Further development of the state's railway systems and other means of interstate transportation would prove beneficial.

Public Works

These suggestions will provide for the skilled laborers and white collar workers. But if the national government chooses to reduce income tax, this will not help the laborer who has been put out of a job. In this case, the state government should sponsor the building of new libraries, schools, and other public works projects, primarily to create jobs. This could be done on the national level, but the thought of a second "New Deal" and the accompanying socialism would be much harder for most people to stomach. We should also encourage use of products manufactured in our own state, such as C.F.&I. steel, to

maintain jobs already in existence.

If the government chooses to reduce the national debt, then an amplification of programs based on the previous suggestions would probably be the best path for the state to follow.

The choice of other government spending would present state problems that would depend on the form taken by the spending. If more money is spent for research, especially space research and the moon race, then Martin could get contracts and we might not be hurt too badly. But if the emphasis is placed on foreign aid, then we are fairly helpless. We could lobby to get the Air Force Academy turned into a training academy for the Peace Corps, but aside from that, we can only hope that some contracts come our way.

It is my belief that the transition in government spending due to disarmament will be a fairly gradual one, giving us time to prepare for its consequences. The important thought, however, is that the time to begin our preparation is now.

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ROBERT B. HARRIS

Robert B. Harris, BS (Arch. Eng) 1940, has been elected counselor for the North Central District of Chi Epsilon, honorary Civil Engineering fraternity.

After receiving his degree from CU he accepted a position as Structural Steel Detailer for the American Bridge Company in Trenton, New Jersey. He was an instructor in Civil Engineering at the University of Connecticut from 1943 to 1944, and he was a teaching assistant at California Institute of Technology from 1946 to 1947. Harris received his MS (CE) from Cal. Inst. of Tech in 1949. From here he went to the University of Michigan where he became an Assistant Professor. Professor Harris was appointed to his present position as Associate Professor of Civil Engineering in 1957. He served in the Navy as a Lieutenant j.g. during WW II.

Professor Harris is a member of the American Society for Engineering Education, American Concrete Institute, Michigan Society of Professional Engineers, Michigan Association of the Professions, and the American Society of Civil Engineers. He has served as Faculty Advisor to the Student Chapter of A.S.C.E. since 1954, as Vice President of the Michigan Section, A.S.C.E. as Chairman of the District 7 A.S.C.E. Conference in 1959, as Vice President of the Michigan Section in 1960, and as President of the Michigan Section in 1961.

Professor Harris holds memberships in the following honorary societies: Chi Epsilon; Kappa Kappa Psi; Phi Kappa Psi; Phi Kappa Phi; Pi Mu Epsilon; and Tau Beta Pi. He recently has been elected a Member of the Supreme Council of Chi Epsilon.

He is a member of the Committee on Scholastic Standing, the Committee on combined Courses with the College of Literature, Science, and the Arts, and the Committee on Placement, all of the College of Engineering. From 1959, to 1962, he was Secretary of the Column Research Council of the Engineering Foundation. He is also the Assistant Chief Marshal for the University.

Professor Harris has played a principal part in the layout and design of large terrain models for wind tunnel tests for smoke pollution and currently has done research on the effects of wind on mobile homes.

He is the author of the following publications: *Two Structural Theories — The Influence Line and Moment Distribution*, 1957; "Can Engineering Teaching be improved," *Civil Engineering*, Oct. 1958; and "The design of Rigid Frame Bents," *Proceedings of ASCE*, May, 1958.

He, his wife, and four children reside in Ann Arbor, Michigan.

LINDEN E. SNYDER

Linden E. Snyder, BSChE '47, is a senior development engineer at Titanium Metals Corporation America in Henderson, Nevada. He was a representative of the Boulder Dam section of the American Chemical Society on the Society's national council which met in Philadelphia, April 7.

JACK R. HALL

Capt. Jack R. Hall, BSAeroE '61, MSAeroE '62, of the Air Force is assigned to Germany for a three-year tour of duty. He recently completed an 18-month tour of duty at Seymour Johnson AFB, North Carolina, where he was with the Tactical Fighter

Squadron flying the F-105. Hall flew in the funeral fly-by for the late John F. Kennedy.

ROLAND E. RAUTENSTRAUS

Roland C. Rautenstrauss, BS (CE) 1946, MS, professor and chairman of Civil Engineering, has been appointed Associate Dean of the faculties to coordinate academic planning and development of the Denver and Colorado Springs Extension Centers.

Rautenstrauss has taught at the Denver Center every semester since he joined the faculty in 1946. He has been chairman of the civil engineering department since 1959.

He was a lieutenant in the Navy Civil Engineering Corps during World War II. He has been a consultant to Boulder, Colorado and U.S. Governmental agencies and to industry and has conducted special schools for State Highway Department personnel.



PROFESSOR RAUTENSTRAUS

The Colorado Engineer is the engineering journal of the University of Colorado, published four times a year. Most of the work of chasing down the material and of putting the magazine together is managed by the students. In this, the final issue for the year, we would like you to

MEET

The COLORADO Engineer

STAFF

LARRY HUSTON

Larry Huston, the retiring editor, has served on the staff for three years. Besides contributing several articles and editorials, he has edited the joke page for the past two years. His other campus activities have included ASCE, secretary of Chi Epsilon, the civil engineering honorary, AES control board, and membership in Tau Beta Pi and Sigma Tau. He has financed his education by part-time work, his wife, and scholarships. In June he and his wife will move to Oakland, California where he will work for Kaiser Engineers International.

ROSS FRAKER

This last year Ross served as the Business Manager of the *Engineer*. This year he will finally come the end of his undergraduate days (hopefully but regretfully) after spending four busy, interesting years trying. Ross has been taking part in groups such as the Superior Student Program, Alpha Phi Omega, A. E. S.,

Tau Beta Pi, Sigma Tau, and others, even the *Engineer* as Circ. Manager. After graduation he plans to go on to graduate school at CU and seek a Ph. D. in Applied Math.

FRED LOVE

Fred, who came to CU from Henderson, Nevada, has acted as Sections Editor of the magazine this year. He is presently a Junior following a five-year curriculum in Chemical Engineering and Business (Finance). Other activities include A.I.Ch.E. (of which he is currently Treasurer), Sigma Tau-Engineering Honorary, and Alpha Chi Sigma—Chemistry Professional Fraternity. In his spare time, Fred is either studying or resting his brain, with the latter possibility having the better odds. The result of this arrangement is lower grades and a thoroughly relaxed brain.

MARK SHERIDAN

Mark Sheridan is a senior in the combined five year Chemical Engineering and Business program. He is

planning to graduate in 1965. Besides writing, he participates in the student chapter of A.I.Ch.E. and is a member of Alpha Chi Sigma, professional chemical-engineering fraternity. On the weekends he enjoys skiing or water skiing, depending on the season.

CHERYL ANDERSON

Cheryl Anderson from Short Hills, New Jersey has been the Assistant Business Manager of the Colorado Engineer this past year. Cheryl is a sophomore in Arts and Sciences, and is majoring in Political Science. Cheryl also serves as an A.W.S. Representative and a member of her wing council. This is Cheryl's second year on the staff.

In addition to Assistant Business Manager, Cheryl has also helped out in circulation, advertising and as a secretary.

BOB BARRY

Bob Barry, This Today editor, is a sophomore in Civil Engineering. He is a graduate of Littleton High



School, Littleton, Colorado. Bob's main extra-curricular activity at present is Alpha Phi Omega, national service fraternity. He also enjoys mountaineering, skiing, and fishing whenever he gets the chance. After graduation, Bob hopes to serve in the Peace Corps and then get into the heavy construction industry.

JUDY BECKER

This year's cover artist, Judy Becker, was a mechanical engineering major for 2 years and at that time helped organize the chapter of SWE now on campus. She changed to Fine Arts and then was employed for a year as a search analyst for Denver Research Institute. She returned to CU this fall and is graduating with a major in pure math. She plans to work in research after graduation.

RON BLACKWELDER

Ron Blackwelder is a fifth year student in Aerospace Engineering Sciences. Besides the regular four years of engineering, Ron has taken a year of Arts and Sciences with the R. J. Tipton Scholarship. He is the president of Tau Beta Pi, national engineering honorary, vice president of the American Institute of Aeronautics and Astronautics, Production Manager for the *Colorado Engineer*, and a member of Sigma Tau, national

engineering honorary. After graduation this June, Ron will leave for Munich, Germany, where he will study fluid mechanics with the Bavarian State Scholarship.

PAUL BUGG

Paul Bugg, Head Proofreader of the *Engineer*, is a sophomore in Arts and Sciences who is majoring in 199 after a somewhat disillusioning freshman year in the Superior Student Program in E.E. He hopes to stay away from his home in Ohio this summer by working on a survey crew in the mountains around Climax, Colorado. Paul delights in watching movies, playing bridge, and proofing galleys, while occasionally using his spare moments to cram.

JOANN CRAM

JoAnn Cram, Book Review Editor, is a Junior majoring in Applied Math. A member of Sigma Tau, Mortar Board, Superior Student Program, Society of Women Engineers, and Society for Industrial and Applied Mathematics, she has recently been elected to receive the Tau Beta Pi Badge. Other activities include the Convocation Committee for E-Days and the steering committee for the campus-wide Aerospace Week May 3-7. Free and other stolen moments are spent on a ski slope trying

to figure out how to avoid trees. She is recognized by her smile and a Beatle? haircut.

RICK CYS

Rick Cys is a sophomore in the combined Chemical Engineering and Business curriculum. He is house manager of Phi Kappa Tau fraternity and a member of Phi Epsilon Phi, sophomore men's honorary. Skiing, intramural sports, and carpentry take up Rick's leisure time.

ELLEN HARRIS

Ellen Harris, a member of the Superior Student Program, is a junior in Mechanical Engineering. During the summer, she worked on an undergraduate research project attempting to discover the effective surface areas of certain plant specimens for the absorption of unidirectional radiation. Her home is near Falcon, Colorado, where her family ranches.

LARRY HILL

Larry Hill is originally from Greeley, Colorado. He now commutes from Wheatridge where he lives with his wife who teaches school in Lakewood. Larry worked this year as editor of the puzzle page and will graduate this June with a degree in Civil Engineering. After graduating he will work in San Francisco.



ROW ONE: (LEFT TO RIGHT) CHERYL ANDERSON, JUDY WALLACE, ELLEN HARRIS, SANDY PYLE.
ROW TWO: CHUCK HANSEN, DICK CYS, PAUL BUGG, MITCH ALLIES.
ROW THREE: MARSHALL SILVER, DENNIS LOTITO, MARK SHERIDAN, ROSS FRAKER, DAVE PARKHURST.
ROW FOUR: BOB BARRY, JIM TOEVS, RON BLACKWELDER, LARRY HUSTON, DAVE PEERCY.

MARY ANN MIKLICH

Mary Ann Miklich: Mary Ann did the cover of the November issue. She has been a P.W.G. (Poor Working Girl), helping put her husband, Don, through school, ever since she graduated from C.U. in 1963. Don is a graduate student working on his doctorate in Psychology. Art is a long standing hobby of Mary Ann's and she has contributed several drawings and sketches for article headings in addition to the cover last fall.

GARY O'KEEFE

Gary O'Keefe is a transfer student in his first semester at the University of Colorado, having previously attended Long Beach, California. He is presently a junior majoring in Civil Engineering. Summers he is engaged in materials testing work with the California Division of Highways. Tennis and handball are among his favorite activities and he hopes to get in some skiing while in Colorado.

DAVE PEERCY

Dave Percy is a sophomore in the College of Engineering, majoring in Applied Mathematics. The year is fairly busy for Dave as he is a member of the band and the track and football squads. His current grade point average is 3.7 and he attends Wesley foundation. This summer he expects to work for the Socony-Mobil field research group from Dallas, Texas working near his home town of Rifle, Colorado.

SANDY PYLE

Sandy Pyle, Office Secretary this year, is a junior in Aeronautical Engineering. She is Vice-President of the Society of Women Engineers and an active member of A.I.A.A. Her hobbies include flying, softball, and most other sports (skiing excluded). She is commuting this semester from her home in Lakewood, Colo., where her father is a wood products manufacturer.

DAVE PARKHURST

Dave Parkhurst, Assistant Editor, is a senior in applied math, with a fifth year to go. Dave is a participant in the Superior Student Program and in the Undergraduate Research Program in Engineering. He is a member of Tau Beta Pi and of Sigma Tau. His job with the Institute of Arctic and Alpine Research fits well with his love for mountaineering.

MARSHALL SILVER

Marshall Silver, this year's Feature Editor, is a junior majoring in Civil Engineering. He is presently a member of Tau Beta Pi, Eigma Tau and Chi Epsilon, Secretary of A.S.C.E., and Scholarship Chairman of Beta

Theta Pi Social Fraternity. He also owns the Silver State Engineering Company, a Boulder firm specializing in geologic mapping. Marshall's outside activities include competitive rifle shooting and adding to his collection of Nineteenth Century literary first editions. Originally from Sherman Oaks, California, Marshall now makes his home in Boulder where he will complete his schooling with the help of various scholarships and grants.

JIM TOEVS

Jim Toevs, a senior in Engineering Physics, is a fourth-year participant in the Superior Student Program. He is a member of Sigma Tau, Tau Beta Pi, Sigma Pi Sigma, and Kappa Kappa Psi, and plays trumpet in the University Band. He spent the last two summers doing research under an NSF undergraduate grant, and is presently engaged in high-energy negative ion research at the University's cyclotron. Outside interests include music, tennis, mountain climbing, and a pretty medical student at the University of California. Jim plans to do graduate work in Physics.

CHUCK HANSEN

Charles E. Hansen, Alumni News reporter, is a junior in Aerospace Engineering. He is in the Air Force ROTC program and intends to receive a degree and a commission in 66. He is from Gunnison, Colo. and is a native of the state.

He has been on the Colorado Engineer staff three years, is a Sigma Tau pledge, a member of Arnold Air Society, and holds a 3.0 grade average.

LARRY FOWLER

Larry Fowler is a senior majoring in electrical engineering. He is a member of the U.S. Air Force attending C.U. under the auspices of the Air Force Institute of Technology. He served this year as vice-chairman of IEEE, Treasurer of Eta Kappa Nu, and Corresponding Secretary of Tau Beta Pi. He is also a member of Sigma Tau and A.E.S.

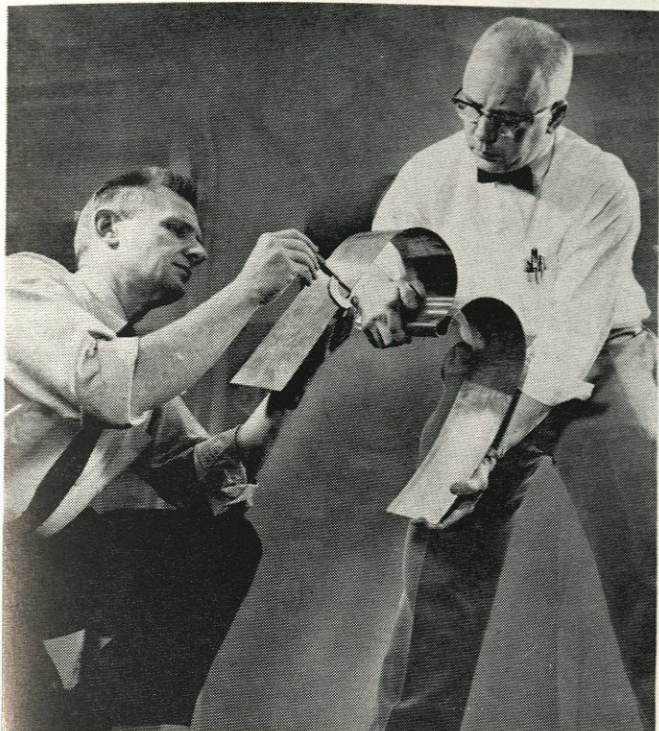
TOM DAVEY

Tom Davey is a senior in Aerospace Engineering. He is a Captain in The Air Force and is being sponsored by the Air Force Institute of Technology. He belongs to Tau Beta Pi and recently won that organization's pledge essay contest. Tom's major interests lie in aviation. He has a commercial pilot's license, as well as being a military jet pilot. After receiving a Masters' Degree in Aerospace Engineering, Tom plans to apply for the Air Force Aerospace Research Pilot School.

COLORADO *Engineer*

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THIS STRIP SHOWS THE ACTION OF CBS ROLLING

THIS TODAY

ROBERT BARRY

C-B-S ROLLING

General Electric Research Laboratory recently announced the invention of a new technique of metal rolling. The new process, in which metal strip is squeezed, bent and pulled simultaneously, is called "Contact-Bend-Stretch" (C-B-S) rolling.

The technique is a result of studies, made by Dr. Louis F. Coffin, Jr., on the effects of cyclic plastic strain on metal. He discovered that metal strip can be made thinner and longer more easily if plastic bending is added to the pressure and tension forces usually applied in metal rolling. In conventional rolling the metal strip is deformed by the pressure of two rollers while the strip is pulled between them under tension. If the metal is bent plastically at the same time, C-B-S rolling takes place. In one form of C-B-S rolling, a small roller with strip wrapped around it lies in a "saddle" between two work rolls. These work rolls revolve in the same direction, rather than in opposite directions, as in conventional rolling mills.

In C-B-S rolling easier deformation of the strip and the consequently smaller forces needed may make it possible to use smaller, lighter, less expensive mills. Also, larger reductions in thickness can be achieved on each pass through the rolls. During

the later stages in the development of the process, stainless steel was reduced from a thickness of 0.090 inches to 0.012 inches in four passes without intermediate anneals. This same reduction, using conventional rolling methods, requires about a dozen passes and several intermediate anneals.

A variety of metals have been rolled using the C-B-S method. These include a number of carbon and alloy steels, Rene 14 and other nickel base alloys, copper, and molybdenum. Since C-B-S rolling permits greater reductions in thickness without intermediate annealing, it will be especially advantageous in rolling materials that harden with working.

LIGHTING PATHFINDER

Dr. Edwin Whitehead, professor of electrical engineering at Illinois Institute of Technology, has invented a simple, inexpensive instrument which registers the path followed by electric current after lightning strikes a power transmission system. This pathfinder is expected to provide information about the path of lightning strokes which will aid in the redesign of power transmission systems in such a way as to minimize lightning-caused power failures.

According to Dr. Whitehead, present theories of lightning paths are unreliable and unscientific. Data

yielded by the pathfinder should help scientists to develop a general law describing how lightning strikes power transmission systems. This will enable electrical engineers to design future high voltage lines in such a way that lightning will strike only on one insulated part of the towers.

Dr. Whitehead said recently that power failures due to lightning are caused by two kinds of trouble. Lightning may strike the high voltage tower, or it may strike the electrical conductor causing failure at the point where the transmission wires are connected to the tower. The pathfinder will provide a scientific method for determining which of these occurs most frequently.

When the pathfinder is connected to a transmission system it records the direction taken by the electric current from any stroke of lightning which causes a power failure. The instrument gives a clear permanent signal indicating the part of the power line hit by the lightning. The signal can be read either from the ground or from a helicopter.

Edison Electric Institute is sponsoring the present research program which involves testing 700 pathfinders on 500 miles of transmission line. Later 7000 of the instruments will be installed on hundreds of miles of line for at least a five-year period.



BELL LAB'S NEW THIN FILM ANALYZER

FILM ANALYSIS BY XENON

A new, quick method for determining the gas and carbon content of thin films has been developed by William G. Guldner of Bell Telephone Laboratories. This method, unique in the field of analyzing gases in metals, uses a xenon flash-discharge lamp to remove thin metallic films easily and quickly from inorganic substrates.

Other methods being used today are not sensitive enough for these analyses. The problems involved are that the amount of material is very small, the thin film is difficult to dissolve or remove from the substrate, and the metals form very stable compounds. For example, before the development of the xenon-lamp technique, nitrogen could not be separated from zirconium or tantalum although it was known to be present. Mr. Guldner has successfully used the xenon lamp method to dissociate simultaneously tantalum compounds of nitrogen, oxygen, carbon, and hydrogen from films deposited on glass substrates. Argon is also evolved from films deposited by sputtering.

In making an analysis, the thin film is placed in a vacuum and flashed with a xenon lamp. The heat absorbed from the flash vaporizes the film completely from the substrate. The gases are collected by conventional vacuum techniques and analyzed by a gas chromatograph, an instrument that separates chemical mixtures by the difference in adsorption properties of the components.

At present, the xenon lamp technique is being used to determine the

composition of thin tantalum films used in electronic circuitry. The films that are used as resistance components are deliberately doped with nitrogen to improve their properties. Additional studies are being made to correlate the electrical and physical properties of the films with their composition. One future use of the xenon lamp technique may be as a quality control tool during the manufacture of thin film components.

ALUMINUM-POLYETHYLENE

A new type of light-weight, high-strength laminate and a process for deep drawing it into a variety of shapes have been developed by Karl Pohl and Arthur Spencer at the Bell Telephone Laboratories. The laminate, made of two aluminum sheets bonded to a solid polyethylene core, is well-suited for many commercial applications. These include paneling for ships and airplanes, small boat hulls, luggage, and automobile body parts.

Unlike other reinforced plastic laminates, this new material can be welded. It can also be riveted, bolted, punched, sheared, and adhesively bonded to a number of other materials. The laminate's flexural properties in relation to its weight are superior to most widely-used commercial materials. For example, a four-pound laminate sheet and a ten-pound steel sheet of equal width would deflect the same distance when subjected to equal bending moments.

The laminate is prepared by first cleaning the aluminum and polyethylene surfaces with acetone. The aluminum is then roughened with a blast

of steel grit, cleaned in trichloroethylene vapor, etched in an acid bath, rinsed, and dried. One polyethylene sheet is sandwiched between two aluminum sheets and this assembly is inserted into a preheated press. The polyethylene melts and forms a strong bond with the aluminum. Pressure is applied to squeeze out any excess molten polyethylene and reduce the laminate to the desired thickness.

Laminates of this type in sheet form are attractive commercially because of their efficient use of materials. In most applications sheet material is stressed in such a way that it tends to bend or buckle. Since maximum bending stresses occur at the surface of a sheet, most of the strength of a homogeneous material is waste and only adds unnecessary weight. A laminate sheet, however, can have a light, relatively weak material for its center where bending stress is small.

The developers of the laminate have also devised a method of forming it into various shapes. The laminate is first secured under a ring opening into a cavity. The ring, which is maintained at room temperature during the deep drawing process, holds the laminate in place as a heated punch descends into the cavity. The heated punch, under pressure from a hydraulic press, softens the polyethylene core and forces the laminate into the cavity. Softening the core allows the aluminum skins to be drawn, in effect, independently of each other; thus, minimizing the stresses in the laminate. The cool laminate underneath the ring forms a seal of hard polyethylene against the pressure of the soft core.



A DEMONSTRATION OF THE RIGIDITY OF THE NEW ALUMINUM-POLYETHYLENE LAMINATE

DEAN'S COLUMN

DEAN PETERS



As we approach the end of the 1963-64 academic year, I feel it is appropriate to discuss the tremendous help our Engineering alumni and friends have given us through their continued support of our activities. This support is given, not only in the form of financial donations, but also in the form of many hours of time taken from an already busy life to consult with us on our Engineering developmental programs and to inform others of our activities here in Engineering.

THE UNIVERSITY OF COLORADO ENGINEERING DEVELOPMENT FOUNDATION is a group of dedicated and outstanding alumni and friends of our College of Engineering who serve the University by helping to formulate and put into effect plans for the development of our College. To give an idea as to the caliber of men who freely devote their time to the development of our College, following is a list of the present members of our Engineering Development Foundation Board of Directors:

Earl W. Almgren — Valmont Plant, Public Service Company — Boulder, Colorado — B.S. (EE), 1922.

Vincent B. Baker, Vice-President, Allied Instructional Developments, Inc., Pittsburg, Pennsylvania, B.S. (EE), 1938.

Wellwood E. Beall, Sr. Vice-President, The Boeing Company — Seattle, Washington. Degree "Aeronautical Engineer," 1948.

Gilbert Beck, Rancher, Phoenix, Arizona. B.S. (Chem. E.), 1933.

C. D. Belt, Manager and Partner, C. D. Belt and Company — Denver, Colorado. B.S. (EE), 1931.

Louis P. Benedict, Vice-President and General Manager, Wm. A. Revelle Corporation — Gardena, California. B.S. (EE), 1957.

Harold E. Benson, Vice-President, Eastman Oil Well Survey Company — Denver, Colorado. B.S. (EE), 1926.

Charles R. Burlingame, Retired. Pittsburgh, Pennsylvania. B.S. (ME), 1918.

Elmer W. Coyer, Chief Engineer, Mountain States Tel. and Tel. Company — Denver, Colorado. B.S. (EE), 1937.

W. Clinton DuVall, Professor Emeritus. Boulder, Colorado. B.E. (EE), 1912.

Harry Ellsberg, Arch. Engineer, Giffels & Rossetti — Detroit, Michigan. B.S. (EE), 1913.

William C. Fagerquist, Engineer, U. S. Bureau of Reclamation — Pueblo, California. B.S. (CE), 1932.

Frank W. Fink, Vice-President, Ryan Aeronautical Company — San Diego, California. B.S. (CE), 1928.

W. M. Hall, President, Charles T. Main, Inc. — Boston, Massachusetts. B.S. (CE), 1916.

Cloid B. Hammer, President, Cal. Cast Product Corporation — Los Angeles, California.

C. A. Herbst, Jr. — Resinoid Engineering Corporation — Skokie, Illinois. B.S. (Chem.E.), 1950.

Charles E. Hornback, Physicist, National Bureau of Standards — Boulder, Colorado. B.S. (E.Phys.), 1951.

Arthur Horner, President, A. S. Horner Construction Company — Denver, Colorado. B.S. (CE), 1922.

Samuel Judd, Member, Phillips, Carter and Reister — Denver, Colorado. B.S. (CE), 1915.

Olin Kalmbach, Vice-President, Tipton & Kalmbach, Inc., — Denver, Colorado. B.S. (EE), 1934.

John C. Kreiling, Assistant Staff Construction Engineer, Colorado Department of Highways — Denver, Colorado. B.S. (CE), 1955.

Frank J. LaRocca, Assistant Superintendent of Combustion Department, The Colorado Fuel & Iron Corporation — Pueblo, Colorado. B.S. (EE), 1935.

G. Elbert Messer, Manager, General Electric Company — Kansas City, Missouri. B.S. (EE), 1926.

Thomas E. Orr, President, Secretary and Treasurer, D&O Products, Inc., — Wichita, Kansas. B.S. (Aero), 1948.

Orley O. Phillips, Member and Partner, Phillips-Carter-Reister, Inc., — Denver, Colorado. Degree "Civil Engineer," 1957.

James W. Pollock, U. S. Atomic Energy Commission — Idaho Falls, Idaho. B.S. (Chem.E.), 1945.

Charles H. Sells, Consulting Engineer. New York City. B.S. (CE), 1914.

Earl J. Shelton, Jr., Director of Development, Eitel-McCullough, Inc., — San Carlos, California. B.S. (ME), 1943.

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Herbert J. Strelesky, Engineering Personnel Manager, Mountain States Tel. and Tel. Company — Denver, Colorado. B.S. (EE), 1938.

A. R. Taylor, Manager Custom Operation Analysis, General Electric's Commercial Engine Operation — Topsfield, Massachusetts. B.S. (ME), 1950.

In addition to two regular meetings of the entire Board on our campus each year, members of the Board regularly meet with our faculty to discuss various aspects of our Engineering program. This type of dedicated support from our Engineering alumni and friends is highly gratifying to those of us on the campus. In addition to supplying us with valuable guidance on our over-all Engineering program at the University of Colorado, the Engineering Development

Foundation Board of Directors, as part of the Engineering Development Foundation, aids us by helping obtain financial support for our activities from our alumni. Support for student scholarships and gifts to Departments for equipment are often foremost in the minds of our alumni when they make a contribution. However, one of the most difficult types of funding to obtain for a University is that for developmental activities of our students and faculty. It is very difficult to obtain full funding from State sources for items such as paying expenses for visiting scientific speakers, expenses for faculty and students to attend special short courses or technical meetings away from campus, support of the *COLORADO ENGINEER*, high school and undergraduate science prizes sponsored by the University, and other activities which are essential for development of our faculty and students as well-rounded Engineers.

The Engineering Development Foundation permits us to carry on this type of activities to, at least, a limited extent by means of a so-called "Dean's Discretionary Fund of the Engineering Development Foundation." As the name indicates, this fund is used at the discretion of the Dean for the development of our over-all activities in the College of Engineering. Examples of the way the fund is used are: the provision of Science Fair Awards for high school students, a mathematics prize for one of our undergraduates, partial support of the *COLORADO ENGI-*

NEER, visits to high schools in the State to discuss Engineering as a career, publication of an Alumni Directory, partial support for bringing outside Engineering speakers to our campus, and publication of an Alumni Newsletter.

The source of the money for the Dean's Discretionary Fund is donations from our alumni through the Engineering Development Foundation. Many of our alumni feel that this type of developmental money is extremely important for the College and, accordingly, designate specifically that their donation should be used for this purpose. I am very pleased that so many of our alumni recognize the extreme importance of having this type of developmental money available for use in the College. It is also significant to note that last year, 96% of our Engineering faculty made a donation to the Engineering Development Foundation, and a large portion of these donations were designated for the Dean's Discretionary Fund. This year, 97% of our Engineering faculty have donated to the fund.

This type of support from our alumni and faculty is a major factor in the forward progress being made in our College of Engineering. I can assure you that the progress our College of Engineering is now making will continue, and I sincerely hope that the support we have had in the past will also continue.

Max S. Peters
Dean

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BOOK REVIEWS

JOANN CRAM

The Science of Science

By scientists of the Westinghouse Research Laboratories Russell Fox, Max Garbuny, Robert Hooke, and Sharon Banigan (executive editor), 243 pp., Walker and Company: 10 West 56th Street, N.Y., 1964; \$5.95.

What is the ultimate purpose of Science? How do scientists themselves regard their professional aims and what is their motivation? How constant are scientific "constants"? What are the links between pure science and applied science?

Scientists want to explain their methods of interpreting physical phenomena, and the rest of the world wants to listen and to understand. This book is the first in a series for interested students and adults, the *Search Books*, which offer a meeting place for the scientist and his audience. *The Science of Science* is written about the basic modern methods and objectives of science, which have been somewhat obscured by the on-surge of complex advances in this field during the past few years. Among the topics the reader will encounter are the methods of science, the language of science, the observable and unobservable phenomena with which science is concerned, various types of experimental apparatus and their use, change and control of phenomena, some limits of observation and other obstacles with which scientists are confronted, constants, the relationship of space, motion, and time, examples of experiments, and two especially informative sections entitled "Some Facts" and "Some Figures." The appendix includes a brief review of calculus, a table of certain scientific symbols, a list of fifty-two scientists and their achievements, and a list of books in which further reading of this type of material can be done. The book is richly endowed with numerous diagrams, tables, and illustrations which assist the reader to understand the ideas presented.

(Grateful acknowledgement to Sharon Varian for the contents of this review).

At last, a book for those of us who have a vague or even more concrete notion of lasers and masers, but have

trouble explaining them to an Arts and Science roommate. Besides, the way the set of laser applications is growing, soon every field of engineering will be affected.

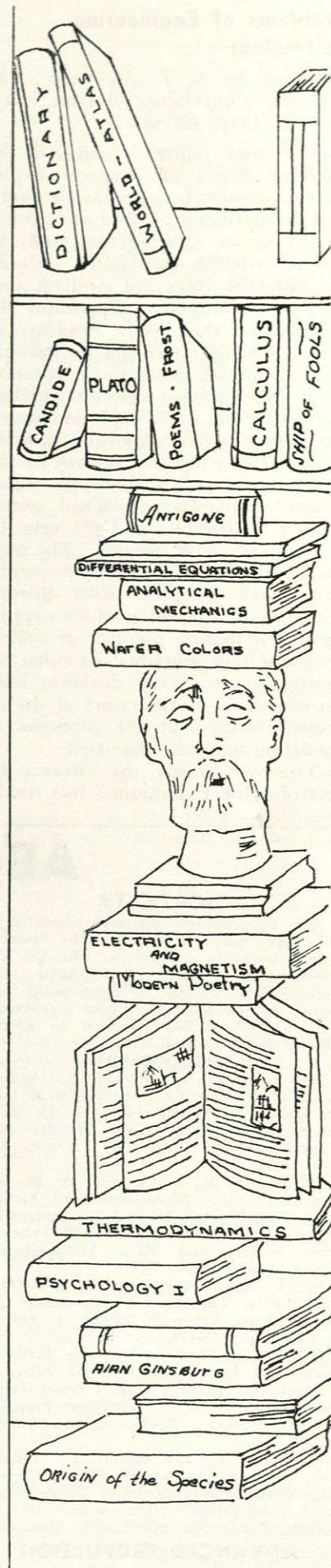
Masers and Lasers: How They Work, What They Do

by Dr. M. Brotherton, Head, Advertising Department, Bell Telephone Laboratories, Inc. 201 pages, McGraw-Hill Company, 1964, \$8.50.

In terms understandable to the interested layman, Dr. Brotherton explains the principles, significance, and usefulness of masers and lasers to science and technology. Starting with the fundamentals of electricity and magnetism, the reader is guided step-by-step through the principles of amplifying with atoms. The basic principles and ideas involved in masers and lasers, the development of the maser principle, and the method of producing laser action by harnessing the orbital electron system of atoms and molecules are discussed.

The sixteen chapters of the book include discussions on: Electromagnetic waves, laser radiation, spectroscopy, atomic theory, nature of the atom, concept of the photon, concept of stimulated emission, traveling-wave ruby masers, ruby and helium-neon lasers, the semiconductor junction laser, uses of masers and lasers, communication with lasers, significance of frequency bandwidth, and a capsule history of masers and lasers.

The following book is very impressive and equally sobering. An authorized translation from the Russian, it is a collection of six papers dealing with the seismic effect of high explosions. The papers are written in excellent technical form with chapters explaining apparatus, and observation methods, and results are likewise clearly presented with graphs of ground displacement at specified distances, trajectories of typical particles, etc. The reports are complete and empirical formulas state conclusions. My reaction to the book is that these people not only know what they are doing by also where they are going. Think I'll blow some dust off my text books.



Problems of Engineering Seismology

Edited by S. V. Medvedev, 111 pages, Consultants Bureau, New York, 1963, \$27.50.

The first paper is entitled the "Seismic Effect of Eruptive Explosions in Nonrock Coherent Ground," and it describes a method and certain results of an experimental study of ground surface oscillations induced by different forces of underground eruptive explosions. Apparatus developed by the USSR Academy of Sciences made it possible to measure ground motion at various distances from the explosion epicenter, including very close to the explosion crater. Consequently, it was possible to mark certain characteristic features in the ground motion in the zone where ground displacement reached several tens of centimeters and the velocity, several meters per second. The measured parameters of ground oscillations were compared with observations of ground motion which were revealed by motion pictures, as well as with the data obtained by other investigators at greater distances from an explosion. The nature of the recorded waves and the problems of modeling them are discussed.

The next article, the "Seismic Effect of Mine Explosions," lists results

of an instrumented study of the seismic effect of explosions in a mine. Ratios are obtained between the charge weight, distance from the explosion, and the intensity of seismic oscillations. The possibility of comparing the seismic effect of explosions with the effects of earthquakes is examined.

"Reduction of the Seismic Effect of Explosions by Microsecond Delay Blasting." Microsecond Delay Blasting (MDB) is a compromise between exploding a large weight of charge to blast out a lot of volume and the safe amount of explosive charge in order to preserve buildings and other structures surrounding the site. This article gives the results of experiments to determine the optimal delay time for reducing the seismic effect in MDB. An empirical formula is derived for the reduction of the seismic effect in MDB as a function of the number of delay groups.

"Correlation between the Velocity of Seismic Oscillations of Particles and the Liquefaction Phenomenon of Water-Saturated Sand." The liquefaction phenomenon named has not yet really been explained or even defined. We know the sand settles and large amounts of water are released, and that this doesn't happen with dry sand or water-saturated

gravel. This short article compares the velocity values of particle oscillations with the liquefaction of water-saturated sand caused by explosions of various charges.

"Instructions for Investigating the Seismic Effect of Explosions on Structures." This article is exactly what the title states: it is an inspection checklist and report form for a structure that has been shaken naturally or by a nearby explosion.

The last article, "The Problem of Investigations of the Seismic Effect of Explosions at the Institute of the Seismic Effect of Explosions at the Institute of Physics of the Earth, USSR Academy of Sciences," summarizes the results of the investigations with respect to engineering seismology. Attention is devoted mainly to the zone nearest to the explosion center, the zone of residual deformations, and the elastic zone. The development of the concept of determining the intensity of ground oscillations and the parameters directly associated with it—the frequency and elastic energy going into the formation of seismic waves—is also traced. In addition, the works on the study of the effect of ground oscillations on structures and the calculation of the radius of seismically dangerous zones during blasting operations is examined.

ABOUT THE AUTHORS

VORTICITY

The experimental material presented in this paper has been supervised by Professor Frank Kreith in conjunction with the Undergraduate Research Participation Program in the College of Engineering, supported by the National Science Foundation. The author is also indebted to Everett Meyers and Burton Dwyre.

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ADVANCED PROPULSION

Fred Love is a Junior following a five

year program in Chemical Engineering and Business. In his spare time, Fred acts as Sections Editor for the *Colorado Engineer* and as Treasurer of the A.I.Ch.E., Student Chapter. He is also a member of Sigma Tau and Alpha Chi Sigma.

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DISARMAMENT AND DEPRESSION

This report is the result of a study undertaken by an engineering economics seminar taught by Professor L. Fishman of the Economics Department in an effort to make an academic subject meaningful on the student level.

RANDOM VIBRATION

Richard Lubinski is a junior majoring in Electrical Engineering. He has worked at The Martin Company in Denver for the past three summers, last summer as a student engineer. He is currently working as an assistant to Dr. J. H. Krenz in the Electrical Engineering department. His outside activities include skiing, swimming, and skin diving.

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Dr. R. S. Novosad

Above-listed individuals of Martin-Denver.

LASER DEVELOPMENT

Frank D. Price is a senior in electrical engineering. Member of IEEE, TB π , HKN, and the CU Judo Club. His interests include astronomy, photography, and skiing.

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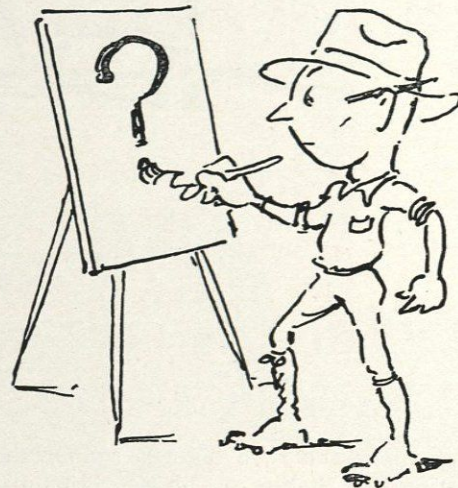
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PUZZLE PAGE

LARRY HILL



Smith drove at a steady clip along the highway, his wife beside him. "Have you noticed," he said, "that those annoying signs for Flatz beer seem to be regularly spaced along the road? I wonder how far apart they are."

Mrs. Smith glanced at her wrist watch then counted the number of Flatz beer signs they passed in one minute.

"What an odd coincidence!" exclaimed Smith. "When you multiply that number by 10, it exactly equals the speed of our car in miles per hour."

Assuming that the car's speed is constant, that the signs are equally spaced and that Mrs. Smith's minute began and ended with the car midway between two signs, how far is it between one sign and the next?

An engineer, noted for his ability to visualize three-dimensional structure, was having coffee and doughnuts. Before he dropped a sugar cube into his cup, he placed the cube on the table and thought:

"If I pass a horizontal plane through the cube's center, the cross section will of course be a square. If I pass it vertically through the center and four corners of the cube, the

cross section will be an oblong rectangle. Now suppose I cut the cube this way with the plane..." To his surprise, his mental image of the cross section was a regular hexagon.

How was the slice made? If the cube's side is half an inch, what is the side of the hexagon?

After dropping the cube into his coffee, the engineer turned his attention to a doughnut lying flat on a plate. "If I pass a plane horizontally through the center," he said to himself, "the cross section will be two concentric circles. If I pass the plane vertically through the center, the section will be two circles separated by the width of the hole. But if I turn the plane so..." He whistled with astonishment. The section consisted of two perfect circles that intersected!

How was this slice made? If the doughnut is a perfect torus, three inches in outside diameter and with a hole one inch across, what are the diameters of the interesting circles?

ANSWERS TO PUZZLES IN THE MARCH ISSUE

(1) Two-Digit Numbers:

The values for D and E (3 and 6) are interchangeable, also for V and O (2 and 5). I find 8 different solu-

tions, or 10 if we include a couple in which A is allowed to have the value 0.

Answers: (a) 36, (b) 27, (c) 25, (d) 54, (e) 29, 38, 47, 56.

(2) The Kitchen Linoleum:

Answer: The linoleum need be cut into only two pieces, as shown by the diagram. Each "step" is 4 feet wide and 3 feet deep. If the right-hand piece is moved one step down and leftward, a square 12 by 12 is formed.

(3) Adam and Eve:

Answer:

The solution	8 3 8 4
with the	8 0 3
maximum	6 2 6
total is	5 0
	8
	9 8 7 1

(4) The Tennis Tournament

Answer: 77 of the entrants have to be eliminated; hence, 77 matches are required.



LARRY HUSTON

A third-grade teacher in Florida was discussing the habits of birds. "When it gets cold up North some friends of ours leave the ice and snow and come to Florida to enjoy the sunshine. Who are these friends we are so glad to see?" she asked. An alert youngster piped up, "Tourists!"

Is it true they don't have phone directories in China because there are so many Wings and Wongs they are afraid too many people will wing the wong number?

At West Point a visitor noticed that all names engraved on a famous battle monument were those of the men in the Union army, killed in action during the Civil War. "Say," he called to a cadet, "what's this?"

"A tribute to the markmanship of the confederacy, Suh!" drawled the cadet.

A young man just received his college degree and rushed out saying: "Here I come, world! I have an A.B."

And the world replied: "Sit down, son, and I'll teach you the rest of the alphabet."

Before my son enlisted, I assured him that the Army would make a man of him. Not long ago I got this letter: "Dear Dad, I have learned to make a bed with the best of them. I do my own laundry, ironing and mending. Every morning I sweep and mop, and once a week we house-clean, and I wash the walls and windows. Between times, I peel potatoes, set tables and wash dishes. Are you sure the Army intends to make a man out of me?"

Overheard in a C.E. class: "On the last quiz, I got docked three percent for having a decimal point upside down."

First there was nothing. Then came the stone age, followed by the bronze age. Next came the machine age, and now we're in the space age. Space is nothing, so we're back where we started.

A man walked into a restaurant and left the door open. A big fat man called out: "Shut the door! Were you brought up in a barn?" The man closed the door, sat down and began to cry. At this the fat man looked uncomfortable and went over to the sorrowful one. Said he, "I'm sorry, 'I didn't intend to hurt your feelings.'" I'm not crying because you hurt my feelings," was the reply, "but the fact is, I was brought up in a barn and every time I hear an ass bray it makes me homesick."

Daffynitions:

Ginger Ale. A drink that tastes like your foot feels when it's gone to sleep.

Golddigger: A girl who breaks dates by going out with them.

Alcoholic rheumatism: Getting stiff in every joint.

Home. Where you can scratch any place it itches.

The regular noontime poker session of a group of Phoenix, Ariz., electronic engineers is neatly labeled with a sign reading: "Probability Seminar."

A white rat, recently returned from the laboratory to his cage, ran up to a fellow rat in great excitement. "I've got Dr. Zilch conditioned!" "How so?" asked his buddy. "Well," said the first rat, "every time I go through the maze he gives me food!"

I think that I shall never see
A girl refuse a meal that's free;
A girl with hungry eyes not fixed
Upon the drink that's being mixed:
A girl who doesn't like to wear
A lot of junk to match her hair;
But girls are loved by guys like me
'Cause I don't like to kiss a tree.

I never kiss, I never neck.
I never say hell, I never say heck.
I'm always good, I'm always nice.
I play no poker, I play no dice.
I never drink, I never flirt.
I never gossip or spread the dirt.
I have no lines or funny tricks,
but what the heck—
I'm only six.

How many magazines does it take to fill a baby carriage? One Made-moiselle, One Country Gentlemen, A Look, A Few Liberties . . . and a Little Time.

A woman on a television audience—participation show was asked the name of her favorite author. "Why, it's my husband," she replied. "Your husband?" questioned the interviewer. "What does he write?" The woman smiled brightly, then answered: "Checks."

There are only two kinds of parking left on campus—illegal and no.



After McNair designs it, Kelly has to manufacture it

In the broad spectrum of engineers and scientists we constantly seek, we can use more manufacturing engineers like Edward Joseph Kelly (right, six years out of Tufts this June). Mark well the distinction between Kelly's responsibility and that of his opponent in the debate pictured. Out of it upon completion of their differing assignments will come a photographic information storage and retrieval device that will bear our "Recordak" trademark, well known in banking and other businesses.

Dave McNair has determined how the mechanical, optical, and electrical components and subassemblies have to work and fit together for the equipment to do its job. He has come up with a working model. Management likes it.

Enter Kelly. His task: to tell us exactly down to the last

detail what we have to do to multiply McNair's working model by x , a number chosen by the marketing people. To make the production-run machines work not merely as well as McNair's hand-built one, but better. To decide which parts we should buy and which we should make. To specify the tooling for the parts we make. To specify also the tools for assembly and inspection. To design the fabrication processes. Better than just designing the processes, to see the need for a process which no previous manufacturing engineer had realized was needed and which happens to make the product an irresistible bargain for the ultimate user and a money-maker for us.

We need that kind of manufacturing engineer so that we can teach him how to run a big business.

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Advancement in a Big Company: How it Works

An Interview with General Electric's C. K. Rieger, Vice President and Group Executive, Electric Utility Group



C. K. Rieger

■ Charles K. Rieger joined General Electric's Technical Marketing Program after earning a BSEE at the University of Missouri in 1936. Following sales engineering assignments in motor, defense and home laundry operations, he became manager of the Heating Device and Fan Division in 1947. Other Consumer-industry management positions followed. In 1953 he was elected a vice president, one of the youngest men ever named a Company officer. Mr. Rieger became Vice President, Marketing Services in 1959 and was appointed to his present position in 1961. He is responsible for all the operations of some six divisions composed of 23 product operations oriented primarily toward the Electric Utility market.

Q. How can I be sure of getting the recognition I feel I'm capable of earning in a big company like G.E.?

A. We learned long ago we couldn't afford to let capable people get lost. That was one of the reasons why G.E. was decentralized into more than a hundred autonomous operating departments. These operations develop, engineer, manufacture and market products much as if they were inde-

pendent companies. Since each department is responsible for its own success, each man's share of authority and responsibility is pinpointed. Believe me, outstanding performance is recognized, and rewarded.

Q. Can you tell me what the "promotional ladder" is at General Electric?

A. We regard each man individually. Whether you join us on a training program or are placed in a specific position opening, you'll first have to prove your ability to handle a job. Once you've done that, you'll be given more responsibility, more difficult projects—work that's important to the success of your organization and your personal development. Your ability will create a "promotional ladder" of your own.

Q. Will my development be confined to whatever department I start in?

A. Not at all! Here's where "big company" scope works to broaden your career outlook. Industry, and General Electric particularly, is constantly changing—adapting to market the fruits of research, reorganizing to maintain proper alignment with our customers, creating new operations to handle large projects. All this represents opportunity beyond the limits of any single department.

Q. Yes, but just how often do these opportunities arise?

A. To give you some idea, 25 percent of G-E's gross sales last year came from products that were unknown only five or ten years ago. These new products range from electric tooth brushes and silicone rubber compounds to atomic reactors and interplanetary space probes. This changing Company needs men with ambition and energy and talent who aren't afraid of a big job—who welcome the challenge of helping to start new businesses like these. Demonstrate your ability—whether to handle complex technical problems or to manage people, and you won't have long to wait for opportunities to fit your needs.

Q. How does General Electric help me prepare myself for advancement opportunity?

A. Programs in Engineering, Manufacturing or Technical Marketing give you valuable on-the-job training. We have Company-conducted courses to improve your professional ability no matter where you begin. Under Tuition Refund or Advanced Degree Programs you can continue your formal education. Throughout your career with General Electric you'll receive frequent appraisals to help your self-development. Your advancement will be largely up to you.

FOR MORE INFORMATION on careers for engineers and scientists at General Electric, write Personalized Career Planning, General Electric, Section 699-11, Schenectady, N. Y. 12305

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